Using routine data to evaluate real-world public health interventions – assessing the reach, impact, and fidelity of The Daily Mile

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Dedication

This thesis is dedicated to all the women in my life (and everywhere) who defied and dreamt; for them and for me.

Thank you.

For my maa, and my fui; and my birthmother, who by giving me up, opened my life to endless possibilities.

But mostly for my noor and granny, Bakhtawar Venkatraman,

1934 – 2013

For your courage, your unwavering faith, and your desire to change the lives of children with congenital heart disease in 1950s India. You did not get to finish your PhD, but I finish mine today, almost an extension of what you began all those years ago. I hope you are proud.

Declaration of originality

I declare that this thesis has been composed solely by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Except where explicitly stated otherwise the work presented is entirely my own.

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Abstract

Background

Public health interventions are often promoted without strong evidence of effectiveness in real-world settings. In England there is a vast amount of routine data available that can be used to evaluate these interventions. Less than 50% of children in England meet the government's physical activity guidelines, which is a major public health concern. Simple, effective interventions for all are required to tackle shortfalls in children's physical activity. The Daily Mile (TDM) is a school-based active mile intervention that has been widely adopted to address this shortfall. This thesis aims to use routine data to evaluate a real-world public health intervention by assessing the reach, impact, and fidelity of TDM.

Methods

This thesis comprises four cross-sectional studies linking various health, education, and census data. In the first study, I created a database of all state-funded primary schools in England and used multilevel models to determine the association between school and local authority characteristics, and registration to TDM. In the second study, I conducted a hierarchical cluster analysis to group local authorities by 'need' and estimated the association between 'need' and registration to TDM. In the third study, I used self-reported physical activity data to compare minutes of MVPA, and the variety of activities reported per week between children attending TDM-registered and non-TDM registered schools. Finally, I assessed fidelity to TDM's core running criteria among children registered using descriptive statistics and multilevel models.

Results

TDM is a wide-reaching intervention with one in five primary schools in England registered. Schools in urban areas and schools with a higher proportion of disadvantaged pupils were more likely to register. TDM appears to be an equitable intervention reaching schools in areas of highest need; registration ranged from one in five schools in low-need areas to one in four in high-need areas. Children attending schools registered to TDM reported a marginally greater variety of activity and 10 additional minutes of MVPA/week during school hours and 26 additional minutes of MVPA/week outside school hours compared to children in non-TDM schools. Fidelity of implementation to TDM remained low, where 30% of those registered reported adhering to TDM's core running criteria.

Conclusion

This thesis demonstrates that routine data can effectively be used to evaluate real-world public health interventions. TDM is a wide-reaching intervention and appears to be equitable. However, it does not seem to impact children's physical activity substantially, and implementation remains low. TDM must be embedded within a broader suite of interventions to increase children's physical activity.

Research Outputs from this PhD

Published peer-reviewed research articles

1. **Venkatraman T**, Honeyford K, Costelloe CE, et al Sociodemographic profiles, educational attainment and physical activity associated with The Daily Mile™ registration in primary schools in England: a national cross-sectional linkage study, *J Epidemiology and Community Health* 2020;75:137-144
2. **Venkatraman T**, Honeyford K, Ram B et al., Identifying local authority need for, and uptake of, school-based physical activity promotion in England–a cluster analysis, *Journal of Public Health (OUP)*, 2021; fdab138
3. Ram B, Chalkley A, van Sluijs E, Phillips R, **Venkatraman T,** Hargreaves DS, et al. Impact of The Daily Mile on children's physical and mental health, and educational attainment in primary schools: iMprOVE cohort study protocol. *BMJ Open* 2021;11(5):e045879

Papers in draft

4. **Venkatraman T**, Honeyford K, van Sluijs EMF et al., Are children at schools registered to The Daily Mile™ more physically active? An analysis of 47,266 children in England
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7. Ram B, **Venkatraman T**, and Saxena S (2019). A systematic review of primary school-based physical activity interventions to determine a core outcome set of child health outcomes and measurement tools. PROSPERO: International prospective register of systematic reviews CRD42019146621. https://wwwcrdyorkacuk/prospero/display_recordphp?ID=CRD42019146621

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Abbreviations

Abbreviation	Definition
95%CI	95% confidence interval
AIC	Akaike information criterion
ANOVA	Analysis of variance
BIC	Bayesian information criterion
BMI	Body mass index
BMIz	Body mass index z-score
CI	Confidence interval
CMO	Chief Medical Officer
CPM	Counts per minute
CPRD	Clinical Practice Research Datalink
EHC	An education, health and care plan
HES	Hospital Episode Statistics
ICAD	International Children's Accelerometery Database
ICC	Intraclass correlation coefficient
IMD	index of multiple deprivation
IQR	interquartile range
IRR	incidence rate ratio
LPA	Low physical activity
MENE	Natural England: Monitor of Engagement with the Natural Environment
MET	Metabolic equivalents
MIE	moderate intensity equivalent
MPA	Moderate physical activity
MRC	Medical Research Council
MVPA	Moderate to vigorous physical activity
NCMP	National Child Measurement Programme
NHS	National Health Service
NPD	National Pupil Database
ONS	Office for National Statistics
OR	Odds ratio
PAM	Partition around medoids
PE	Physical education
QALY	Quality adjusted life years
RCT	Randomised controlled trial
RE-AIM	RE-AIM Framework (Reach, Effectiveness, Adoption, Implementation, Maintenance)
RR	Risk ratio
SCT	Social Cognitive Teory
SD	Standard deviation
SDT	Self Determination Theory
SEN	Special education needs
SMD	Standardized mean difference

SOPLAY	System for Observing Play and Leisure Activity in Youth
TDM	The Daily Mile
TiDier-PHP	Template for Intervention Description and Replication - population health and policy
VPA	Vigorous physical activity
WAY	What about YOUth survey
WHO	World Health Organisation

Thesis overview and structure

Several public health issues of concern translate to high health and social care costs, such as obesity, physical inactivity, and poor diet. It is vitally important to design, implement, and evaluate potential interventions that can effectively improve public health. Routine data on health, education, and demography are widely available in England. These data are extensively used in primary and secondary care for population health surveillance and to assess the impact of policies and interventions. This, in turn, enables the understanding of health behaviours and monitoring population health at a national scale that is not otherwise possible. However, its use to evaluate nationwide public health interventions, especially physical activity interventions is limited.

Less than 50% of children in England meet the government's physical activity guidelines.[1] To address this shortfall, a wide suite of interventions is available and implemented to increase children's physical activity. Many of these interventions are school-based. Schools are considered ideal settings for children to meet most of their physical activity requirements since they spend a large proportion of their time at school, and most children in England attend schools. More importantly, this is when physical activity starts declining in children and steadily declines even further in adulthood. One such school-based intervention is The Daily Mile (TDM). It was created in 2012 by a school head teacher, Elaine Wiley, to address physical inactivity in children in a primary school in Scotland. Since then, it has been widely adopted by schools both in England and across the world. This adoption in England, in part, has been driven by the United Kingdom Government's official endorsement of the intervention as a practical solution to the rising childhood physical inactivity and obesity crisis.

The evidence base is increasingly showing that school-based physical activity interventions are not particularly effective at increasing children's activity. To an extent, this is due to effectiveness studies being conducted in small, non-generalisable, controlled settings, and poor implementation of interventions when scaled. Finding scalable public health interventions that are effective and equitable is a challenge. TDM is an example of a public health intervention that scaled up organically, at least initially, prior to policy and monetary promotion and adoption. Evaluating it presents a novel opportunity to study behaviour change at a population level; to understand the features of schools that adopt it and aim to change behaviour; its impact

on a national level; and its fidelity across a large nationally representative population. Routinely available data are in a leading position to facilitate this as it covers population health nationally and is a cost-effective method of evaluating interventions compared to more traditional methods.

In this thesis, I take an overall epidemiological approach and focus on population health outcomes rather than individual or physiological outcomes in children. This approach indeed leads to different conclusions than if I had used sports and exercise science, for example, as the guiding discipline of the thesis. My choice of approach stems from the fact that I am interested in solutions to public health problems and effectively using the vast amounts of routine data available in England. This approach also dictates the structure of this thesis and the order in which I conducted this thesis' studies.

This thesis has nine chapters and is structured as follows:

- *Chapter 1* describes how this thesis and work is embedded in the wider context of existing literature. The chapter begins by providing an overview of public health and important concepts leading to public health interventions and how their success is measured. I then present the value of routinely available data and its relationship to public health and intervention evaluations. Next, I summarise the importance of physical activity for children's health, measurement of physical activity, trends in activity, physical activity recommendations, and opportunities within the school day that interventions can target. This chapter provides an overarching review of the effectiveness and implementation of school-based physical activity interventions before focussing on school-based running programmes and active miles more explicitly. The chapter ends with an overview of The Daily Mile, its inception, and theories that provide mechanisms by which it might work.

- *Chapter 2* reviews, summarises, and critiques the current literature specifically on the effectiveness and implementation of The Daily Mile.

- *Chapter 3* highlights the knowledge gaps and, in turn, the rationale and justification for this thesis. It is followed by this thesis' aims, objectives, and corresponding hypotheses.

- *Chapter 4* provides an overview of the methods, including each study design, the datasets used, and the corresponding population and outcomes. I describe the methodological approach, research design, and process. Finally, I describe in detail the data sources used in this thesis.

- *Chapter 5* reports the first original study of this thesis. It is titled *Reach of The Daily Mile,* and is a cross-sectional linkage study that examines the primary school and local authority characteristics associated with registration for The Daily Mile in England. The results suggest that one in five primary schools in England is officially registered to The Daily Mile, and schools in urban areas, and those with a higher proportion of disadvantaged pupils, are more likely to register.

- *Chapter 6* is titled *Equity of The Daily Mile.* In this chapter, I use cluster analysis to examine local authority areas most in 'need' of physical activity promotion for children in England. I use the clusters generated to assess whether school populations registered to The Daily Mile are representative of the needs of the general population. The results suggest that the 'need' of children's physical activity promotion in England varies distinctly and spatially across England. Further, schools in high-need areas are more likely to register to The Daily Mile than schools in low-need areas.

- *Chapter 7* is titled *Impact of The Daily Mile.* In this chapter, I use data from the Active Lives Children and Young People Survey. I compare reported physical activity (minutes of moderate to vigorous physical activity) in primary school children registered to The Daily Mile with those not registered. I then compare the variety of reported physical activity in primary school children registered with The Daily Mile to those who are not. Results suggest that children registered to The Daily Mile report more activity (minutes of moderate to vigorous physical activity) and a larger variety of activities during school hours, outside school hours, and in total.

- *Chapter 8* is titled *Fidelity to The Daily Mile.* In this chapter, I assess if children in schools registered to The Daily Mile indeed report doing a daily mile by adhering to its

core running criteria of 15-minutes of running in school, outdoors, and moderate to vigorous physical activity at least three times a week (de-facto daily mile). Next, I examine the association between registration to The Daily Mile and within school variation of self-reported activity, using de-facto daily mile as a case study. This last piece of work attempts to validate whether registration to The Daily Mile can be considered a proxy measure for participation in The Daily Mile.

- *Chapter 9* reviews the thesis and discusses its policy and research implications. I describe some general limitations of the thesis, and revisit the context within which this thesis lies before stating my conclusions.

1. Public health, physical activity, and children's health

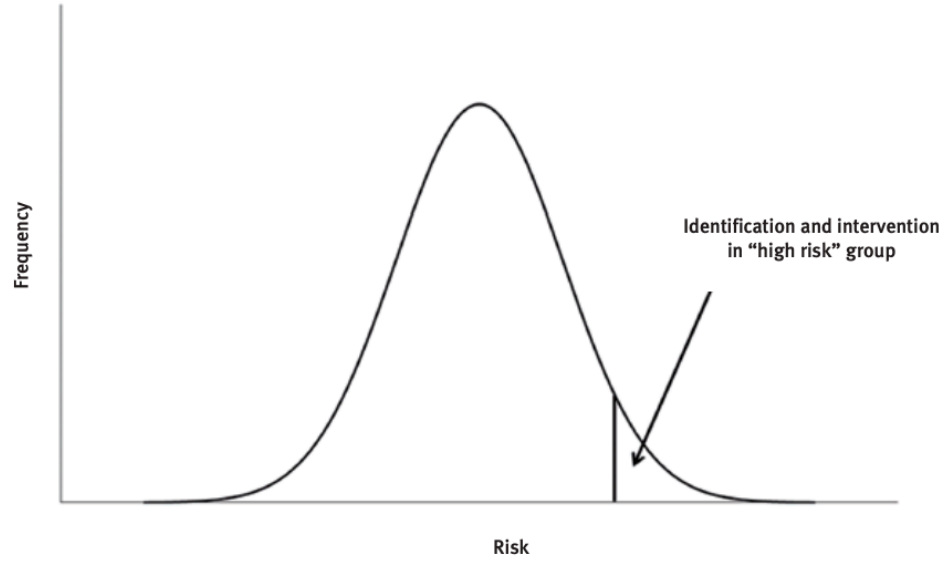
Overview

In this chapter, I summarise the literature relevant to this thesis. I begin with providing an overview of the value of routinely collected data to public and population health. I then expand this to describing how routinely collected data has been used to monitor population health needs effectively and evaluate interventions to improve health. I discuss how this data can be used for the entire process of intervention evaluations, beginning with the reach of the intervention, following through to the impact at the population and individual level, and ending with fidelity. I move on to consider the differences between complex settings versus complex interventions and how this distinction matters both for designing and implementing interventions, and for evaluating them. Thereafter, I provide a critical overview of 1) the evidence of the effect of physical activity on children's health, 2) opportunities to increase children's physical activity during the school day and 3) the effectiveness and implementation of school-based physical activity interventions that led to the creation and adoption of active mile interventions.

1.1 Public health improvement approaches

Low levels of physical activity in children is considered one of the greatest public health challenges. Public health is the science of protecting and improving the health of people and their communities. Public health covers the entire spectrum of health and wellbeing, focussing on protection, prevention and promotion.[2] It protects the health of entire populations that can range from small local neighbourhoods to entire countries and regions of the world.[2] Activities to strengthen public health capacities aim to promote conditions under which people can live healthy lives, improve their health and wellbeing, and prevent and eradicate diseases.[3] Geoffrey Rose in his seminal paper[4] argued that individual and population approaches to improving health are fundamentally different and achieve different aims. The former focusses on 'high-risk' individuals, which seeks to protect those most susceptible to disease (Figure 1.1). In contrast, the latter focusses on controlling the causes of incidence and tries to shift the whole distribution of exposure in a population.[4] While the population strategy is behaviourally appropriate and focuses on prevention and the underlying causes of incidences of diseases, population approaches frequently yield small benefits to individuals and are therefore not particularly popular.[5]

Figure 1.1 Rose's high-risk prevention strategy where risk is measured and used to separate "high risk" groups from "normal" groups

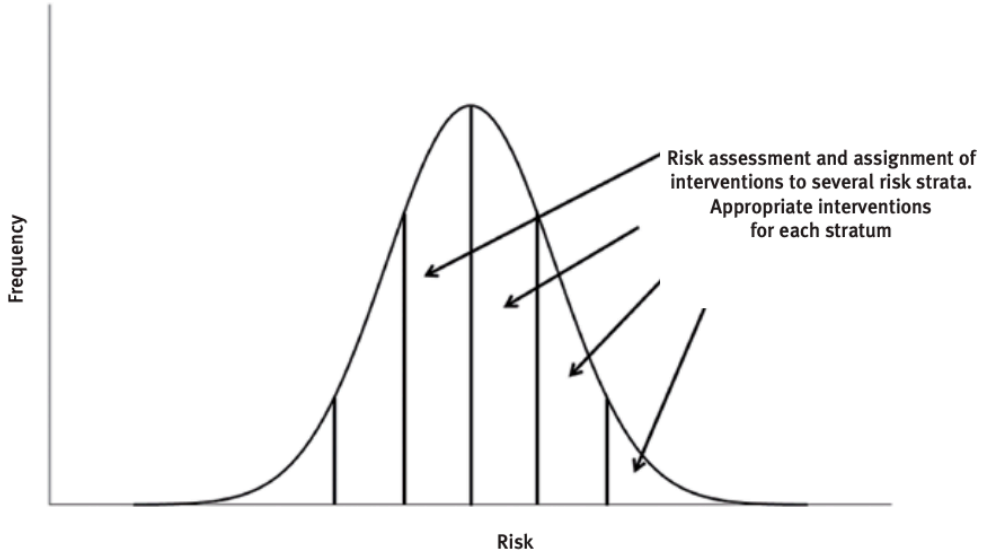


Taken from: Burton H, Sagoo GS, Pharoah P, Zimmern RL. Time to revisit Geoffrey Rose: strategies for prevention in the genomic era?

Based on Rose's work, Burton et al. suggested a third approach to disease prevention – the "stratified prevention" approach. They argue that segmenting the population by risk into a

number of individual groups or strata allows each group to have different interventions applied to it, thereby maximising benefits and minimising harms (Figure 1.2).[6] This stratified approach can also serve as a basis for ensuring that interventions reach both high- and low-risk populations. This risk might not be limited to just clinical and biological risk, but also risk based on sociological, ecological, and demographic risks, all of which are critical facets of disease distribution and risk.[7] Public health interventions, in theory, aim to create equitable health distributions within populations while simultaneously improving overall population health.[8] However, these interventions are often not distributed equally throughout a population, and health policies and interventions may exacerbate health inequalities.[7] Therefore, whether public health practitioners and policymakers take the overall population health or high-risk approach as suggested by Rose, or the stratified prevention approach as suggested by Burton, population health strategies must consider the potential effect on both the whole population and on those with differing levels of disease risk within a population, including those in disadvantaged, under-represented or under-served groups who are often left out.[7,9] When applied to physical activity, there are inequalities in children's physical activity and access to environments that are conducive to increasing activity, such as green space. Therefore, interventions aimed at increasing physical activity in children must target all children, but especially those most vulnerable.

Figure 1.2: The "stratified prevention" strategy allows categorisation of the population into multiple groups with different interventions applied in the different groups based on need



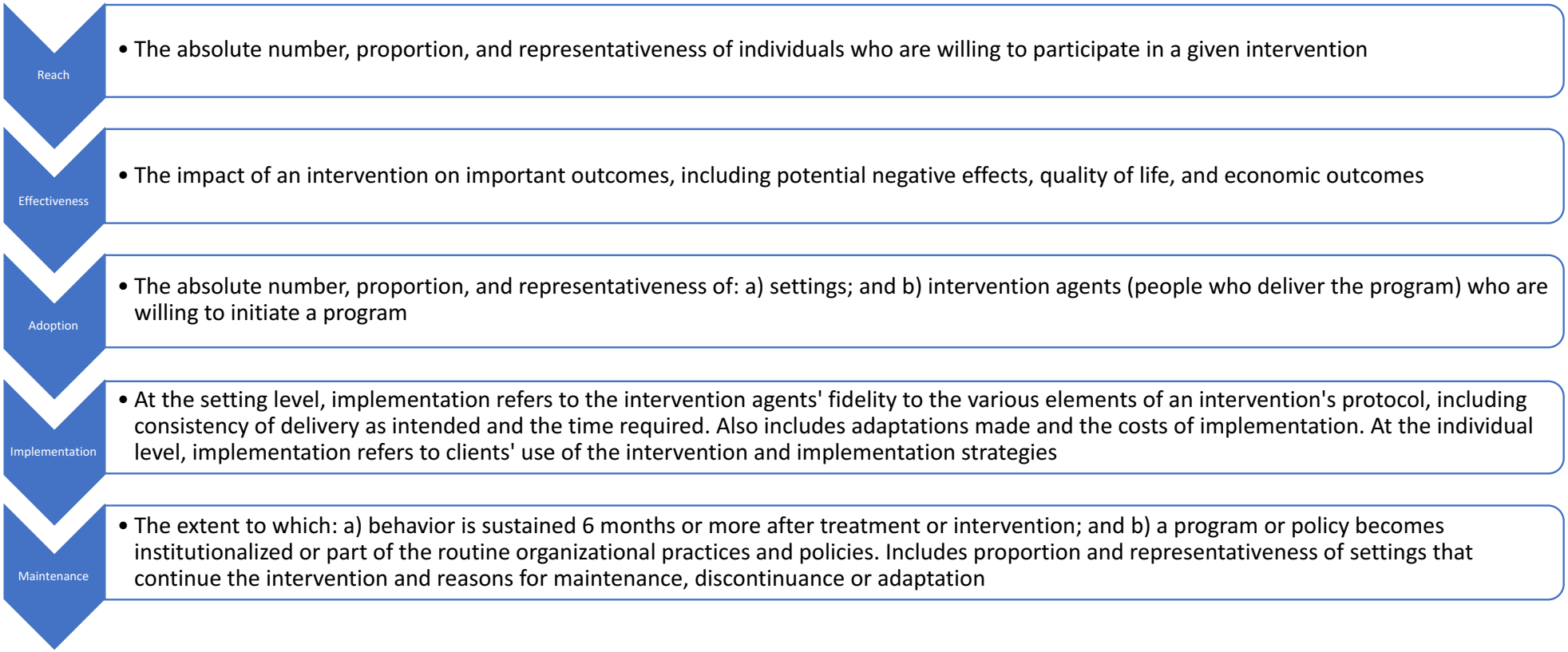
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1.2 Public health interventions

1.2.1 Success of public health activity interventions

The success of public health interventions is not solely based on whether they are able to change the public health behaviours they are designed to target. The RE-AIM model lists five dimensions that measure the success of public health interventions – reach, efficacy, adoption, implementation, and maintenance (Figure 1.3).[10] There is a need to think beyond measuring and stressing on the efficacy, with generalisability of the intervention context, it's reach, equity, and implementation being core components of success. Reach is defined as the absolute proportion, and representativeness of individuals who are willing to participate in a given intervention.[11] Given the inequalities observed in children's health such as childhood obesity[12–15] and physical activity,[16,17] interventions should reach whole populations, especially those who are disadvantaged. A potential method of assessing reach of public health interventions is to segment the population based on risk (Figure 1.2) and assess whether the intervention has reached those in the median and those on the truncated right end of risk (high-risk population). However, a systematic review found that even among those interventions evaluated against the RE-AIM model, while *reach* was most commonly reported, it was also most commonly reported incorrectly in that representativeness across individual- and organizational-levels, was reported far less frequently.[11,18] This review also found that that adoption and maintenance were also reported far less frequently,[18] with effectiveness being most frequently reported. This is unsurprising as policymakers and governments tend to focus on efficacy rather than reach, implementation, fidelity and maintenance.[19] School-based physical activity interventions and physical activity interventions aimed at children in general have found limited success when delivered under real-world conditions or at scale.[20,21] This can partly be explained by the lack of appropriate planning at the design and evaluation stage around all the facets critical to the success of public health interventions, namely reach, equity, implementation and maintenance, as when scaled, these interventions' effectiveness is substantially reduced.[18,21,22]

Figure 1.3 RE-AIM Framework



Adapted from: Glasgow RE, Vogt TM, Boles SM. (1999) Evaluating the public health impact of health promotion interventions: The RE-AIM framework; *American Journal of Public Health*

1.2.2 Complex interventions versus complex settings

Complexity in public health programmes can occur in two spheres – it can be a property of the intervention and/or a property of the setting within which the intervention is implemented.[23] The Medical Research Council's (MRC) guidance on complex interventions states that complexity within interventions exists in the "number of interacting components; the number and difficulty of behaviours required by those delivering or receiving the intervention; the number of groups or organisational levels targeted by the intervention; the number and variability of outcomes; and the degree of flexibility or tailoring of the intervention permitted".[24,25] Given that complex interventions are made up of multiple components, it can be difficult to assess the 'active ingredients' of the intervention likely to be responsible for changes in health outcomes.[23] In contrast, simple interventions are single-component interventions where there is a clear pathway between the intervention and the health outcome.[24] Petticrew argues that there are in fact no 'simple' and 'complex' interventions, but "that simplicity and complexity are instead pragmatic perspectives adopted by researchers to help describe and understand the interventions in question".[24] Most medical interventions when inspected in detail are 'complex', but classifying them as 'simple' allows researchers to answer straightforward questions that follows a linear path from intervention to outcome.[24] However, both simple and complex approaches to evaluating interventions are required – one focussing on individual outcomes (simple approach) and the other focussing beyond individual 'effectiveness', incorporating system-level effects of the intervention and more complicated processes such as reach and implementation.[24] The other sphere in which complexity can occur is the setting in which the intervention is implemented. Schools, primary care settings and hospitals are examples of complex settings. The complexity within settings include the operations, structures, and relations that exist in each setting.[26,27]

Schools have been described as complex social systems whose functioning is determined by interactions between a range of constantly changing factors such as teachers, staff, pupils and parents.[28] Further, these interactions exist both between activity settings and within activity settings where interventions are implemented such as classrooms.[26] Schools are themselves nested within the larger education systems, and they rapidly evolve in response to external pressures, expectations, technologies and perceptions.[29] Thus, interventions implemented in complex systems such as schools are likely to have diverse, far-reaching, and non-linear effects due to the multiple processes that influence them. However, these might not all be measurable,

and even if they are, they might not be measurable in the short to medium term.[29] Further, interventions implemented in complex settings are subject to variation in implementation and a key component of successful interventions is the ability for adaptation and adjustment in dynamic settings to suit the context in which they are being implemented.[30–32]

1.3 Public health and the value of routinely collected data

The foundation of public health is population health surveillance and monitoring which covers the ongoing systematic collection, analysis, and interpretation of health-related data. Routine data can be defined as non-targeted data obtained from ongoing data collection systems associated with the health and social services.[33] This is essential to setting priorities and planning of rational health policy, implementation, and evaluation of public health practice.[34,35] Robust surveillance systems are vital to reducing the number of people that become patients, is important for epidemiologists to understand the underlying causes of disease, and to create effective policies that facilitate disease prevention.

Evidence-based medicine and evidence-based policy are two commonly used terms in public health. Evidence based-medicine is defined as "…the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients".[36] Evidence-based medicine is focused at the individual-clinical level, which when translated and extrapolated to the population level can be complicated, uncertain, and variable based on the context.[31] Given public health relates to the population and not the individual, the concept of evidence-based policy is more meaningful as the decision-making context shifts from the individual to the population.[32] Evidence-based policy is not as extension of evidence-based medicine.[37] In evidence-based policy the 'decision-making context' is as important as the level of 'evidence'.[32] Evidence-based medicine is rooted in assessing efficacy and effectiveness, and the systems for determining the level of evidence is traditionally derived from randomised trial data over observational studies.[38] However, for policymakers, the most useful and relevant data seldom originate from controlled trials. Policy makers are concerned about the 'distributional consequences' of their policies which pertain to:

- who has to pay
- whether they can pay
- how much do they have to pay

- who benefits
- whether the benefit covers a large enough population to warrant implementation

This data cannot be acquired from controlled clinical trials.[31] The real-world relevance and generalisability of data obtained from controlled trials for large-scale policy is challenging. Randomised controlled trials (RCTs) are traditionally done in non-representative su-populations often due to them being limited by narrow inclusion criteria.[39] Further, trials are commonly conducted under artificial conditions that differ from real-world settings, reducing their usefulness to real-world evidence-based policy. These issues are reflected in studies where large inconsistencies occur between efficacy results from controlled trials and when scaled up, the effectiveness in real-world settings; with the effectiveness in real-world settings often being substantially lower.[22] The transition from the individual-clinical level to the population-policy level shifts the focus from efficacy and effectiveness to feasibility and implementation; again, with context being central. Further, evidence-based policy needs to match population needs to have a substantial impact on improving health. Controlled trials often exclude those with differing needs, underrepresented populations, and disenfranchised populations, such as women, those from ethnic minorities, older adults or patients with comorbidities;[40,41] thus rendering their results non-generalisable and unable to match the needs of the population.

Routine population-based data plays a fundamental role in creating and evaluating evidence-based policy. It enables assessment of overall population needs, not just of certain subgroups or overrepresented populations as can be the case with data from trials. Using routine data to evaluate public health programmes has many benefits. These data are usually readily available through open-source repositories such as the Public Health Fingertips website in England. It is low cost, therefore allowing for cost-effective real-world evaluations of policy. It can also be very useful for identifying hypotheses and a precursor to investing in a large-scale trial.[42] Routine data are valuable for initial assessment of disease surveillance and intervention evaluation to assess trends and offer baseline data on expected levels of population health or a disease. The liberal inclusion criteria, high external validity, no interference with routine care, and minimal selection bias tackles the problem of generalisability often arising from RCTs.[43] It also enables the study of specific conditions and subgroup effects which is often not possible in RCTs because they might not be powered to detect these differences and certain subgroups

are underrepresented.[40,41] Policy makers and governments often need to act quickly; real-world data sources provide current results for policymakers permitting them to formulate timely evidence-based health policy.[42] However, there are also limitations to the routine data. It is not always up-to-date and might not reflect current population needs; additionally, there can be a lack of completeness, some variables of interest may not be collected, and occasionally these data might be subject to political influences and manipulation.[43]

In England a large amount of routine data are collected[44] and these data can be used for research purposes. Access to some of these data needs to be applied for through formal channels, often through NHS Digital, while some datasets are available publicly in open repositories. Examples of online repositories of local authority level data and health indicators are Public Health England Fingertips[45] and the United Kingdom Data Service which is one of the largest data repositories of its kind in the world, containing social and economic data including United Kingdom census data and government funded surveys as well as qualitative and business data.[46] Another commonly used routinely available dataset in England is the Clinical Practice Research Datalink (CPRD), an ongoing primary care database of anonymised medical records from general practitioners.[47] These routine data also include data on monitoring the health needs of children. The National Child Measurement Programme (NCMP) is a nationally mandated public health programme that records the height and weight of all primary school children in England when they leave and enter primary school. The programme has been ongoing since 2006 and is one of finest resources of its kind in the world to monitor childhood obesity.[48] Its strengths include collecting data on the weight status measured as BMI for over 1 million children which includes 98% of all children in England entering and leaving primary school each year.[48] However, NCMP data is limited to BMI as a marker for obesity BMI acts as a proxy for lean and fat mass but does not reflect body composition or fat distribution.[49] In children specifically, height and weight rapidly increase, making BMI an uncertain measure of weight status. Additionally, BMI has been found to underestimate body fat in South Asian children and over-estimate body fat in Black African children.[50,51] BMI Other markers such as waist and hip circumference or subcutaneous fat measurement such as triceps skinfold thickness might be better measures in some circumstances.[49,50]

Routine data have been used to evaluate public health and policy interventions.[52] Using routine data for intervention evaluations has added benefits over other methods e.g., trials, allowing key questions to be answered such as[42]:

- Does it work in real-world settings?
- Would it work in the settings being considered and is it generalisable?
- How much less effective would it be compared with ideal settings, is there better evidence for alternative interventions?
- What other interventions have occurred in the timeframe being studied that might interact with this intervention?

Public health cannot exist in a silo independent of education, social, fiscal, environmental, and infrastructural policy as they all intersect and contribute to health inequalities, one of the most critical features of public health.[53] Routine data from other fields linked to health data have been shown to be vital to understanding the risks to population health and are important for planning for health needs. Studies that have integrated non-health data to health data have had a major policy impact. For instance, a study that evaluated the impacts of Brexit on fruit and vegetable intake and cardiovascular disease in England was picked up by numerous news outlets and was likely to have reached key government officials and policymakers.[54]

1.4 Physical activity and public health

Physical inactivity has a major effect on mortality and morbidity across the population. Globally, physical inactivity causes 6% of the burden of disease from coronary heart disease, 7% of type 2 diabetes, and 1 in 10 premature deaths which equated to more than 5.3 million of the 57 million deaths that occurred worldwide in 2008[55,56] Physical inactivity is not only detrimental to the health and wellbeing of individuals and the population, it is also responsible for a substantial economic burden.[57] Thus, physical inactivity is a major threat to the population economically and for public health, requiring a targeted and concerted effort to reduce it that begins in early life.[58,59]

1.4.1 Defining physical activity

Physical activity has been defined as “any bodily movement produced by skeletal muscles that requires energy expenditure”.[60] It refers to all movement including that done during leisure

time, during work (occupational), in the household, in the form of transport to go to and from places, from sports and other activities, and the location in which it is done is a common way of categorising it.[61] Physical activity is a complex multidimensional behaviour; it is closely linked to energy expenditure, exercise, physical fitness, and sedentary time. While related, there remain important distinctions between them, and there are a several frameworks that describe this relationship.[61–64] These frameworks form an important basis of our understanding of the complex multidimensional nature of physical activity, and the multifaceted pathways they take to shape children's health. Sedentary behaviour, though closely linked with physical activity and physical inactivity, is in fact, a distinct behaviour. It is defined as is defined as "any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents, while in a sitting, reclining, or lying posture".[65] Sedentary behaviour is not just physical inactivity by another name. They are inherently different behaviours, and individuals in the population that are inactive and highly sedentary must be considered when designing public health interventions.[65,66] Understanding and classifying health behaviours and their corresponding effect on outcomes provides a useful tool for measuring the effect of certain behaviours (physical activity) and planning appropriate interventions to modify behaviours that can be health enhancing.

There are various subconstructs to children's physical activity which include type, time, frequency, and intensity – all of which are subsequently associated with health outcomes. Physical activity can be qualitatively categorised as 'type', which can be broke down into team sport, individual sport, recreation and family activities, and active transport. It can be quantitatively categorised as 'frequency', which is defined as how often an individual is active over a given period of time; 'duration' which describes how long an individual is active for; and 'intensity' which refers to "the rate at which the activity is being performed or the magnitude of the effort required to perform an activity or exercise" and can be thought of as how hard an individual needs to work to perform an activity.[67]

Duration and frequency of physical activity are typically measured as the number of hours per week of physical activity. Intensity is usually measured as Metabolic Equivalents (METs). MET is the ratio of a person's working metabolic rate relative to their resting metabolic rate. One MET is defined as the energy cost of sitting quietly and is equivalent to a caloric consumption of 1kcal/kg/hour.[67] Intensity can be more broadly classified as sedentary, low-

intensity physical activity (LPA), moderate-intensity physical activity (MPA), and vigorous-intensity physical activity (VPA). Sedentary corresponds to ≤ 1.5 METs.[65]
LPA corresponds to 1.0-2.9 METs, MPA corresponds to 3-5.0 METs and VPA corresponds to >6 METs.[63] MPA and VPA are often combined and referred to as moderate to vigorous physical activity (MVPA) as it is these intensities that correspond to the greatest improvements in health.[68]

1.5 Physical activity and children's health

Children's physical activity has been linked to numerous health and wellbeing outcomes as described in this section.

1.5.1 Physical health outcomes

The relationship between physical activity and cardiorespiratory and musculoskeletal fitness in children and adolescents is well established and the increasing intensity and volume of physical activity is associated with larger effect sizes.[69–71] A positive dose–response gradient between VPA and aerobic fitness has been observed longitudinally in children; but this dose-response relationship was not observed for LPA and MPA, suggesting VPA should be an integral part of children's activity schedule.[72] A recent meta-analysis of 563 children including 16 RCTs and one non-RCT found that high-intensity interval training compared with moderate-intensity continuous training had a moderate beneficial effect on cardiorespiratory fitness. Regular physical activity, mainly aerobic physical activity, has shown beneficial effects on cardiometabolic health outcomes in children and adolescents.[71] A pooled analysis of over 20,000 children found that independent of sedentary time and after adjusting for potential confounders, MVPA was significantly associated with multiple cardiometabolic outcomes including systolic blood pressure, fasting triglycerides, high-density lipoprotein cholesterol, and insulin.[73] There is an inverse association between physical activity and clustered cardiovascular risk factor scores in young children (6 to 9 years), where the clustering of cardiovascular risk factor scores was the greatest for those least physically active compared to those most physically active.[74,75] As with fitness, greater intensity of activity is associated with more favourable cardiometabolic health outcomes, with intensity being more important than duration of activity; suggesting that high-intensity activity should be promoted in children, even in short bouts.[72,76–78] Other physical health outcomes such as bone health are also

positively associated with physical activity. Longitudinal studies have consistently found total physical activity, especially MPA and VPA, to be associated with higher bone mineral density and bone mineral content.[79,80] A similar trend is observed in cross-sectional studies.[70] Further, bone loading activities can be integrated into children's physical activity like jumping, playing games and running, can help protect from bone-related conditions such as osteoporosis and fractures later in life.[71]

Several studies have investigated the relationship between adiposity and excess weight status, and physical activity, but results remain inconclusive as the relationship between the two is complex.[70] There is some evidence to suggest that higher levels of activity may be associated with healthy weight status in children and adolescents. However, most evidence is from cross-sectional and prospective observational studies, making it difficult to infer the directionality of the relationship.[71] Among longitudinal studies, the relationship between physical activity and adiposity is mixed with some studies finding small positive associations.[70] There has also been some suggestion of reverse causality and a more complex bidirectional relationship between adiposity and physical activity in children.[81–84] One longitudinal study of children aged seven to ten years found that over three years, body fat percentage was predictive of changes in physical activity, but physical activity levels were not predictive of subsequent changes in body fat percentage over three years.[82] Similarly, another longitudinal study in eight to eleven-year-old children found high-fat mass index at baseline was associated with lower physical activity and higher sedentary time after 200 days but not vice versa, even in normal-weight children, suggesting that fatness might predict lower activity rather than the other way round. Further, childhood obesity is a complex problem driven by systemic and upstream factors that warrant a whole system-wide targeted approach, with physical activity only being one part of that solution.[19,85]

1.5.2 Mental health and wellbeing

Physical activity might improve mental health in children and young people by building self-esteem, confidence, and cognition. While mental health has no standard definition, it includes conditions such as anxiety and depression, which are linked to self-esteem, emotional stability, and subjective well-being.[86] Over the last decade, there have been numerous studies and reviews have assessed the association between physical activity and mental health in children.[86,87] The evidence base in the early 2000s was largely driven by cross-sectional

studies, hence excluding temporal relationships.[88–92] A recent systematic review and meta-analysis which included papers from 2005 to 2015 and one of the few that included children (and not only adolescents) concluded that physical activity, especially when done regularly and VPA in childhood and adolescence is associated with improved concurrent symptoms of depression; it has a weak but significant effect on future depressive symptoms. Further, cross-sectional studies showing smaller effects for association between physical activity and depression compared to longitudinal studies.[93] This weak association was also reflected in a 2019 review of reviews.[86] Physical activity seems to have a larger effect on individuals who are already depressed rather than those from mixed and healthy samples, suggesting that physical activity might be likened to psychological and pharmaceutical therapies in reducing symptoms.[71,86,94,95]

More evidence is required to discern whether the association between depression and physical activity is indeed weak or is a result of methodological limitations (especially using device-based estimates for physical activity and in targeted subgroups of children who are more likely to see benefits of physical activity on their mental health). There is currently nconcrete evidence or agreement on the association between physical activity and anxiety in children.[86] The interest in understanding the relationship between self-esteem and physical activity has greatly increased over the last decade. However, the definition and measurement of self-esteem is not consistently used in the literature with physical and social-perceptions being used interchangeably with self-evaluation and self-esteem.[86] Overall, there is no consensus on the association between self-esteem and physical activity[86] and the direction of the relationship is uncertain.[96] However, it may benefit overweight and obese adolescents by improving their physical self-perception even if the effect on subsequent physical activity is marginal, suggesting a differential effect in certain subgroups.[97] Unlike some other physical health outcomes, there is no evidence of a dose-response relationship between physical activity and mental health outcomes in children.[86]

1.5.3 Cognitive function and academic performance

The biological mechanism underpinning the relationship between cognitive function and physical activity is that physical activity modifies the human brain and aids neurological health through increased metabolism, blood supply and oxygenation, and hormone delivery [88,98–100]. In recent years, the integrative field of education and cognitive ability, and physical

activity has gained a lot of traction with numerous studies being published.[86] The three main cognition outcomes that have been studied are cognitive function, academic achievement, and brain structure and function.

In a review of reviews that included 25 systematic reviews and meta-analyses, most reviews concluded that there are positive associations or effects for physical activity on cognitive functioning and/or academic achievement in children. Further, 90% of the meta-analyses included found meaningful effect sizes.[86] However, two systematic reviews that used device-based measurements for physical activity found no association, suggesting methodological issues associated with the assessment of physical activity and its subsequent impact on academic achievement.[70,101] There is evidence to suggest a differential impact of physical activity on cognition and academic performance in certain subgroups. For instance, a 2018 Cochrane review[102] found high-quality evidence to conclude that when compared to standard practice, adolescents who were obese or overweight who were exposed to interventions with only a physical activity component showed improved mean cognitive executive function scores. Further, Biddle's recent review of reviews found that for cognitive function, the meta-analytic effect sizes for those without cognitive impairment were small but significant (0.20–0.43), though larger effects were shown for those with attention deficit hyperactivity disorder from 6 to 10 weeks of aerobic exercise (0.58–0.84).[103] While the association between cognitive function and physical activity is clearer, this is not the case with academic performance. There are some positive associations between physical fitness and academic achievement, but not as much for physical activity interventions.[104] Lastly, when assessing the effects of physical activity and fitness on brain structure (e.g., neural architecture) and function, studies show physical activity and aerobic fitness is beneficial for brain structures that support executive functioning (including neural networks), and memory.[104]

Two large systematic reviews by Singh *et al.* in 2019 [105] and Donnelly *et al.* in 2016[106] found opposing effects of physical activity on cognitive function and academic achievement in children. Singh et al. concluded that there is currently inconclusive evidence for the beneficial effects of physical activity on cognitive and overall academic performance in children but strong evidence for positive effects of physical activity on maths performance. On the other hand, Donnelly *et al.* concluded that there are positive associations among physical activity, fitness, cognition, and academic achievement. Both reviews state that further high-quality research is warranted using device-based measures of physical activity, validated and reliable

measures of cognitive function and academic performance, and the need to the understand more granular features of physical activity such as type, amount, frequency, and timing and its association to cognition. However, Donnelly et al.'s findings are endorsed by the American College of Sports Medicine.[86]

For children to be functioning at their optimum cognitive ability, it is a combination of adequate intelligence quotient and executive function, which comprises motivation, the ability to make decisions, set goals and practice self-control [107]. These are key skills required for healthy children as they pass through the life course. The fact that increased physical activity might benefit children beyond physical and mental health can help win the support of a wider range of stakeholders that are central to children's growth and development: those in the teaching environment, the government, and resource allocating bodies. Overall, the literature does support the view that physical activity and fitness are beneficial for the cognitive health and performance of young people, making a case for integrating physical activity into children's lives at school in the form of physically active learning and classroom breaks.[86,104,108] These types of proximal outcomes (cognitive function, academic performance and mental health), are important for raising the profile of physical activity in schools (and with parents and other stakeholders).

1.6 Physical activity guidelines and recommendations

Given the extensive health and wellbeing benefits of physical activity, it has been considered vital for children and adults to get a necessary 'dose' of physical activity that can enable healthy behaviours and outcomes.[109] To ensure and standardise this process, physical activity guidelines and recommendations are widely disseminated. Physical activity guidelines have been present since the early 1990s.[110,111] The United Kingdom created its own set of guidelines, the first of which was published in 1998 and much like the United States' guidelines at the time,[112] stated that children should accumulate one hour's physical activity per day of at least moderate intensity through lifestyle, recreational and structured activity forms. A secondary recommendation was that children take part in activities that help develop and maintain musculoskeletal health on at least two occasions per week.[113] While much has changed in the field of physical activity research since the 1990s, the recommendations set out by the WHO in 2020 are similar to what was proposed in the 1990s. In 2020, the WHO

recommended that children between the ages of 5-17 should accumulate an average of 60 minutes of MVPA daily across the week.[58] The quality and consistency of physical activity guidelines is fundamental as they serve as an important tool for health professionals, policymakers, researchers, teachers, parents and children. A recent review aimed to systematically identify, compare and appraise the quality of national and international physical activity guidelines for children and adolescents.[114] They identified 50 national and international guidelines and recommendations that varied in relation to date of release, targeted age group, and guideline wording about the type, amount, duration, intensity, frequency and total amount of physical activity. Overall, the United Kingdom's guidelines faired relatively well when assessed against global comparators and are almost identical to the WHO's guidelines[68,114]

1.7 Measuring physical activity

There are three typical ways of measuring physical activity in children – direct observation, device measurement, and self-reporting which can be through questionnaires or logs. Each method has its respective advantages and disadvantages and is widely used to measure children's physical activity.

1.7.1 Direct observation

In direct observation to measure children's physical activity, an independent and often trained observer monitors and records children's physical activity for a pre-determined length of time.[115–117] Observers record their observations in a coding form or through a handheld computer device to give an instantaneous rating of a child's level of physical activity.[118] Direct observation typically occurs in natural and restricted settings such as home or school classrooms [117,119] and has widely been used to assess children's physical activity, albeit in the late 1990s and early 2000s, and has since been used less frequently.[115,120–122] A popular direct observation method is known as SOPLAY – System for Observing Play and Leisure Activity in Youth. Observers track children's physical activity levels, activity types, genders, and other demographic data (age, ethnicity) during a specified time.[118] This method is still used to date[120] and is especially helpful when studying physical activity in young children who have cognitively not fully developed and therefore have difficulty in accurately recalling detailed information about their physical activity.[123] This is a flexible method and has advantages. Observational procedures allow for gathering contextual information such as

the location, time, and clothing when performing activity.[124] It can also be used to assess play area and built environment attributes such as accessibility, usability, supervision, and equipment provision. This helps researchers quantify physical activity within the system and the contextual features that it is operating within. It can also provide more granular details of physical activity such as the type and variation of the activities being performed,[119] which might be especially useful when assessing implementation of interventions which are known to vary widely in real-world settings.[125,126] However, there are a number of disadvantages of using direct observation. It is a costly and energy-intensive method and not a suitable for large-scale recordings of physical activity over long periods of time.[124] Direct observation may produce biased estimates of children's activity due to the concept of 'reactivity'. Reactivity is when children modify their behaviour during the period of observation or measurement (e.g., if a child knows they are being observed, they might modify their physical activity behaviour).[127,128] Further, it can be difficult to get ethical approval to conduct direct observation,[124] is intrusive,[129] can be imprecise, and may be incapabale of providing objective measures of energy expenditure.[127]

1.7.2 Device measurement

Device-based measures are a popular method of measuring children's physical activity due to their accuracy and ability to log physical activity levels from a large number of children. These devices include accelerometers, pedometers, armbands, and heartrate monitors.

Heart rate monitors as a method of measuring energy expenditure and physical activity have been used in both children and adults and can provide an objective indicator of the physiological effect of physical activity.[124] Heartrate monitors rely on the linear relationship between heart rate and energy expenditure during steady-state exercise. However, this linear relationship does not hold at the two ends of the activity spectrum – i.e., for rest and low-intensity physical activityand very high-intensity physical activity.[119] These inconsistencies can occur as physical activity is confounded by numerous unrelated factors such as caffeine, stress, body position, gender, age, body composition, emotional stress, ethnicity, environmental stress, muscle mass, and fitness level, all of which affect this linear relationship between heart rate and the volume of oxygen consumed.[117,119,124,130–136] This may be particularly problematic in measuring children's activity as they spend a large proportion of

their day in LPA or being sedentary in classrooms.[117] There are some more limitations to its use such as the lag in heart rate response after movement, which might mask the intermittent activity patterns of children.[117,129] However, heartrate monitors have certain advantages over other devices. For instance, measuring changes in heart rate can be a superior value of physical activity relative to cardiovascular impact. However, they cannot distinguish between different causes of raised heart rates (activity, pain, emotional stimuli).[129] They are relatively unobtrusive unlike direct observation techniques. They can provide real-time data on the frequency, duration, and intensity of physical activity and can be worn with relative ease over weeks.[119] Due to the limitations of this method of measuring children's physical activity, there is wide consensus in the literature that heartrate monitors are more appropriate to categorise children's overall physical activity levels (i.e., highly active, somewhat active, sedentary) than to measure the exact amount of physical activity.

A more cost-effective alternative to heartrate monitors is pedometers. They provide a total volume of physical activity and have shown to have favourable validity and reliability, especially when measuring steps over long periods of time in a free-living population, including children.[137–142] They have the advantage of being more cost-effective than other devices and have been found to be a useful motivational tool to encourage activity; making them suitable to use for population-based estimates.[124,143] Additionally, their simplicity in usability and design and ability to record short and incidental durations of activity which can be missed with self-report measures make them a popular measurement device that can be used in children.[119,124,144] However their use is limited to documenting relative changes in physical activity, ranking individuals by their physical activity levels, and measuring overall activity, given there is some consensus among experts that total steps per day is a fitting gross indicator for physical activity in children.[145,146] Their drawbacks that limit their use are their inability to record physical activity involving horizontal motion occurring during periods of inactivity, leisure activity, or solely upper body movements.[119] Unlike accelerometers that can record the magnitude of movement, intensity and duration of physical activity, pedometers record any movement above a given threshold as a unit of activity, regardless of whether it results from walking, running or jumping.[119,124,136] In children, where different activities correspond to different energy expenditure with subsequent varying health benefits, both the context of the movement and intensity and duration is of importance.[58] Finally, pedometers are not designed to record intensity, frequency, or duration of

activity,[129,132,136] have considerably poorer real-time data storage capacity than accelerometers[124,147] and can also induce reactivity in subjects,[124,144] limiting their use.

Over the last few decades, accelerometers have become a popular method of measuring children's physical activity. Accelerometers measure body movements in terms of acceleration, measured in 'counts', in real time.[119,124,148] Due to the accelerometer's ability to calculate time spent being active in a certain intensity across a certain period of time, they are often used to record whether children are meeting specific physical activity guidelines, which are usually a combination of time and intensity of physical activity measured across days or weeks.[119,149] For accelerometer data to be reliable, studies have found that they need to be working for seven days and must be monitored throughout this period, including weekdays and weekends, which might sometimes pose a problem when assessing non-home based interventions in children.[124] Accelerometers have become one of the most commonly used methods for assessing physical activity in children[136] due to numerous advantages, including their small size, design and wearability, which can be less burdensome to children compared to other devices such as heartrate monitors.[124,150] Further, they are able to provide an objective, nonreactive and reusable measure of activity,[132] can capture varying intensities of physical activity,[151,152] and are able to accurately capture static and dynamic behaviours.[153,154] Their large data memory makes them particularly useful for monitoring activity over extended periods of time on minute-by-minute monitoring basis. However, accelerometers, especially newer models, can be expensive, require specialised hardware, software and programming skills. Other limitations include their inability to account for the context or type of physical activity (cycling, carrying objects) or differentiate between sitting and standing or the increased energy expended with walking up an incline.[124,131,136] Further, accelerometer activity counts and energy expenditure depends on the count cut-point applied to the data; however, there is a lack of standardised cut-points and no consensus in the literature on which cut-points are best, making comparability of results difficult which can differentially affect measurements of physical activity intensity.[119,124,155]

1.7.3 Self-report questionnaires

Self-report recall questionnaires are a form of subjective assessment of physical activity. They are known as subjective measurements as they rely on responses from individuals. Questionnaires typically ask about past activity over a predefined time frame and may be self-

completed, completed by proxy or administered by an interviewer. Questionnaires measure a variety of characteristics including mode, duration, frequency, intensity, and type of physical activity. They can also include habitual and/or recent activity, and leisure and non-leisure activities. They vary based on how data are reported and can be classified as activity scores, time (minutes or hours), and calories.[156,157] Parental proxy methods are often used for young children (aged below ten), but might not be an accurate assessment of their activity.[129]

Self-report questionnaires to measure physical activity is a more feasible and cost-effective method when evaluating physical activity in large studies across time.[158,159] Though accelerometers have challenges and are more costly than self-report questionnaires, they are still used in large surveillance studies such as Biobank and the National Health and Nutrition Examination Survey. Self-report questionnaires rely on an individual's recall ability, and therefore one's cognitive ability. This is specifically challenging for children who have not developed cognitively.[156,158] This cognitive immaturity increases the risk of recall bias. This in turn can lead to measurement errors of the 'dose' of physical activity resulting in potential overestimations of physical activity due to social pressure or underestimations due to the type of activity recalled by an individual, especially children. For instance, these self-report questionnaires are more likely to capture physical activity that can be easily recalled from the 'retrievable memory'[160]. This may lead to underestimation of physical activity as more structured types of activity are more easily recalled (e.g., a football lesson) as opposed to shorter and more incidental and sporadic bursts of activity (e.g., running to the shops). Further, social desirability pressures may lead to respondents overestimating their levels of physical activity.[156,158,161]

Assessing the reliability and validity of self-report physical activity questionnaires is vital to understand their value and scope of use. Reliability can be defined as the "consistency with which a test or an observer measures what is intended to be measured and the extent to which the measurement is repeatable". There are three testable forms of validity: content validity, construct validity, and criterion validity. Content validity is "the degree to which the content of a measurement instrument is an adequate reflection of the construct to be measured".[162] Construct validity is "the degree to which the scores of a measurement instrument are consistent with (a priori drafted) hypotheses".[162] Hypotheses could include internal relationships, i.e., structural validity, or relationships with other instruments/questionnaires. Criterion validity is "the degree to which the scores of an instrument are an adequate reflection

of a gold standard".[162] Considerable research has assessed the reliability and validity of self-report physical activity in children and is reflected in the systematic reviews that have been published since the new millennium.[158,159,163–165] Reliability is almost always evaluated with a test-retest method to measure the consistency of a questionnaire, and validity is mostly evaluated using correlation coefficients, with the Bland-Altman technique being the most popular.[158] The most recent systematic review concluded that no physical activity questionnaire in children was of high methodological quality and showed positive evidence for reliability and validity.[159] Another systematic review found that while some questionnaires have moderate to good reliability (correlation coefficients were 0.62–0.71 for existing and 0.74–0.76 for new questionnaires), objective criterion-related validity was poor across the board.[158]

Despite their limitations, self-reported studies have some advantages that make them frequently used in large epidemiological research and surveillance studies (inexpensive and reduced burden on respondents and administrators). Further, accelerometers which are most commonly used to assess children's activity, cannot provide information on the type and context of the physical activity that questionnaires can.[159] Some surveys such as the Active Lives Surveys in England contain in-depth information on the types and context of the activity done and allow for analysis that objective measures do not.[166]

1.8 Physical activity levels and trends among children over time and as they age

Children's physical activity has been steadily falling since the 1990s and is a growing concern.[59,167,168] A recent 2018 global pooled analysis of 298 population-based surveys with 1.6 million participants aged 11-17 years old found that in 2016, 81·0% (95% uncertainty interval 77·8–87·7) of students aged 11–17 years were insufficiently physically active (77·6% [76·1–80·4] of boys and 84·7% [83·0–88·2] of girls). Their estimates for the United Kingdom found that overall, in 2016, almost 80% of adolescents in the United Kingdom were insufficiently active (79·9% (77·3–82·3)). Another large study in 2015 using data from The International Children's Accelerometry Database (ICAD) which comprises accelerometer data from twenty studies in ten countries (including the United Kingdom) and 27,637 participants found that physical activity levels varied by country. They found that the proportion of boys aged 9-10 accumulating >=60 minutes MVPA every day ranged from approximately 7% in the least active countries to approximately 30% in the most active countries. For girls, this was

approximately 1% in the least active countries to approximately 11% in the most active countries. Approximately 40% of the participants in the ICAD data were from the United Kingdom, and England specifically was considered 'intermediately' active compared to other European countries (e.g., Denmark, Estonia and Norway). These low levels of physical activity are prevalent across Europe. A study of 7,684 European children aged 2.0–10.9 years from eight European countries found that the proportion of children meeting the recommendations varied greatly by country and gender, ranging from 2% (Cyprus) to 15% (Sweden) in girls and from 9.5% (Italy) to 34% (Belgium) in boys. Additionally, cpm and MVPA was higher in boys compared to girls from the age of five years and boys engaged in a wider range of MVPA; sedentary time was higher for girls compared to boys. However, there was no overall difference in light activity by sex.[169]

While using device-based measures provides more robust estimates of children's physical activity, they are expensive to use in large epidemiological surveillance and monitoring studies. In England, there are two main national surveys that measure compliance with the child MVPA recommendations: Health Survey for England and Active Lives Children and Young People Survey.[170] Both surveys rely on self-reported measures for children's activity. The latest estimates from the Active Lives Children and Young People Survey pre-Covid-19, from 2018-2019, found that 47% of children and young people, representing 3.3 million children in England were meeting the Chief Medical Officers 2019 guidelines of taking part in sport and physical activity for an average of 60 minutes or more MVPA/day across the week. However, 29% (2.1million) did less than an average of 30 minutes MVPA/day.[16] Sport England ran the survey during the Covid-19 pandemic from mid-May to late-July 2020 (n=20,000 responses), when restrictions in England were easing and schools reopened for children in reception (beginning of primary school) and Year Six (end of primary school. The 2019-2020 survey's sample size was lower than the previous year owing to the pandemic and was predominantly completed at home. The proportion of children and young people reporting they were active from mid-May to late-July 2020 fell by 2.3% compared to the previous year. This resulted in just over 100,000 fewer children meeting the recommended level of activity compared to the same period the previous year.[171] However, these estimates are likely to overestimate activity levels of children as self-reported data are subject to recall bias [172] and as it is likely to exclude children who are disadvantaged, who also tend to be less physically active.[173] Concerns have also been raised about unstandardised and validated surveys being administered to assess physical activity in the population over the Covid-19 pandemic.[172]

The Active Lives Children and Young People Survey has been ongoing since 2016. While the survey has not been validated, they did not ask children to recall their activity pre-pandemic, reducing mood-congruence bias which has been a concern in other studies that have aimed at understanding physical activity levels during the Covid-19 pandemic.[172] While there are known limitations to self-reported physical activity data, they do play an integral role in understanding physical activity patterns and trends across the population.[174] The results of the survey from 2021-2022 will be critical to assessing how children's long-term engagement in activity has been affected by the Covid-19 pandemic and associated lockdowns.

The latest wave of Health Survey for England completed in 2015, based on self-reported data found that 22% of children aged five to 15 met the physical activity guidelines. This was 23% in boys and 20% in girls.[175] However, concerns have been raised about the validity of Health Survey for England questionnaire.[176] A validation study done on the Health Survey for England questionnaire found that it substantially overestimated physical activity with a statistically and biologically significant bias in MVPA of around two hours/day. For boys (n = 64), the mean difference between the questionnaire and the accelerometer in MVPA was +127 min/day (95% CI +91 to +163), and for girls this was +118 min/day (95% CI +91 to +144). Further, the discrepancy between Health Survey for England's estimates of the proportion of children meeting the recommendations compared with the accelerometer validation study was substantially large – 83% vs 3% for boys and 56% vs 2% for girls.[176]

In one wave in 2008, Health Survey for England included device-based measures (accelerometers) for physical activity.[177] The results from 2008 found that using accelerometer data from approximately 1700 children, only around one in five children had achieved the intermediate level of 'some activity' (at least 30 minutes of MVPA on each day), with 47% of boys and 61% of girls in the low activity group. Further, their results found that 33% of boys and 21% of girls met the government recommendations for physical activity, which at the time stated that children must do at least an hour of at least
moderate activity every day. The accelerometer findings approximated those of the self-reported data of children where 32% of boys and 24% of girls met the government recommendations. However, the accelerometer data indicated a larger discrepancy in the activity of older vs younger children when compared to self-reported data where in one instance, 51% of boys aged 4-10 years had met the recommendations as opposed to 7% of boys aged 11-15 years. In girls, this was 34% of girls aged 4-10 years compared with no girls meeting the recommendation aged 11-15 years. Their results also showed that self-report may

underestimate MVPA in younger children and overestimate MVPA in older children. Additionally, a prospective cohort study using device-measured accelerometery data from the Millennium Cohort Study of 6,497 children aged 7-8 years in England found that children spent a median of 60 min (IQR 47–76) in MVPA/day; and a slightly higher proportion of children met the Chief Medical Officer's guidelines compared to data from Health Survey for England (51% of children (38% girls and 63% boys)).

Globally, in a pooled analysis between 2001 and 2016, the prevalence of insufficient physical activity significantly decreased by 2.5% for boys, though there was no significant change for girls.[59] The same study found that in the United Kingdom, there was 1.5% reduction in prevalence of insufficient physical activity in boys from 2001 to 2016 (2001 estimate: 76.2% (73.8–78.5); 2016 estimate: 74.7% (71.6–77.5)). For girls, there was a 0.2% increase from 2001 to 2016 (2001 estimate: 85.2% (83.2–87.1); 2016 estimate: 85.4% (83.2–87.4)), meaning from 2001 to 2016, a slightly higher proportion of girls in the United Kingdom became physically inactive, and a slightly a smaller number of boys were physically inactive.[59] The decline in physical activity is seen both over time as demonstrated above, and over the life course where physical activity tracks from childhood to adolescence. A large study in 2015 using data accelerometer data from ICAD, a study including twenty studies in ten countries (including the United Kingdom) and 27,637 participants found children's physical activity decreased with age.[178] They found similar sex differences as the global pooled analysis[59] where boys were more active and less sedentary than girls at all ages. After ages 5–6 years old, there was an average difference in physical activity of 31 average accelerometer counts per minute (cpm) (29 cpm in boys, 32 cpm in girls), between each age group. Further after five years of age there was an average cross-sectional decrease of 4.2% in total physical activity with each additional year of age (3.7 % decrease in boys, 4.6 % decrease in girls). This decline in physical activity was explained mainly due to lower levels of light-intensity physical activity and greater time spent sedentary. Importantly, physically active lifestyles develop very early in childhood and the stability of physical activity is moderate to high along the life course from youth to adulthood[179] and from early to late childhood.[180] When tracking individual components of physical activity, that is, bouts of sedentary time, LPA, MPA, and VPA from early (3-5 years) to late childhood (9-11years), in both girls and boys, the total volume and smaller bouts tracked strongly over time (compared to longer bouts). Further, total volume and bouts of sedentary time increased while for LPA this decreased,[180] highlighting the need for interventions to focus on reducing sedentary time from an early age in children by converting sedentary time to LPA, MPA and VPA. This decline in activity by age has also been observed

in England specifically. Using accelerometery data to analyse change in children's physical activity and sedentary time between Year 1 (5-6 years) and Year 4 (8-9 years), there was a decrease in CPM from 747 to 673 in boys and from 686 to 587 in girls. Boys' time spent in MVPA reduced from 72 to 69 and girls' from 62 to 56 minutes per day.[181] This corresponds to both girls and boys spending more time being sedentary. Considering children are both less active over time, and physical activity decreases with increasing age, with stable trajectories across the life course, those two discoveries together can be detrimental to children's health in the long term. Further, given that active children tend to remain active adults, targeting interventions at a young age is recommended in order to have the largest sustained impact and prevent age related decline in children's physical activity.[182]

It is also important to note that as the physical activity recommendations and guidelines change, the proportion of children meeting them varies and large discrepancies can be observed. For instance, the 2011 Chief Medical Officer's Guidelines stated that children aged five to fifteen should engage in at least 60 minutes of MVPA daily of which 30 minutes should be done in school. The data from the Active Lives Children and Young People Survey 2017-2018 found that less than 20% of children were meeting these guidelines.[183] When the following year the guidelines changed and stated that children aged five to fifteen should engage in an an average of at least 60 minutes of MVPA daily,[68] the data in the same survey found that 47% were meeting the recommendations – a difference of 27% children in two years.[16]

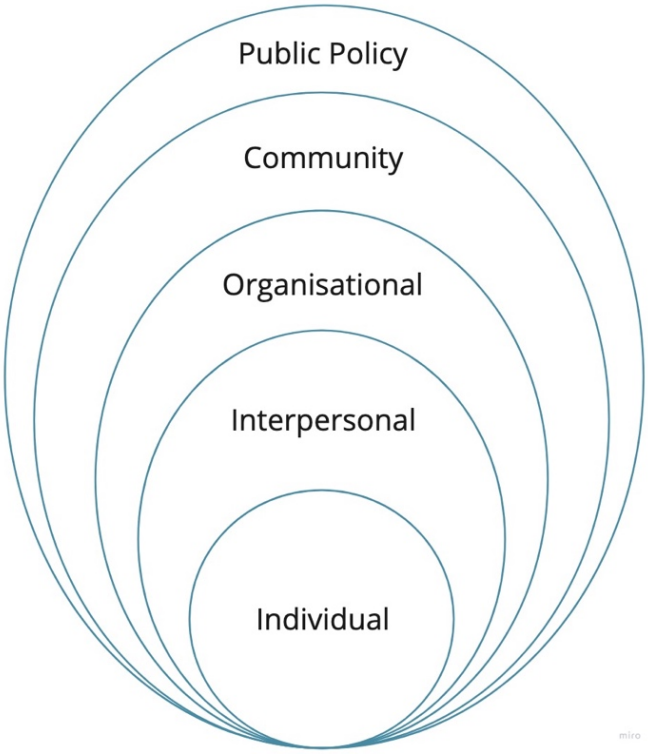
Regardless of the dataset used and method of measurement, a large proportion of children in England and the world are not physically active, with girls consistently being less active than boys. A targeted approach that focuses on multiple determinants of children's activity at both the individual and system level are required to increase children's activity and turn the tide. This includes population surveillance, studying the effectiveness, cost-effectiveness and implementation of potential policies and strategies, and implementing verified system-wide policies at scale.[184,185]

1.9 Determinants of physical activity in children

Successful public health programmes previously have been built on an acute understanding of health behaviours and the contexts in which they occur.[186] The socio-ecological model provides a holistic framework for understanding physical activity behaviour in children that

goes beyond individual characteristics. It enables a more overarching understanding of children's activity by incorporating the interrelationships between the individual and the social, physical and policy environments in which the individual child belongs.[187] These broader contexts include family, teachers, friends, neighbourhood associates, formal and informal organisations, design of the built environment, and services that facilitate or inhibit physical activity.[188] The socio-ecological models provide a comprehensive approach necessary for examining physical activity which is a complex behaviour, and the multilevel factors that are determinants of children's physical activity that may influence one's ability to be sufficiently physically active.[189] It allows for identifying the most appropriate strategies to promote physical activity by identifying individual determinants: behavioural facets like sedentary time; social environmental contexts such as family, teachers, peers, and friends; and physical environmental features such as the built environment and availability of physical activity equipment (Figure 1.4).[190,191] The success of using a socio-ecological model in designing interventions has been previously demonstrated. A socio-ecological approach promoting physical activity in adolescence showed weight benefits maintained two and a half years after intervention cessation and the efficacy could be even larger in the most sedentary and least wealthy adolescents.[192]

Figure 1.4 Socio-ecological model



Adapted from McLeroy KR, Bibeau D, Steckler A, Glanz K. An ecological perspective on health promotion programs. *Health Educ Q* 1988, 15:351–377

At the core of the socio-ecological model is the *individual (*child*).* A child's intrapersonal correlates can increase or decrease the likelihood of them being physically active. Such correlates include sex, age, ethnicity, beliefs, and self-efficacy. Being female has been consistently negatively associated with physical activity, with girls constantly being less active than boys.[193–195] This trend is also reflected in British child populations as seen in the physical activity prevalence rates in the Active Lives Children and Young People Survey, Health Survey for England, and smaller-scale studies.[196–199] There is also a strong evidence base that age is a strong correlate for children's activity;[194,195,200] studies have found an inverse relationship between age and physical activity, with decreasing levels of activity with increasing age from childhood.[178,201] A recent study using multilevel modelling to assess variation in children's MVPA and the effect of fixed (sex, age) and random effects (neighbourhood, school, friend groups) found that the largest proportion of variability in device-measured MVPA was attributable to individual levels correlates (half of the total residual variability for boys and two-thirds of the variability for girls).[202] However, other correlational research studies testing theories and models focusing on individual dispositions that increase physical activity found that individual dispositions explain, at best, 20–40% of

the variance in physical activity[203–205] suggesting the need to focus on broader, multilevel, ecological approaches to physical activity promotion. However, the focus of children's physical activity policy in England has been on changing individual lifestyle determinants through behaviour and education and is based on individual agency.[19,206,207]

While some of these determinants are non-modifiable, individual determinants such as low physical fitness that are consistently shown to be negatively associated with physical activity levels in adults, are modifiable.[208] In addition to biological and demographic factors, psychological, cognitive and emotional factors have also been identified.[209] In children, intention and knowledge of the benefits of physical activity and self-efficacy were positively associated with overall physical activity.[210] When children and adolescent populations were studied together, perceived fitness, competence, and physical appearance showed positive associations to physical activity. Self-efficacy, explained as an individual believing that they are capable of exercising control over themselves and their habits, was positively associated with physical activity in children and in terms of emotional wellbeing, 'affective judgement', explained as pleasure or displeasure of performing an activity, was also associated with physical activity.[211]

At the *interpersonal* level, peers, family, and teachers influence children's physical activity. Parents can shape children's physical activity by parental modelling, encouragement, support for physical activity, and parental physical activity levels.[212] Parental support has been consistently positively and significantly associated with child activity.[213] However, questions remain about whether this is a direct correlation or there are mediating factors at play (e.g., parental support for physical activity increases a child's self-efficacy, leading to increased levels of activity). A recent systematic review found a majority of studies observed a positive relationship between parent and child physical activity levels, regardless of the age of the child, the gender of the parent-child dyad, and the physical activity outcome.[214] There are other parental correlates of physical activity in children such as family socioeconomic status. These correlates can be difficult to change, but they may help identify populations for implementing targeted interventions rather than act as the focus of an intervention itself.[212] However, children spend a large proportion of their days away from their parents, at school, among teachers and peers. Therefore, it is important to identify these *interpersonal* relationships and their effect on children's activity. Teachers play a significant role in influencing children's physical activity both when they motivate children and when they partake in activity with

children.[215] Finally, in addition to support from parents and teachers, children who have supportive friends and peers have also been found to be more physically active compared to those who experience negative peer interactions and might be less physically active.[216] Therefore, interventions that promote and facilitate this are more likely to be effective and potentially more sustainable.

At the *organisational* level, the home, the neighbourhood, and school are important correlates. At the school level, the availability of physical activity programs and equipment and at the neighbourhood level, features such as pedestrian and cyclist safety structure is positively associated with children's physical activity.[217] It has been consistently found that the time children spend outdoors is positively associated with their physical activity.[209] Therefore, the built and natural environment should be accessible to children and set up to facilitate activity. While the home environment has previously not been given as much importance in relation to children's activity, changing the home physical environment (e.g., introducing a television limiting device) can positively impact children's activity.[218] The *community* level, also known as the institutional level, corresponds to the structures and systems within individuals operate. In the case of this thesis, it relates to the school setting. Safe walking, transport and cycling routes to school,[219] school facilities, the school natural and built environment (sports facilities, gyms, permanent facilities,[220,221] and school-based physical activity policy,[222,223] all influence children's physical activity. Finally, the *public policy* level relates to global advocacy, national and local regulations and laws, and policies covering the whole system that can facilitate wide-ranging actions across multiple sectors and domains.[224] Understanding how and why individuals adopt physically active lifestyles is key to drive up physical activity levels across populations. Outlining these determinants and studying their association to physical activity is crucial to developing effective, practical interventions that can target modifiable determinants and behaviours in children. Non-modifiable correlates of activity such as sex and ages can serve as markers of potential risk factors, targets of future intervention strategies, and indicators for progress over time. Therefore, interventions targeting determinants at all levels are more likely to be successful than those that target determinants in silos.[224] Physical activity policy must include a collection of interventions that focus on determinants at every level.

1.10 Children's physical activity interventions

Interventions aimed to increase children's physical activity have been implemented across various settings including in the community, schools, homes, and combination settings. They usually have only a physical activity component but often include education and diet as well. In this section, I will describe why schools are considered an ideal setting to increase children's activity and give examples of opportunities within the school environment and day that can be used to increase children's activity.

1.10.1 School-based approaches to physical activity

School-based physical activity interventions are embedded within a broader ecological context and should be recognised as such when designing, implementing, and evaluating them, as described in Figure 1.4 and section 2.8. Taking a socio-ecological approach allows for recognising interpersonal drivers of behaviours while also recognising more important factors that influence this behaviour such as policy, the socio-cultural environment, and physical characteristics. The integration of health, physical education (PE), and school sport has made schools responsible for supporting their pupils to be active and helping them achieve the physical activity recommendations.[225] The United Kingdom government has encouraged schools to introduce programmes that can positively influence children's physical activity without competing with curriculum time such as active breaks, active learning, classroom-based activity and creating an overall active environment within schools.[226] Physical activity is a complex behaviour that requires a whole system-based approach to create change, with schools being an integral part of that system.[227] There are multiple occasions for children to be physically active over the course of the school week, including during break times, sport, PE lessons and active travel to and from school. Studies have shown interventions directed at these distinct time points can increase children's physical activity.[228,229]

Schools have been considered an ideal environment to target interventions to increase children's activity,[230] and are an integral part of the WHO's target of a 10% relative reduction in prevalence of insufficient physical activity globally.[231] While schools alone cannot reverse the trends in children's inactivity, it is also unlikely that this trend can be reversed without strong school-based physical activity policies and programmes. Most children in England have access to schools. In England as of early 2021, there were 4.71 million children enrolled in state-funded primary schools, implying the potential for school-based policies to

reach almost all children.[232] Schools provide an opportunity to implement interventions in non-selective groups and can make interventions equitable by requiring little to no individual agency.[233] Schools, unlike any other institutions have the most continuous and intensive contact and influence on children during their first two decades of their lives,[230] and it is the developmental age when health behaviours become embedded.[234] This continuous and intensive exposure to schools across children's lives allows for the 'dose' of physical activity to be kept constant, which can be beneficial. However, for school-based interventions to be successful, they need to be closely aligned to education policy.[235] Additionally, they need to be adaptable to allow for variation in implementation that suits the complex social and physical environment operating in schools, enabling their sustainability.[236]

Schools can provide children with a structured environment and schedule to be physically active. The Structured Days Hypothesis suggests that children in 'structured' environments (schools) with adult supervision (teachers) engaging in pre-planned activity (TDM) are more responsive to engaging in physical activity and regulating obesogenic behaviours.[237,238] In addition to the structure, schools can help create both formal and informal occasions for children to be active using pre-existing school infrastructure and resources.[239] Notably, targeting interventions at schools is useful as this is the time that children's physical activity starts declining[178] and it allows an opportunity to create an active lifestyle that can be tracked to adulthood.[179]

1.10.2 Physical education

PE lessons are designed to make children fit and health and to improve health literacy.[240] In the United Kingdom, PE is mandatory in the National Curriculum at all stages of education. It provides an opportunity for children to develop competence to excel in a broad range of physical activities, ensure children are physically active for sustained periods of time, that children engage in competitive sports and activities that can lead them to live healthy and active lives.[241] For children in Key Stage 1 (5-7 years), pupils should be taught to master basic movements including running, jumping, throwing and catching, as well as developing balance, agility and coordination, and begin to apply these in a range of activities; participate in team games, developing simple tactics for attacking and defending; and perform dances using simple movement patterns.[241] For children in Key Stage 2 (7-11 years) pupils should be taught to: use running, jumping, throwing and catching in isolation and in combination; play competitive

games, modified where appropriate (badminton, basketball, cricket, football, hockey, netball, rounders and tennis); and apply basic principles suitable for attacking and defending.[241] These current policies demonstrate the change in PE priorities from fitness and competition to refocussing physical activity on developing skills and encouraging children to understand the benefits of regular physical activity.[240,241]

The whole school day and PE lessons are key opportunities for children to accumulate physical activity. Given PE is mandatory for children in the United Kingdom across all ages, quality PE could have important health implications at the population level.[242] Currently, the United Kingdom Association for Physical Education recommends pupils should be actively moving for 50–80% of the available PE lesson time, though no intensity level of activity is stated.[243] A recent systematic review focused on primary school children found that students spent a mean (95% CI) 44.8 (28.2–61.4)% of PE in MVPA,[244] below what is recommended by the United Kingdom Association for Physical Education. This insufficiency of MVPA during PE lessons has been consistently reported since the early 2000s, both in a review in 2005[245] and in children of varying ages, and in a review in 2017 that focussed on secondary school children[246]. These findings should be viewed as a reflection of the noteworthy changes to PE policy in the United Kingdom over that time period.[225] The most recent cross-sectional analysis of British children in year 7 (12-13 years old) found, on average, pupils spent 23.8% of PE lessons in MVPA, and there was a relationship between enjoyment of PE to fitness which did not vary by sex.[247] This suggests that while PE provides a novel opportunity to increase children's activity, current evidence shows that it is unable to provide children with adequate amounts of MVPA. When interventions designed to increase MVPA in school PE lessons have been introduced, they have been able to increase MVPA during PE. A systematic review synthesised this evidence to find students in intervention conditions spent 24% more lesson time in MVPA compared with students in usual practice conditions (standardized mean difference = 0.62).[242] The interventions that underly this increase in MVPA include teacher professional learning focusing on class organisation, management and instruction, and supplementing usual PE lessons with high-intensity activity.[242] PE lessons are a primary vehicle to increase children's activity. However, their success should be measured solely based on the amount of MVPA children accumulate during that time, as there are other important markers of PE quality such as enjoyment of physical activity and the development of physical literacy in children, both of which are important to create sustainable behaviour changes.[248]

1.10.3 Classroom-based physical activity

School-based physical activity interventions can be directed at regular education classrooms by integrating learning with physical activity, which can help teachers buy-in as they do not have to choose between academics and health interventions.[249] Preliminary evidence suggests that children in primary schools in the United Kingdom spend 70% of class time sitting[250] and could benefit from integrating learning with physical activity in the form of physically active learning. There are two mechanisms by which introducing physically active learning could benefit children. Firstly, long hours spent sedentary in childhood can track into adulthood and have adverse health effects, and secondly, physically active learning might improve children's cognitive functioning, academic achievement, and behaviour.[236] Due to these reasons, there have been a number of classroom-based physical activity interventions implemented. These range from standing desks, physically active learning, curriculum focused active breaks, and movement integration.[251] Physically active lessons are popular and are teacher-led sessions that incorporate physical activity into the teaching of academic content and are different from 'activity' or 'brain breaks', which are sessions of classroom-based physical activity without educational components.[249] They can help children meet the physical activity recommendations when compared with extending recess and PE during the school day.[252]

In recent times systematic reviews that have synthesised their effectiveness on physical activity, and educational outcomes, have found mixed evidence overall,[253–255] and have highlighted certain methodological considerations.[256] Daly Smith et al.,[256] argues that previous reviews are lacking since it is important for studies and reviews to distinguish between acute and chronic classroom movement breaks and physically active learning interventions; the former relies on immediate blood flow and changes to the brain biochemistry, whereas the latter relies on altering brain structure and function.[256] Nevertheless, most systematic reviews to date have found a positive relationship between classroom-based physical activity and physical activity levels in children.[252,253,255,257] Watson et al., found that in their included studies, there was a 2-16% increase in MVPA during intervention lessons and 2-12% increase in school day MVPA, suggesting added value of classroom-based physical activity both during lesson time and across the day.[257] However, in their meta-analysis that included three of the total 39 reviewed, they found no effect of classroom-based physical activity on physical activity (standardised mean difference = 0.40 (95% CI: -0.15,0.95).[257] For school-based physical activity interventions to be sustainable teacher buy-in is crucial[258] and this is

the same for classroom-based physical activity interventions.[259] Given the competing nature of physical activity and educational outcomes in schools, if classroom-based physical activity can improve both, teachers might be more likely to implement them, and it can be an important facet for sustained implementation.[259] The evidence on the effect of classroom-based physical activity on cognitive outcomes is mixed,[253,256,257] with the most recent systematic review finding no effect.[256] Though evidence suggests that classroom behaviour[256,257] and on-task behaviour[255,257] improved in children following classroom-based physical activity. Overall, studies evaluating the effect of classroom-based physical activity interventions are of low-to-medium quality, and more robust evidence is required to understand their effectiveness and implementation fully.[253,256]

1.10.4 Recess and breaks

One of the most common forms of physical activity break during the school day is recess and children can accumulate up to 40% of their daily physical activity requirements during this time.[260] Recess and playtimes can also contribute to 44% of school-day step counts.[261] Recess and lunchtime periods are mandatory in English schools, offering a chance to almost all children in England to be physically active, and present the single greatest opportunity for children to be active through the year, including the least active children.[261–263]

Given the opportunity that recess, breaks, and playtime offer for physical activity promotion in children, it is critical for them to remain in place and even be enriched with interventions to further help contribute to children's activity levels. Further, a five-year longitudinal study tracking changes in children's recess and lunchtime physical activity levels among primary school children found that there was an age-related decline in children's physical activity. They observed significant decreases in recess and lunchtime MVPA with larger decreases occurring in older children. Additionally, the contribution of recess to daily MVPA increased in younger children over time ($p<0.001$) though significant decreases were observed in the older cohort ($p<0.001$), suggesting a need for interventions in primary and secondary schools to foster physical activity during recess.[264] This need has been reflected in the literature where over the last decade, a number of interventions have been introduced within school setting recess settings to increase children's physical activity. These include, playground modifications,[265–268] loose equipment (e.g., balls, ropes),[267,269–271] and structured school recess.[272–274] Subsequently, there have been a number of reviews, predominantly

narrative reviews, that have aimed to synthesise the evidence on the effectiveness of interventions that have intended to increased children's activity during recess and playtimes.[275–280] Despite numerous intervention trials and studies, and systematic reviews, the evidence of the effectiveness of such strategies is mixed.[275–280]

The focus of most of the systematic reviews that have assessed the impact of recess setting interventions on children's activity has been focussed on assessing MVPA, and not on LPA or sedentary time. One meta-analysis that quantified the impact of recess interventions on children's physical activity found a positive and significant mean difference between pre-test and post-test time after implementing a recess intervention.[280] However, this meta-analysis included studies implemented on preschool children which is problematic as preschool recess settings are different to school settings.[275] A recent review that included studies from 2011 to 2020 included 43 studies, of which 42 were in primary schools and one was in a secondary school.[275] School recess-based interventions ranged from multicomponent interventions to structured school recess, loose equipment, natural environments, playground modifications, playgroup density, and unstructured school recess.[275] The results from included multicomponent interventions were inconsistent. However, this seems plausible since multicomponent, as the name suggests, included multiple components and teasing out the effectiveness of these and the different combinations is analytically difficult. Several studies included in the review introduced structured and/or organised activity to recess times, though the results of their effectiveness were mixed and inconsistent. This could be explained by the potential time spent on organising and implementing more structured activity.

School recess provides an opportunity for all children to be active in the school day where the physical activity dose can be kept consistent. However, more research is required to address some of the current limitations in the literature including using device-based measures for activity, tracking changes in activity longitudinally across multiple time points, and allowing sufficient time for the intervention to show possible effectiveness.

1.10.5 After school physical activity

The after-school period provides occasions for children to accumulate their daily physical can be used to target interventions to increase physical activity. This can be in the form of active

commuting, school-extra-curricular physical activity, which in England is frequently done in the form of structured sports coaching and team practice,[262] and single sport interventions. Participation in after-school programmes can be beneficial to children's health and has been shown to make a notable contribution to children's daily physical activity,[281] but evidence on their overall effectiveness is mixed.[282] The most recent systematic review and meta-analysis found the pooled intervention effect of after-school intervention at endpoint follow-up was 4.84 min/day of MVPA (95% CI −0.94 to 10.61).[282] A study by Gortmaker et al., found the largest significant mean difference in MVPA from baseline to end of intervention in the intervention versus the control group was 10.5 min/day (95% CI 1.5 to 18.6, p=0.017).[283] However, Gortmaker et al's intervention targeted children already participating in an after-school physical activity programme. Their intention was to optimise physical activity in children by altering this pre-existing programme. Thus, it might not have been the actual intervention that corresponded to an increase in children's MVPA, but optimisation of the setting that enabled this increase. After school interventions have been shown to be particularly beneficial in certain subgroups of high-risk children, including those from deprived background who are particularly at risk for weight-related comorbidities [284] and children who are overweight or obese.[285] Further, evidence from the Avon Longitudinal Study of Parents and Children indicated that the biggest peaks of physical activity within a day took place during the after-school period,[286] suggesting that this might not be the most appropriate time to intervene to increase children's activity, but as an aid to increase activity overall through multicomponent interventions.[287]

1.11 Effectiveness of school-based physical activity interventions

School-based physical activity interventions previously have been shown to be associated with increased levels of self-reported physical activity in children in two large robust systematic reviews in 2007 and 2013.[288,289] Ever since there has been a huge shift in measuring physical activity where using device measurement tools such as pedometers and accelerometers is now more common.

A recent review in 2019 by Love et al using only accelerometer-assessed daily minutes of MVPA found that school-based physical activity interventions are not effective at increasing minutes of MVPA across the whole day, and this was consistent across genders and different

deprivation groups. This is important given that inequalities in children's physical activity have been observed both globally and in the United Kingdom.[290–292] In England specifically, based on the Active Lives Survey for Children and Young People 2019-2020, those from low affluence families are the least likely to be active, where 53% met the government recommendation in the most affluent group, followed by 45% in the medium group, and only 38% in the least affluent group. However, these data are based on self-report and have known issues (Section 1.7). Overall, studies in the UK and globally, using device-based measures of physical activity, have shown no clear social patterning in children's adherence to the physical activity guidelines when using maternal education,[293] maternal and paternal education[294] and composite measures of deprivation such as the Index of Multiple Deprivation[295]. However, there has been evidence of differences in activity levels based on ethnicity, which can be considered a proxy measure of deprivation.[296,297] Specifically, in England, an analysis of VPA from the Millennium cohort study, using device-based measures of VPA among children aged seven to eight years old demonstrated clear socioeconomic (measured by maternal education) and ethnic differences in children's time in VPA. Those from certain minority ethic groups and those from a lower socioeconomic group accumulated less of their daily activity from VPA. This is pertinent as VPA is more strongly associated with adiposity, obesity, and overall health.[298] While Love et al. showed that school-based physical activity interventions are not effective at increasing minutes of MVPA across the whole day across different deprivation groups, there have been interventions that have failed to reach those most in need due to access, complexity, competing interests of caretakers (e.g., parents), cultural beliefs, and limited access to safe play space.[299–302]

Love et al restricted their inclusion criteria in their systematic review to controlled trials for which they could obtain device measured minutes of MVPA across the whole day. They justified their use of only MVPA across the whole day citing reasons of school-based physical activity interventions showing magnified effects in school (compared to the whole day) as seen in other studies.[303] However, measuring minutes of MVPA in school and outside school separately is important to investigate any potential compensatory effects of in-school interventions or potentially other mediating effects that may in fact lead to an increase in activity outside school as a result of implementing in-school intervention. This was addressed in another recent meta-analysis that specifically investigated in-school activity.[304] They found no evidence of a positive effect from school-based physical activity interventions on MVPA in children in schools.[304] A recent pooled analysis by Hartwig et al., of 6,621

children and adolescents aged four to 18 years from 20 controlled trials assessed the impact of school-based physical activity interventions on cardiorespiratory fitness and device-measured physical activity.[305] They found that school-based physical activity interventions produced minor improvements in students' cardiorespiratory fitness by 0.47 mL/kg/min and modestly increased physical activity with approximately one additional minute per day of both MPA and VPA. They did also find that benefits with differential based on gender, with boys accumulating more VPA and had almost double the increase in cardiorespiratory fitness compared with girls. This suggests that school-based physical activity interventions might be better suited for boys than girls, given that the differences in facilitators and barriers to physical activity differ for boys and girls.[306] Nevertheless, a systematic review that specifically examined the effectiveness of school-based physical activity interventions for adolescent girls found minimal increases in girls' physical activity levels but found promise in multicomponent interventions and those underpinned by theory.[307] This idea was disproved in a recent trial by Jago et al.[308] who evaluated the effectiveness of PLAN-A, a school-based peer led physical activity program for adolescent girls underpinned by theory found that the intervention was not effective at increase MVPA. Focussing on specific school-based interventions in England that aimed to increase children's physical activity and evaluated, such as PLAN-A,[308] WAVES,[309] Active for Life Year 5,[310] Action 3:30,[311] and GoActive[312] have also all found little to no positive impact on children's activity.

1.12 Implementation of school-based physical activity interventions

Reasons for school-based interventions not being effective include the complex nature of interventions that have multiple components,[309,310] leading to poor implementation, or high implementation rates but variability in implementation (e.g., not delivering all the components of the intervention).[309] Another reason is the long time-gap between designing interventions to implementing and evaluating them, and the lack of a whole-systems based approach that targets schools, homes, communities, and upstream determinants.[310,312]

Moreover, the one reason that has consistently been cited as an explanation for the ineffectiveness of school-based physical activity interventions to increase children's physical activity levels has been implementation and adherence issues.[313–316] Implementation is defined as "a specific set of activities designed to put into practice an activity or programme of known dimensions".[317] This encompasses all the processes of programme delivery,

including fidelity, dose delivered and dose received, quality, responsiveness, differentiation and adaptation [318].The United Kingdom Medical Research Council's guidance on process evaluations, a method commonly used to evaluate complex health interventions clearly outlines the need to understand the effect of implementation while trialling the intervention and post-evaluation scale up.[319] Further, for an intervention to prove successful, it depends greatly on the context and its multiple components such as skills, pre-existing circumstances, resources and attitudes. [319–322] Pre-existing circumstances and contexts that the intervention is delivered in will have different causal pathways owing to the different populations and settings. As outlined by Durlak and DuPre,[318] it is vital to understand the implementation of these interventions to put into context the efficacy results. It is important to understand the barriers and facilitators associated to successful implementation, and to examine whether levels of fidelity change the outcomes being studied in relation to physical activity.

Behavioural interventions in children in general, including those targeting physical activity, diet, sleep, and sedentary behaviour show larger effect sizes in efficacy trials, compared with effectiveness studies, which are often explained by poor implementation fidelity and the delivery agent of the intervention.[323] A recent systematic review found that scaled-up obesity prevention and treatment interventions in real-world settings, which include school-based physical activity interventions intervention, show less than 75% of the effect seen in efficacy trials like RCTs.[22] This was also observed in a systematic review that only evaluated physical activity interventions in community settings delivered at scale where there was a loss of 59% in effect sizes of scaled-up interventions from pre-scale.[324] A prevalent reason for this loss is due adaptations to the interventions when scaled-up and can be in the form of service setting adaptations (e.g., physical location of delivery, who delivers the intervention), target audience adaptations, mode of delivery adaptations (e.g., frequency of duration of interventions), and cultural adaptations.[22] Another reason for loss of efficacy when scaled-up is the sustainability of school-based physical activity interventions that show initial positive effects in the short-term but fail to remain sustainable often due to their multicomponent nature.[325–327]. Kennedy et a. most recently used the RE-AIM framework to study implementation at scale of school-based physical activity interventions.[328] They report that few school-based physical activity interventions are scaled-up. Among those that are scaled-up, the number of students exposed to the interventions is not commonly reported with the representativeness and characteristics of students exposed even more rarely reported; citing a

real gap in the literature to understanding which children are exposed to scaled-up school-based physical activity interventions.[328]

The pathways between school-based physical activity interventions and overall physical activity are complex and influenced by numerous determinants in school, in the community, and in the household of a child, influencing both the amount of activity a child accumulates, but also the type (sport, structured activity, unstructured/incidental activity, and in-school and after-school activity.[329] A systematic review[258] outlined the factors most prevalent in the literature for school physical activity implementation. These were: time, availability and quality of resources, a supportive school climate, training support for technical and programme staff, self-efficacy including ease of implementation and teacher engagement. Their review also found that dose delivered and received were the most commonly reported process evaluation terms, with fidelity rarely being mentioned. This could be a testament to the challenges in measuring fidelity effectively in real-world settings.

1.13 Using routine data to evaluate school-based physical activity interventions

Routine data is valuable both for designing and informing public health policies and interventions, and for evaluating them. Interventions to improve health and social care are widely implemented in the United Kingdom such as in the form of healthcare delivery through integrated care systems,[330] and improving overall health by reducing childhood obesity in the form of the United Kingdom soft drinks levy.[331] Assessing the impact of these health interventions enables both public health practitioners and policymakers to set priorities, improve services, tweak existing services, and informs future policy. However, these interventions are not always evaluated to a high quality, and sometimes not evaluated at all, owing to onerous data collected, cost, and time restrictions.[52,332] Governments often need ‘quick policy wins’, leaving little time for evaluation of interventions before moving on to another intervention.[19] This is visible with the UK’s childhood obesity policies over the last three decades, which have mainly focused on diet and physical activity in children, with a greater emphasis being placed on the former.[19] Theis et al., found that the way policies are proposed means the majority are unlikely to be implemented or evaluated. In part, because a substantial proportion of policies and strategies by the government puts the onus on individuals where governments have inclined to prioritise the delivery of information and capacity building in their obesity strategies rather than taking a more active approach in directly determining the

choices available to individuals through system-level measures (e.g., a recent exception of the Soft Drinks Industry Levy).[19] By taking a less interventionist approach and relying on individual agency to change behaviour, the government's approach is less likely to be equitable and effective.[19,233] Taking a more interventionist approach to health policy can facilitate evaluations of these interventions using routine data that might not be possible when relying predominantly on individual agency and choices, as uptake and equity are difficult to measure when the data are not collected.[331]

In England, national physical activity policies relating to children and young people have evolved over time with the four cornerstones of physical activity policy comprising national guidelines on physical activity, setting population goals and targets, surveillance or health-monitoring systems, and public education.[333,334] National goals and targets for children's physical activity have focused primarily on schools providing physical education and sport with other strategies such as active travel, the availability of sports clubs, and education campaigns to increase awareness of the guidelines with the public.[207] National policies require national data and national evaluations. However, they are rarely done for physical activity interventions or policies.[207] This in part might be because there has been no single behaviour change intervention to alter physical activity habits in children nationally and the government strategy has relied on setting guidelines and targets of physical activity that children should reach instead of providing means to achieve them. Interventionist approaches can be evaluated using routine data. The United Kingdom soft drinks industry levy was evaluated against changes in soft drinks purchased by British households.[331] These types of evaluations are critical to understanding human behaviour in real-world settings as the potential impact that policies might have without creating artificial trial settings. Setting targets and goals for children to meet the physical activity recommendations in England that go beyond policies that focus solely on delivery and accessibility of physical activity opportunities is important. This will allow for metrics to be placed along the pathway from creating opportunities for children to be active to metrics such as the proportion of children meeting the CMO's recommendations moving in a positive direction. These large scale-studies and policies can most easily be evaluated with routine data – to assess impact at the population level.

I have not found evidence of routinely available data being used on a national scale to evaluate a school-based physical activity intervention in England. Partly this is because there has been no single school-based physical activity intervention that has had national reach. When there

has been, in the case of Change4Life, a campaign focused on promoting physical activity in children aged five to 11 years in England,[335] this was not evaluated robustly and nationally at scale.[335,336] Routine data presents a novel opportunity to assess the impact of interventions at scale, but more importantly, routine data allows for a realistic and cost-effective evaluation that controlled trials do not allow. Further, RCTs, the gold standard for clinical research, is not considered the most appropriate evaluation strategy for school-based physical activity interventions due to issues in implementation in real-world settings, the importance of context, and the demonstrable loss in efficacy from controlled settings to real-world settings.[21,22,85,319,337] School-based physical activity interventions do not exist in isolation as a health policy but are closely tied to education and social care policy. By linking routine data from health, education, and census records, it is possible to explore the multifaceted impact of school-based physical activity policy.

1.14 Active mile initiatives

School-based running programmes offer pupils an occasion to be active during the school day through activities such as running, jogging, and walking. Active mile initiatives can be defined as "initiatives that support pupils to be active during the school day by providing regular opportunities for them to move around a marked route for a dedicated period of time (for example 15 minutes) and at a self-directed pace".[338] It is thought that children running continuously for this pre-specified time and over a pre-determined route cover an approximate distance of a mile, thereby coming to be known as 'active-mile' initiatives/programmes/interventions.[338] School-based active mile initiatives are widely promoted across the United Kingdom and endorsed by the government in national policy as a practical solution to increasing levels of childhood inactivity and obesity.[339,340] There are a range of active miles available with the most commonly adopted ones being The Daily Mile™, Marathon Kids, and The Golden Mile. Smaller local initiatives following the principles of an active mile do also exist.[126,338,341] Overall, active miles share similar features but they also differ[338] based on:

- when they are implemented (e.g., after school, before school, as a classroom break)
- how they are implemented (e.g., whole-school approach or opt-in)

Public Health England's policy briefing lists practical reasons for schools to adopt active miles including: it being easy to implement; implementers require no additional training; no equipment is required to do active miles; they can be done at a minimal cost; and they can be an inclusive activity.[338]

1.14.1 Effectiveness and implementation of active mile initiatives

Active-mile initiatives have high acceptability among teachers and children, can make a meaningful contribution for children to accumulate activity and MVPA in school, and present an opportunity for regular physical activity in school settings as part of a wider school-based approach.[338] Active miles have been evaluated and studied in the United Kingdom and elsewhere. For instance, Marathon Kids, an active mile initiative that gives primary school children the opportunity to walk and/or run the distance of a marathon over the school year has been studied in England by Chalkley et al.[125,342–344] and in the United States of America by Springer et al.[345] Other school-based running programmes similar to active mile initiatives have also been studied for their effect on cognitive outcomes (on-task behaviour).[346] Since this thesis is specifically focused on evaluating TDM and due to the large (>15) number of papers published on TDM over the past three years, the next chapter will systematically summarise the literature on the effectiveness and implementation of TDM.

Chalkley et al. have explored the barriers and facilitators of a school-based running programme (Marathon Kids) and examined pupil experiences of the same programme. Features and outcomes of the programme, programme implementation decisions, and the school climate acted as both facilitators and barriers to the programme. Physical, social, and educational aspects of the school (school culture, whole-school engagement, PE and physical activity policies and goals, and the built and physical environment) were either barriers or facilitators. Further, there was variability in the implementation of Marathon Kids and teachers noted that flexibility of the programme was important to increase their autonomy on when and how to implement it to suit the setting and context of the school.[125] Rigidity in implementation of school-based interventions has been recognised as a characteristic of an ineffective implementer as there is no 'one size fits all' approach.[347]

Studying children's perspectives and responses to active miles is important to create sustainable behaviour change. A qualitative study exploring pupil experiences to an active mile found that pupils experienced benefits to psycho-social outcomes (e.g., motivation and confidence) that led to enjoyment.[342] Importantly, children perceived the active mile to increase their fitness and ability to participate in physical activity. This is key as the 'true test' for active miles should be to increase children's running in schools, and attempt to create lasting behaviour change. If because of these physiological gains, children feel they can engage in more physical activity outside schools or in other settings, active miles can be part of the solution to the physical inactivity crisis. Further, pupil autonomy to participate facilitated enjoyment; when their autonomy was taken away from them to create a more controlling environment, this autonomous motivation was destabilised, leading to negative consequences.[342,348]

Marathon Kids has also been evaluated on its impact on self-reported physical activity, fruit and vegetable consumption, and related psycho-social factors among children aged eight to ten years old in a low-income primary school in Texas.[345] Overall, children participating in the active mile Marathon Kids reported being more physically active from running over a seven-day period compared to children not doing the active mile (mean = 4.22 vs. 3.97 times, respectively. p=.035). They also reported positive impacts from Marathon Kids on fruit and vegetable consumption, psychosocial correlates such as athletic identity self-concept, physical activity outcome expectations, and self-efficacy.[345] Other school-based running programmes resembling an active mile have also been studied. Stylianou et al., in 2014 investigated the effect of a before-school running/walking programme on children's physical activity in 251 primary school children in one school in America. They found that children ran between 0.6 and 1.0 mile per day during the running/walking club and there was a significant increase in the average daily distance students covered over time which differed by age and gender with older children and boys covering larger distances.[349] Subsequently in 2016, Stylianou et al. published another study using device-based measures for physical activity (pedometers) and evaluated the effect on children's activity levels in two schools. They found that children accumulated 1502 to 1731 steps during the walking/running club and spent 50% and 57% of the programme doing MPVA in school A and B respectively. More importantly, they found that children did not compensate their activity during the school-day on days they attended the club.[350] This evidence suggests that active miles can be a means to increase

children's activity, however, real-world large-scale population level evaluations are required to evaluate all aspects of Marathon Kids specifically and other active miles.

1.15 The Daily Mile™

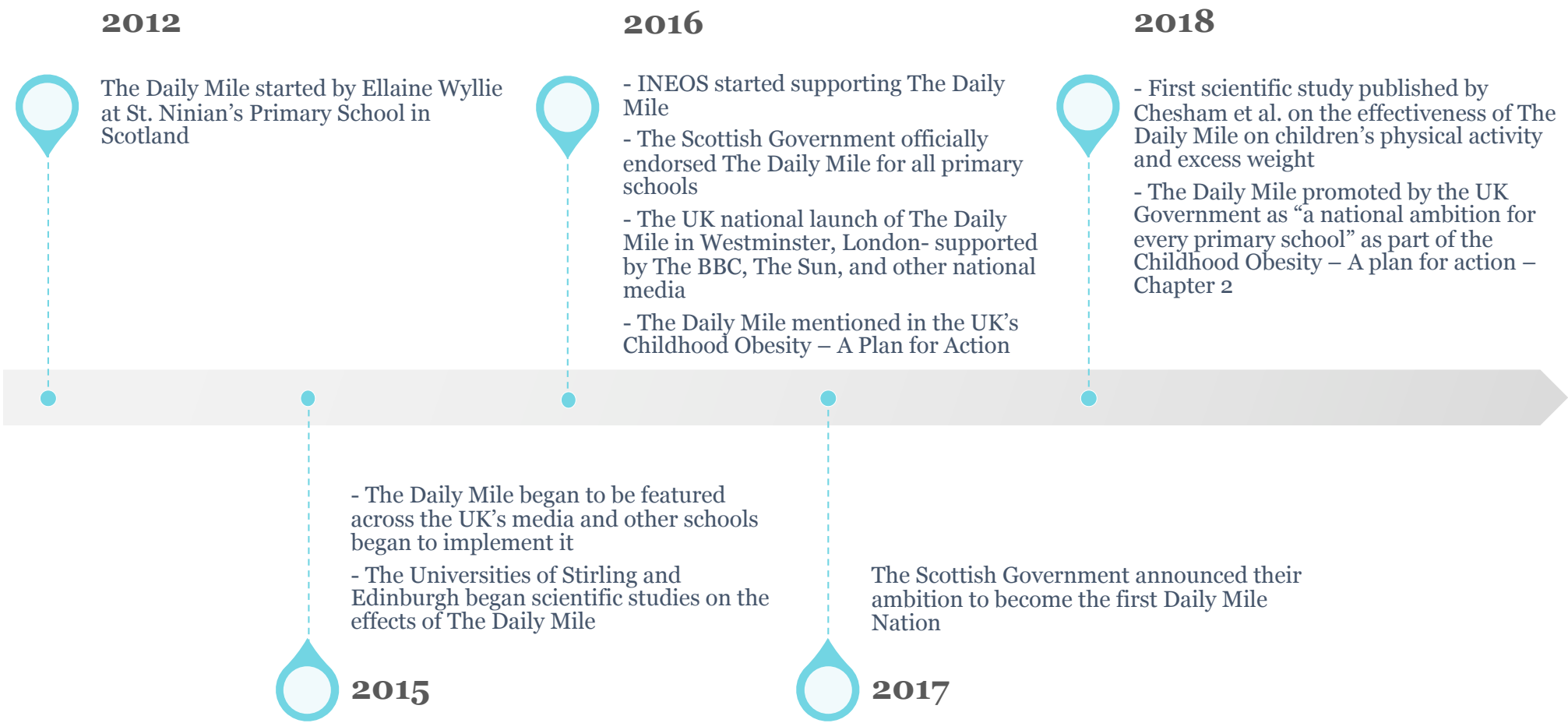
1.15.1 A brief history

The Daily Mile began in 2012 and was founded by Ellaine Wyllie, the head teacher of St Ninian's Primary School in Stirling, Scotland (Figure 1.5). Ellaine Wyllie had become increasingly concerned about the lack of fitness in the students at her school and thought a practical solution to this would be to get children to run or jog at their own pace for 15 minutes a day. This was the motivation behind TDM.[351] Initially, TDM was started as a school-based active mile initiative by a school head-teacher and grew organically and with some media interest. In 2016, INEOS, a large British chemicals company started supporting and funding TDM which led to the creation of The Daily Mile Foundation.[352] In parallel, TDM was cited in official government policy in the policy briefing: 'Childhood Obesity – A Plan for Action' as a practical approach to tackling childhood obesity in the United Kingdom.[340] In 2017, the Scottish Government wrote to schools, nurseries, colleges and universities urging them to help Scotland become the first Daily Mile Nation.[353] The second edition and revised plan of the Childhood Obesity – A Plan for Action published by the government in 2018 extended its previous recommendations from 2016, to state that as support for schools in their role to reduce childhood obesity, they will "promote a national ambition for every primary school to adopt an active mile initiative, such as The Daily Mile".[354] No other specific physical activity intervention was named other than TDM, suggesting significant support from the government for schools to implement it. Most recently, it was included in the School Sport And Activity Action Plan that endorsed active miles as an integral part of children's routines to establish physically activity behaviours.[355]

The government adoption of TDM as a key element of their plan to reduce obesity in 2018 was based on one small pilot study.[356] In addition, TDM was not designed as an intervention to reduce childhood obesity but as an initiative by a head-teacher with an acute understanding of the school system who was worried about poor fitness levels in pupils. Over eight years TDM morphed from a single school intervention to improve fitness in primary school children into a

strategy and official policy to reduce childhood obesity. This has occurred without a known key clear relationship between physical activity and obesity.[81,82]

Figure 1.5 The Daily Mile – Key Dates and Timeline



1.15.2 Intervention components and distinct features

The Daily Mile is a school-based active mile intervention where children run or jog at their own pace for 15 minutes at least three times a week in schools. There are ten core principles described by The Daily Mile Foundation. Some of the core features that set The Daily Mile apart compared to other active miles such as Marathon Kids is that there is no goal setting or reward, no equipment involved, no celebration, no role modelling, and no official monitoring or tracking of progress.

Over time, although not officially through The Daily Mile Foundation, there have been changes to the core intervention components in how TDM is being practiced. For instance, Marchant et al. found that children and teachers often used rewarding and goal setting to track children's progress and increase their motivation.[357] Hanckel et al. found that both children and teachers introduced competitive elements to keep children engaged.[126]

The 10 Core Principles of The Daily Mile according to The Daily Mile Foundation are*

1) **Quick -** It takes just 15 minutes with no time spent changing, setting up or tidying up. Transitions between class and route should be slick.
2) **Fun -** The Daily Mile is physical activity in a social setting and must be fun for the children. They can chat to their friends as they run along enjoying the experience together.
3) **100% -** It's always fully inclusive – every child, every day. They should all be out together in the fresh air. Children with mobility difficulties should be supported to take part
4) **Weather -** Treat the weather as a benefit, not a barrier. Children enjoy being outside in the different types of weather, connecting with nature and being aware of the seasons.
5) **Route -** Ideally, your Daily Mile route should have a firm and mud-free surface – most schools use the playground or an existing path. Incorporating child-pleasing loops and squiggles works well.
6) **Risk -** Risk assess the route in order to ensure The Daily Mile is a safe activity. Please see a sample risk assessment, here.

7) **When to go -** The Daily Mile should happen during curricular time, at least three times a week. Ideally, the class teacher should decide when to go out – they know their class and can respond flexibly to their needs.
8) **Clothes -** The children run in their school clothes without changing into kit, putting jackets on if it's cold or damp and taking sweatshirts off if it's warm.
9) **Own pace -** The children go at their own pace. Done properly, it's not a walk – able-bodied children should aim to run or jog for the full 15 minutes with only occasional stops to catch their breath, if necessary.
10) **Simple -** Keep it simple. Resist the temptation to over complicate it. It should always be social and fun. From time-to-time, you may wish to connect it to the curriculum or do something seasonal, for example, running 'Laps to Lapland'.

In order to report the key features of TDM as a public health intervention and my interpretation of it, I have used The Template for Intervention Description and Replication for Population Health and Policy (TIDieR-PHP). It is a helpful tool to improve the reporting of key features of interventions, so that they can be replicated.[358] Table 1.1 summarises the TDM as an intervention 'as intended' based on the core principles listed by The Daily Mile Foundation and has been adapted from Hanckel et al[126].

Table 1.1: Summary of The Daily Mile as described by The Daily Mile Foundation using the Template for Intervention Description and Replication in Public Health Programmes (TiDieR-PHP)***

TIDieR-PHP item	The Daily Mile*
Brief name	The Daily Mile
Why	• To encourage all children to take part in running regardless of their ability or fitness • To provide a classroom break for children to be outdoors for fresh air • To promote social, emotional, and mental health, wellbeing, and fitness
What - materials	• A firm and mud-free surface • A risk assessed route • No change of kit or additional clothing or equipment required • No 'set up or tidy up' • No staff training required and no extra workload for teachers
What and how	• 15 minutes of self-paced activity where children run or jog and can occasionally walk to catch their breath, if necessary • Outdoors within the school boundaries and during the school day • Social - can chat to their friends as they run along enjoying the experience together

	• Non-competitive – 'The Daily Mile should not be driven by spreadsheets, measurement or league tables'
Who provided	• Schools sign up to The Daily Mile Foundation and are given a 'welcome pack' • Teachers are responsible for implementation – they take children out to do TDM
Where	• Within the school boundaries in a safe and risk-assessed environment • Outdoors where children are exposed to fresh air • TDM began in Stirling, Scotland. It now has international reach
When and how often	• During curriculum time • Not as a replacement for PE • Everyday ideally, but at three times a week at the minimum
Planned and unplanned variation	• Time – teachers can implement it any time of the day • Inclusive – all children take part regardless of 'age, ability or circumstances' • 'Keep it simple and stick to the core principles' – when TDM is altered such as 'introducing a 'daily skip' or 'daily scoot', implementing it before or after school, or reducing it to once or twice a week… it is no longer sustainable'

Note: *quoted material from the The Daily Mile website 'Core principles' and other pages
****** This table has been adapted from Hanckel et al The Daily Mile as a public health intervention: a rapid ethnographic assessment of uptake and implementation in South London, United Kingdom (2019)* [126]**

There are some differences in the core features of The Daily Mile compared to other active miles. For instance, Marathon Kids is based on a reward and goal-setting mechanism in the short (laps) and long term (digital tracking system) for children while TDM is not. Additionally, the mechanisms underlying their potential effectiveness vary. Thus, I chose to summarise the evidence on TDM separately owing to TDM's distinct features and the relatively smaller evidence-based around other active miles compared to TDM.

1.15.3 Pathways for TDM's potential effectiveness

TDM's core principles chime with some fundamental psychological theories of motivation and behaviour change and might explain its potential effectiveness at increasing children's activity. School-based health behaviour interventions that are supported by behavioural theories are more likely to change behaviour compared to those that are not.[359] Although TDM was not designed based on theory, some have suggested that it can be linked to psychosocial theories such as Self Determination Theory (SDT) and Social Cognitive Theory (SCT) which can help understand its appeal, widespread reach and supposed effect on children's motivation.[360,361]

SDT provides a framework for understanding human motivation and personality. SDT has been widely used to both explain and understand children and adults' physical activity behaviour to further advance intervention design and evaluation.[362–365] Its core principles are *autonomy, competence, and belonging or relatedness*.[348]

- *Autonomy*: An individual's motivation is high when it is autonomous. For instance, when motivation is derived from the individual finding satisfaction in being active (or doing TDM), it is autonomous. Further, TDM can facilitate autonomy in children by empowering them to set their pace and in teachers by allowing them to choose when and how to implement TDM.
- *Competence*: TDM is a 'simple' intervention in that it does not have many subcomponents and relies on children running or jogging at a self-selected pace (also driving autonomy). It is a simple skill that can be easily achieved while also being sufficiently challenging and it has clear instructions that can be followed while also building health literacy in children.
- *Relatedness* or *belonging:* In principle, TDM is supposed to inclusive of all children, is supposed to be a whole-school approach that can help reduce cross year group boundaries and provides an occasion for children to connect to each other and with teachers.

The autonomy, competence and relatedness/belonging can lead to high quality motivation based on identity, motivation, and value. While TDM in principle is not supposed to include goal setting, Marchant et al.[357] found that children and teachers often used rewarding and goal setting to track children's progress and increase their motivation. These methods are supported by Bandura's SCT[366,367] that stipulates self-monitoring, goal setting, and rewards to be important drivers behind behaviour and regulation. As with SDT, SCT offers postulates on how to predict and change behaviours with self-efficacy being an important construct. Self-efficacy has been widely recognised as one of the strongest correlates of physical activity and a large number of studies have found it to be strongly and consistently associated with physical activity.[368–370] Understanding children's physical activity motivation can help design interventions that are underpinned by theory, and with those that have already been widely taken such as TDM, it provides a basis to understanding its popularity and apparent effectiveness. Retrospectively connecting TDM to potential theories is just one

way of explaining its broad appeal and supposed motivating impact on pupils. While TDM was not set out based on psychosocial and behaviour change theory, it is entirely plausible that its widespread popularity can be explained as it aligns with known psychosocial and behaviour change theories. Recognising the psychological factors that underpin interventions presents potentially modifiable targets for interventions to increase children's activity and is essential to creating sustainable behaviour change.

The next chapter will systematically review and summarise the literature on the implementation and effectiveness of TDM on children's health and wellbeing specifically, for which there is now a substantial evidence base.

2. The Daily Mile's effectiveness and implementation

Overview

In the previous chapter, I identified TDM as a school-based active mile intervention that may provide a means to increase children's physical activity. In this chapter, I critically appraise the key sources of literature that investigate the effectiveness of TDM on children's health and wellbeing outcomes and assess its implementation in the literature.

2.1 Methodology for literature review

To investigate the effectiveness and understand the implementation of TDM on children's health and wellbeing, the search terms were restricted to 'The Daily Mile'. Given TDM only began in 2012, and the evidence base is relatively small compared to a broader topic such as school-based physical activity interventions, I did not add any other search terms (e.g., fitness) as I was interested in summarising all the studies to date that studied TDM – its effectiveness and its implementation.

2.2 Search Strategy

I searched two databases Pubmed and Web of Science. I searched Pubmed from inception to April 28th, 2021, and considering PubMed has a delay in uploading recent articles, I also searched Web of Science for the same dates. I searched both databases for articles that included the term "The Daily Mile". The search was limited to those written in English. I also searched manually for articles that might have been missed in the databases on Google Scholar and Google.

"The Daily Mile" OR "TDM" OR "The Daily Mile™"

2.3 Results of Literature Search

The papers included in the review were chosen on the pretext that they either 1) evaluated the effectiveness of TDM on children's health and wellbeing outcomes and/or 2) described the implementation of TDM. I excluded all protocols, conference abstracts, commentaries and responses, and government briefing documents. Table 2.1 below is a summary of the 13 studies from the search strategy of the databases as well as the manual searches.

Table 2.1 Characteristics of studies evaluating the effectiveness and implementation of The Daily Mile

Author and Reference	Year	Country	Type	Design	Scope	Population	Follow-up	Outcomes
Ryde**[371]**	2018	Scotland	Qualitative	Interpretive - semi-structured interviews	I	School staff	NA	NA
Chesham**[356]**	2018	Scotland	Quantitative	Quasi-experimental pilot	E	Children aged 4-12 years (n=391)	3 months for control group and 8 months for intervention group	• Accelerometer-assessed average daily MVPA and sedentary time • Cardiorespiratory fitness – 20m shuttle run • Adiposity – skinfolds at 4 sites
Ward**[372]**	2019	England	Qualitative	Interviews and focus groups	I	Children and school staff	NA	NA
Brustio**[373]**	2019	Italy	Quantitative	Quasi-experimental	E	Children mean age 6-9 years (n=795; 486 in experimental group and 309 in control) Teachers (n=33)	3 months	Children outcomes: • Height • Weight • Waist circumference • Cardiorespiratory fitness - 6-minute run test • Standing long jump Teacher survey: perceived positive or negative effects on participants or organisation perceived appropriateness easy or difficult factors affecting implementation resources needed for implementation satisfaction

								intention to use
Harris**[120]**	2019	England	Mixed	Multi-method process evaluation	I/E	Children aged 2-11 years (n=277)	3 months (12 weeks)	• Reach • Dose • Fidelity • Exertion • MVPA – direct observation
Hanckel**[126]**	2019	England	Mixed	Rapid ethnographic assessment	I/E	Children and teachers in 5 schools Routine data used for quant analysis Participant (children) observation – 12 classes in 5 schools		• Sociodemographic characteristics of schools participating in TDM • Variation in implementation using TIDieR- PHP
Morris**[374]**	2019	England	Quantitative	Randomised control trial	E	Children aged 7-10 years (n=303)	Immediate post 1 bout of TDM	• Executive function • Maths fluency • Accelerometer MVPA
Malden**[375]**	2019	Scotland	Qualitative	Interpretive – open ended interviews	I	Children	NA	NA
Booth**[376]**	2020	Scotland	Quantitative	Citizen science project with a repeated measures design	E	Children – mean age 10.2 years, SD = 0.7 (n=7337)	Immediate post 1 bout of TDM	• Cognition (inhibition, verbal, and visuo-spatial working memory) • Children's Feeling Scale and Felt Arousal Scale
De Jonge**[377]**	2020	Netherlands	Quantitative	Multi-arm, partly randomized controlled trial	E	Children aged 8-12 years (n=536)	12 weeks	Cardiorespiratory fitness - shuttle run test

Breheny**[378]**	2020	England	Quantitative	Randomised control trial	E	Children aged 7-10 years (n=2280)	4 months and 12 months	• BMIz • Cardiorespiratory fitness • body fat percentage • child-reported quality of life • child-wellbeing (middle years development instrument) • teacher-rated academic attainment • cost per QALY
Marchant**[357]**	2020	Wales	Mixed	Natural experiment	I/E	Children aged 9-11 years (n=336)	3 and 6 months	Fitness – 20m shuttle
Brustio**[379]**	2020	Italy	Quantitative	Quasi-experimental	E	Children mean age = 9 ± 1 years (n=548; experimental 279 and control 269)	3 and 6 months	• Cardiorespiratory fitness as 6 min run test (primary outcome) • waist-to-height ratio • BMI

I: Implementation; E: Effectiveness I/E: Implementation and Effectiveness; MVPA: Moderate to vigorous physical activity; BMI: Body mass index; BMIz: Body mass index z-score; N: sample size; NA: missing; SD: standard deviation; QALY: quality adjusted life years; TIDieR- PHP: Template for Intervention Description and Replication - population health and policy

2.4 The Daily Mile and children's physical health

TDM's impact on children's physical health has been studied in England, Wales, Scotland, the Netherlands, and Italy.[356,357,373,374,377,378] Impact has been assessed across all primary school years ranging from children aged 6 to 12 years old.[356,357,373,374,377,378] Outcomes included cardiorespiratory fitness either by shuttle runs or the 6-minute run test.[356,357,373,377]

2.4.1 Physical activity levels

The association between physical activity and TDM was studied by Chesham et al,[356] Morris et al [374] and Harris et al [120]. Children's physical activity has been studied as a result of participation in TDM or while doing TDM. Chesham et al.'s small pilot quasi-experimental study including two schools in Scotland found that after three months in the control group and eight months in the intervention (TDM) group, on average those exposed to TDM had an increase in device measured MVPA by approximately 9 minutes. However, the mean difference hid variation in how children responded to TDM; where 55% increased their MVPA, but 45% in fact decreased their MVPA. This indicates that potentially not all children responded positively to TDM.[356] However, this study has significant limitations that have been summarised by Daly Smith et al.[380] including a small sample size (n= 391) and being restricted by location (2 schools in Stirling, Scotland). Further, there were varied exposure durations which create unequal dose-response conditions; the intervention group was exposed to TDM for 28 weeks compared to the control groups who were only followed up for 12 weeks. In addition, they did not control for seasonality which is important for children's activity as they are more active in the spring and summer.[381]

Morris et al found that children accumulated five to 15 minutes of MVPA as a result of one bout of TDM using device-based measures. However, as with Chesham's results, Morris et al found large amounts of variability for MVPA where the most active child spent almost the whole duration of TDM doing MVPA as opposed to the least active who spent only 33% of TDM in MVPA (remaining in LPA). They also found that children who participated in one bout of TDM also spent significantly less time in LPA versus control and sedentary time was also significantly lower during TDM versus control. Harris et al. using direct observation (SOFIT) found that children in key stage 1 (5 to 7 years) spent 100% of the time allocated to doing TDM engaging in MVPA and those in key stage 2 (7 to 11 years) spent 13 minutes of

engaging in MVPA. However, there are known limitations to using direct observation methods for measuring physical activity as described in chapter 2, section 2.6.1. Further, this study also used a small sample restricted by geographical location and the intervention group (TDM) was determined by teachers who volunteered to do TDM with their class, potentially introducing selection bias.

There is some evidence of compensation of activity among children who are active in schools (e.g., reduced activity outside schools) on the day and across the week. While Morris and colleagues did not investigate this compensation, Chesham et al., found that a change in MVPA was associated with a change in sedentary behaviour (inverse relationship), suggesting that children were not compensating for an increase in physical activity by being sedentary. Chesham et al., have been the only group to study the effect of TDM on children's sedentary behaviour and reported a reduction in children's sedentary time (decrease in ~18 minutes/day) during TDM. However, given the limitations of Chesham's study, the notion of compensation of activity both on the day and across the week requires further investigation. Overall, from these studies and other qualitative findings,[342,357] there is evidence that TDM and active miles can provide a meaningful contribution to children physical activity in schools through a structured bout of activity. This in turn can contribute to children meeting the physically activity guidelines. However, these findings, including no compensation in activity needs to be replicated in larger studies using real-world data in diverse samples to validate them.

2.4.2 Fitness

Six studies have examined the effect of TDM on cardiorespiratory fitness thus far. Chesham et al.[356] Marchant et al.[357] and Breheny et al.[378] conducted their studies in the United Kingdom in samples of two, six, and 40 schools respectively. Chesham et al.[356] were the first to assess the impact of TDM on children's fitness. As part of their small quasi-experimental study in two schools in Scotland, they found that in the intervention group (TDM), fitness increase by 39.1 m (shuttle run) and VO2 max increased slightly. Marchant's study including 6 schools in children age 9-11 years (n=336) found an increase in children's cardiorespiratory fitness measured using the 20m shuttle run.[357] Notably, they found that this improvement in fitness was observed among both high and low deprivation groups where both groups demonstrated equal increases in shuttles between baseline and follow-up (deprived: 4.7 ± 13.4, non-deprived: 4.8 ± 16.0). However, the confidence intervals in this

study are large with a high amount of variation in the changes observed.[17] Given the large variation observed in their study, definitive conclusions about the association between TDM and children's cardiorespiratory fitness cannot be made. Finally, Breheny's large RCT in 40 schools in Birmingham including over 2000 children, the largest thus far, found no effect of TDM on children fitness using the British athletic linear track test.[378] However, 50% of data for the measure of fitness were missing and their analysis on the complete case and imputed dataset using multiple imputation found no statistically or clinically significant effect of TDM on fitness.

Brustio et al. in Italy conducted two studies to evaluate the effect of TDM on fitness.[373,379] The first, conducted in 2019 in five primary schools over three months found an improvement in children's aerobic fitness using the 6-minute run test among those who participated in TDM compared with those who did not.[373] However, they did not analyse intensity of activity or amount of activity, which would have strengthened their analysis. Subsequent to this study, they investigated the dose-response relationship between TDM and cardiorespiratory fitness in 548 children at three and six months.[379] There results conferred a dose-response relationship. At three and six months, participating in TDM on average three times per week was more beneficial for children's fitness measured with the 6-minute run test. Participating in TDM two times per week provided some improvement in the initial three months but did not provide any further improvement in fitness at six months, though the improvements were sustained. Markedly, in this study, Brustio et al. adjusted their analysis for baseline BMI, which has not been done thus far by other studies, taking into account the preliminary weight status of children. This is important as children of differing weight status might respond to TDM differently, with some groups potentially benefiting from it more. However, their study was not randomised with teachers and children volunteering, introducing some selection bias. Further, given that the dose response relationship observed where performing TDM three times a week facilitated the greatest improvement in fitness, in the long term there are important consequences for implementation of TDM. Further, questions about the opportunity cost of TDM remain if benefits of TDM are dose dependent.

De Jonge et al. in the Netherlands studied the effects of performing TDM for 12 weeks on the aerobic fitness levels of primary school children and also assessed whether additional personal support for teachers impacted the effectiveness of TDM.[377] They split children into three groups as control, implementing TDM, and implementing TDM with additional support. TDM

was associated with increased physical activity in both intervention groups. They found that aerobic fitness was most improved in the group without additional personal support. This potentially supports themes that have emerged from qualitative research that teachers perceive TDM to be a simple and easy to implement intervention.[126,357,371] However, this must be read with caution as the trial was only for a 12 weeks, and teacher support has been shown to be important for long-term implementation and sustainability for school and classroom-based interventions.[382,383] While the quantitative evidence on the effectiveness of TDM on children's fitness is still unclear, as also stated by Public Health England's briefing on active miles,[338] two qualitative studies[126,357] have found that both teachers and children perceive improvements in children's fitness as a result of TDM.

2.4.3 Weight status and body composition

Three studies have assessed the effect of TDM on weight status (body mass index) and/or body composition (adiposity). Chesham et al. found improvement in relation to children's body composition measured using skinfold assessment at four sites (a relative decrease of 1.4 mm (0.8–2.0 mm, SMD = 0.246, p = 0.036)).[356] Chesham and colleagues are the only group that have found a positive effect of TDM on children's weight status or body composition thus far. Brustio's 2020 study evaluated the dose-response relationship between TDM and BMI and waist-to-height ratio in primary school children.[379] They did not find any difference when practising TDM two or three times a week. Weight status measured as BMI z-score was the primary outcome in Breheny et al.'s large RCT in Birmingham, and the study was powered to detect changes in BMI. A secondary outcome was body fat per cent. They found that 12 months after the start of the intervention, there was an increase in BMIz for both the intervention and control group and this increase was smaller in the TDM group compared to the control group (mean difference= −0.036, 95% CI −0.085 to 0.013, p = 0.146). However, this was both clinically and statistically non-significant, suggesting no impact of TDM on BMIz. They also found no difference in children's body fat per cent at 12 months. Breheny et al. concluded that while they found that TDM did not have a clinically important effect on BMIz overall, there was evidence of a modest intervention effect on BMIz for girls, consistent with findings for body fat percentage. However, it is critical to note that they mention in their methods that their study was not powered to detect this sex-specific difference. Therefore, this sex-specific result requires further investigation.

It is worthwhile to note that the field is seeing robust, expensive trial methodologies used within complex school settings to study low-risk interventions proving effectiveness is not as important as understanding implementation and real-world effectiveness and uptake. Further, Breheny et al.'s choice of primary outcome is debatable given the complex relationship between physical activity, BMIz, and excess weight. Their robust trial would have allowed for more useful physical activity-related outcomes to be studied along with implementation in a large trial.

It is difficult to draw firm conclusions about the effect of TDM on children's physical health outcomes due to the different measurements and outcomes used, the different ages of children being studied, small sample sizes, and unequal dose-response times in the control and intervention groups across the different studies; the results are not directly comparable and more robust research is required in real-world settings and large, diverse samples.

2.5 The Daily Mile and psycho-social and educational outcomes

2.5.1 Psychosocial outcomes

Qualitative studies have examined the association between TDM and a range of psychosocial outcomes. Marchant et al found that many pupils acknowledged the associations between physical activity and wellbeing and reported happiness and improvements in self-esteem during or after participation in TDM.[357] Harris and colleagues also found that many students reflected on happy experiences when participating in TDM.[120] Studies have shown positive development of teacher-pupil rapport as a result of TDM.[120,375,384] This has also been observed for other active miles as reported by Chalkley et al.[125] Further, Harris et al. also reported that older children were particularly keen for teachers to model physical activity rather than observe and be part of the activity. Three studies reported friendships and positive peer relationships as an outcome of TDM.[120,126,372] The most consistent finding is the benefit pupils gain from spending time with friends and building and strengthening peer relationships. However, children did not always report positive psycho-social benefits from TDM. Both Harris et al and Ward et al found that TDM could be stigmatising and a socially isolating experience. For instance, Harris et al. found that a minority of children were teased for being slow or unfit. Thus, while TDM in principle is 'non-competitive and fun', children's

experiences varied.[120] Similarly, Ward and Scott (2021) found that TDM could turn into a potentially isolating social space for children as a result of falling out with friends.[372]

2.5.2 Educational outcomes

On-task behaviour has been qualitatively explored in four studies.[120,357,371,375] Harris et al. reported a positive effect of TDM on on-task behaviour where teachers and students subjectively perceived improvement in attention on return to class. This positive association was also reported by Ryde et al. in their qualitative study interviewing school staff where teachers noted positive classroom behaviour immediately after TDM was implemented.[371] This is important given that the acute effects teachers observe may be more important for continued participation and implementation compared with long term outcomes such as cardiorespiratory fitness. In contrast, Marchant et al., and Malden and Doi reported mixed outcomes. Marchant et al. found that conflict existed between both children and teachers' perceptions of the effect of on children's behaviour and concentration.[357] Some teachers observed improvements in pupils' behaviour and concentration following participation in TDM. This was supported by children who felt that doing TDM resulted in more efficient class work. However, some children reported feeling tired and having low energy levels after participating in TDM, thereby negatively effecting their concentration. Additionally, teachers reported difficulties in settling children back to the class after TDM. Overall, the association between behaviour and TDM is mixed and requires further exploration.

Although six[120,357,371,374–376] studies have assessed the impact of TDM on cognition and academic performance, only two have use quantitative approaches; one by Morris et al. in 2019 [374] and the other by Booth et al in 2020.[376] The study designs, cognitive tasks, comparison groups, covariates, and sample sizes were vastly different making any comparison difficult. Morris et al. assessed the impact of TDM on executive function and maths fluency immediately post one bout of TDM in a randomised controlled trial in children aged seven to 10 years (n=303). Executive function can be defined as "the ability to hold in mind information in working memory, to inhibit fast and unthinking responses to stimulation, and to flexibly shift the focus of one's mental frame, is more or less the foundation for the intentional, volitional self-directed control of behaviour."[385] They found that TDM had no significant impact on executive function, irrespective of the individual dose of MVPA derived from TDM (demonstrated through a subgroup analysis including only children who achieved >=10

minutes of MVPA). Children in the intervention group had increased maths fluency scores post intervention, and those in the control had decreased scores, but none of these were significant. Overall, Morris et al. concluded that one bout of TDM did not have an immediate effect on children's executive function or academic performance measured as maths fluency. Booth et al.'s[376] results opposed Morris and colleagues'. Booth used a citizen science study design[386] to examine the acute impact of classroom physical activity breaks on cognition measured as inhibition, verbal, and visuo-spatial working memory, and on affective wellbeing measured with the Children's Feeling Scale and Felt Arousal Scale. A citizen science study involves citizens actively contributing to science either with their intellectual effort, or surrounding knowledge, or their tools and resources.[387] In this study, teachers were responsible for conducting the study and teachers and pupils collected data.

As with Morris et al.'s study, these outcomes were measured immediately post intervention. However, unlike Morris et al who used two groups, intervention (TDM and control), they used three groups

- 15 minutes of self-paced activity (similar to TDM)
- 15 minutes of near maximal exhaustion activity (bleep test)
- a control group who did not exercise at all but still had a classroom break and were outdoors

Overall, they reported that 15 minutes of self-paced outdoor activity improved children's cognition and wellbeing, compared with both other activities. They found a significant difference in change score associated with self-paced activity compared to control for all outcomes except the visual-spatial working memory task, though the effect sizes were small. Further, they also found statistically significant differences in all outcomes when self-paced activity (TDM) was compared to the bleep test, with effect sizes ranging from 0.06 to 0.22. Mediation analysis found that the effect was higher after self-paced activity compared to both the other groups. This positive relationship partially accounted for the improved performance on verbal working memory associated with self-paced activity compared to both other groups. While Booth et al. had a much larger sample than Morris et al., 7337 versus 303 children respectively, there were several limitations to their study, including measurement error and bias resulting from teachers self-selecting their classes to participate. Further, their models did not consider clustering at school level. Both Booth et al. and Morris et al. evaluated cognitive function and/or academic performance after one bout of TDM (or self-paced activity for 15 minutes). Given the opposing results, overall, the effect of one bout of TDM or TDM like self-

selected pace activity on academic performance and cognition requires further research to be able to draw firm conclusions. These types of proximal outcomes, such as mental health and cognition, are especially important for raising the profile of physical activity in schools (and with parents and other stakeholders). Given that inactivity increases a child's risk of cardiovascular disease and type 2 diabetes later in life is probably considered less important to stakeholders than that TDM (and other school-based physical activity interventions) might have short-term impacts on their mental health, well-being, happiness, friendships and their performance at school, and is potentially one of the selling points of TDM.

2.6 Cost effectiveness and implementation of The Daily Mile

TDM is frequently regarded as a no or very low-cost intervention. No equipment is required, no additional kit or change, and running or walking is generally considered a 'free' sport. However, TDM is implemented in schools and occurs during curriculum time, requiring school staff to supervise the activity. These costs need to be analysed. One study has evaluated the cost effectiveness of TDM.[378] Breheny et al.'s 2020 RCT including 40 schools in Birmingham showed support for TDM as a cost-effective intervention, especially in girls. Importantly, staff costs associated with supervising children participating in TDM were offset by the improvement in children's quality of life;[378] important for teacher buy-in and long-term sustainability of TDM.[125,388]

Six studies have explored the implementation of TDM, including the facilitators and barriers to implementation and covers populations in England, Scotland and Wales.[120,126,357,371,375,389] Most of this work has been focussed on how TDM is implemented in the school setting and how it is incorporated into schools in practice. Hanckel et al.[126] completed a rapid ethnographic assessment of TDM in Lewisham, South London. They evaluated implementation in real-world settings against TDM Foundation's 'core principles' using the TiDier-PHP checklist. Marchant et al. conducted focus groups with children and interviewed teachers and headteachers to understand the factors behind successful implementation in Wales,[357] and Ryde et al. did the same in Scotland.[371] Similarly, Ward and Scott[389] aimed to understand the meanings derived from practicing TDM from pupil and teacher perspectives. Malden and Doi focussed on assessing barriers, facilitators and perceived benefits of TDM from the perspectives of teachers,[375] and Harris et al. conducted a process evaluation of TDM in one primary school in the East Midlands in England.[120]

TDM has been found to be simple and easy to implement in school settings.[357,371,389] It's simple intervention components in relation to the type of activity, the frequency and duration, in principle, has been found to be suitable to the primary school context, and has been one of the reasons behind it's widespread adoption.[371] TDM was created by a primary school head teacher who had an acute understanding of the primary school setting and what could be implemented in this context. Ryde et al. found that the way TDM was developed, trialled and rolled out, initially as a grassroots movement, could explain some of its reach and uptake. Adaptability of TDM to suit the school setting, which in turn promotes teacher autonomy to implement TDM as best suitable, has consistently been reported.[120,357,371,375] One of TDM's core principles states that TDM should be implemented at any time of the day and should not replace PE. Individual classroom teachers decided when it was best to make children do TDM, either rigidly as part of the time table, or more flexibly based on children's mood and behaviour.[357,371] Marchant et al. reported that rigid implementation of TDM based on the core principles that lacked variety disengaged pupils. To address this and maintain children's enthusiasm, elements of play were incorporated into TDM.[357] Hanckel's study has extensively covered these variations in implementation.[126] While TDM is supposed to be 'social, non-competitive and fun', in practice, Hanckel et al. found that both children and teachers introduced competitive elements to keep children engaged. However, whether these adaptations that alter the simple intervention components lead to changes in adherence, implementation, and impact are yet to be studied.

Another theme that has emerged is time of day that it is completed, whether it is implemented as an addition to PE or as a replacement for it, and whether it is implemented during curriculum time or during play time. Teachers have cited time and competing demands due to the curriculum and teaching time as a barrier to implementation.[126,357,371,389] However, some schools restructured their day due to accommodate TDM and some implemented TDM before PE lessons to reduce disruption to curriculum time.[120,126,357] Another way teachers responded to these challenges was to implement TDM during break times. However, there has been some suggestion that if TDM is implemented during breaks,[120] it is more likely to exclude children who would traditionally not participate in physical activities.[341]

The dose of TDM has been particularly difficult to measure, especially given the wide variation in implementation.[126] TDM is supposed to be a whole-school approach where every child

runs or jogs at their own pace for 15 minutes a day. In real-world settings, there is variation both in terms of whether the whole school implements TDM and whether children actually jog or run for the entire 15 minutes. The latter is especially important when evaluating TDM against health outcomes as in trial settings, the health effects are measured when adherence levels are high. Most studies report that in practice, the whole school does not implement it, it is rarely implemented every day, and some take the approach that 'anything is better than nothing'.[126,357,375] The most common reason TDM was not implemented every day is time and academic pressures on teachers and children, some of which come from parents, children's age and ability to take part every day. Additionally, it was because schools sometimes did other physical activity interventions.[126,357,375] Harris et al.'s process evaluation reported a high level of dose and reach where primary school children did TDM 95% of the days that they were assessed for. However, the study was restricted to one primary school, limiting its generalisability.[120] Although promotional materials state that TDM takes only 15 minutes to complete, studies report taking longer to implement it due to the administration time of moving children out of the classroom and settling them down to start learning again after TDM.[120,126,357,371,375,389] Further, most children were not active for that whole time period, especially doing MVPA,[374] and a substantial number of children walk instead of run or jog.[126,357,371,375] This is important as the health benefits associated with physical activity required activity of at least moderate intensity.[58,390]

One of TDM's core principles says it should include all children and is a wholly inclusive intervention. Ward and Scott, and Hanckel et al. both report that TDM was inclusive of all children.[126,389] Hanckel et al. found that while all children in a class did mostly participate, there were gender differences in how TDM was undertaken and observed. For instance, girls were more likely to interact with each other while doing TDM than boys.[126] Another principle of TDM is that it is supposed to be done in all weathers. However, in practice, the weather has been widely reported as a barrier to implementation.[120,126,357,371,375,389] This is important as studies assessing TDM must account for the weather when evaluating both effectiveness and implementation.

Although there has been a substantial amount of research done on the implementation of TDM, including facilitators and barriers, the evidence base continues to evolve and further research is required to understand influences on the quality of implementation and delivery, and sustainability of TDM in schools, especially given it is not a 'one-size-fits-all' approach. Public

Health England's implementation briefing of active miles recommends that they, including TDM, must be part of a comprehensive whole-schools based approach.[341] There is still a need to study the fidelity of TDM in large real-world settings to assess implementation, dose, and reach in real-world settings.

2.7 Conclusions from the literature review

This systematic review of the literature on TDM has shown that TDM has been investigated in relation to implementation and its impact on children's health and wellbeing across Europe. So far, its impact has been studied in small trials ranging from samples of 200 to 2000 children. The evidence of TDM's impact on children's cardiorespiratory fitness is moderate. It has the ability to make a meaningful contribution to children's physical activity levels during the school day by providing approximately 10 additional minutes of MVPA. Its impact on other physical health outcomes such as body composition and weight status is uncertain and requires further high-quality studies. In terms of psychosocial outcomes, the most compelling evidence is of TDM's impact on pupil and teacher rapport and positive peer relationships among children. TDM's impact on cognition and on-task behaviour still requires more research given the opposing conclusions of Booth et al. and Morris et al.'s studies. There is support for TDM being a cost-effective intervention, especially for girls, based on Breheny's cost-effectiveness analysis in the largest RCT assessing TDM. Overall, TDM has been shown to have some benefits. However the opportunity cost of implementing TDM over other interventions is not widely explored other than in a critical review by Thorburn (2020).[391] TDM has been widely implemented with facilitators and barriers to implementation being studied from the pupils and teachers perspectives. The evidence base surrounding TDM is evolving and a large cohort study, the IMprOVE study, is now underway to assess the impact of TDM on mental health and wellbeing outcomes, including sleep, in addition to physiological and behavioural outcomes.[392] However, large-scale, nationwide, real-world studies are required to be able to draw firm conclusions on TDM's reach, impact, and fidelity – all of which can be studied by leveraging and using routinely available data in England.

The next chapter will describe the rationale behind this thesis and lay out the studies and corresponding objectives.

3. Scope, aims, and objectives

Overview

In the previous chapter, I critically evaluated and summarised the literature on the effectiveness and implementation of TDM. I conducted a review of the literature to ensure the novelty of my work. This led me to identify gaps in the literature, which prompted my thesis objectives. In this chapter, I justify the work I have done and outline the aims and objectives for my thesis.

3.1 Thesis rationale

Kennedy et al.'s systematic review using RE-AIM found that among those school-based physical activity interventions that are scaled-up, the number of students exposed to the intervention is not usually reported. Further, the representativeness and characteristics of students exposed were even more rarely reported.[328] TDM is an active mile initiative that began in Scotland in 2012 and has grown as a 'grassroots movement' with over 12000 schools representing 3.1 million children being registered according to TDM Foundation.[393] However, the characteristics of schools registered to TDM have not been studied. This is important given that children's physical activity levels and its determinants differ among populations.

All previous studies of TDM have focussed on evaluating TDM's effectiveness on various health and wellbeing outcomes in children or have focussed on understanding TDM's implementation, associated barriers and facilitators, and perspectives of those responsible for implementation. Matching public health interventions to the population's needs is more efficient and equitable than blanket policies directed at whole populations[394]. In recent years, there has been a push to consider the accumulation of health risks to plan for health needs.[185] There are numerous interconnected determinants associated with physical activity in children; categorising how these might be clustered and spatially dispersed across England is important. This allows for subsequent identification of high need areas and to assess whether interventions reach populations that could benefit from them the most. Nobody thus far has focussed on understanding the reach and equity of the TDM. Given TDM's growth as a grassroots movement with a self-selecting population presents a novel opportunity to study uptake, reach and the equity of a public health intervention. Pilot testing interventions through a phased approach on smaller, diverse populations is important before national rollout or uptake; saving resources and time. [394] This has not been the case with TDM where the evidence base was limited before enormous uptake across the world (Figure 1.5). It is vital to understand whether an intervention like TDM can be sustained over time, reach high risk populations, and is equitable and generalisable. Burton et al.'s stratified approach[6] to public health is a useful tool that helps consider whether the public health intervention, in this case TDM, is reaching the 'highest risk' population in addition to the whole population. While Rose's high risk population approach is useful, as previously mentioned, it might not always be equitable.[7,395] Using routine data allows for large-scale evaluations using real world data; to study whether TDM is being delivered in areas that need it most.

TDM's impact on children's physical activity has only been quantitatively evaluated in controlled, experimental settings, limited by geographic location. Routine data will enable the investigation of the impact of TDM on children's physical activity in a large population of children, permitting population level effects to be detected. Our understanding of the effectiveness of school-based physical activity interventions is closely tied to the measurement of physical activity, which has evolved over time. Initial evaluations focussed on self-reported data. However, in more recent years here has been a shift to measure physical activity objectively using devices such as accelerometers. Self-reported data are known to have inherent bias as recall can be affected by social pressures in children to report higher levels of activity [156,396]. However, collecting objectively measured data using accelerometers tends to be expensive. It is therefore often limited to small samples[119,164,165] which is not ideal for evaluating physical activity interventions in large scale studies in real-world settings. However, as previously mentioned, there are certain surveillance datasets that do include accelerometer derived measures of physical activity such as Biobank and Millenium Cohort Study. However, in this thesis, I rely on using children's physical activity data that is routinely available in England and includes TDM registration data and is measured using self-report questionnaires. Further, previous studies have examined the effect of TDM on physical fitness and activity levels in non-representative samples of children, using device-based measures in 200 to 2000 children. Most studies are limited to single sessions of TDM and examining their effect on a day's MVPA in children. However, it is important to assess MVPA across the week, both inside and outside school, allowing an assessment of activity across different settings. The United Kingdom government's national curriculum for PE for children in primary schools (key stage 1 and 2) states that children must develop competence to excel in a broad range of physical activities.[240] Considering constraints on time and resources in schools,[397] children might be limited to single element interventions that are easy to implement such as TDM, but that solely build competence in one activity (e.g. running), thereby reducing the variety of types of activity children engage in. Thus, it is important to assess whether children who are registered to do TDM stop engaging in other activities that are key to their development.

Fidelity of implementation of school-based-physical activity interventions is a known issue, where often poor fidelity translates to poor effectiveness.[21] In part, this is because schools are dynamic and complex settings. Interventions implemented in schools are subject to

variation in implementation owing to the complexity within school settings that include the operations, structures, and relations that exist within a school. TDM is comprised of various components, however, the core running component is the 'active ingredient' of the intervention. It is important to assess whether 'registration to TDM', which is a measure I have had to rely on due to the nature of this PhD using only routine data, can be considered a proxy of participation to TDM. Further, given I have used self-reported physical activity data to assess the impact of TDM on children's activity, it is important to assess the reliability of the data and when variation exists, to be able to quantify this.

The MRC guidance for developing public health interventions is based on identifying the evidence base, developing theory, and modelling the processes and outcome. The second step is to evaluate feasibility and piloting the intervention, moving on to evaluation, and then large-scale implementation.[25] However, this is not always followed. With the grassroots and non-prescriptive nature of the intervention, as in the case of TDM, which was widely taken up before any piloting of feasibility studies. In this case, that is, if large scale implementation of an intervention is already under way, the MRC guidance suggests, a quasi-experimental or an observational design is appropriate.[25] My PhD will include four observational studies addressing the gaps identified in the literature.

3.2 Aims

The overall aim of this thesis is to use routine data to evaluate a real-world public health intervention.

The specific aims of this project and thesis are:

- *To leverage nationally representative routinely collected data to conduct a real-world evaluation of a public health intervention.*
- *To create a national school's database as a resource that can be used for research beyond this project.*
- *To make a novel and valid contribution to the children's physical activity literature by examining the reach, impact, and fidelity of one of England's largest and most popular school-based physical activity interventions.*

- *To conduct research relevant to the current policy landscape on children's physical activity in England so that both health and education policymakers interested in empirical evidence can be better informed.*

3.3 Hypotheses and thesis objectives

Many schools, particularly those in urban areas, have limited access to outdoor space or have concerns about the risks of exposing children to air or traffic pollution, which could act as disincentives for uptake of TDM that involves running outside. Further, primary schools that lag in performance league tables do not prioritise activities such as TDM that may compete with curricular time.

Objective 1: To examine primary school and local authority characteristics associated with registration for TDM.

Local authorities with similar needs are clustered together across England and poorer health behaviours cluster together.

Objective 2: To examine local authority areas most in 'need' of physical activity promotion for children in England.

Considering TDM is a grassroots movement, high-need areas may be self-identifying populations and therefore have greater uptake. Alternatively, high-need areas may lack resources to implement the intervention and therefore have less uptake.

Objective 3: To assess whether school populations registered in TDM are representative of the needs of the general population.

Children attending schools registered to do active miles, such as TDM may be more active across the school week compared with children attending schools not registered to active miles as these initiatives may provide additional compulsory structured physical activity during the school day (based on the Structured Days Hypothesis). However, it is possible there may be some compensatory effects whereby children doing active miles in school may do less physical activity outside school. This compensation may be social and psychological from children or parents (e.g., if their child has done additional activity in school via an active mile initiative, they may be less likely to engage children in out of school activity). It might also be biological compensation, as outlined in the ActivityStat hypothesis[398] which suggests that children

reach an overall mean level of activity that is stable (i.e. when activity is increased in one domain, it is reduced in another to achieve stable energy expenditure). These 'trade-offs' might lead to reduced overall activity in children.

<u>Objective 4:</u> To compare reported physical activity (minutes of MVPA) in primary school children attending schools registered to TDM compared to those who are not.

Children in TDM registered schools will have reduced variation in the types of physical activity they are exposed to in school because TDM utilised the limited amount of 'free' time and time earmarked for activity in school, compared to children in non-registered schools. Children in TDM registered schools will have increased variation in the types of physical activity they are exposed to outside school because they are fitter, gain competence and autonomy to be able to do more types of activities.

<u>Objective 5</u>: To compare the variety of reported physical activity in primary school children attending schools registered to TDM compared to those who are not.

A larger proportion of registered children report doing a de-facto daily mile (compared to non-registered) if adherence to TDM's core running criteria is 'high', and all children registered report a de-facto daily mile if adherence is perfect. However, fidelity of implementation for school-based physical activity interventions is a known issue, so adherence might be low and children reporting a de-facto daily mile might be equivalent in registered and non-registered schools.

<u>Objective 6:</u> To assess if children attending schools registered to TDM report doing a daily mile by adhering to its core running criteria of 15-minute running in school outdoors three times a week.

If there is very strong agreement in children reporting a de-facto daily mile, there would be very low variation within schools officially registered to TDM. This is because high fidelity in TDM registered schools would mean limited variation in how children respond to doing a de-facto daily mile, meaning, they would agree with each other. However, considering known implementation problems, fidelity might be low and therefore within-school variation high.

<u>Objective 7:</u> To examine the association between TDM registration and within school variation of self-reported activity - using de-facto daily mile as a case study.

The subsequent chapters combine the objectives as follows:

- *Chapter 5* – Reach of The Daily Mile addresses objective 1.
- *Chapter 6* – Equity of The Daily Mile addresses objectives 2 and 3.
- *Chapter 7* – Impact of The Daily Mile addresses objectives 4 and 5.
- *Chapter 8* – Fidelity of The Daily Mile addresses objectives 6 and 7.

4. Methods

Overview

Previous chapters have outlined the research and policy contexts this thesis fits within. Chapter 1 and 2 highlighted the evidence base around school-based physical activity interventions, which increasingly is finding a lack of impact of interventions at the individual level. Many studies used controlled trials to evaluate effectiveness, however, a gap exists in the translation of evidence from trials to reflect in real-world settings.[22,399] *This thesis relies on using routinely collected data in England to answer my research questions as it allows for large-scale studies using nationally representative samples that can have extensive policy implications and tends to be more cost-effective than controlled trials.*

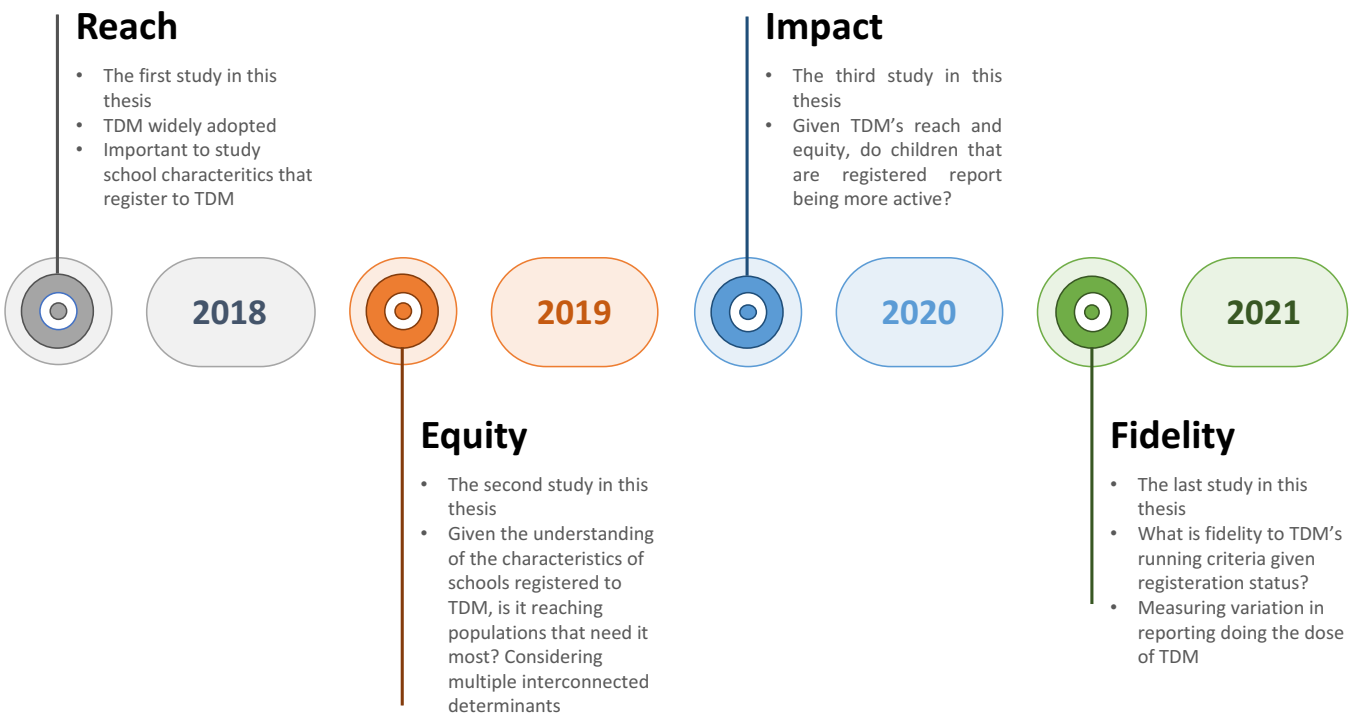
The thesis objectives with their study designs, outcomes and analysis methods are displayed in Figure 4.2. This chapter first details the datasets used in the analyses and describes their strengths and limitations. ***The detailed methods, core measures and assumptions, and statistical analyses used to answer the objectives of this thesis are reserved for that respective study chapter.*** *This chapter marks the change from discussing the context and literature this thesis sits within to focussing on original contributions that arise from this work.*

4.1 Research design

This thesis includes four cross-sectional studies (Figure 4.1). These studies include analyses at the local authority level, school level, and individual child level. I use routinely available data for all four studies. The first two studies include extensive data linkage and the last two rely on a single data source with data on TDM linked at the source.

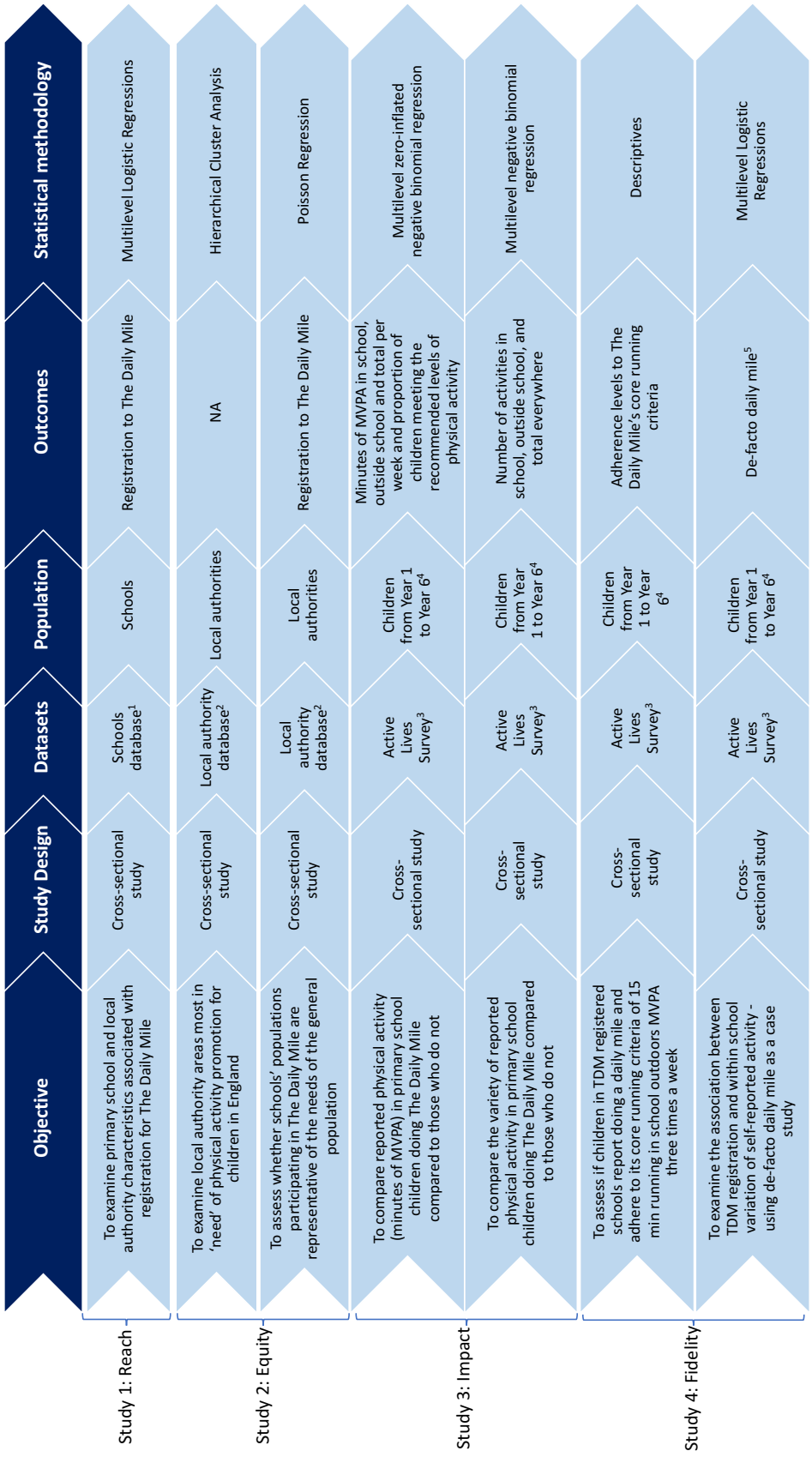
4.2 The Research Process

Figure 4.1: The research process and timeline



Given how TDM initially began and spread as a grassroots movement, it presented a novel opportunity to start by studying where TDM was being taken up and assess the types of schools and the areas that were inclined to adopt it. This decision to begin with these studies was also based on data availability. Study 1 (Reach) and study 2 (Equity) used routinely available public data that was accessible on open-source government data repositories. However, the data needed for Study 3 (Impact) and Study 4 (Fidelity) required a formal application to Sport England and incurred a delay. Further, I had initially planned to use individual child level data from the National Children Measurement Programme. However, delays to data access and the application being rejected and stalled by NHS Digital due to the Covid-19 pandemic required me to redesign the studies and use alternate data.

Figure 4.2 Outline of thesis objectives, study designs, datasets, populations, outcomes and statistical methods



Legend:
[1]Schools Database created by linking school level data from School Census, extracts of the National Pupil Database, and local authority indicators from Active Lives Adults Survey, Active Lives Survey Children and Young People, and the National Child Measurement Programme
[2]Local authority database created by linking local authority level data from Active Lives Adults Survey, Active Lives Survey Children and Young People, National Child Measurement Programme, Department for Education School Census, What About YOUth Survey, Department for Education Special Educational Needs Statistics, and Natural England: Monitor of Engagement with the Natural Environment
[3]Active Lives Survey Children and Young People Survey 2018-2019
[4]Children in Year 1 (5-6 years old) and Year 6 (11-12 years old)
[5]Children reporting running/jogging (MVPA) in school for 15 minutes at least 3 times a week

Table 4.1: Datasets used for PhD Studies, years of data and aggregation

Study Number	Objective of thesis	Datasets used	Year(s)	Level	Aggregation*** (mean of values across years)
1 – Reach	1. To examine primary school and local authority characteristics associated with registration for TDM.	Registration to The Daily Mile	2019 (August)	School	No
		School Census[400]	2013-2019	School	Yes – 2013-2019
		National Pupil Database Key Stage 2 Extract[401,402]	2015-2018	School	Yes – 2015-2018
		National Pupil Database Absence Extract[401,402]	2012-2018	School	Yes – 2012-2018
		Active Lives Adult Survey[403]	2017-2018	Local Authority	No
		Active Lives Children and Young People Survey[166]	2017-2018	Local Authority	No
		National Child Measurement Programme[48]	2017-2018	Local Authority	No
2 – Equity	2. To examine local authority areas most in 'need' of physical activity promotion for children in England. 3. To assess whether schools' populations participating in TDM are representative of the needs of the general population.	Registration to The Daily Mile	2019 (August)	School	No
		School Census[400]	2017-2018	Local Authority	No
		Department for Education special educational needs statistics[404]	2017-2018	Local Authority	No
		Active Lives Adult Survey[403]	2018-2019	Local Authority	No
		Active Lives Children and Young People Survey[166]	2018-2019	Local Authority	No
		National Child Measurement Programme[48]	2018-2019	Local Authority	No

		Natural England: Monitor of Engagement with the Natural Environment (MENE) survey[405]	2015-2016	Local Authority	No
		What About YOUth (WAY) survey[406]	2014-2015	Local Authority	No
3 – Impact	4. To compare reported physical activity (minutes of MVPA) in primary school children attending schools registered to TDM compared to those who are not. 5. To compare the variety of reported physical activity in primary school children attending schools registered to TDM compared to those who are not.	Active Lives Children and Young People Survey[166]	2018-2019	Individual	No
4 – Fidelity	6. To assess if children attending schools registered to TDM report doing a daily mile by adhering to its core running criteria of 15-minute running in school outdoors three times a week. 7. To examine the association between TDM registration and within school variation of self-reported activity - using de-facto daily mile as a case study.	Active Lives Children and Young People Survey[166]	2018-2019	Individual	No
***** In order to minimise loss of observations due to missing data in a single year, I used the mean of available data across years**					

4.3 Data Sources

4.3.1 Registration to The Daily Mile

The common dataset used across all studies is The Daily Mile Foundation database. Data on school registration to TDM was provided by The Daily Mile Foundation. All schools that officially register to TDM's official website are included in the dataset. There is no information on registration date and time or data on whether schools that register actually participate. Throughout this thesis I have used data from The Daily Mile Foundation's list of registered schools, however, when used, it has been considered an intention to participate rather than a proxy for participation. These data are from August 2019 with no updates in subsequent years. Schools not officially registered to TDM were assumed not to be taking part. The constant 'exposure' in this thesis is registration to TDM. I have had to rely on registration to TDM instead of participation due to constrains on data availability. However, I address limitations with relying on registration in the last empirical chapter of this thesis (Chapter 8), where I assess the reliability of registration to TDM in relation to actual participation.

I will now outline and describe the data sources used in each individual study of this thesis (Table 4.1).

4.3.2 Thesis Study 1 (Objective 1): Reach of The Daily Mile

Study 1 addresses objective 1 of this thesis which is: To examine primary school and local authority characteristics associated with registration for TDM. Study 1 includes data at both the school and local authority level. To address this objective, I first merged school level data from the School Census, and The Key Stage 2 and Absence Extracts of The National Pupil Database. Then, I merged local authority level data to the school's database I created to include local level indicators on child and adult excess weight and physical activity. Thereafter, I linked local levels data from the Active Lives Survey for Children and Young People, Active Lives Adults Survey, and the National Child Measurement Programme (Figure 4.3).

Note: Throughout this thesis, local authority refers to upper tier local authorities in England. There are a total of 152 upper tier local authorities in England. They include counties and unitary authorities which include metropolitan districts, London boroughs, unitary authorities, and county councils.

School Level Data

4.3.2.1 Department for Education School Census

The School Census collects aggregate information annually from all state funded schools and includes data on more than 15,000 schools and over 4.5 million children,[400] including pupil numbers, ethnicity, or if they are disadvantaged. The National Pupil Database includes pooled data, based on multiple data collections on pupils aged 3-19 years in state funded schools in England. It contains data on pupils' educational attainment from national annual standardised assessments conducted each academic year, and whether a child has any special educational needs.[401]

4.3.2.2 National Pupil Database

The National Pupil Database (NPD) is an aggregated dataset at the school level, based on multiple data collections from 2000, including children and young people aged 2-19 years in state funded schools in England. All pupils in a specific year sit tests on certain days during the school year and the scores from these are recorded every year. It is an open cohort which links pupil characteristics to information about academic attainment providing detailed information about children's education at different stages, including primary school. The NPD also includes information about pupils -gender, ethnicity, first language, eligibility for free school meals, any special educational needs and school attendance [402].

Key Stage 2 data

The National Curriculum in England in the United Kingdom is divided into four key stages. They are age-related, incorporating all pupils of a particular age at the beginning of each academic year. Key Stage 2 runs for a duration of 4 years from school years 3-6 and includes children between the ages of 7-11 years. At the end of Key Stage 2, children undergo tests and teacher assessments are provided. English and mathematics are currently tested at the end of Key Stage 2 (Science tests were discontinued in 2010). The English level is aggregated from separate reading and writing tests. Collecting data on children's educational scores allows to evaluate academic performance and inform independent research. It makes possible a particularly well-informed discourse relating to equity, life chances, and social mobility. The most widely used indicator of academic attainment in a school is the percentage of pupils reaching the expected standard in reading, writing, and maths.

Pupil absence in schools in England data extract

Schools can provide absence data using a reason code or by using total figures for the number of half day sessions missed due to authorised or unauthorised absence. A small proportion of schools have provided both a breakdown of absence by reason and totals. In addition, a small number of schools do not have the required software to provide absence data by reason and are therefore only able to provide overall totals [407].

Local Authority Level Data

4.3.2.3 The Active Lives Adults Survey

The Active Lives Adult Survey is an annual survey conducted by Ipsos Mori on behalf of Sport England. Sport England is a semi-autonomous, publicly funded body under the Department for Digital, Culture, Media and Sport. Their main objective is to promote and develop public sport and physical activity in England.[408]

The Active Lives Adult Survey includes data on adult self-reported physical activity, height and weight. This survey uses a 28-day reference period for adults to record the number of minutes of physical activity (of at least 10 minutes) and then divides the number of minutes by four to calculate a weekly average. The data obtained from the survey are weighted to be representative of the whole population at each level of geography. Weight status data from the survey has also been age-standardised to improve comparability of excess weight prevalence between local authorities. The estimates are weighted to be representative of the national population.[403,409]. For Study 1 of this thesis, I use data from 2017-2018.

4.3.2.4 Active Lives Children and Young People Survey

For this thesis, I used data from the Active Lives Children and Young People Survey at both the local authority and individual level. In this section, I will specifically outline the local authority level data used while the individual data used is described in Section 4.3.4.

Ipsos MORI conducst the Active Lives Child and Young People Survey on behalf of Sport England, who commissioned the survey with additional funding from Public Health England,

Arts Council England and the Department of Transport. This is a school-based survey that collects self-reported physical activity data from children across approximately 2,000 schools in England. The survey uses a seven-day reference period to record the activity children had done on each day. The estimates are weighted to be representative of the national population.[410] For Study 1 of this thesis, I use data from 2017-2018.

4.3.2.5 National Child Measurement Programme for obesity in children

The National Child Measurement Programme (NCMP) is a nationally mandated public health programme in England, which was introduced in 2006. School nurses measure the height and weight of over one million children during the year they reach the age of four and enter primary school in what is called the 'Reception' year (age 4-5 years) and again during the final year of primary school or 'Year 6' (age 10-11 years). It has achieved a high response rate and now measures 98% of children in 98% of state-funded primary schools to produce reliable estimates of childhood weight status.[411] I used these data to define the prevalence of children with excess weight status at the beginning (reception) and end (Year 6) of primary school when children are 5-6 and 10-11 years old, respectively. Children are classified as overweight (including obese) if their BMI is on or above the 85th centile of the British 1990 growth reference (UK90) according to age and sex. For Study 1 of this thesis, I use data from 2017-2018.

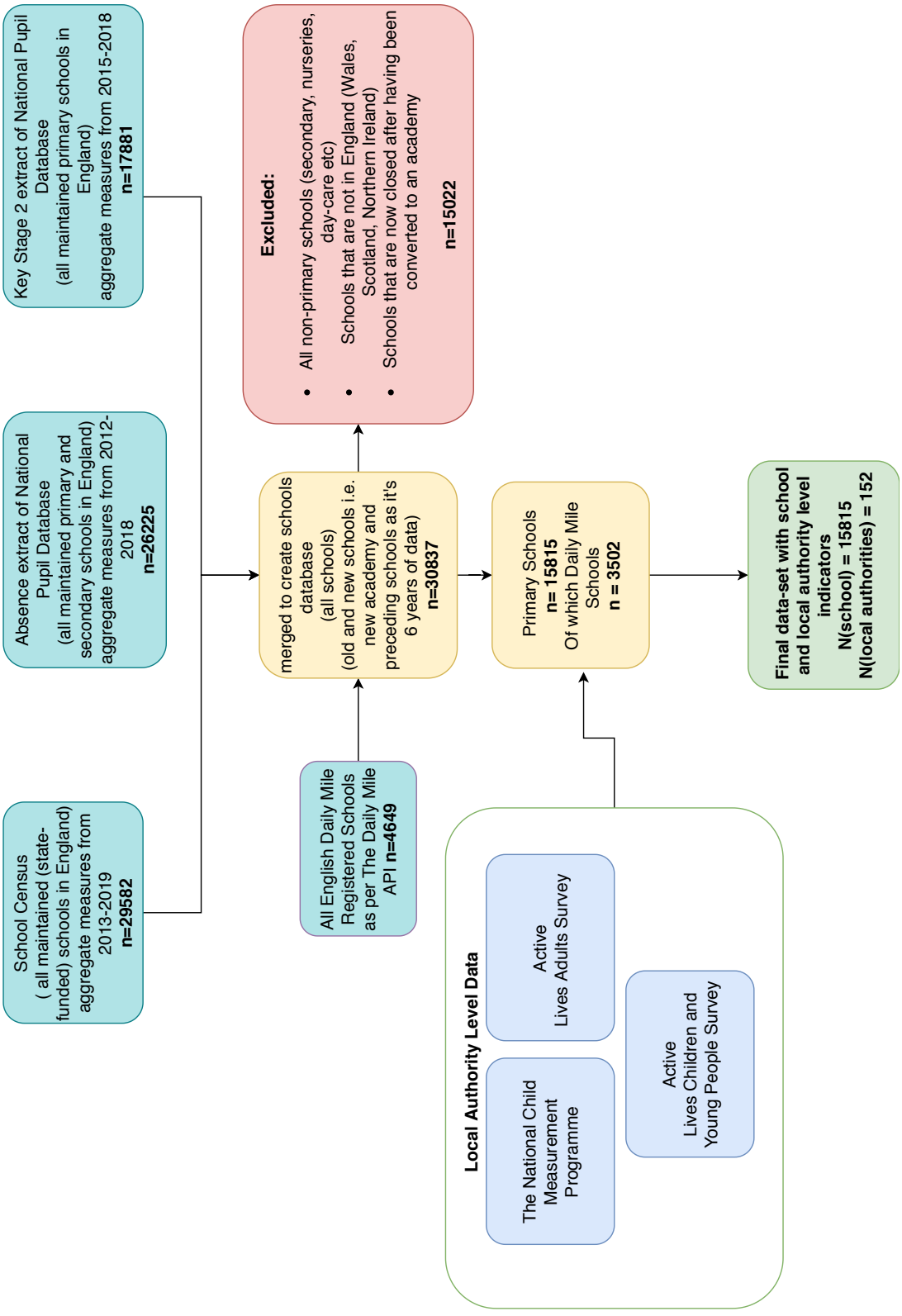
4.3.2.6 Primary School's Database Creation

I created a school's database linking data from the National Pupil Database extracts on Key Stage 2 and Absence, the School Census. I did this for all state-funded primary schools in England, including academies and free schools that report directly to the central government, and local authority-controlled schools that report to local government. I included all primary schools in the 2018 School Census that had a valid Unique Reference Number. I excluded secondary schools, nurseries, and day care centres and removed schools that were closed on the date of data collection, for example, those that had converted to an academy, to avoid duplication. In order to minimise loss of observations due to missing data in a single year, I used the mean of available data from up to six years from the School Census and the Absence extract of the National Pupil Database, and from up to three years of educational attainment data from the National Pupil Database.[401,412] Within the primary schools' database, I

defined TDM registration as all primary schools that were officially registered with The Daily Mile Foundation on 1st August 2019.

To this primary school's database, I linked local authority profiles of obesity prevalence and physical activity in each local authority. I linked local authority level data on adult's excess weight status and physical activity from the Active Lives Adults Survey from 2017-2018; children's physical activity from the Active Lives Children and Young People Survey 2017-2018; children's excess weight status from the National Child Measurement Programme 2017-2018. The final dataset had 15,815 school, of which there were 3,502 official schools registered to TDM in England (**Figure 4.3**).

Figure 4.3: Primary School's Database Creation



4.3.3 Thesis Study 2 (Objective 2 and 3): Equity of The Daily Mile

Study 2 addresses objective 2 and 3 of this thesis which are: To examine local authority areas most in 'need' of physical activity promotion for children in England; and to assess whether schools' populations participating in TDM are representative of the needs of the general population. Study 2 includes data only on the local authority level and has some common data sources from Study 1; however, these datasets are from different years. The only school data included in this Study is data on registration to TDM.

Local authority data linkage

In this study, I merged local authority data from:

- Active Lives Adult Survey (Section 4.3.2.3) from 2018-2019. I use data from this survey to quantify local authority prevalence of physically active adults and the prevalence of adults with excess weight status.
- Active Lives Children and Young People Survey (Section 4.3.2.4) from 2018-2019. I use data from this survey to quantify local authority prevalence of physically active children.
- National Child Measurement Programme, (Section 4.3.2.5) from 2018-2019. I use data from this survey to quantify local authority prevalence of children with excess weight status.
- Department for Education School Census (Section 4.3.2.1) from 2017-2018. I use data from here to quantify local authority prevalence of deprivation in children.
- Department for Education Special Education Needs Statistics (detailed below - Section 4.3.3.1)
- Natural England: Monitor of Engagement with the Natural Environment survey (detailed below - Section 4.3.3.2)
- What About YOUth Survey (detailed below - Section 4.3.3.3)

4.3.3.1 Department for Education Special Education Needs Statistics

The Department for Education special educational needs statistics is based on pupil-level data collected through the school-level annual school census. An Education, Health and Care (EHC) plan details the education, health and social care support that is to be provided to a child or young person who has Special Educational Needs (SEN). The local authority draws it up after an EHC needs assessment of the child has determined that an EHC plan is necessary, and after

consultation with relevant partner agencies. This dataset includes various types of primary needs in children including, Specific Learning Difficulty; Moderate Learning Difficulty; Severe Learning Difficulty; Profound & Multiple Learning Difficulty; Social, Emotional and Mental Health; Speech; Language and Communication Need; Hearing Impairment; Visual Impairment; Multi-Sensory Impairment; Physical Disability; Autistic Spectrum Disorder.[404] Data on the primary types of need is collected for pupils on SEN support or those with an EHC plan.

I use these data to quantify the local authority prevalence for children with social, emotional and mental health needs. This is one of the most common needs in children, especially among 'looked after children' (40%) and pupils with a primary type of need 'Social, emotional and mental health' had the highest permanent exclusion rate in 2017-2018.[413] These data were from 2017-2018.

4.3.3.2 Natural England: Monitor of Engagement with the Natural Environment survey

The Monitor of Engagement with the Natural Environment survey collects data on engagement with the natural environment (all green open spaces in and around towns and cities as well as the wider countryside and coastline), focusing on visits to the natural environment. During each survey interview, respondents are asked to indicate how many visits they have taken to the natural environment in the last seven days. Their survey includes data from approximately 45,000 respondents. The estimates are weighted to be representative of the national population.[414] I use data from this survey to quantify the proportion of people who utilise outdoor space for exercise or health reasons. These data were from 2015-2016.

4.3.3.3 What About YOUth Survey

The What About YOUth survey has local level data on a range of topics relating to young people, including emotional wellbeing, diet, and physical activity. The survey randomly selected around 300,000 15-year-olds from the Department for Education's National Pupil Database, which contains details of every pupil in England. They had around 120,000 completed questionnaires being returned. The estimates are weighted to be representative of the national population.[406] I use data from this survey to quantify the adolescent sedentary time in local authorities. These data were from 2014-2015.

4.3.4 Thesis Study 3 (Objective 4 and 5): Impact of The Daily Mile

Study 3 addresses objectives 4 and 5 of this thesis which are: To compare reported physical activity (minutes of MVPA) in primary school children attending schools registered to TDM compared to those who are not; and to compare the variety of reported physical activity in primary school children attending schools registered to TDM compared to those who are not.

In Study 3 I only use individual child level physical activity data from the Active Lives Children and Young People Survey 2018-2019 referred to as the "Active Lives Survey" hereon to address the corresponding objectives. Each individual child (observation) within the Active Lives Survey has an indicator for whether they attend a school registered to TDM or not. These data are built-in to the survey by Sport England and school registration to TDM is as of April 2019.

4.3.4.1 Active Lives Children and Young People Survey 2018-2019

Overview and Sample Design

The Active Lives Survey (is a publicly funded survey commissioned by Sport England that collects data on children aged 5 to 16 years from schools (every year, since 2017). Schools were drawn from the Department for Education list of schools (Edubase 2017-2018). The database contained 24,281 schools, from which certain types of establishments were removed (such as Nurseries, Pupil Referral Units, Special schools, Technology and Technical colleges, Studio schools, Sixth form colleges, schools with fewer than 30 pupils or containing only one year group). As a result, there was a sample frame of 21,351 schools. Of these 6,101 were selected as the main sample and 2,003 as a reserve sample. The reserve sample comprised up to five primary and five secondary schools in each local authority but not every local authority had sufficient schools. Up to ten primary schools in each local authority were selected. Reserve schools were only asked to complete the survey in local authorities when insufficient responses had been obtained from the main sample.

The survey is filled in schools in the Spring, Summer and Autumn terms. Schools in the main sample were allocated a term using systematic random sampling. The survey was designed to include 35% of the schools in the autumn term, 35% in the spring term and 30% in the summer term; 2,136 were included in the main sample for the autumn term, 2,136 for the spring term

and 1,829 in the summer term. In the spring and summer term, there was a need to involve reserve schools – 237 and 207 schools respectively in each corresponding term.

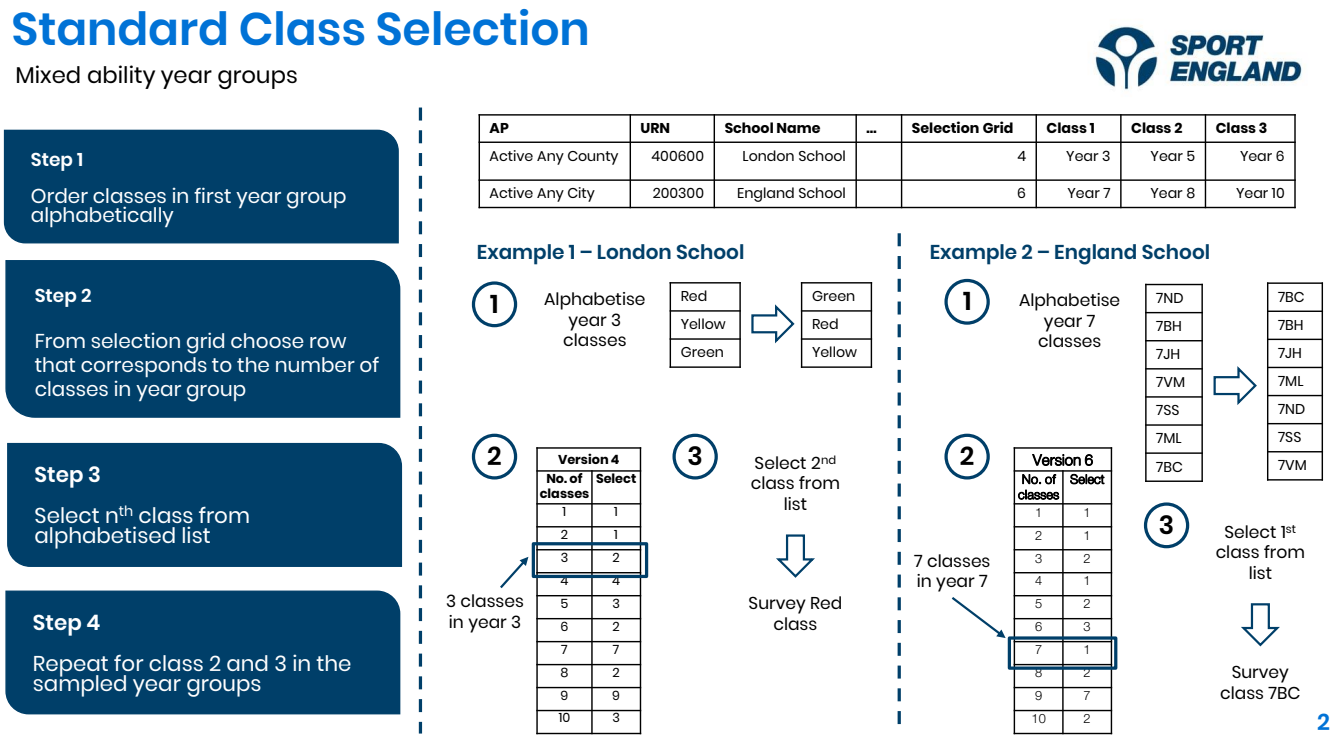
Schools with a probability of selection of one or greater were automatically included in the sample. The remaining schools were selected with a probability proportional to size.
For each school, one class from up to three-year groups was selected. For schools with only two eligible year groups, only two were selected.

The process for standard class selection for mixed ability year groups is as follows (Figure 4.4):

- Step 1: Order classes in the first year group alphabetically.
- Step 2: From the selection grid choose the row that corresponds to the number of classes in the year group (e.g., 3 classes in year 3).
- Step 3: Select n^{th} class from the alphabetised list.
- Step 4: Repeat for classes 2 and 3 in the sampled year groups.

Class selection differs based on the type of school and year groups such as no mixed ability classes, single sex classes in a mixed sex school, small single year group classes, some mixed year group lasses, small school with all mixed year group classes.

Figure 4.4 Sport England's standard class selection guide



Once a school and the respective year groups were selected, Active Partnerships communicated this to the school and were responsible for requesting schools to participate. Active Partnerships did this either directly or via third parties. Once a school had agreed to participate, they used a Kish Grid provided by Ipsos MORI to select one mixed ability class within each of their selected year groups. URLs for the online surveys were then provided to each school. There were unique URLs for each school but not each pupil or parent.

Response Rate

Sport England does not collect information on how many children from each class answered the survey. I determined a 31% response rate for schools since 1,907 schools responded with partial or complete pupil responses out of 6,101 schools invited in the main sample. Of these 1,907 schools, 1,102 were state primary schools.

Questionnaire:

All children were asked to self-complete the online survey. There was a short simple questionnaire of 13 items for pupils in Years 1-2 (aged 5-7 years) that covered simple demographic questions, children's attitudes to physical activity and their means of

transportation to school. There was a longer 50 item questionnaire for pupils from Years 3 to 6 (aged 7-11 years). Parents of pupils in Years 1-2 additionally completed the 50-item questionnaire by proxy for their children. Questions included type of physical activity, location (in and out of school), duration (time spent doing), and intensity done in the preceding 7 days. The questionnaires can be found in Appendix A.

Type of activity:
Data collected from respondents: Children and parents were asked to select activities they (or their children) did from a list of activities provided (e.g., football, riding a scooter for fun or to get to places like school, friends' houses or the park).

Location:
Data collected from respondents: In school and outside school location of activity was filled in by the respondent. The respondent was asked which days they (or their child) did each activity they previously selected while at school during normal school hours, or outside school hours.

Data processed by Sport England: Location could further be broken down into indoor and outdoor activity; for e.g., in school indoor or in schools outdoors etc. The indoor/outdoor location of activities was assumed using a standard approach at Sport England Appendix B.

Duration of activity:

In school: Duration of all in-school activity was processed by Sport England. For all activities in school, durations have been imputed using a standard set of times related to the year group and type of activity based on data for outside school; information from teachers on PE and break time durations; and the results of an objective measurement study done by Sport England.

Outside school: Duration of outside school activity was first collected from respondents and then processed by Sport England. Children and parents (Years 1-2) provided duration information for activity done outside school as six response groups (less than 10 minutes, less than half an hour, about half an hour, about three-quarters of an hour, one hour, more than an hour, and children in year 3 to 6 had an option 'Don't Know').

Each child's exact allocated time in minutes was then imputed based on evidence from an objective measurement study.

The details on the objective measurement study and further detail on the validation done have not been made available by Sport England. For more detail on duration of activity, see Appendix C. Please see Appendix D for the Active Lives Children and Young People Survey 2018/2019 Technical Note that describes the validation of the Active Lives Survey data done by Sport England.

Intensity: All activity was assumed to be of moderate intensity for children in Years 1 and 2. Children in years 3 to 6 were asked to report intensity of activities as either moderate or vigorous. Moderate activities were defined as activities that a child reported made them breathe faster, raised their heart rate, or made them feel a little out of breath. Vigorous activities were defined as activities where a child reported becoming hot or tired, or if they were out of breath or sweating. Moderate-to-vigorous was a combination of these.

Sociodemographic data

The survey includes key demographic data for children on year group, gender, ethnicity, family affluence scale, and disability status and impairments. At the school level, matched on school location, there is data on rurality, deprivation (Index for Multiple Deprivation), school size, Ofsted rating etc.

The Daily Mile data within the survey

The survey includes an indicator for whether a child attends a school officially registered to TDM or not. This variable is built-in to the survey by Sport England. The date of registration is as of April 2019. Registration to TDM data was provided to Sport England by The Daily Mile Foundation.

Other physical activity data

Attitudes to physical activity and physical literacy

The Active Lives Survey also includes data about children's attitudes to physical activity. Children in Year 3 to 6 were asked four questions about their attitude towards enjoyment, confidence, competence and understanding of physical activity.

Wellbeing

Children in Year 1 and 2 filled in a simple smiley face questionnaire to express whether they felt happy, neither happy nor sad, sad. Children in Year 3 to 6 filled in the ONS happiness yesterday question which is "How happy did you feel yesterday?". The survey also collected data on individual and community development, sport spectating (whether a child went to see a sporting event) and whether they had done any volunteering at least twice in the last 12 months to support sport and physical activity.

Clustering data

School: The survey includes a variable which identifies the school. All the responses from the same school have the same unique school identifier. All pupils with the same unique school identifier go to the same school. However, it is not possible to identify which school pupils attend from the unique school identifier (i.e., the school URN used by the Department for Education), just that they are clustered within the same school.

Local Authority: The sample was stratified by Local Authority. There is a variable within the data that identifies all responses from the same local authority. However, the variable does not show which local authority this is.

4.3.4.1.1 Validation of Active Lives Children and Young People Survey 2018-2019

Sport England imputes data before datasets are made freely available where information on duration, location or intensity of activity was missing to ensure activity variables could be calculated for every child in the survey.

The physical activity data from the Active Live Survey is self-reported (either by children or their parents by proxy). While Sport England do mention in their Technical Note for the survey that their derived and imputed activity data for children is based on an objective measurement study where children used a waist worn accelerometer and completed the questionnaire so that their objective data could be compared with the data collected in the questionnaire, the detail provided by Sport England on this is limited.

For more information on the sampling, technical information and imputation used in the survey, please refer to Sport England's Active Lives website[415] and Appendix A, B, C and D.

4.3.5 Thesis Study 4 (Objective 6 and 7): Fidelity to The Daily Mile

Study 4 addresses objective 6 and 7 of this thesis which is to assess if children in TDM registered schools report doing a daily mile by adhering to its core running criteria of 15 min running in school outdoors MVPA three times a week; and to examine the association between TDM registration and within school variation of self-reported activity - using de-facto daily mile as a case study.

As with Study 3, in Study 4 I only use individual child level physical activity data from the Active Lives Children and Young People Survey 2018-2019 (with embedded TDM data for children) to address the corresponding objectives.

4.3.6 Access and Ethical approval required to use these data

Ethical approval for Study 1 and 2 was granted by the Imperial College Research Ethics Committee (Reference 19IC5320) (Appendix E). Study 3 and 4 did not require ethical approval as it used publicly available, de-identifiable, anonymised data with TDM registration data being linked to the Active Lives Children and Young People Survey 2018-2019 by the data owner, Sport England, before I was given access.

5. Reach of The Daily Mile

Overview

Previous chapters offered potential reasons for why a large proportion of children in the United Kingdom and the world do not meet the physical activity recommendations and why interventions, including TDM have not been particularly successful. One of the main reasons has been fidelity of implementation of complex interventions that are not sustainable. TDM has been found to be an easy-to-implement intervention, provides teachers with autonomy and has been recommended in official policy documents by the United Kingdom Government to address shortfalls in children's physical activity. However, there is no evidence of its distribution within England or of the characteristics of school populations that register. Many schools, particularly those in urban areas, have limited access to outdoor space or have concerns about the risks of exposing children to air or traffic pollution, which could act as disincentives for uptake of TDM and other active mile interventions that involve running or jogging outside. Key performance indicators of educational attainment in United Kingdom schools are firmly tied to performance in reading and writing scores. Thus, it is possible that primary schools that lag in performance league tables do not prioritise activities such as TDM that may compete with curricular time. The current chapter addresses this gap. The relevant thesis objective is: ***To examine primary school and local authority characteristics associated with registration for The Daily Mile.*** *The work presented in this chapter has been previously published.*[416]

5.1 Methods

5.1.1 Design

This was a cross sectional study of all state-funded primary schools in England.

5.1.2 Data sources

I created a school's database linking health and education data from the School Census, the National Pupil Database, Active Lives Adult Survey, Active Lives Children and Young People Survey, and the National Child Measurement Programme, with TDM registration data provided by The Daily Mile Foundation (Figure 5.1). This linkage has been previously described in Chapter 4 (Section 4.3.2.6) with all the data sources detailed in Section 4.3.2.

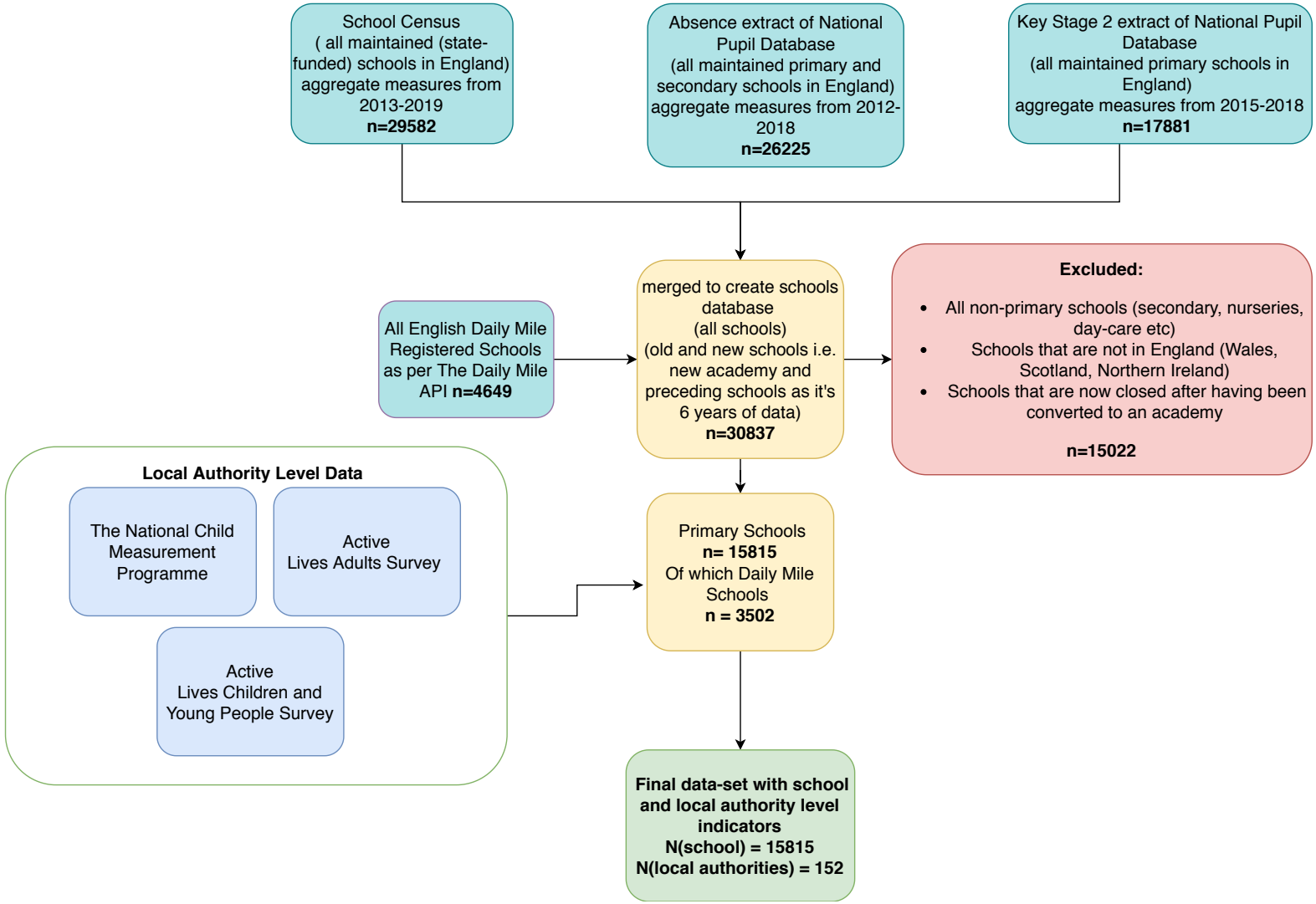
School profiles

The School Census collects aggregate information annually from all state funded schools and includes data on more than 15,000 schools and over 4.5 million children.[400] It holds data on pupil characteristics including pupil numbers, ethnicity, if they are disadvantaged, or whether they have any special educational needs (Table 5.1). The National Pupil Database includes pooled data, based on multiple data collections on pupils aged 3-19 years in state funded schools in England. It contains data on pupils' educational attainment from national annual standardised assessments conducted each academic year.[401] It also includes data on pupils' absences. More details on these datasets are listed in (Section 4.3.2).

Local authority profiles

There are a total of 152 counties and unitary authorities in England which include metropolitan districts, London boroughs, unitary authorities, and county councils which were defined as local authorities for this study.[417] The National Child Measurement Programme is a nationally mandated surveillance programme that collects height and weights converted to weight status for over 1 million children which includes 98% of all children in England entering and leaving primary school each year.[48] The Active Lives Adult Survey collects data on self-reported physical activity and weight status of adults, and the Active Lives Children and Young People Survey contains self-reported data on children's physical activity in England.[418] I linked population profiles of obesity prevalence and physical activity in each local authority to the schools' database. More details on these datasets are listed in (Section 4.3.2).

Figure 5.1: Flow diagram of routine data sources used to create database of primary schools in England used in this study



5.1.3 Population

This study's population included all state funded primary schools in England, including academies and free schools which report directly to the central government, and local authority-controlled schools which report to local government. I included all primary schools in the 2018 School Census that had a valid Unique Reference Number. I excluded secondary schools, nurseries, and day care centres and removed schools that were closed on the date of data collection, for example those that had converted to an academy, to avoid duplication.

5.1.4 Key Measures

Outcome:

Within the primary schools' database, I created a binary variable to define TDM registration. Registration was defined as all primary schools that were officially registered to do TDM till 1st August 2019, assuming that schools that were not officially registered with TDM Foundation were not taking part in TDM.

Predictors:

To examine primary school and local authority characteristics associated with registration for TDM, I selected ten candidate variables that are proxy indicators of school characteristics and pupil health and wellbeing. At the school level, variables included the size of the school, school type, rurality of the school, percent of disadvantaged pupils in the school, percent of pupils whose first language is known or believed to be other than English was used as a proxy measure for ethnic diversity in the school, and educational attainment. At the local authority level, variables included adult and child physical activity levels, and adult and child excess weight status prevalence. In England, one in five children is overweight or obese at the beginning of primary school, increasing to one in three by the end of primary school.[419] Among adults in England in 2017, 64% were overweight or obese.[420]
The association between parental excess weight status and child excess weight status is well supported by the literature, with studies maintaining the presence of familial risk factors when examining childhood obesity.[421–423] Similarly, a recent systematic review found observed a consistent positive, albeit weak, relationship between parent and child physical activity regardless of the children's age, gender, parents-child dyad, and type of physical activity.[424] Therefore, it was relevant to include adult measures of obesity and physical

activity. Further obesity and physical activity are socially patterned in both adults and children. In adults, income as an indicator of deprivation has been found to be inversely associated with obesity[425,426] This inverse trend between deprivation and obesity in children is also well documented, especially in high income countries like the United Kingdom.[427–429] Additionally, free and accessible physical activity resources in natural sites and outdoor space is an encouraging strategy for tackling the physical inactivity in both children and adults at the population level.[430–432] For detailed definitions of these predictors, see Table 5.1.

Table 5.1: Variables included in models to examine primary school and local authority characteristics associated with registration for The Daily Mile

Variables for models	Data Source	Definition
School Variables		
Pupil Number	School Census	Number of boys and girls enrolled in the school according to the school census.
School Type	School Census	Local authority-controlled or Academy
Rurality	School Census	Office for National Statistics Classification: Rural: Hamlets and Isolated Dwellings, Town and Fringe, and Village Urban: Urban city and town, Major Conurbation, and Minor Conurbation.
Percent disadvantaged pupils	School Census	Eligible for free school meals or have been in the last six years; Looked After Children, or those who have previously looked after by the state but are now adopted or are subject to a special guardianship order, a child arrangements order, or a residence order; Children with parents in the armed forces.
Percent of pupils whose first language is known or believed to be other than English	School Census	A proxy measure for ethnic diversity: A pupil's first language is defined as any language other than English that a child was exposed to during early development and continues to be exposed to in the home or community.
Educational attainment – Percent of pupils reaching the expected standard in reading, writing, and maths	National Pupil Database	Educational attainment defined as the expected standard in reading, writing, and mathematics. It is a scaled score of 100 or above that is derived from standardised testing. A scaled score of 100 or more signifies a child is working at the expected national standard, while a score below 100 indicates that a child hasn't reached the government expected national standard. The

		maximum score possible is 120, and the minimum is 80.
Local Authority Variables		
Adult Physical Activity Levels	Active Lives Adults Survey	Percent adults reporting they are doing moderate or vigorous activity for more than 150 minutes a week.
Child Physical Activity Levels	Active Lives Children and Young People Survey	Percent children reporting they are doing moderate or vigorous activity for 30 minutes or more of both at school and outside school every day.
Adult Excess Weight Status Prevalence	Active Lives Adults Survey	Percent of adults (aged 18+) classified as overweight or obese.
Child Excess Weight Status Prevalence	National Child Measurement Programme	Percent of children classified as overweight or obese at reception, the beginning of primary school when children are 5-6 years old.

5.1.5 Statistical analysis

I compared school and local authority characteristics of primary schools registered to TDM with those that were not registered. I also examined the local authority health profiles of child and adult physical activity and obesity prevalence in areas in which primary schools were located. I used t-tests to compare continuous variables (e.g. % white pupils) and chi-squared tests to compare categorical variables (e.g. counts of schools by region) by registration to TDM.

Due to the hierarchical nature of the data, I used multilevel models to determine the association between school and local authority characteristics associated with TDM registration, and to assess variation in registration at school and local authority levels. To investigate the variation explained at different levels, I built a sequential series of models that is explained below.

5.1.5.1 Model building

After checking the need to account for clustering, I fitted a multilevel model with intercept only to examine the variability of TDM registration between local authorities (Model 1a). This empty/intercept-only model was used to calculate the intraclass correlation coefficient (ICC), which gives the between-local authority variability for the outcome variables. In multilevel analysis, the ICC assesses the proportion of variance in the outcome (e.g., TDM participation) that is present at the group level (e.g., local authority). The ICC for multilevel logistic

regression is given by the formula: $\rho = \tau_{00}/(\tau_{00} + \pi^2/3)$, where τ_{00} is the variance of the random intercept and $\pi^2/3$ is the level-1 error variance.[433–435] The proportion of variation in TDM participation that is present at the school level is given by $1 - \rho$. y. Next, to test whether school characteristics explained variation in registration, I extended Model 1 by adding school-level characteristics (Model 2a). Finally, I extended Model 2 by adding local authority characteristics (adult and child excess weight status and physical activity) (Model 3a) to determine the extent of variation explained

To examine primary school and local authority characteristics associated with registration for TDM, I selected ten candidate variables that are proxy indicators of school and pupil health and wellbeing. These were identified from the literature and by consensus among my PhD supervisory team (Table 5.1). These variables were then included in regression models. As the numeric values of the variables of interest in the models were on different scales of magnitude, I scaled all the continuous variables for the multilevel models through division by the standard deviation for the analyses ($\boldsymbol{\zeta = \frac{x-\mu}{\sigma}}$). All school and local authority characteristics were included in the final model (model 3), which assessed the association between school and local authority characteristics with TDM registration. For all the models, variables with an alpha level of <0.05 were considered statistically significant.

5.1.5.2 Model comparison

Models 1a, 2a, and 3a were also run as logistic regressions, without the local authority level random effect (model 1b, 2b and 3b respectively). This was to obtain a log likelihood ratio χ^2 test, to test the multilevel logistic regression model against the corresponding non-hierarchical logistic regression model to assess the goodness-of-fit. Results of the log likelihood ratio χ^2 test, along with the Akaike Information Criterion values showed that multilevel models were preferred. Model 3a was chosen as the best fit for the data and was the final model.

5.1.6 Missing Data

To minimise loss of observations due to missing data in a single year, I used the mean of available data from up to six years from the School Census and the Absence extract of the National Pupil Database, and from up to three years of educational attainment data from the National Pupil Database. Thereafter, I used a complete case analysis to run the models. I

conducted a sensitivity analysis to explore differences in characteristics between schools included and excluded from the models (Table 5.2). I did not consider the use of imputation methods as the same size was large even in the complete case, and the sensitivity analysis for included versus excluded observations did not show any meaningful differences.

Table 5.2: Sensitivity Analysis of missing data for variables included in the models

Variable	**Included Primary Schools (N=12214) N(%)**	**Excluded Primary Schools (N=3601) N(%)**
School Type		
Academy	3395 (27.80)	718 (19.93)
Local authority controlled	8819 (72.20)	1184 (32.88)
Missing	**-**	1699 (47.18)
Office for National Statistics Rurality Classification		
Hamlets and Isolated Dwellings (Rural)	618 (5.05)	148 (4.10)
Town and Fringe (Rural)	1425 (11.66)	302 (8.39)
Village (Rural)	1774 (14.52)	298 (8.28)
City and Town (Urban)	4776 (39.11)	1236 (34.32)
Major Conurbation (Urban)	3236 (26.49)	1475 (40.96)
Minor Conurbation (Urban)	385 (3.17)	142 (3.95)
Missing	-	-
	Included Primary Schools (N=12214) mean (SD)	**Excluded Primary Schools (N=3601) mean (SD)**
Pupils whose first language is known or believed to be other than English (%)	14.00 (19.98)	20.73 (24.79)
Pupils reaching the expected standard in reading, writing, and maths (%)	62.15 (14.73)	65.12 (13.87)
Disadvantaged pupils (%)	28.94 (18.71)	40.07 (19.34)
	Included local authorities Mean (SD) (N=124)	**Excluded local authorities Mean (SD) (N=28)**
% Adults who report being physically active for 150 minutes or more per week)	61.84 (5.32)	62.43 (5.77)
% Children reported as doing moderate or vigorous physical activity for 30 minutes or more of both at school and outside school every day	14.02 (2.83)	All missing
% Adult Excess Weight	65.05 (4.62)	62.52 (8.12)
% Overweight or obese children Reception (aged 5 years)	22.51 (2.91)	22.52 (2.83)
% Overweight or obese children in Year 6 (aged 11 years)	34.32 (4.57)	36.82 (3.36)
N = sample; SD = standard deviation		

5.2 Results

5.2.1 School characteristics and local authority population health profiles

Between 2012 and 2018 there were 15,815 state funded primary schools in England (Table 5.3). Of these, 3,502 schools (22.14%) were registered to do TDM. School populations ranged from 7 to 1,431 pupils (mean 275), and 30% of pupils were classed as disadvantaged overall.

TDM schools had greater mean pupil numbers compared to non-TDM schools (300 vs 269 respectively). The proportion of disadvantaged children in TDM schools was higher than non-TDM schools (32% vs 30% respectively). In line with this sample, which was all state funded primary schools across England, 72% of TDM schools were under local authority control and 28% were academies (including free schools). A greater proportion of TDM schools were located in urban areas, especially the major conurbations of London, the West Midlands, West Yorkshire, Tyneside, Merseyside, and Greater Manchester (Table 5.3). Further, TDM schools had a higher proportion of pupils whose first language was not English (18% vs 15% respectively), a higher proportion of pupils from black and minority ethnic groups, and higher academic progress measures compared with non-TDM schools (0.21 vs 0.11 respectively). The registration of TDM ranged from 16% in the East Midlands region to 31% in Inner London.

There are a total of 152 counties and unitary local authorities in England, all of which were in this sample (Table 5.4). Across all local authorities, the mean percentage of children meeting recommended levels of physical activity was 14%, and the proportion of overweight or obese children rose from 1 in 5 (at age 5) to around 1 in 3 (at age 11). Approximately 60% of adults reported being active for 150 minutes of more per week based on the Active Lives Adult Survey. This is possibly an overestimation given that it is self-reported and does not match the statistics from device-based measures.[436]

Table 5.3: **Sociodemographic characteristics of primary schools in England by The Daily Mile registration (level-1), (n=15815)**

	All Primary Schools N=15815 mean (SD)	**Daily Mile Registered Schools N=3502 mean (SD)**	**Non-Daily Mile Registered Schools N=12313 mean (SD)**	**p-value**	**# Schools reporting (N)**
School Size (Number of pupils)	275.92 (156.72)	299.79 (157.41)	269.13 (155.87)	<0.001[1]	15815
Disadvantaged pupils (%)	30.06 (19.07)	31.87 (19.46)	29.52 (18.92)	<0.001[1]	13585
% Ethnic group					
White	79.29 (24.57)	76.00 (26.64)	80.2 (23.86)	<0.001[1]	15815
Asian	7.94 (15.52)	9.54 (17.47)	7.48 (14.88)	<0.001[1]	15815
Black	4.35 (9.54)	5.32 (10.77)	4.07 (9.13)	<0.001[1]	15815
Mixed	5.21 (4.17)	5.58 (4.32)	5.10 (4.12)	<0.001[1]	15815
Other	2.6 (4.33)	2.89 (4.50)	2.52 (4.28)	<0.001[1]	15815
Unclassified	0.77(1.64)	0.78 (1.53)	0.77 (1.66)	0.602[1]	15743
Pupils known to be eligible for and claiming free school meals (%)	14.06 (11.19)	15.1 (11.52)	13.8 (11.10)	<0.001[1]	15743
Absence rate (%)	4.10 (0.87)	4.13 (0.86)	4.10 (0.87)	0.042[1]	15815
Pupils whose first language is known or believed to be other than English (%)	15.51(21.34)	17.97 (22.85)	14.81 (20.84)	<0.001[1]	15743
SEN Pupils with a statement or EHC plan (%)	1.93 (2.68)	1.97 (2.52)	1.92 (2.72)	0.36[1]	13585
Pupils reaching the expected standard in reading, writing, and maths (%)	62.45 (14.67)	62.69 (14.15)	62.38 (14.83)	0.292[1]	13585
Progress measure for reading, writing, and maths	0.13(1.84)	0.21 (1.77)	0.110 (1.86)	<0.05[1]	13548
	All Primary Schools N (%)	**Daily Mile Registered Schools N (%)**	**Non-Daily Mile Registered Schools N (%)**	**p-value**	
School Type					

Academy	4113 (26.01)	927 (28.44)	3186 (8.54)	0.33[2]	14116
Local authority controlled	10003 (63.25)	2332 (71.56)	7671 (21.48)		
Office for National Statistics Rurality Classification					15815
Hamlets and Isolated Dwellings (Rural)	766 (4.84)	134 (3.83)	632 (5.13)	<0.001[2]	
Town and Fringe (Rural)	1727 (10.92)	314 (8.97)	1413 (11.48)		
Village (Rural)	2072 (13.1)	335 (9.57)	1737 (14.11)		
City and Town (Urban)	6012 (38.01)	1199 (34.24)	4813 (39.09)		
Major Conurbation (Urban)	4711 (29.79)	1408 (40.21)	3303 (26.82)		
Minor Conurbation (Urban)	527 (3.33)	112 (3.2)	415 (3.37)		
Region					15815
North East	1492 (9.43)	203 (5.8)	598 (4.86)	<0.001[2]	
North West	1839 (11.63)	639 (18.25)	1734 (14.08)		
Yorkshire and the Humber	686 (4.34)	334 (9.54)	1338 (10.87)		
East Midlands	801 (5.06)	247 (7.05)	1245 (10.11)		
East of England	2373 (15)	412 (11.76)	1427 (11.59)		
West Midlands	1061 (6.71)	332 (9.48)	1323 (10.74)		
Inner London	2508 (15.86)	214 (6.11)	472 (3.83)		
Outer London	1728 (10.93)	285 (8.14)	776 (6.30)		
South East	1655 (10.46)	501 (14.31)	2007 (16.30)		
South West	1672 (10.57)	335 (9.57)	1393 (11.31)		

[1]p-value derived from t test comparing variable and TDM registration

[2]p-value derived from chi squared test comparing variable and TDM registration

SEN: Special Educational Needs

EHC: Education, health and care plan

Progress measures are a value-added measure that pupils' results are compared to the actual achievements of other pupils nationally with similar prior attainment. Progress scores will be centred around 0, with most schools within the range of -5 to +5[437].

N = number/sample

SD = standard deviation

Table 5.4: Characteristics of local authorities included in the study in England (level-2), (n=152)

	Mean (SD)	Local authorities reporting (N)
% Adults who report being physically active for 150 minutes or more per week)	62.21 (4.37)	124
% Children reported as doing moderate or vigorous physical activity for 30 minutes or more of both at school and outside school every day	13.98 (2.35)	152
% Adult Excess Weight	65.26 (4.10)	152
% Overweight or obese children Reception (aged 5 years)	22.35 (2.54)	150
% Overweight or obese children in Year 6 (aged 11 years)	33.66 (4.04)	150
SD = standard deviation; N = number/sample		

5.2.2 Characteristics associated with registration to The Daily Mile

Table 5.5 presents results of the modelling process. I found significant variation in school registration to TDM by local authority. This is reflected in the likelihood ratio of the $\chi 2$ test comparing the ordinary logistic to the multilevel model that was significant. Additionally, the random intercept of the null model (intercept only model 1a) was 0.34. The estimated local authority level effects from the intraclass correlation coefficient (ICC) of model 1a was 0.094. This infers that approximately 9.4% of the total variance in TDM registration by schools is explained by local authority effects.

After adjusting for school-level characteristics (model 2a), schools in a major urban conurbation showed almost 50% higher odds of being registered for TDM (OR 1.46(95%CI 1.24-1.71)) compared to those in cities and towns. Further, schools with a higher proportion of disadvantaged pupils had higher odds of being registered as a TDM school compared with schools with a lower proportion of disadvantaged pupils; whereby an increase of 1 standard deviation (19%) in the proportion of disadvantaged pupils produces, on average, a 16% increase in the odds of being a TDM school (unscaled adjusted OR 1.16(95%CI 1.0-1.33)).
In the fully adjusted model, that included school and local authority variables (model 3a), I found no significant associations between school registration with TDM and a school's educational attainment measures, pupils whose first language was not classified as English which was a proxy measure for the ethnic composition of the school, and local authority prevalence of child and adult physical activity, child and adult excess weight status.
I found that local authority effects explained 9.4% of the residual variance in TDM registration by schools and the schools' characteristics explained 90.6%. When school characteristics were added to the intercept only model, only part of the variation observed in model 1a (2.6%) was explained (model 2a ICC=0.068). The ICC for Model 3a=0.064, dropping only very marginally from Model 2a, even after adding local authority prevalence of excess weight status and physical activity variables for children and adults. This suggests that local authority prevalence of adult and child physical activity and excess weight status account for only ~0.4% of the variation seen in schools' TDM registration.

Table 5.6 presents the results of the same models as in Table 5.5, without the random effect for school. These models were used to derive the likelihood ratio of $\chi 2$ test comparing the ordinary logistic to the multilevel models, i.e., model 1b compared to 1a, model 2b compared to 2a, and model 3b compared to model 3a.

Table 5.5: **Multilevel multivariable logistic regression of school and local authority characteristics on The Daily Mile registration in England (level-1 N=12,214 primary schools; level-2 N=124 local authorities) using scaled parameters**

#	Parameters	Model 1a: intercept only		Model 2a: + school variables		Model 3a: + local authority variables		
		OR (95% CI)	Standard Error	Scaled OR (95% CI)	Standard Error	Scaled OR (95% CI)	Standard Error	Unscaled OR (95% CI)
1	**Local authority-controlled School~~**			1.06 (0.96, 1.17)	0.05	1.07 (0.96, 1.19)	0.05	
2	**Hamlets and Isolated Dwellings (Rural)¥**			0.95 (0.75, 1.21)	0.12	0.96 (0.76, 1.22)	0.12	
3	**Town and Fringe (Rural)¥**			1.01 (0.87, 1.19)	0.08	1.03 (0.87, 1.21)	0.08	
4	**Village (Rural)¥**			0.88 (0.75, 1.04)	0.08	0.88 (0.74, 1.04)	0.09	
5	**Major Conurbation (Urban)¥**			1.46*** (1.24, 1.71)	0.08	1.46*** (1.22, 1.74)	0.09	
6	**Minor Conurbation (Urban) ¥**			1.04 (0.73, 1.48)	0.18	0.93 (0.63, 1.37)	0.2	
7	**% of pupils whose first language is known or believed to be other than English**			1.00 (0.95, 1.05)	0.03	1.01 (0.95, 1.07)	0.03	1.23 (0.33, 4.59)
8	**% of pupils reaching the expected standard in reading, writing, and maths**			0.99 (0.95, 1.04)	0.02	1.00 (0.96, 1.05)	0.02	0.98 (0.50, 1.91)
9	**% disadvantaged pupils**			1.01** (1.00, 1.02)	0.00	1.01* (1.00, 1.02)	0.004	1.16 (1.02, 1.33)

10	**% overweight or obese adults**					0.97 (0.86, 1.11)	0.07	0.89 (0.51, 1.52)
11	**% physically active adults**					0.93 (0.83, 1.05)	0.06	0.73 (0.44, 1.22)
12	**% physically active children**					1.02 (0.93, 1.11)	0.04	1.04 (0.85, 1.26)
13	**% children who are overweight or obese**					0.97 (0.88, 1.07)	0.05	0.92 (0.72, 1.17)
	Model Summary							
Intercept		0.29*** (0.26, 0.32)	0.05	0.22*** (0.18, 0.26)	0.088	0.22*** (0.18, 0.26)	0.09	
ICC		0.09		0.07		0.06		
Likelihood ratio χ2 test (ordinary logistic vs multilevel logistic model)		557.42***		302.24***		247.12***		
AIC/BIC		16185.3 (BIC)		14290.5 (BIC)		12688.2 (BIC)		
		16170.0 (AIC)		14207.8 (AIC)		12577.0 (AIC)		
***p≤0.05; **p≤0.01; ***p≤0.001**								
~~ (reference group = Academy) **¥ (reference group = City and Town**								
Parameters 1 to 13 all are fixed-effects estimates; ICC = intraclass correlation coefficient; AIC = Akaike information criterion; BIC = Bayesian information criterion; OR = Odds ratio;								

Table 5.6: Multivariable logistic regression of school and local authority characteristics on The Daily Mile uptake in England using scaled parameters (N=15815 primary schools)

Parameters	Model 1b: intercept only		Model 2b: + school variables		Model 3b: + local authority variables	
	OR (95% CI)	Standard Error	Scaled OR (95% CI)	Standard Error	Scaled OR (95% CI)	Standard Error
Local authority-controlled School			1.03	0.05	1.03 (0.93, 1.13)	0.05
Hamlets and Isolated Dwellings (Rural)¥			0.91	0.12	0.94 (0.75, 1.18)	0.12
Town and Fringe (Rural)¥			0.94	0.08	0.96 (0.82, 1.12)	0.08
Village (Rural)¥			0.821*	0.08	0.84* (0.71, 0.98)	0.08
Major Conurbation (Urban)¥			1.67***	0.05	1.70*** (1.51, 1.91)	0.06
Minor Conurbation (Urban) ¥			1.13	0.12	1.02 (0.79, 1.33)	0.13
% pupils whose first language is known or believed to be other than English			0.99	0.02	1.00 (0.95, 1.06)	0.03
% pupils reaching the expected standard in reading, writing, and maths			1.00	0.02	1.01 (0.97, 1.06)	0.02
% disadvantaged pupils			1.01	0.003	1.01 (1.00, 1.01)	0.003
% overweight or obese adults					1.01 (0.94, 1.08)	0.04
% physically active adults					0.95 (0.89, 1.01)	0.03
% physically active children					1.00 (0.97, 1.05)	0.02
% children who are overweight or obese					0.93** (0.89, 0.98)	0.02
Model Summary						
AIC	16725		14508		12822	
*p≤0.05; **p≤0.01; ***p≤0.001						
¥ (reference group = City and Town AIC = Akaike Information Criterion; OR = Odds ratio						

5.3 Discussion

5.3.1 Summary of chapter findings

- One in five primary schools across England has registered with TDM since 2012. The distribution varies across the ten English regions but is much higher in London and major urban conurbations where over a third of primary schools are registered.
- After adjusting for school and local authority characteristics, larger primary schools in urban areas and a higher proportion of disadvantaged children were more likely to have registered for TDM.
- There was no association between TDM registration and area-based physical activity or excess weight status, or schools' educational attainment.
- Additionally, there was evidence of variation in registration of TDM in different local authorities that was not accounted for by characteristics of schools and its pupils.

5.3.2 Strengths and Limitations

To my knowledge, this study is the first national study to characterise primary school uptake of a whole school-based physical activity intervention. Its strengths are its size and use of routine data that is nationally representative of around 4.7 million children in over 15,000 state funded primary schools and all local authorities in England[438], reducing selection bias. The use of multilevel models allowed me to account for the clustering of pupil data within schools, and population health indicators in local authorities, as well as adjust for important confounders. The decision to take an average of multiple years of data reduces the missing data but also selection bias due to the potential of some schools being more or less likely to submit data to the government.

However, there are a number of important limitations to this study. The models included 12,214 of the 15,815 schools due to missing data. However, the sensitivity analysis (Table 5.2) showed that there was no selection bias as schools modelled were similar to those excluded. The accuracy of registration data for TDM provided by The Daily Mile Foundation, which contains a list of schools registered to do TDM via their online official website, was not validated. I consider registration to be an intention to adopt TDM rather than a proxy measure of participation in TDM.[313,318] I was unable to obtain physical activity for individual children or schools and have instead relied on reported area-based measures of children's physical activity that is subject to recall bias.

5.3.3 Possible explanations and comparison of findings with previous literature

This studies' findings that more TDM registered schools were located in major urban conurbations, such as London, could be a result of media campaigns and promotion of TDM and public health endorsement of TDM in some local authorities.[439,440] Sport England in partnership with The Daily Mile Foundation have invested £1.5 million in funding 13 coordinators across England to increase uptake and implementation of TDM; this could explain its widespread uptake.

There is mixed evidence surrounding the association between children's physical activity and living in urban or rural areas.[441,442] Some studies [442,443] have found that children in urban areas are less physically active compared with rural areas. This is expected, given the multiplicity of ways in which attributes of the physical and built environment affect physical activity in children and adults.[444] Nonetheless, the finding of this study may be evidence of a successful movement to drive up physical activity among children in urban areas. This is important as 33.5% of the United Kingdom population lives in major urban conurbations, and include Greater London, the West Midlands, West Yorkshire, Tyne and Wear and, Merseyside and Greater Manchester.[445]

Additionally, I found that after adjusting for rurality and ethnicity, having a higher proportion of disadvantaged pupils in a school increased the odds of adopting TDM. This is inconsistent with previous studies,[446] which have found that people from lower socio-economic groups are less likely to be physically active compared with those from higher socio-economic groups. However, TDM has been found to be a 'simple' and 'easy-to-implement' intervention, potentially making it more accessible to disadvantaged populations who have previously excluded from complex interventions.[108]

My finding that schools registering for TDM have similar educational attainment to the wider population of schools, also suggests it is a wide-reaching intervention that reaches both high and low performing schools. The evidence base about the effect of school-based physical activity interventions, active miles, and TDM itself on cognition and educational attainment is limited.[105,374] However, it is not possible to draw an causal links in this study. The findings only state that TDM has been taken up in both high and low achieving schools. Further,

previous studies of school-based physical activity interventions have not shown they are effective in increasing MVPA in children.[21,282,447] One of the possible reasons for this may lie in difficulties implementing complex interventions at scale. Qualitative research suggests there is considerable adaptation that occurs in areas where TDM has been successfully implemented[384] and may underpin TDM's success as a growing movement.

After adjustment I found local authority health profiles of TDM registered schools were comparable to non-registered schools with respect to child and adult excess weight, and child and adult physical activity. I found no studies examining the impact of local authority on adoption of school-based physical activity interventions in children, but Rind et al. found significant and distinctive variation in physical activity across local authorities in England in adults.[448] In England, where almost 65% of state schools are local authority controlled, local authority commitment to school-based physical activity interventions is vital in helping children reach physical activity recommendations. It is important to mention that this lack of association with area-based measures does not preclude a school-level or pupil-level effect.

5.4 Conclusion

One in five primary schools in England has registered for The Daily Mile since 2012. TDM appears to be a wide-reaching school-based physical activity intervention that is reaching more disadvantaged primary school populations and schools in urban areas. TDM registered schools include those with both high and low educational attainment, and areas with high and low physical activity.

6. Equity of The Daily Mile

Overview

Chapter 4 investigated the reach of TDM across England, where I found that schools with a higher proportion of disadvantaged pupils, and schools in urban areas were more likely to register to TDM. There was significant local authority variation in school registration to TDM; and a large amount of residual variation in school registration to TDM that remained even after accounting for a multitude of school characteristics, and local authority prevalence of adult and child obesity and excess weight. The method used in the previous study was a multilevel logistic regression model. This method was only able to assess direct relationships between each individual school and local authority characteristic and registration to TDM. The current study investigates the equity of TDM and builds on the previous study by considering the links between determinants of children's physical activity, whether these determinants cluster together, and assesses whether TDM is taken up in areas and populations that need it most.

The relevant thesis objectives are – ***Objective 2: To examine local authority areas most in 'need' of physical activity promotion for children in England*** *and* ***Objective 3: To assess whether school populations registered to TDM are representative of the needs of the general population.*** *The work presented in this chapter has been previously published.*[449]

6.1 Introduction

Matching public health interventions to the needs of the population is more efficient and equitable than blanket policies directed at whole populations[394]. In recent years, there has been a push to consider the accumulation of health risks to plan for health needs.[185] For instance, physical activity, diet, sedentary behaviour and deprivation can interact in complex ways to determine the excess weight status of individuals, with the added understanding that deprivation affects all these factors both individually and collectively.[450] Previous studies have not reported how children's need for physical activity is spatially clustered across England and describing this need is important for public health practitioners. It is also not known how physical activity interventions are spatially distributed and whether it matches need or not.

The previous study suggested that TDM is a wide-reaching intervention; where groups with traditionally lower levels of physical activity were more likely to register with TDM. However, questions about whether TDM is reaching all populations that could benefit from it the most remain unanswered. Additionally, there was also a need to further investigate the residual local authority variation observed in study 1. Lastly, one of the potential explanations offered for the widespread reach of TDM in the previous chapter has been the placement of national coordinators in England, funded by Sport England in partnership with The Daily Mile Foundation to increase registration and implementation to TDM. However, it is not known whether TDM is taken up more widely in areas where these coordinators are located. This study aims to address these unanswered questions.

6.2 Methods

6.2.1 Study Design

This was a cross sectional study of all upper tier local authorities in England.

6.2.2 Data sources and defining need for physical activity

For this study, I created a pragmatic definition of need based on the literature, expert steering group, and data availability. To define local authority area 'need', I first conducted a literature review to identify relevant determinants of children's need for physical activity interventions and matched this against what was routinely available in England via the Public Health Fingertips website.

My assessment of local authority health 'need' included measures of children's mental health, children and adults physical activity, adolescent sedentary time, children and adults excess weight status, access and utilisation of outdoor space for exercise, and the proportion of children on free school meals as a measure of deprivation. Although there are many determinants that could have been used to measure the health profiles by area and the need for physical activity interventions in children, I was restricted by what was routinely available across England at the local authority level through the Public Health Fingertips data repository. I linked local authority level publicly available data on multiple health indicators extracted from Public Health England[45] for all 152 upper-tier local authorities in England. These include metropolitan districts, London boroughs, unitary authorities, and county councils.

The data sources, year of data, and the relevant health measures I extracted from them are listed in Table 6.3. Where available, I used the most recent data for each data source; this was not the same year for each data source. The data sources I used were the Active Lives Surveys (adults, and children and young people), National Child Measurement Programme, Department for Education Special Education Needs Statistics, Natural England: Monitor of Engagement with the Natural Environment survey, and Department for Education School Census. For a detailed description of the data sources used in this study, please refer to Chapter 4, Section 4.3.2. Data on uptake of TDM was provided by The Daily Mile Foundation.

The next section describes the definitions for each determinant of children's physical activity I included in this study, the relevant data source it was extracted from, and the year of extraction.

6.2.3 Determinants included in 'need' and their definitions

Children's Physical Activity

I defined children's physical activity as the percent of children in a local authority aged 5-16 years that met the 2019 United Kingdom Chief Medical Officers' recommendations for physical activity. Note that this different from the definition used in the previous study. The 2019 recommendations state that children should participate in an average of at least 60 minutes MVPA per day across the week, as opposed to the previous definition which stated

that children should participate in at least 60 minutes MVPA per day across the week of which 30 minutes should be done in school. The survey uses a 7-day reference period to record self-reported activity children participate in on each day. The estimates are weighted to be representative of the national population.[410] This data was collected from the Active Lives Survey for children and Young People from the years 2018-2019.

Adult's Physical Activity

I defined adult physical activity as the percent of respondents in a local authority aged 19 and over, with valid responses to self-reported questions on physical activity, doing at least 150 minutes MVPA per week in bouts of 10 minutes or more in the previous 28 days. The estimates are weighted to be representative of the national population.[403,409] These data was extracted from the Active Lives Adult Survey from the year 2018-2019. The survey uses a 28-day reference period to record the number of minutes of physical activity (of at least 10 minutes) and then divides the number of minutes by four to calculate a weekly average (e.g., 2 hours of physical activity over the 28 days equates to 30 minutes per week).

Adolescent Sedentary Time

I defined adolescent sedentary time as the percentage of 15-year-olds who responded to questions in the What About YOUth survey with responses indicating that participants spent "About 7 or more hours a day" doing sedentary behaviours on weekdays. These data were self-reported and from 2014-2015. The estimates are weighted to be representative of the national population.[406]

Children's Excess Weight

I included children's excess weight status at two time points in this study – once at the beginning of primary school (children aged 5-6 years) and once at the end (children aged 11-12 years). I defined excess weight status as the percent of children classified as overweight or obese in a local authority. Children are classified as overweight (including obese) if their BMI is on or above the 85th centile of the British 1990 growth reference (UK90) according to age and sex. This data was extracted from the National Child Measurement Programme from 2018-2019; a nationally mandated surveillance programme that that collects objectively measured height and weight for children, converted to weight status for over 1 million children (98% of all children) entering and leaving primary school in England each year.[48]

Adult Excess Weight

I defined adult excess weight status as percent of adults (aged 18+) in a local authority area with BMI classified as overweight (including obese) (>=25kg/m2), calculated from the adjusted height and weight variables. This was derived from the Active Lives Adult Survey, 2018-2019, which includes questions on self-reported height and weight. The prevalences are weighted to be representative of the whole population at each level of geography. They have also been age-standardised to improve comparability of excess weight prevalence between local authorities.[403,409]

Demographics

I used free school meal uptake as a proxy measure for deprivation in this study. Previous research has shown that this simple binary measure is a very good indicator of socio-economic disadvantage.[451] I defined free school meal uptake as the percentage of pupils known to be eligible for and claiming free school meals who attend a state funded nursery, primary, secondary or a special school. This data was extracted from the Department for Education School Census for the years 2017-2018.

Further, I defined children's mental health needs as the percent of school pupils with Special Education Needs (SEN) where the primary need is social, emotional, and mental health in a local authority area. This data was extracted from Department for Education special educational needs statistics of 2017-2018.

Outdoor space

I defined the utilisation of outdoor space for exercise/health reasons as the weighted estimate of the proportion of residents in each local authority taking a visit to the natural environment for health or exercise purposes in the previous 7 days. Visits to the natural environment are defined as time spent "out of doors" e.g., in open spaces in and around towns and cities, including parks, canals and nature areas; the coast and beaches; and the countryside including farmland, woodland, hills and rivers. This could be anything from a few minutes to all day. It may include time spent close to home or workplace, further afield or while on holiday in England. These estimates do not include routine shopping trips or time spent in one's own garden. This data was extracted from the Natural England: Monitor of Engagement with the Natural Environment (MENE) survey of 2015-2016 and these estimates are weighted.[452]

6.2.4 Statistical analysis

Only local authorities with complete data for all variables were included in the cluster analysis. I analysed local authorities with missing data for patterns of missingness and ran a sensitivity analysis run to explore differences by health behaviours in excluded versus included local authorities.

I ran a cluster analysis to enable grouping of observations, in this case local authorities, based upon similarity across the set of characteristics defined above ('need'). I standardised (converted to Z-scores) all the variables before any analysis to minimise the influence of different measurement scales of each of the variables. This standardisation is important when each variable is measured on different scales. For instance, weight status is measured as BMI as opposed to physical activity which is measured as minutes of activity which has a larger range. In circumstances where one variable has a much greater range of possible values than another variable, then the values will cover a greater range and a greater distance between values. Due to this, the variable with a larger range might emerge to be the primary driver of what designs the clusters; given that hierarchical clustering uses distance as the basis of grouping. Standardising the variables before clustering provides a means to make the relative weight of each variable in the clustering equal by transforming each variable to a unitless measure.

Choosing a clustering method

To determine the most appropriate clustering method, I used the R package clValid.[453] This allows simultaneous comparison of multiple clustering algorithms such as hierarchical (divisive and agglomerative), k means, and partition around medoids (PAM) to identify the best clustering approach. Hierarchical clustering was the best clustering algorithm for the data. There are two types of hierarchical clustering – agglomerative and divise. Agglomerative clustering is also known as a 'bottom-up' approach where initially, every data point is a cluster of its own. The algorithm takes the nearest (most similar) clusters and merged them as it moves up the hierarchy until all the data points are part of a single cluster. On the other hand, divise clustering is a 'top-down' approach where initially, all the datapoints are part of one cluster. This one cluster then splits up as it moves down the hierarchy.

There are a number of linkage methods that can be used. These include complete linkage, single linkage, average linkage and Ward's minimum variance method. I used Ward's linkage method as it identifies the strongest clustering in the data. Ward's linkage reduces the variance in each cluster and maximises the homogeneity, this means that the local authorities have similar interpretable profiles. It enables maximising the variance between clusters and minimises the variance within a cluster.

Determining the optimum number of clusters

I first computed dendograms to picture the hierarchical relationship between the data and visually assess how many clusters were present in the data. Then, I used the clValid package to determine the optimum number of clusters. In addition, I used the R package NbClust to further determine the optimum number of clusters.[454] This package uses 30 indices for choosing the best number of clusters for the data. These indices include the Dunn index, Rubin index, Gap statistic, the Calinski and Harabasz index and others.[453]

Quality of clustering solution

I assessed internal measures to determine the quality of the cluster solution by calculating the silhouette coefficient indicating cohesion and separation. The silhouette coefficient ranges from − 1 to + 1; a high value indicates that the object is well matched to its own cluster and poorly matched to neighbouring clusters. I also calculated stability measures, specifically, the average proportion of non-overlap, which measures the average proportion of observations not placed in the same cluster by clustering based on the full data and clustering based on the data with a single column removed and ranges from 0 to 1. For a good clustering algorithm, the average proportion of non-overlap value should be small.[455]

To examine and confirm cluster profiles and differences between health behaviours ad-hoc, I used Analysis of Variance (ANOVA) and tested for multiplicity using Tukeys test. The coefficient of variation was also calculated to present a normalised measure of the variation in variables to help assess their weight in cluster formation. The coefficient of variation can be employed to qualitatively determine which variables best describe each cluster. Further, to using the cluster membership derived from the cluster analysis, I derived real value means and standard deviations for each variable by cluster.

Need and association with TDM

I estimated the association between the 'need' for physical activity interventions in local authorities and uptake to TDM in the clusters derived from the hierarchical cluster analysis with incidence rate ratios (IRR) and their 95% confidence intervals via a Poisson regression.

6.3 Results

6.3.1 Missing data

Children's physical activity prevalence had the most amount of missing data, where 14% of all local authorities had missing data (21 of 152 local authorities). This was followed by the utilisation of outdoor space for exercise and health reasons where 9% of all local authorities had missing data (14 of 152) (Table 6.1). I did not consider the use of imputation methods as the existing sample was too small to conduct imputation. Further, the sensitivity analysis for included versus excluded observations did not show any meaningful differences (Table 6.2).

Table 6.1: Missing data by parameter

Parameter	Number of local authorities with missing data (N)	% of local authorities with missing data (%)
Excess Weight Status at Age 5-6	5	3
Excess Weight Status at Age 11-12	5	3
Children Physical Activity Prevalence	21	14
Children using Free School Meals	0	0
Children's mental health needs	1	0
Adolescent Sedentary Time	5	3
Adult Excess Weight Prevalence	3	1
Adult Physical Activity Prevalence	3	1
Utilisation of Outdoor Space	14	9

The cluster analysis was run on a complete case of the data which comprised of 123 of 152 local authorities. A deeper evaluation of the missing data showed that there were certain local authorities that had missing data for almost all the variables (e.g., City of London and Isles of Scilly) (Appendix F). These were excluded from the cluster analysis.

I investigated any systematic differences in the parameters included in the cluster analysis by their inclusion/exclusion status (Table 6.2). There were no substantial differences between included and excluded local authorities in terms of the parameters and health behaviours. There

was a slightly higher prevalence of children meeting the physical activity recommendations in the excluded local authorities (49% vs 45%). All the other parameters were similar across included and excluded local authorities.

Table 6.2: Sensitivity Analysis to investigate differences in included and excluded data for local authorities

Parameter (%)	Included local authorities with complete data Mean (SD)	Excluded local authorities due to missing data Mean (SD)
Excess Weight Status at Age 5-6	22.79 (2.69)	22.82 (3.00)
Excess Weight Status at Age 11-12	34.93 (4.48)	35.88 (4.48)
Children Physical Activity Prevalence	45.26 (6.38)	49.16 (5.90)
Children using Free School Meals	14.27 (5.63)	15.65 (7.53)
Children's mental health needs	2.47 (0.58)	2.70 (0.63)
Adolescent Sedentary Time	70.73 (4.34)	70.65 (5.00)
Adult Excess Weight Prevalence	62.08 (6.35)	59.37 (8.81)
Adult Physical Activity Prevalence	65.62 (5.44)	66.87 (6.17)
Use of Outdoor Space	17.72 (4.10)	19.38 (5.38)

In the included local authorities for the cluster analysis, less than half of children met the recommended levels of physical activity (45%) (Table 6.3). 1 in 5 children were classified as having an excess weight status (overweight or obese) at the beginning or primary school, increasing to 1 in 3 children at the end of primary school. Further, 2.5% of school children across local authorities were identified as having social, emotional and mental health needs. More than 60% of adults were overweight or obese in and 70% of adolescents reported a being sedentary for 7 hours per day.

6.3.2 Study population

I included all upper-tier local authorities in England in the analysis. I identified complete data for 123 of 152 (82%) local authorities across England (Table 6.3).

Table 6.3: County and Unitary Authority characteristics including variable definitions and data sources

Measure	Definition	Data Source	Year	Number of local authorities reporting	Mean Prevalence across local authorities (Standard deviation)
Children's physical activity	Percent of children in a local authority aged 5-16 years that meet the United Kingdom Chief Medical Officers' recommendations for physical activity (an average of at least 60 minutes moderate-vigorous intensity activity per day across the week).	Active Lives Children and Young People Survey, Sport England	2018-2019	131	45.3(6.4)
Adult physical activity	Percent of respondents aged 19 and over, with valid responses to questions on physical activity, doing at least 150 moderate intensity equivalent (MIE) minutes physical activity per week in bouts of 10 minutes or more in the previous 28 days.	Active Lives Adult Survey, Sport England	2018-2019	149	65.6 (5.4)
Adolescent sedentary time	Percentage with a mean daily sedentary time in the last week over 7 hours per day at age 15	What About YOUth (WAY) survey	2014-2015	147	70.7 (4.3)
Excess weight status at age 5-6	Reception: Percent of overweight (including obesity)	National Child Measurement Programme	2018-2019	147	22.8 (2.7)
Excess weight status at age 11-12	Year 6: Percent of overweight (including obesity)	National Child Measurement Programme	2018-2019	147	34.9 (4.5)

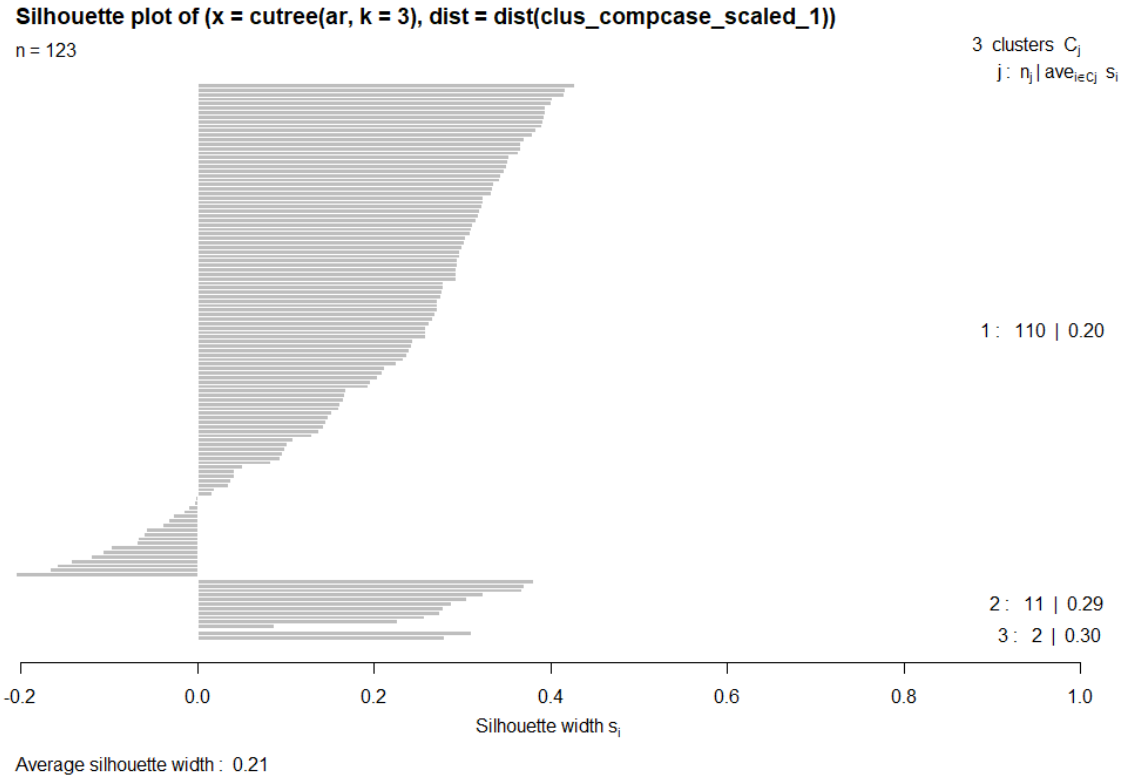
Adult excess weight status	Percentage of adults (aged 18+) classified as overweight or obese	Active Lives Adult Survey, Sport England	2018-2019	149	62.1 (6.4)
Free school meals: % uptake among all pupils	Percent of pupils known to be eligible for and claiming free school meals who attend a state funded nursery, primary, secondary or a special school.	Department for Education School Census	2017-2018	152	14.3 (5.6)
School pupils with social, emotional and mental health needs: % of school pupils with social, emotional and mental health needs	The number of school children who are identified as having social, emotional and mental health needs expressed as a percentage of all school pupils.	Department for Education special educational needs statistics	2017-2018	151	2.5 (0.6)
Utilisation of outdoor space for exercise/health reasons	The proportion of residents in each area taking a visit to the natural environment for health or exercise purposes. Visits to the natural environment are defined as time spent "out of doors" e.g., in open spaces in and around towns and cities, including parks, canals and nature areas; the coast and beaches; and the countryside including farmland, woodland, hills and rivers. This could be anything from a few minutes to all day. It may include time spent close to home or workplace, further afield or while on holiday in England.	Natural England: Monitor of Engagement with the Natural Environment (MENE) survey	2015-2016	138	17.7 (4.1)

6.3.3 Cluster formation and definition

6.3.3.1 Choosing the best clustering algorithm

After evaluating the internal and stability measures of different clustering methods, I used a hierarchical agglomerative clustering algorithm (bottom-up) to identify subgroups within the data. The average proportion of non-overlap favoured a hierarchical cluster analysis with the optimum number of clusters being 3, where the value was small = 0.04. The silhouette coefficient for the hierarchical cluster analysis using 3 clusters was 0.21 in the total sample, indicating a fair model (Figure 6.1)

Figure 6.1: Silhouette coefficient of a clustering solution with 3 clusters



The hierarchical agglomerative algorithm computes the Euclidean distance between each local authority based on average scores of the need variables I identified. It identifies the two local authorities that have the lowest distance score and links them in a cluster and repeats this process until one cluster remains containing all the local authorities. The agglomerative algorithm was superior to divise (clustering solution 0.91 vs 0.79 respectively). Further, to measure the dissimilarity between two clusters of observations, I tried different approaches

(average, centroid, Ward, and complete). Ward's linkage method identified the strongest clustering structure in the data – with a clustering structure of 0.91 (Table 6.4). This clustering approach computes the sum of squared distances within the clusters and merges them to minimize it. This process of agglomeration leads to a reduction in the variance of each resulting cluster and maximizes the within-group homogeneity.[456]

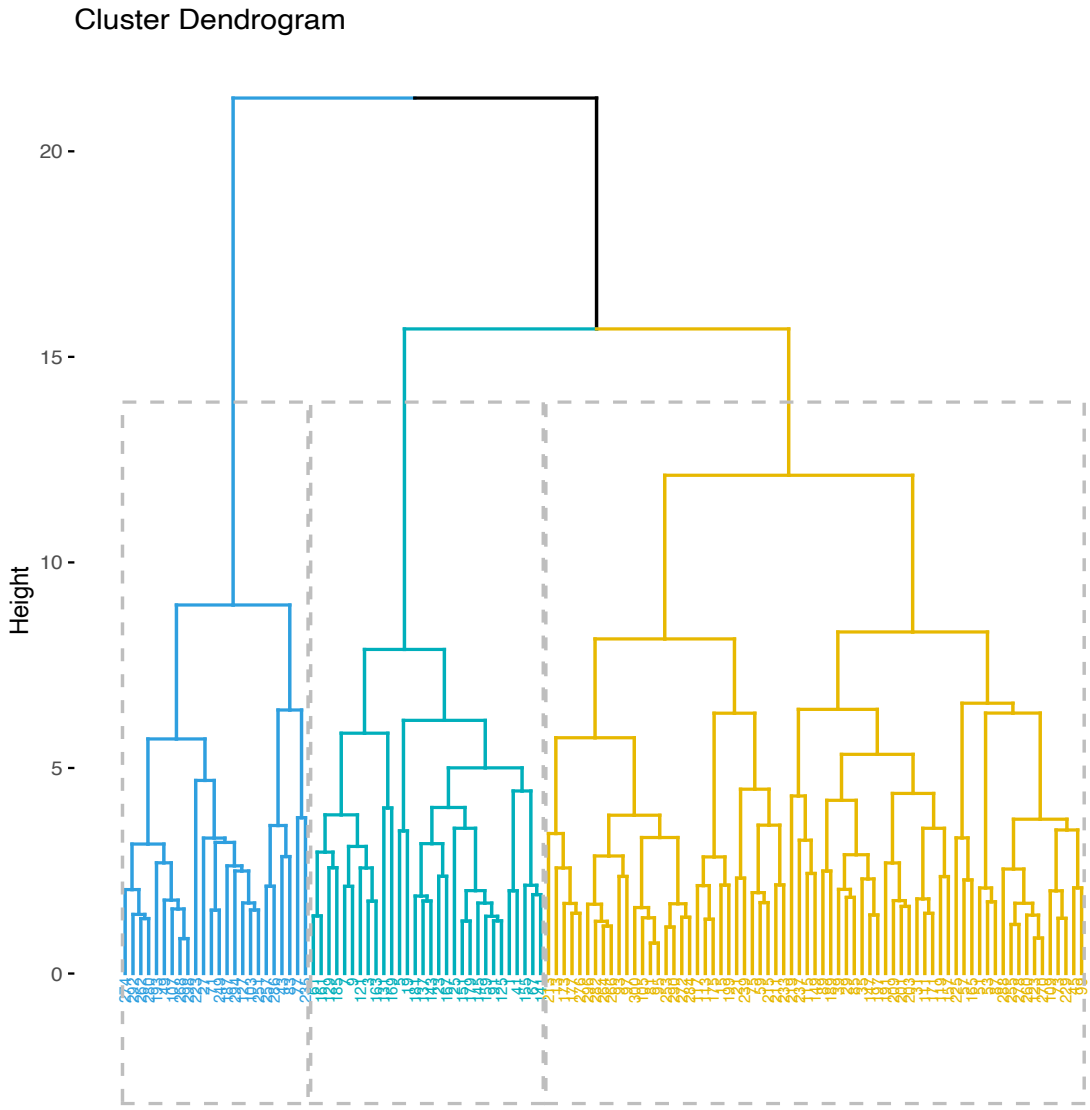
Table 6.4: Clustering methods and clustering solution score

Clustering Method	**Score*** **
Agglomerative	0.91
Divisive	0.79
Agglomerative Linkage method	**Score*** **
Average	0.67
Single	0.50
Complete	0.1
Ward	0.91
******values closer to 1 suggest strong clustering structure***	

6.3.3.2 Determining the optimum number of clusters

Dendograms provide a way to visualise the hierarchical relationship between the data. Each leaf in the dendogram corresponds to one observation, in this case, a local authority. As you move up the tree, local authorities that are similar to each other are combined and grouped together into branches, which then fuse at a higher height. The order of the items reflects the similarity between local authorities; that is, local authorities placed next to each other horizontally are more similar than local authorities placed further apart. The lines extending vertically from each item and then joining other items horizontally show where items are grouped at higher levels of relationship. Visually, there were three distinct clusters in the data (Figure 6.2).

Figure 6.2: Dendogram for the clustering solution

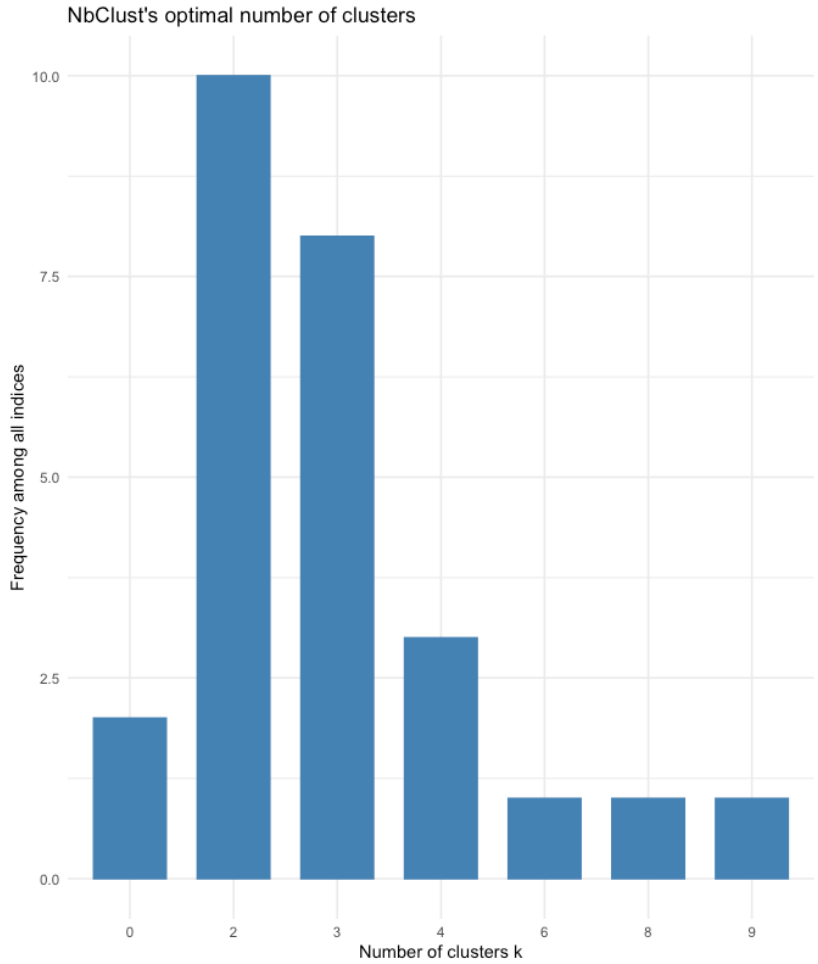


The R package clValid indicated 3 clusters being the optimum number for the data. Using NbClust to determine the optimum number of clusters for the data, 10 indices proposed 2 as the best number of clusters, and 8 proposed 3 as the best number of clusters (Figure 6.3a). The Hubert index is a graphical method of determining the number of clusters. In the plot of Hubert index, a significant knee corresponds to a significant increase of the value of the measure i.e., the significant peak in 'Hubert index second differences' plot. The D index is a graphical method of determining the number of clusters. In the plot of D index, a significant knee (the significant peak in D index second differences plot) corresponds to a significant increase of the value of the measure (Figure 6.3b).

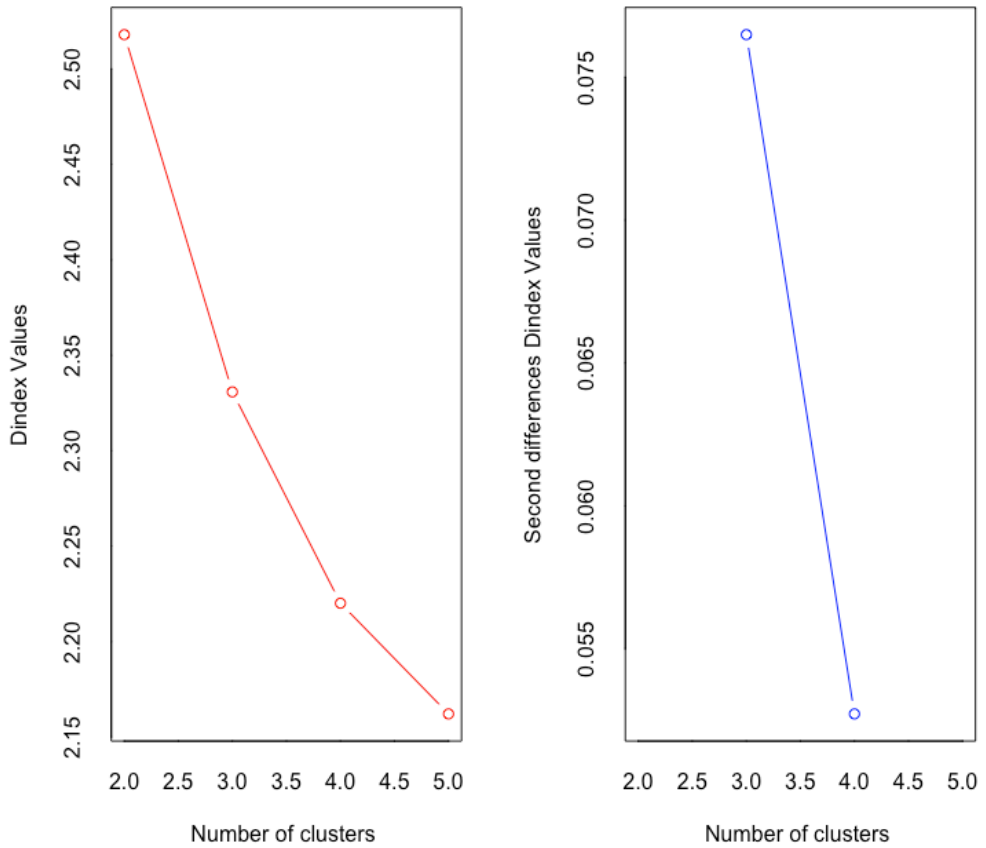
There is no definitive answer to choosing the optimum number of clusters since it is an exploratory approach. The resulting cluster solution must be grounded in theory but is also context dependent. I chose a pragmatic approach to selecting the optimum number of clusters based on the results of multiple indices, but also found that choosing 3 clusters was more informative for the data than 2.

Figure 6.3: Determining the optimum number of clusters

a: NbClust's assessment of the optimum number of clusters for the data



b: Hubert index and D index to determine the optimum number of clusters



6.3.4 Cluster profiles

Three clusters were generated from the hierarchical cluster analysis. Cluster 1 had 30 local authorities (24.4% of 123 local authorities), cluster 2 had 69 (56.1% of 123 local authorities), and cluster 3 had 24 (19.5% of 123 local authorities) (Figure 6.4a) (Appendix G for list of local authorities by cluster). Variables with greater variation are more important in cluster formation as they allow for higher discrimination between clusters. Coefficient of variation values were highest among children's indicators suggesting that they were most important in cluster formation (Table 6.5).

Local authorities in cluster 1, described as 'high-need' areas displayed the poorest health outcomes overall, apart from the utilisation of outdoor space for exercise and health reasons, compared to local authorities in the medium and low-need clusters and comprised of 30 local authorities. A total of 38% of children in these local authorities were overweight or obese at the end of primary school, and 42% of children were meeting the recommended levels of physical activity. Further, there were more than double the proportion of children on free school meals in this cluster compared to those in the healthiest 'low-need' cluster and almost 70% of adults in these local authorities were overweight or obese. These local authorities are concentrated in certain areas such as the West Midlands, South Yorkshire, and the North East of England (Figure 6.4a).

Cluster 2 described as 'medium-need' areas comprised of 69 local authorities. The local authorities in the medium-need cluster had moderate values for all health behaviours except for the utilisation of outdoor space for exercise and health reasons. Medium need local authorities were spread across England but were more concentrated in north and central England.

Cluster 3 described as 'low-need' areas comprised of 24 local authorities had the best health outcomes across all health behaviours. It had the least deprived children and had the highest utilisation of outdoor space. 57% of the adult population was either overweight or obese, 13% less than adults in the high-need local authorities, and less than half of children met the recommended levels of physical activity. These local authorities comprised of some of the most affluent boroughs of London, a large proportion of the East of England, affluent areas of South West England (e.g. Bath), and parts of South East England (e.g. Buckinghamshire).

Table 6.5: Cluster outputs and characteristics of counties and unitary authorities according to the need for physical activity interventions assessed

#	Clusters	High-need areas(N=30) Cluster1 Mean Prevalence across local authorities (SD)	Medium-need areas (N=69) Cluster2 Mean Prevalence across local authorities (SD)	Low-need areas(N=24) Cluster 3 Mean Prevalence across local authorities (SD)	Coefficient of variation	F	p value
	Local authority indicators of health need						
1	Excess Weight Status at Age 5-6 (%)	25.2 (1.2)	22.9 (1.9)	19.5 (1.9)	11.6	114.0	< 0.001
2	Excess Weight Status at Age 11/12 (%)	38.2 (3.0)	35.4 (3.3)	28.6 (2.6)	12.9	112.9	< 0.001
3	Children Physical Activity (%)	42.8 (6.5)	44.6 (5.8)	49.0 (6.1)	14.1	13.5	< 0.001
4	Children on Free School Meals (%)	17.6 (4.0)	14.3 (4.6)	8.4 (1.8)	36.3	67.4	< 0.001
5	School pupils with social, emotional and mental health needs (%)	2.5 (0.5)	2.4 (0.6)	2.3 (0.5)	22.9	2.5	0.12
6	Adolescent Sedentary Time (%)	75.5 (1.2)	70.2 (2.9)	66.4 (3.8)	6.0	135.4	< 0.001
7	Adult Excess Weight (%)	68.2 (3.2)	61.9 (4.7)	57.9 (4.6)	8.9	76.7	< 0.001
8	Adult Physical Activity (%)	60.2 (2.9)	66.1 (4.5)	69.6 (4.5)	8.1	69.0	< 0.001
9	Use of Outdoor Space (%)	17.8 (4.6)	17.0 (3.2)	18.6 (4.6)	22.2	0.4	0.55
	SD: standard deviation *Differences between clusters were observed by ANOVA test.* *All three clusters are significantly different at p < 0.001 (Tukey post hoc) for all variables except 5 and 9* *F=F statistic; ratio of two variances* *N= number of local authorities* ***Colour coding:*** *Red: poorest implication for health* *Blue: moderate implication for health* *Green: superior implication for health*						

Figure 6.4:Maps

Figure 6.4a: Map showing the geographic distribution of need identified

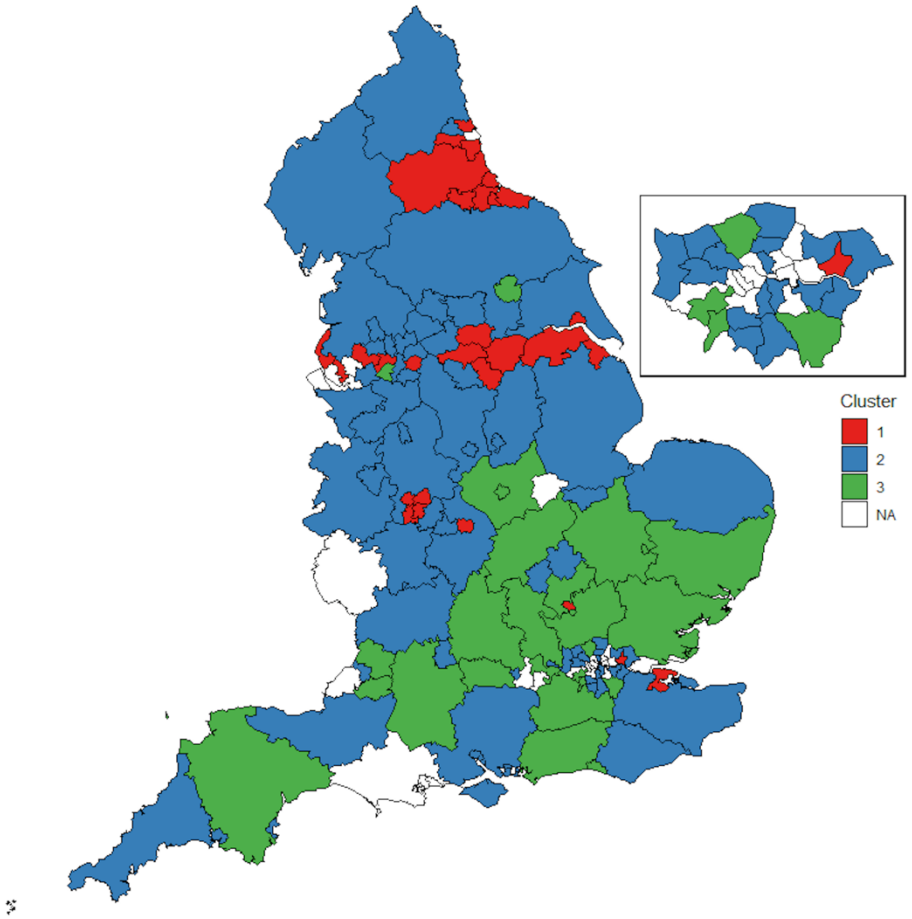
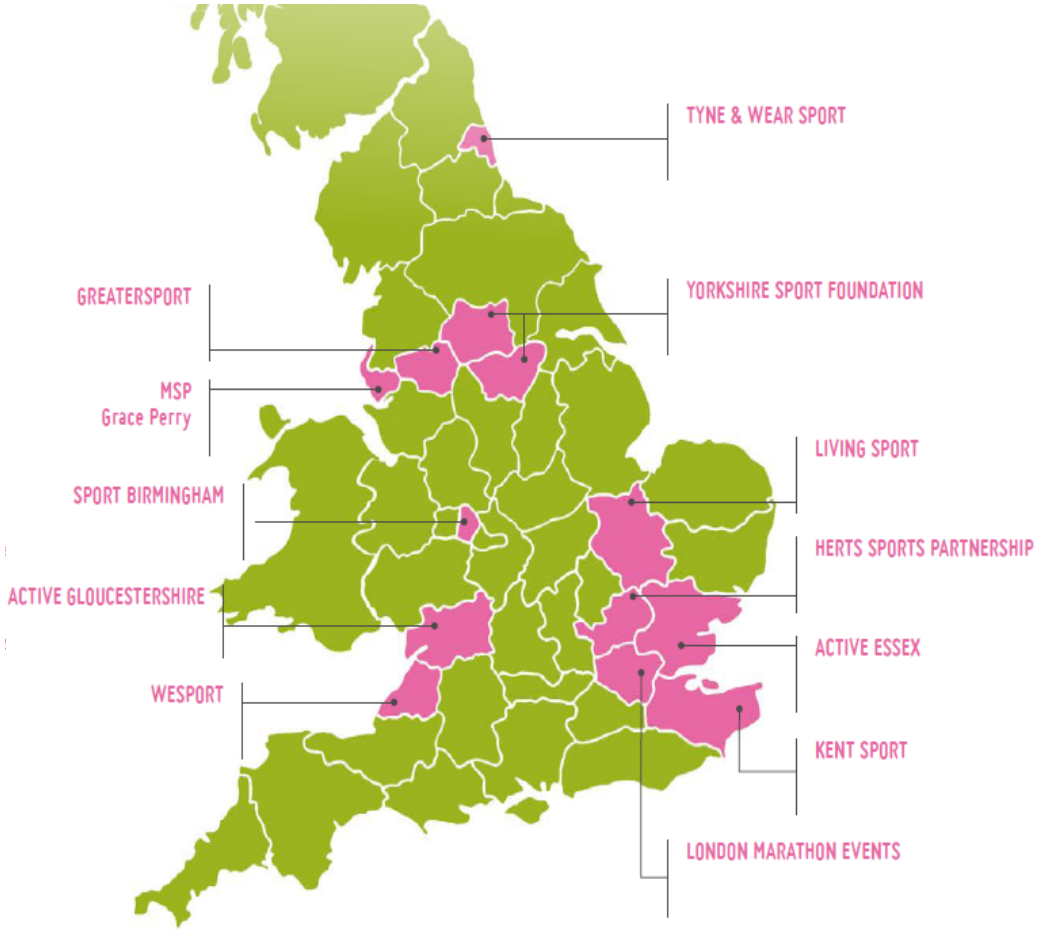


Figure 6.4b: Map showing Sport England coordinators (image produced by The Daily Mile Foundation)



6.3.5 The Daily Mile uptake associated with 'need'

Highest uptake for TDM was in schools in local authorities defined as high need. These schools were 25% more likely to register to take part in TDM (IRR 1.25 (95% CI 1.12, 1.39) p<0.001) compared with those in areas with low need (Table 6.6).

Table 6.6: Incidence rate ratios of uptake to The Daily Mile by clusters

Cluster	N and % of registered TDM schools	IRR (95% CI)	p
Cluster 1 High-need	530 (25.09%)	1.25 (1.12, 1.39)	<0.001
Cluster 2 Medium-need	1841 (21.48%)	1.07 (0.98, 1.16)	0.127
Cluster 3 Low Need	755 (20.11%)	Reference	

Figure 6.4a is a map showing the geographic distribution of need identified and Figure 6.4b illustrates the location of Daily Mile coordinators across England that are funded by Sport England. There is a match in some areas between where these coordinators are placed, and the need identified through this study. For instance, there is a designated coordinator in Greater Sport (Manchester) and the local authorities of Salford and Wigan, which are part of Greater Manchester are part of the high-need cluster. However, in some parts of England there is no match between need and the location of coordinators. For instance, there are 5 coordinators covering almost the entire South East of England, while this region has only 2 high-need local authorities (Medway and Barking and Dagenham in London). Similarly, there is only one coordinator placed in the North East (Tyne and Wear Sport). This is not in full alignment with need, where in the North East, a single coordinator is responsible for increasing children's physical activity across 10 high-need local authorities.

6.4 Discussion

6.4.1 Summary of chapter findings

- I identified three distinct clusters of high, medium, and low need for physical activity interventions in 129 local authorities representing approximately 4.5 million primary school children in England.
- The three clusters were characterised by different determinants of children's health need for physical activity promotion.
- The important drivers of need included children on free school meals, children's social emotional and mental health needs, children's physical activity, and use of outdoor space for exercise and health reasons.
- School populations located in the highest need cluster for physical activity interventions were 25% more likely to be registered to do TDM than the schools in the lowest need cluster, where registration ranged from 1 in 5 schools in the low-need cluster to 1 in 4 in the high-need cluster.
- The distribution of coordinators does not match need, highlighting the need to equitably invest in the healthcare system for children to reduce the inequalities observed.
- It is essential to monitor the needs of the population so appropriate interventions can be planned and implemented.

6.4.2 Strengths and limitations

A major strength of this study is its size and representativeness of the whole United Kingdom population. Another strength is the clustering design which advances on previous research by taking into account the interaction of a number of determinants of children's physical activity. Further, this was the first study to examine how health behaviours and built environment features are clustered and spatially distributed across England. Visualising the determinants of children's physical activity distinctly spatially clustered across local authorities in this study is a powerful tool for illustrating their coexistence. This study provides a robust methodology to evaluate interventions with the awareness of the interactions between the underlying determinants these interventions aim to target. Similar analyses could be applied to a number of other policies and determinants to monitor the needs of the population so appropriate interventions can be planned and implemented.

However, there are some important limitations to consider. While the public health metrics used in this study were identified and quality assured by Public Health England, some of the data were missing, particularly for local authorities in London. However, the sensitivity analysis of included and excluded local authorities did not show any meaningful differences in them. Self-reported data, such as physical activity data was used for this study and is subject to recall bias. Further, data on uptake to TDM was obtained via TDM Foundation that is based on whether a school officially registered to the website, and whether schools actually implement TDM has not been validated. School registration to TDM may not equate to effective implementation across the school. Moreover, schools not officially registered may have adopted another active mile initiative or other activities similar to TDM. I used data from differing years for each dataset which might not be an accurate representation of the health of the population at the time. The use of upper tier local authorities in this analysis is intended to make the results useful for local authority and national policymakers. However, this means that the clustering observed could be influenced by variation in types of local authority and within local authorities. There may also be variation at a more granular level (lower-tier local authorities). Thus, using smaller areas may remove some of this variation and allow for the detection of smaller differences. Additionally, this was a cross-sectional study and can only identify a snapshot of clustering of health behaviours and its association with TDM registration. Longitudinal studies would determine the changing health needs of the population and help examine implementation of TDM over time. Finally, I weighed the variables equally in the cluster analysis; however, some determinants might be more important than others (for e.g., children's physical activity could have been weighted more than deprivation). This in turn would change the clustering solution as the variables that are weighted more heavily would drive the clustering.

6.4.3 Possible explanations and comparison of findings with previous literature

This study showed that local authorities with low physical activity, high sedentary behaviour, high excess weight, and high deprivation were clustered together. This is consistent with previous studies where patterns of high physical activity has been shown to be significantly associated with parental education[457,458] and parental income[459,460]. Further, I found that local authorities with the poorest health outcomes (high-need cluster) were concentrated in northern England and those with the best health outcomes were concentrated in the south

(low-need cluster). A 2011 study[461] found similar clustering patterns when identifying local authorities with multiple health and social needs – where membership of the worst cluster was focussed in the North of England, and the local authorities with the best health outcomes were in the East and South East. They reported that people in local authorities in the cluster with the worst health outcomes face a lifelong public health deficit across numerous health outcomes including healthy eating habits, teenage pregnancy, physical activity in children, and ultimately reduced life expectancy. Although some behaviours have improved, this study indicates that little has changed over the last ten years with respect to clustering of the health behaviours we analysed and how they are distributed across the country. The "stratified prevention" approach described by Burton et al (Section 1.1) argues that segmenting the population based on risk or need into individual strata mean that interventions can be targeted appropriately and at times, differential interventions can be implemented based on population need.[6] This study shows that the TDM is reaching everybody, taking the overall population approach described by Rose, which is superior to the individual health approach.[4] More importantly, it also shows that TDM is reaching those with the most need, who are often overlooked.[7] This is important as the risk would be that TDM would only reach low-need populations, those that cannot potentially benefit from it the most.

This study reports that schools defined in high-need local authorities were more likely to register to TDM compared with schools in low-need areas. This implies that schools which register with TDM may have the potential to reduce inequalities in physical activity in children. Similar findings were observed in a study conducted over two years in Canada that implemented a school-based physical activity intervention in disadvantaged neighbourhoods.[462] After adjusting for potential confounders, the study found that physical activity levels of children in disadvantaged neighbourhoods approximated to those of children in wealthier neighbourhoods. In addition, they found the intervention reached high-need groups such as children with low activity levels and those that were overweight.

A potential explanation for the increased uptake of TDM in high-need areas could be that it is a grassroots movement driven by the self-determination theory, which explains human motivation as a product of three innate psychological needs – autonomy, competence and relatedness.[463] Studies have shown consistent support for a positive relationship between more autonomous forms of motivation and exercise, with identified regulation predicting initial short term adoption. Considering TDM is teacher-led, teachers possibly self-identify children

in their schools as populations that could benefit from TDM. Further, the United Kingdom government's mention of TDM in its child obesity strategy may have resulted in some local authorities actively promoting it. TDM is a ready-made package that schools can spend their Sports Premium resources on, and this could be driving the uptake. Widespread adoption (95% of pupils) of TDM has been observed in the short term in one school in England.[120] However, for long-term physical activity adherence in children, intrinsic motivation is vital.[463,464] While it is possible that TDM can initially increase physical activity in children[356,378] in an equitable manner, it must be coupled with other behaviour change interventions that facilitate this intrinsic motivation which includes enjoyment and inherent satisfaction of physical activity. Other more direct explanations for why TDM has been taken up widely across England is the presence of national coordinators whose main responsibility is to increase uptake and implementation of TDM across England.[465] However, coordinator locations do not always match need, that is, there are not sufficient coordinators in high-need areas compared to low-need areas, suggesting the mechanism that is driving uptake to TDM in high need areas is different. Finally, TDM has seen large amount of investment into ad campaigns and adverts to increase awareness of the intervention that could explain the widespread uptake.

6.5 Conclusions

Evidence suggests that TDM is an equitable intervention reaching local populations in areas with the highest health needs.

Chapter 5 of this thesis studies the reach of TDM. This current chapter went on to build from that work to evaluate the equity of TDM. The next chapter, Chapter 7, moves one step ahead in the intervention evaluation process to investigate the potential impact of TDM.

7. Impact of The Daily Mile

Overview

Chapter 5 and 6 assessed the reach and equity of TDM across England. I found that TDM is wide-reaching intervention with one in five primary schools in England having registered, and it seems to be an equitable intervention reaching those that can potentially benefit from it the most. The current chapter will assess the potential impact of TDM by evaluating the self-reported running of children in schools that had registered and not-registered for TDM.

The relevant thesis objectives are – ***Objective 4 and 5.***

This chapter is divided into 2 parts

- ***Part 1 addresses Objective 4: To compare reported physical activity (minutes of MVPA) in primary school children doing The Daily Mile compared to those who do not.***
- ***Part 2 addresses Objective 5: To compare the variety of reported physical activity in primary school children doing The Daily Mile compared to those who do not.***

7.1 Introduction

The Structured Days Hypothesis suggests that children in 'structured' environments (schools) with adult supervision (teachers) engaging in pre-planned activity (TDM) are more responsive to engaging in physical activity and regulating obesogenic behaviours.[237,238] Therefore, I hypothesised that children attending schools registered TDM may be more active across the school week compared with children attending schools not registered to active miles as these initiatives may provide additional compulsory structured physical activity during the school day. However, it is possible there may be some compensatory effects whereby children doing active miles in school may do less physical activity outside school. This compensation may be social and psychological from children or parents (e.g., if their child has done additional activity in school via an active mile initiative, they may be less likely to engage children in out of school activity). It might also be biological compensation, as outlined in the ActivityStat hypothesis[398] which suggests that children reach an overall mean level of activity that is stable (i.e. when activity is increased in one domain, it is reduced in another to achieve stable energy expenditure). These 'trade-offs' might lead to reduced overall activity in children.

Children can get their dose of physical activity from either doing a lot of different activities less frequently or the same activities repeatedly. In the former, children have high variety in the types of physical activity, and in the latter, children have a reduced variety of types of physical activity. While TDM is meant to be a 15-minute intervention, it is likely to take longer than that, with some estimates suggesting a total of 30 minutes of disruption to class time.[126,375] There is potential for children in TDM schools to therefore have a reduced variety in the types of physical activity. It would make logical sense for TDM children to have higher MVPA overall, and higher MVPA in school from running specific activities. However, that could be a consequence of reduced activity attributable to other activities like dance, or team sports. Studies have shown that frequency of activity affects MVPA overall, and frequency and variety both affect MVPA, but variety alone does not affect MVPA.[466,467] With the added understanding that TDM affects variety and frequency, I do not know how that affects MVPA since I hypothesise that TDM increases frequency of activity (running) but reduces the variety.

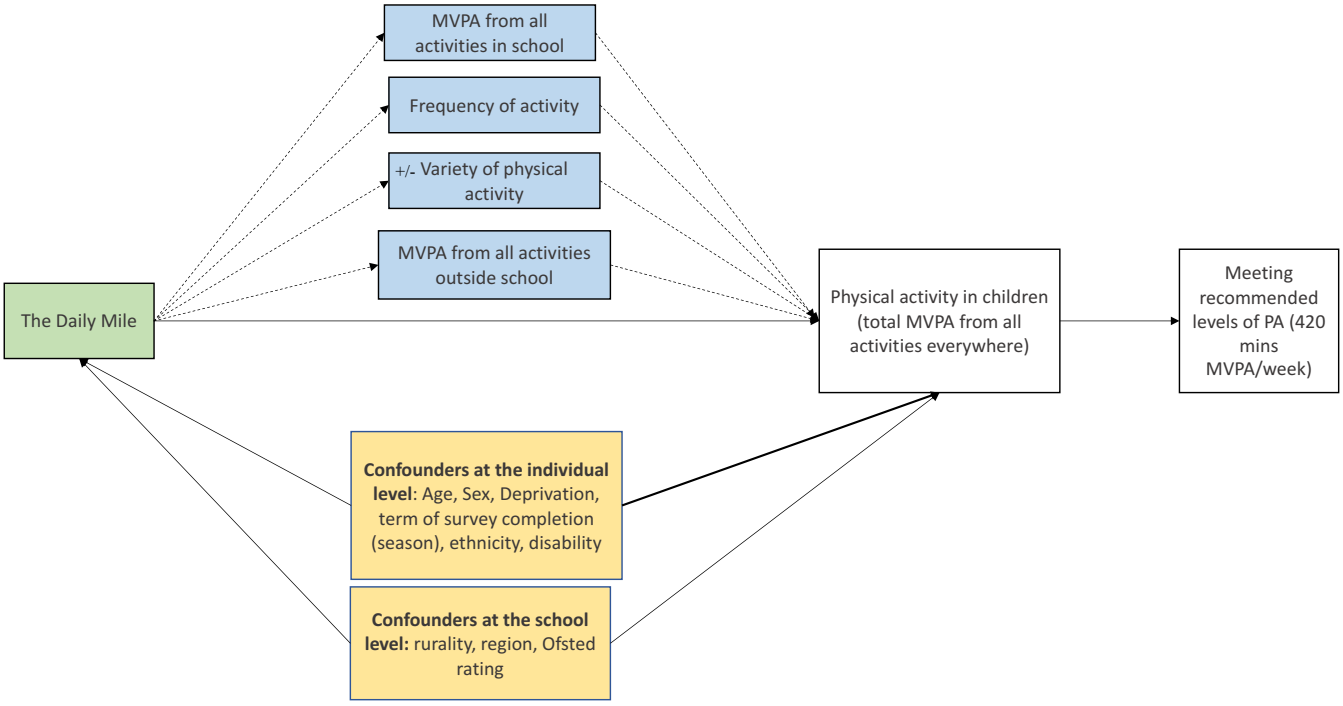
TDM has been found to be easy-to-implement[375] and stands out where previous complex interventions have been unsuccessful. Previous small regional studies have shown TDM increases children's physical activity and cardiorespiratory fitness during the first twelve

months of adoption.[357,373,377,378] It has been shown to provide approximately an extra 10 minutes of MVPA over the day,[356,374] and contribute towards children achieving the physical activity recommendations. Children in both affluent and deprived postcodes gain fitness benefits from TDM,[357] which is important given the inequities observed in children's physical activity in the UK.[409] Previous studies have examined the effect of TDM on physical fitness and activity levels using device-based measures in 200 to 2000 children. However, important questions remain about whether increasing physical activity in school is compensated for by children being more sedentary active outside of school settings, or if higher activity during school hours leads to higher activity across the school week. This study addresses these gaps by using The Active Lives Children and Young People Survey (referred to as the "Active Lives Survey" hereon).

The Active Lives Survey provides a novel opportunity to examine individual differences in self-reported physical activity in a large nationally representative sample. The Active Lives Survey provides activity data for children during school hours and outside school across the whole week, allowing an assessment of activity across different settings, a concern noted in previous studies.[398]

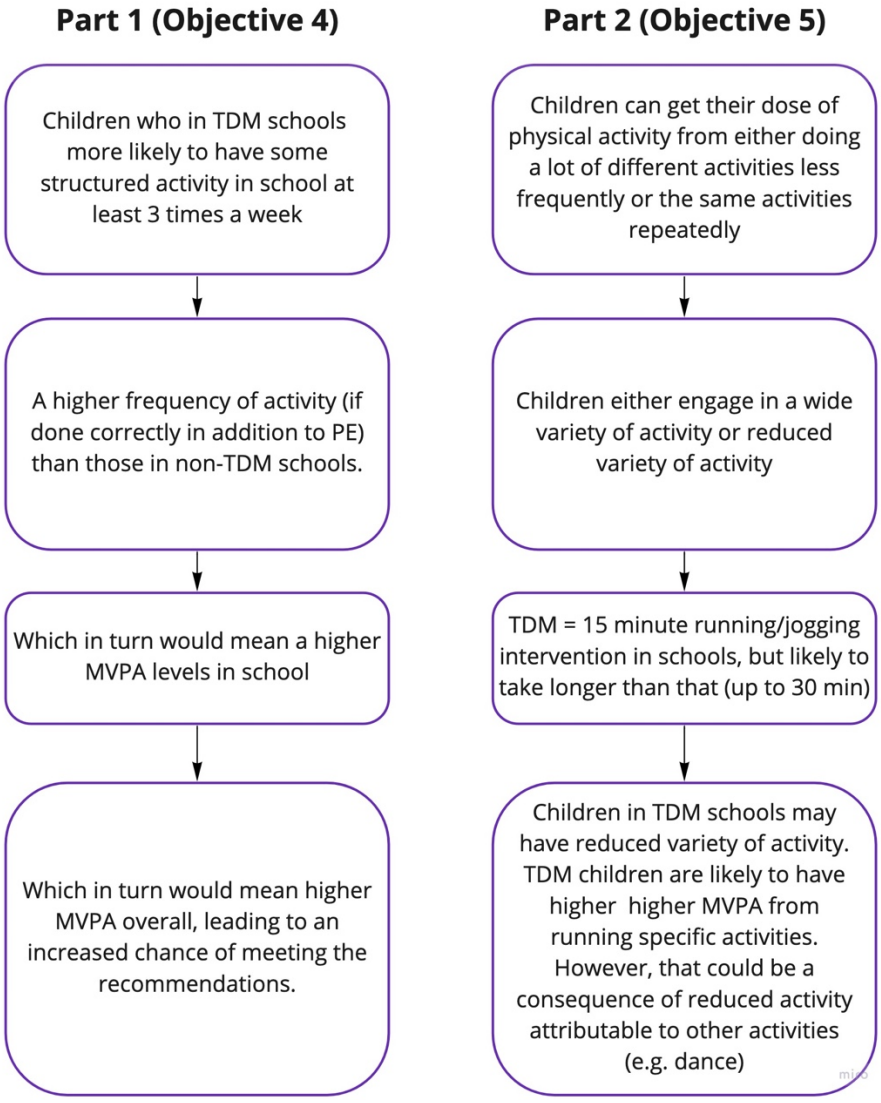
7.2 Mechanisms between The Daily Mile and Physical Activity

Figure 7.1: Potential mechanism of interactions between The Daily Mile and physical activity in children



TDM began as an intervention to increase physical activity in children. After it's widespread adoption, policy makers quickly adopted it as a potential solution to children increasing their physical activity levels to meet the recommendations(420 minutes MVPA/week).[68] This did not, however, reflect the original aim of the intervention. Since the widespread adoption TDM the intervention has been defined as fifteen minutes of running or jogging at least three times a week. This would contribute only 45 minutes a week and is, therefore, unlikely to, in isolation, help children meet the recommended levels of physical activity. However, there are several potential pathways by which TDM might make children. With respect to the objectives of this study, some of the mechanism that might underly the association between TDM and physical activity in children are listed below (Figure 7.2).

Figure 7.2: Potential mechanisms of action



7.3 Part 1: To compare reported physical activity (minutes of MVPA) in primary school children attending schools registered to The Daily Mile compared to those who are not (Objective 4)

7.3.1 Study Design, data source and setting

This was a cross-sectional study using data on children in England from the Active Lives Survey from 2018 - 2019. The Active Lives Survey is a publicly funded survey commissioned by Sport England that collects physical activity data on children aged 5 to 16 years from schools (every year, since 2017). The sample included all children from primary school year groups 1 (aged 5-6 years) to 6 (aged 10-11 years) in the survey. For more information on the Active Lives Survey, refer to Section 4.3.4.

7.3.2 Measures

Exposure

Children attending schools officially registered to The Daily Mile Foundation's database on April 2019 were assigned to the TDM group, and all other schools to the unexposed group. TDM data linkage to the Active Lives Survey was done by Sport England.

Outcomes

The primary outcome was minutes of MVPA from all activities, during school hours over the course of one week. The secondary outcomes were minutes of MVPA from all activities outside school in one week; total minutes of MVPA from all activities across the week; and the proportion of children meeting the recommended levels of physical activity (average 60mins MVPA/day across the week).

Covariates

Inclusion of covariates into the models was theoretically informed *a priori*. Covariates included adjustments for age (self-reported), gender (self-reported), ethnicity (self-reported), disability (self-reported), deprivation (matched on school location), season (term of survey completion), rurality (matched on school location), and Ofsted rating of the school (matched on school unique reference number). Data on the covariates were collected by Sport England as part of the Active Lives Survey (Table 7.1).

Table 7.1: **Covariates and their definitions**

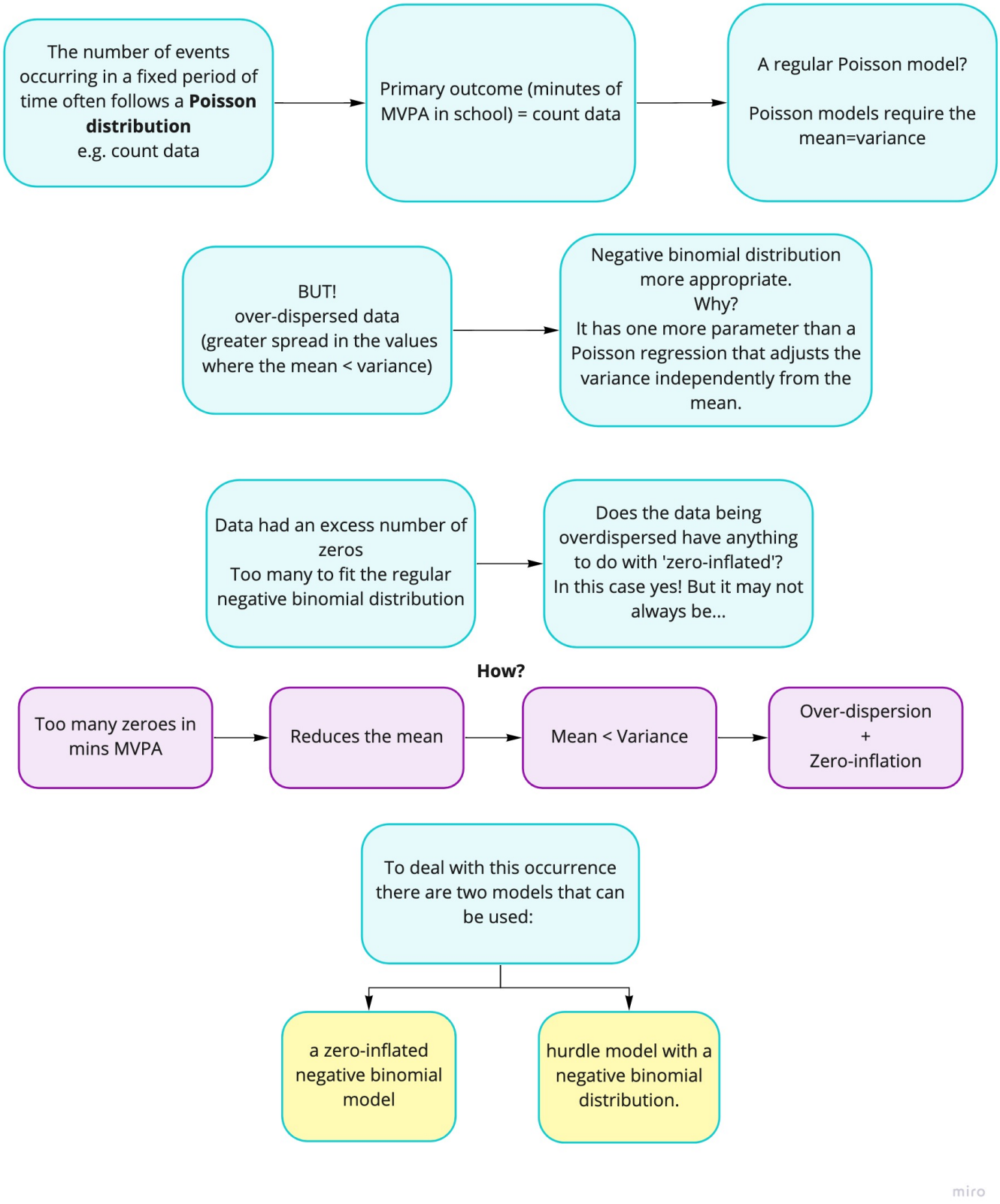
Covariate	Description	Source
Age (School Year Group) *	Age was categorical variable and was based on school year of the child, ranging from Year 1 (aged 5-6 years) to Year 6 (aged 10-11 years)	Self-reported in the Active Lives Survey
Gender*	Gender was a categorical variable with three categories: girl, boy, and other	Self-reported in the Active Lives Survey
Ethnicity*	Ethnicity was a categorical variable and divided into 6 groups – White, White other, Asian, Black, mixed, prefer not to say.	Self-reported in the Active Lives Survey
Disability*	A child's disability status was divided into 2 categories – whether or not a child has a disability or special educational need, or not	Self-reported in the Active Lives Survey
Deprivation (IMD)	Deprivation was based on the Index of Multiple Deprivation (IMD) matched on geography based on school location. Higher scores mean higher deprivation. This was a nominal variable.	Matched on geography based on school location
School grade (Ofsted¥) *	Ofsted effectiveness was a categorical variable and was split into 4 grades: 1 is 'outstanding', 2 is 'good', 3 is requires improvement', and grade 4 is 'inadequate'. A 'missing' Ofsted rating is also included. Grades are matched on school level information.	Matched on school level information
Rurality*	Rurality was 2 categories based on the Office for National Statistics Classification – Rural: Hamlets and Isolated Dwellings, Town and Fringe, and Village; Urban: Urban city and town, Major Conurbation, and Minor Conurbation	Matched on geography based on school location
Term of survey completion*	Term of survey completion was based on which term the child filled in the survey and is being used a proxy measure for season. They could complete the questionnaire either in spring (January – April), summer (May to early July), or autumn (September – December). The sample size is slightly uneven between the terms, with more in the autumn and spring than the summer terms.	Allocated by Sport England based on when school was sampled

¥ An indicator of the quality of an institution following an inspection from UK's Office for Standards in Education, Children's Services and Skills
**** categorical variable***

7.3.3 Modelling over-dispersed and zero-inflated data

The number of events occurring in a fixed period of time often follows the Poisson distribution, a common example being count data. The primary outcome (minutes of MVPA in school hours) was count data; I therefore considered a standard Poisson model (Poisson models require the mean=variance). However, the data showed overdispersion (greater spread in the values where the mean < variance); thus, the negative binomial distribution was more appropriate as it has one more parameter than the Poisson regression that adjusts the variance independently from the mean. However, the data had an excess number of zeros to be able to fit the regular negative binomial distribution and was 'zero-inflated'. The overdispersion and excess zeros observed can be linked to each other. The distribution of counts such as minutes of MVPA often have a larger than expected number of observed zeros. This in turn reduces the mean, and where the mean < variance. In this case, the outcome data was both overdispersed and zero-inflated (had excess zeros). To deal with this occurrence there are two models that can be used: a zero-inflated negative binomial model or hurdle model with a negative binomial distribution (Figure 7.3).

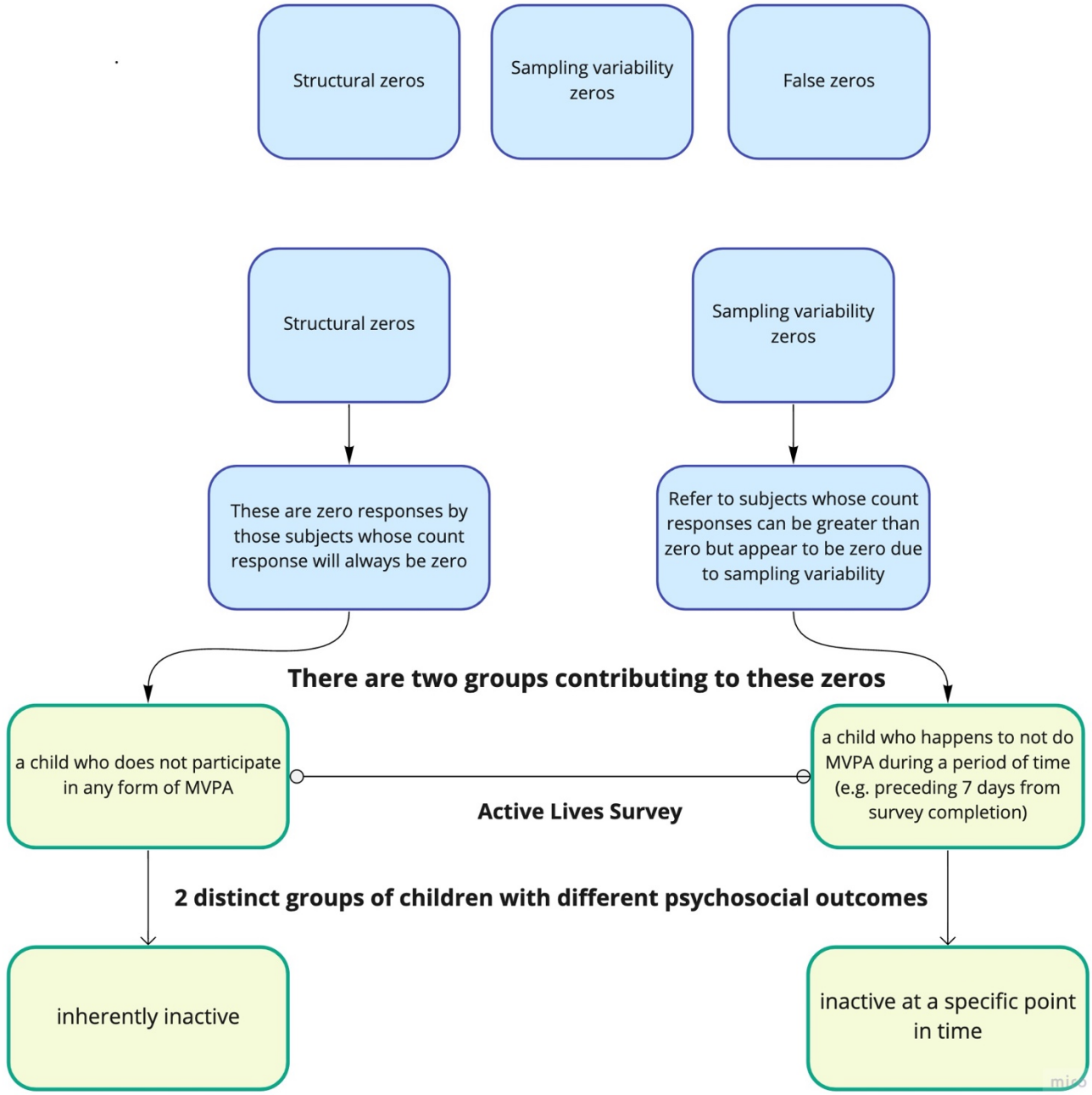
Figure 7.3: Investigation of overdispersion and zero-inflation



Zero-inflated negative binomial models and hurdle models both account for excess zeros observed. However, they have an important distinction on how they interpret and treat zero

counts. Zero counts can either be structural or due to sampling variability. It is vital, both conceptually and methodologically, to pay close attention to structural zeros in such count variables. Structural zeros refer to zero responses by those subjects whose count response will always be zero, in contrast to random (or sampling) zeros that occur to subjects whose count responses can be greater than zero but appear to be zero due to sampling variability. It is important to consider the excess zeros by hypothesising that there are two distinct groups contributing to the amount. For example, in terms of the Active Lives Survey, observing the minutes of MVPA, a structural zero in MVPA outcomes represents a child who does not participate in any form of MVPA, while a random zero corresponds to a child who happens to not do MVPA during a period of time (e.g., when the survey was conducted). Therefore, the structural and random zeros represent two distinct groups of children with different psychosocial outcomes; those that are inherently inactive when referring to MVPA and those who are inactive at a specific point in time (Figure 7.4).

Figure 7.4: Types of zeros within the Actie Lives Survey



Zero-inflated models assume that some zeros are observed due to some specific structure in the data (e.g., children reporting zero may be because they are physically disabled and are wheelchair bound or are children who only engage in low intensity physical activities); these represent the structural zeros since they cannot participate in MVPA. The second group reports no MVPA but are more amenable and have the potential to increase their MVPA and report non zero counts; they simply have not yet reached a reporting threshold beyond zero and are

sampling zeros. For e.g., these children can participate in MVPA but report zero minutes of MVPA because they were ill when the survey was done. Thus, these children are part of a negative binomial process which includes a portion of zeros but models an increasing involvement in MVPA.

In contrast, the hurdle model assumes that all observed zeros are structural and the positive non-zero data (i.e., children who report more than 0 minutes of MVPA) have a sampling origin that follow a truncated negative binomial distribution. An example of this is the number of diabetes glucose tests a person has taken over the last month. In this case, it is safe to assume that only people without diabetes will report zero tests during the last month and those with diabetes will report some positive (not zero) number of tests during the last month. Here, the zero observations come from only one structural source: people without diabetes. If a person is considered diabetic, they do not have the scope to score zero tests taken in the last month and will always score a positive number of tests in a Hurdle model with a truncated negative binomial distribution.

In this case, I concluded that there is a mix of both structural and sampling zeros for minutes of MVPA within the Active Lives Survey. There is most likely a mix of children; those that report zero MVPA because they are inherently inactive, and those that report zero by chance/at random/due to sampling. It would be unlikely for all the children reporting zero to be structural (e.g., child could have been ill in the 7-day look-back period of the survey).

7.3.4 Methods

7.3.4.1 Variable Manipulation

To conserve sample size, I coded missing data for IMD, Ethnicity and Ofsted variables as another level of the variable called ‘Missing’. Further, to produce neater models, I collapsed year groups 1 and 2 together, 3 and 4, and 5 and 6. The survey for children of year groups 1 and 2 are filled in my parents and thus seemed suitable to condense them. I also condensed IMD from deciles to quintiles for ease of model interpretation.

7.3.4.2 Modelling

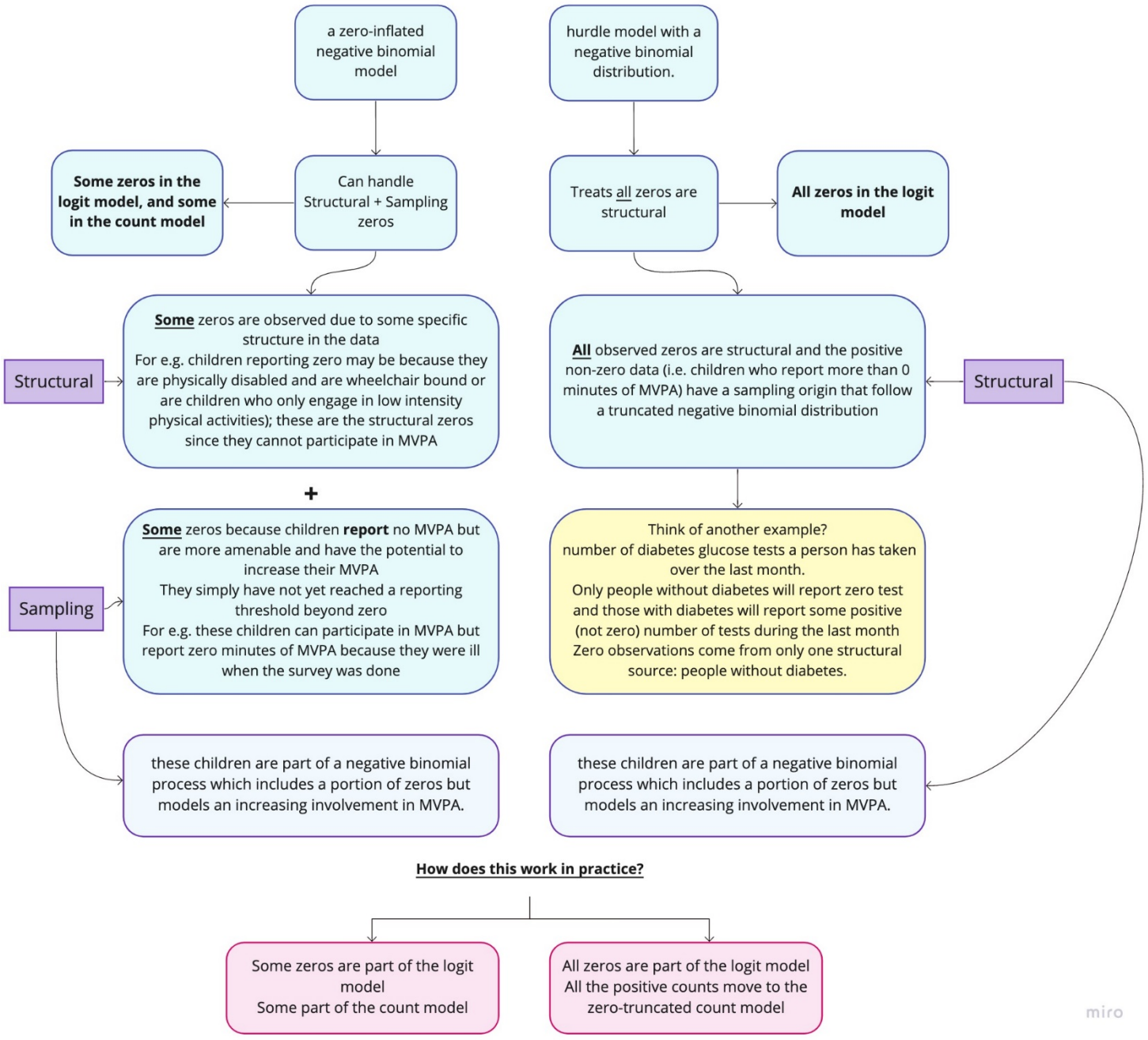
The data for the outcomes of interest are overdispersed and zero-inflated. Based on the assumption that the zeros observed are both structural and due to sampling variability, the zero-inflated negative binomial model with a random effect for school was considered appropriate (Figure 7.5). This is a two-part model. However, both parts predict zero counts. The count model predicts some zero counts, and on the top of that the zero-inflation binary model part adds zero counts, thus, the name zero "inflation". This is more suitable (than for example, hurdle models) for situations where there are two types of zeros, i.e., structural zeros and sampling zeros. These models were adjusted for age, sex, ethnicity deprivation, disability, season, rurality, and Ofsted rating.

To test zero inflation, I performed a Vuong test for all the final zero inflated negative binomial models to confirm whether the zero-inflated model is a significant improvement over a standard negative binomial model. However, this was done on models without a random intercept for school as the Vuong statistic does not support mixed models. I cross referenced trends and coefficients in the non-hierarchical mixed model and the hierarchical mixed model with the random intercept for school to ensure that the assumption I made of using the non-hierarchical model in Vuong's test was feasible.

The models treated children in Non-Daily Mile registered schools as the reference category. Differences in MVPA for children in TDM and non TDM schools were reported using odds ratios (any reported participation in physical activity model) and rate ratios (MVPA among those who reported any physical activity).

As elaborated above, in this case, I concluded that there was a mix of both structural and sampling zeros for minutes of MVPA within the Active Lives Survey. There is most likely a mix of children; those that report zero MVPA because they are inherently inactive, and those that report zero by chance/at random/due to sampling. Thus, a zero inflated negative binomial model will be most appropriate to model the outcome of interest (since it is overdispersed, zero inflated, and zeros being structural and random).

Figure 7.5: **Modelling strategy taking into account zero-inflation and overdispersion**



7.3.4.3 Sensitivity analysis (interaction)

Analysis of interactions between exposure and covariates

The literature as described in Chapter 1 suggests that the impact of the TDM, or any physical activity intervention, could be modified by specific characteristics of the children. I hypothesised that impact of the TDM could be modified by specific characteristics of the children, specifically gender, age (year group) and deprivation. I considered the inclusion of

interaction terms between gender, year group, and deprivation to assess their impact of the following characteristics on outcomes between the study arms. The significance of a subgroup effect was assessed by an interaction test between the covariate and the treatment arm. I used p-values to check whether the interaction terms were significant and the AIC for model fit. I chose to include the interaction terms separately due to concerns of over fitting the models.

7.3.5 Results

7.3.5.1 Missing data

Missing data varied between 4 and 6% for the majority of variables (Table 7.2). However, the variables of IMD, ethnicity and Ofsted rating of the school had more missing data. Thus, for these variables, I created a new level 'missing' to conserve sample size, reducing a loss of 21% children in the sample to 13%. Further, to produce more interpretable models, I combined school year groups 1 and 2 together, 3 and 4 together, and 5 and 6 together. The survey for children of year groups 1 and 2 are completed by parents and seemed suitable to combine them. Similarly, I condensed IMD from deciles to quintiles. I did not consider the use of imputation methods as the same size was large (N= 49561) even in the complete case.

Table 7.2: Missing data by variable

Variable	Missing (N (%))
Minutes MVPA everywhere from all activities	2916 (5.36)
Minutes MVPA in school from all activities	2916(5.36)
Minutes MVPA outside school from all activities	2916(5.36)
Gender	3804 (6.99)
Rurality	2343(4.30)
Ofsted Rating	6906 (12.68)
Season	2343 (4.30)
Ethnicity	3577(6.57)
Region	2343(4.30)
IMD Child Quintile	4838 (8.89)
Daily Mile	2415 (4.43)
School Year (Age)	2343(4.30)
Disability	3871 (7.11)
Meeting the recommended levels of physical activity (420 mins MVPA/week)	2916 (36)

7.3.5.2 Overdispersion and excess zeros in the Active Lives Survey for Children and Young People for physical activity outcomes

A challenge in self-reported data is interpreting children who report zero activity. As seen in the Table 7.3, of children reporting 0 MVPA in school hours (n=3880), 2831 also report 0 all intensity in school, implying that these 2831 children do no physical activity at all. Given this category includes all activity, including running to the shops and other types of incidental activity, I was interested in understanding this further. Further, that also leaves 1049 children (3880-2831) who report some low intensity activity in school, just not MVPA. Similarly, of children reporting 0 MVPA outside school (n=3860), 2472 also report 0 all intensity outside school, suggesting that these 2472 children do no physical activity at all. However, that also leaves 1388 children (3860-2472) who report some low intensity activity outside school, just not MVPA. And lastly, of children reporting 0 MVPA everywhere (n=2276), 1586 also report 0 all intensity everywhere, suggesting that these 1586 children do no physical activity at all. However, that also leaves 690 children (2276-1586) who report some low intensity activity everywhere, just not MVPA.

It is critical to focus on the 1586 children report 0 activity from all activities of all intensities everywhere, which means that these children claim to not be active at all. I examined these 1586 children for any similarities between them or explanations as to why they may be reporting 0 (e.g., they are disabled or they were from Year groups 1 and 2 because parents were filling them in, or from year groups 2 and 6 because these are the years for children to sit their SATs). However, there were no apparent patterns or similarities shared by these children (Table 7.4). Some of the zeros may be structural – that is they may represent children who take part in no activity. These children would respond with a zero for any sampling period. However, some zeros are part of the random sampling, they may have taken part in no activity in the previous seven days, or not remember or actively disengage from the survey. If indeed these children were all reporting zero as a result of not being engaged with the survey and filling it out dishonestly, I could consider deleting these children from my analysis as their data would be rendered invalid. However, I did not believe that this is the case for the 1586 children reporting 0 activity of all intensities everywhere. It is also possible that children who report 0 activity are unaware of this. This survey is based on children answering questions about the time they spent engaging in a certain activity in the preceding week. The actual intensity of the activity in derived by Sport England. It is very possible that a proportion of children (especially the younger ones who self-report) who report 0 activity are unaware of the activity they actually

engage in because of what they recognise physical activity as being (for example, a 30 min walk to and from the shop). In this case, the child is engaging in low intensity physical activity (walking) but does not think of it as 'physical activity' and thus does not report it as such. This is also likely among parents who report activity for children from Year 1 and Year 2, who may not be fully aware of all the activity that their child is participating in. I therefore concluded that a proportion of the 1586 zeros observed are random and a proportion are structural.

Table 7.3: Zeros in the Active Lives Survey by Outcome

	Primary Outcome – MVPA in school hours	**Secondary Outcome – MVPA outside school hours**	**Secondary Outcome – MVPA everywhere**
Children reporting zero MVPA (N %)	3880 (9% of all children in survey)	3860 (8.5% of all children in survey)	2276 (5% of all children in survey)
Of those reporting 0 MVPA, how many reporting 0 all intensity	2831	2472	1586
Some low intensity activity	1049	1388	690
MVPA: moderate to vigorous physical activity; N: number of children			

Table 7.4: Characteristics of children reporting zero minutes of all activity of all intensities everywhere

	Zero minutes of all activity of all intensities everywhere (N=1586) N(%)	**More than zero (N=49945) N(%)**	**Overall (N=54447) N(%)**
Daily Mile			
Non-DM	1297 (81.8)	39797 (79.7)	41535 (76.3)
DM	287 (18.1)	10081 (20.2)	10497 (19.3)
Missing	2 (0.1)	67 (0.1)	2415 (4.4)
Year Group			
1	36 (2.3)	2081 (4.2)	2119 (3.9)
2	48 (3.0)	2094 (4.2)	2147 (3.9)
3	263 (16.6)	10597 (21.2)	10974 (20.2)
4	331 (20.9)	10549 (21.1)	11032 (20.3)
5	482 (30.4)	12690 (25.4)	13321 (24.5)
6	426 (26.9)	11934 (23.9)	12511 (23.0)
Missing	0 (0)	0 (0)	2343 (4.3)

Ethnicity			
White British	894 (56.4)	32116 (64.3)	33320 (61.2)
White other	56 (3.5)	1882 (3.8)	1965 (3.6)
Asian	85 (5.4)	2544 (5.1)	2658 (4.9)
Black	57 (3.6)	1425 (2.9)	1505 (2.8)
Mixed	115 (7.3)	3442 (6.9)	3615 (6.6)
Other	80 (5.0)	1928 (3.9)	2045 (3.8)
prefer not to say	243 (15.3)	5445 (10.9)	5762 (10.6)
Missing	56 (3.5)	1163 (2.3)	3577 (6.6)
Gender			
Boy	788 (49.7)	22758 (45.6)	23834 (43.8)
Girl	631 (39.8)	23695 (47.4)	24527 (45.0)
Other	93 (5.9)	2140 (4.3)	2282 (4.2)
Missing	74 (4.7)	1352 (2.7)	3804 (7.0)
IMD (Deprivation) Quintiles			
1 (most deprived)	212 (13.4)	6062 (12.1)	6343 (11.6)
2	345 (21.8)	10274 (20.6)	10742 (19.7)
3	271 (17.1)	9485 (19.0)	9880 (18.1)
4	368 (23.2)	11209 (22.4)	11694 (21.5)
5 (least deprived)	301 (19.0)	10528 (21.1)	10950 (20.1)
Missing	89 (5.6)	2387 (4.8)	4838 (8.9)
Disability			
no disability	644 (40.6)	23767 (47.6)	24634 (45.2)
Disability	611 (38.5)	17573 (35.2)	18405 (33.8)
prefer not to say	264 (16.6)	7165 (14.3)	7537 (13.8)
Missing	67 (4.2)	1440 (2.9)	3871 (7.1)
Term/Season			
Autumn	975 (61.5)	15652 (31.3)	16767 (30.8)
Spring	492 (31.0)	19098 (38.2)	19810 (36.4)
Summer	119 (7.5)	15195 (30.4)	15527 (28.5)
Missing	0 (0)	0 (0)	2343 (4.3)
Rurality			
Urban: Major Conurbation	395 (24.9)	11162 (22.3)	11704 (21.5)
Urban: Minor Conurbation	42 (2.6)	1261 (2.5)	1316 (2.4)
Urban: Town/City	870 (54.9)	27311 (54.7)	28490 (52.3)
Rural: Town / Fringe	193 (12.2)	6271 (12.6)	6525 (12.0)
Rural: Village	71 (4.5)	3194 (6.4)	3301 (6.1)
Rural: Hamlets / Isolated Dwellings	15 (0.9)	746 (1.5)	768 (1.4)
Missing	0 (0)	0 (0)	2343 (4.3)
Ofsted rating			
Outstanding	207 (13.1)	8254 (16.5)	8563 (15.7)
Good	1064 (67.1)	32898 (65.9)	34352 (63.1)
requires improvement	126 (7.9)	3959 (7.9)	4118 (7.6)
Inadequate	13 (0.8)	493 (1.0)	508 (0.9)
Missing	176 (11.1)	4341 (8.7)	6906 (12.7)

Based on tables 7.3 and 7.4, I assume that because children are reporting 0 MVPA everywhere, it does not necessarily imply that they are not doing any physical activity. As discussed above, a proportion of them are engaging in some low intensity physical activity. In the case of children having reported 0 MVPA in school, there are instances where children report some MVPA done outside school, and some low intensity activity done inside school (Table 7.3). Additionally, there were no specific characteristics of children who reported zero, e.g., they were not all a certain age or ethnicity (Table 7.4). Not all the observed zeros have been accounted for structurally – as mentioned above, a child completely the survey dishonestly and reporting 0 would be considered a random zero. I therefore believe that the zeros observed in the outcomes of interest in this survey are both structural and random and should be treated as such when selecting the correct modelling approach.

7.3.5.3 Representativeness of the Active Lives Survey

The socio-demographic characteristics of survey respondents was nearly aligned with the 2011 census – children from ethnic minorities were sampled representatively as the census, however, the most deprived children (IMD 1) were under- surveyed. Similarly, data from the youngest children from year 1 and 2 (aged 5-7) were under-surveyed. A possible explanation for this is because physical activity data was obtained by parent self-report for these two year-groups. Further, TDM school profiles within the Active Lives Survey matched the profiles of all TDM schools in the school census as I found in Chapter 5 and 6.

There were 49,561 children in this sample, of whom 20% attended schools registered for TDM (N=10,017). Children and school characteristics were broadly representative of child and school populations in England (Table 7.5). However, there was an underrepresentation of younger children (9% in year 1 and 2 compared to approximately 45% in other year groups). Overall, 46% (22,642 of 49,561) of children were meeting the recommended levels of physical activity.

Table 7.5: Characteristics of children attending schools registered for The Daily Mile and not registered – data from Active Lives Child and Young People Survey (2018-2019)

	Daily Mile (N=10017) (20.2%) N (%)	**Non-Daily Mile (N=39544) (79.8% N (%)**	**Total (N=49561) N (%)**

School Year group (Age in years)¬¤			
1 and 2 (5-7 years)	994 (9.9)	3206 (8.1)	4200 (8.5)
3 and 4	4026 (40.2)	16828 (42.6)	20854 (42.1)
5 and 6 (10-12 years)	4997 (49.9)	19510 (49.3)	24507 (49.4)
Gender			
Boy	4736 (47.3)	18554 (46.9)	23290 (47.0)
Girl	4847 (48.4)	19216 (48.6)	24063 (48.6)
Other	434 (4.3)	1774 (4.5)	2208 (4.5)
Ethnicity			
White British	6428 (64.2)	26188 (66.2)	32616 (65.8)
White Other	375 (3.7)	1526 (3.9)	1901 (3.8)
Asian	645 (6.4)	1950 (4.9)	2595 (5.2)
Black	340 (3.4)	1109 (2.8)	1449 (2.9)
Mixed	754 (7.5)	2738 (6.9)	3492 (7.0)
Other	400 (4.0)	1522 (3.8)	1922 (3.9)
Prefer not to say	1075 (10.7)	4511 (11.4)	5586 (11.3)
Disability			
Disability	3631 (36.2)	14318 (36.2)	17949 (36.2)
No disability	4866 (48.6)	19420 (49.1)	24286 (49.0)
Prefer not to say	1520 (15.2)	5806 (14.7)	7326 (14.8)
Deprivation (Index of Multiple Deprivation Quintiles)Ω			
1 – most deprived	1566 (15.6)	4483 (11.3)	6049 (12.2)
2	2299 (23.0)	7858 (19.9)	10157 (20.5)
3	1665 (16.6)	7677 (19.4)	9342 (18.8)
4	2491 (24.9)	8707 (22.0)	11198 (22.6)
5 – least deprived	1372 (13.7)	9060 (22.9)	10432 (21.0)
Season of survey completion			
Autumn (September – December)	2723 (27.2)	13263 (33.5)	15986 (32.3)
Spring (January – April)	3914 (39.1)	14906 (37.7)	18820 (38.0)
Summer (May to early July)	3380 (33.7)	11375 (28.8)	14755 (29.8)
Rurality			
Rural	1652 (16.5)	8482 (21.4)	10134 (20.4)
Urban	8365 (83.5)	31062 (78.6)	39427 (79.6)
School Grade (Ofsted)¥			
Outstanding	1423 (14.2)	6764 (17.1)	8187 (16.5)
Good	7032 (70.2)	25652 (64.9)	32684 (65.9)
Requires improvement	1405 (14.0)	2516 (6.4)	3921 (7.9)
Inadequate	79 (0.8)	416 (1.1)	495 (1.0)
Meeting the physical activity recommendations*¬			
Not meeting	5163 (51.5)	21756 (55.0)	26919 (54.3)
Meeting	4854 (48.5)	17788 (45.0)	22642 (45.7)

¬¤ ***Year 1*** *= beginning of primary school (children aged 5-6 years); Year 6 = the end of primary school (children aged 11-12 years)*
¥ *An indicator of the quality of an institution following an inspection from UK's Office for Standards in Education, Children's Services and Skills*
*****¬*Meeting the physical activity recommendations of >= 420 minutes of MVPA across the week*
Ω *based on school postcode*
Note*: Missing data not reported for each variable – any totals less than 100% (ie: gender, age, ethnicity, disability, rurality, Ofsted rating, season, IMD, region) are a result of missing data (Section X)*

7.3.5.4 Crude differences in physical activity by school registration to The Daily Mile

Prior to adjustment, children attending schools registered to TDM reported a median of 115 (IQR: 50, 215) minutes of MVPA inside school, compared with children attending non-TDM schools (105 minute), (IQR: 45, 200). Similarly, children attending schools registered to TDM reported higher levels of physical activity outside school (267 (IQR: 105, 580) minutes compared to 245(IQR: 95, 540)) and total MVPA (395 (IQR: 175, 795) minutes compared to 360 (IQR: 160, 735)) compared to children attending non-TDM schools (Table 7.6).

Table 7.6: Physical activity levels across different settings by registration status to The Daily Mile

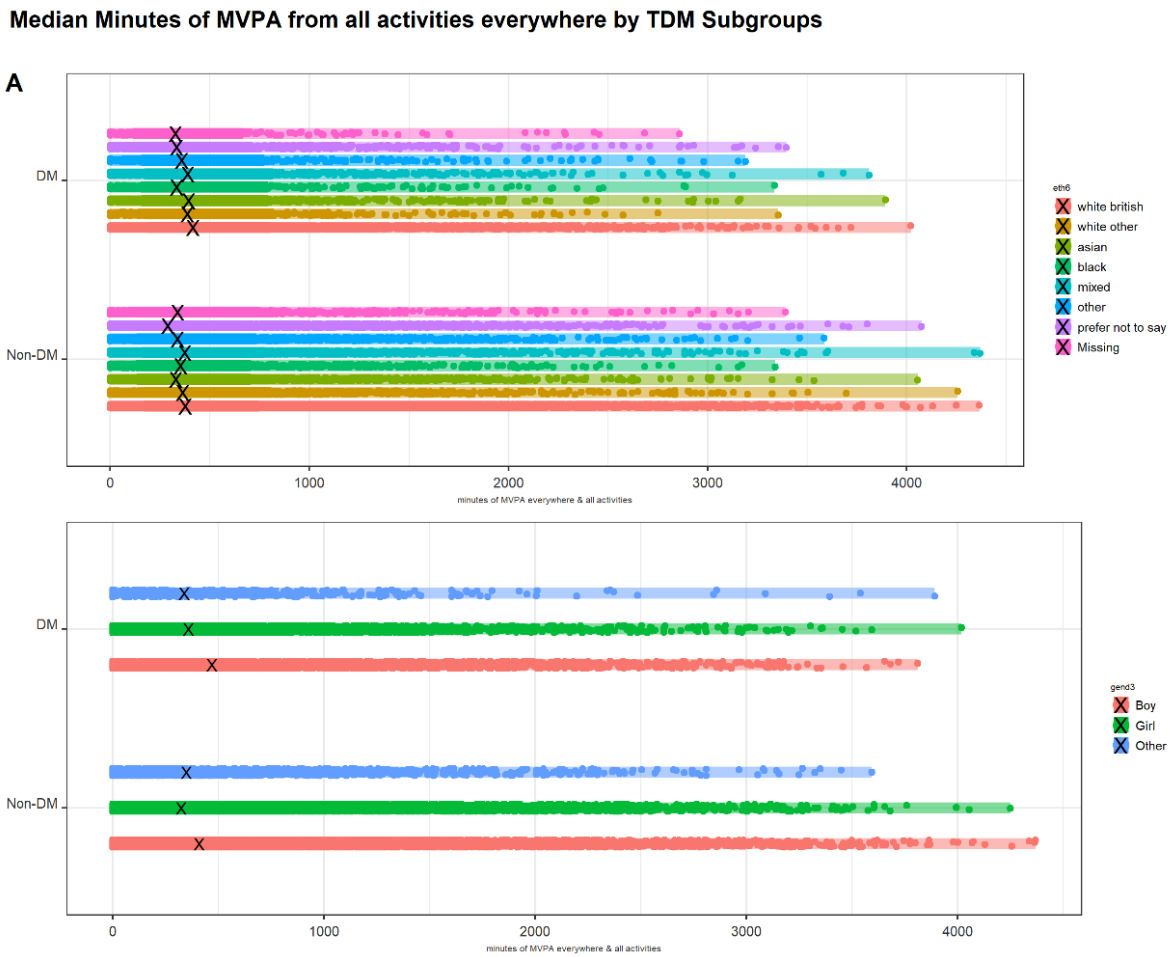
	Registered to The Daily Mile (N=10368)		**Not Registered to The Daily Mile (N=41094)**	
	Median minutes MVPA	IQR	**Median minutes MVPA**	IQR
In school hours	115	50, 215	105	45,200
Outside school hours	267	105, 580	245	95, 540
Total	395	175, 795	360	160, 735

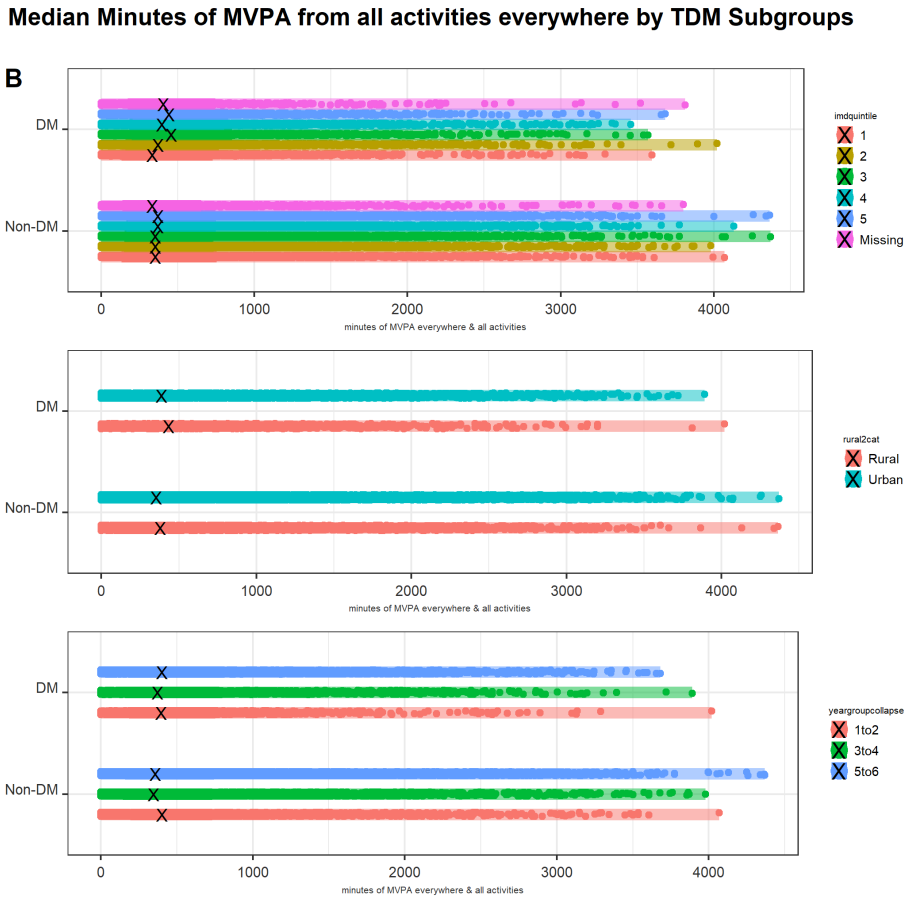
IQR*: inter quartile range*
MVPA: Moderate to vigorous physical activity

Across all subgroups including gender, age, term of survey completion (season), ethnicity, deprivation, disability status, Ofsted rating, and rurality, children attending schools registered to TDM reported a higher total of minutes of MVPA compared to children not in TDM school (Figure 7.6). When observing median MVPA by TDM status and gender, girls overall, regardless of TDM, had the lowest reported MVPA; and boys seemed to 'benefit' more from

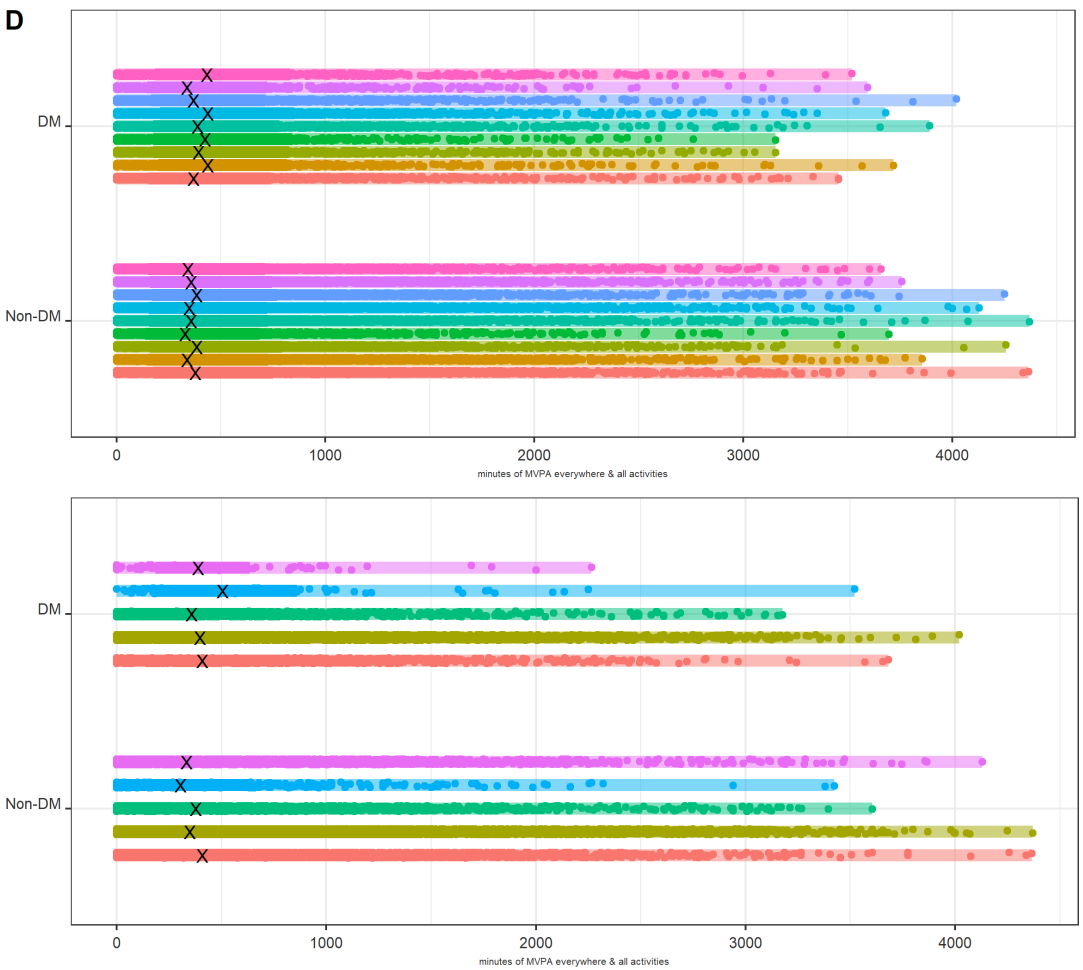
TDM than girls. TDM children among all year groups reported higher median MVPAs compared to non TDM children, except for the youngest children in year 1-2, whose parents reported their activity levels. This difference was most profound in year 5-6. The starkest difference was among Asian children; where Asian children attending schools registered to TDM reported almost 65 minutes more MVPA than non TDM Asian children. Further, the differences in physical activity by TDM status were more marked at the start of the school year falling from 40 to 35 to 5 minutes between autumn, spring and summer. In terms of deprivation (IMD), the highest MVPA was observed in TDM children in IMD 3 (middle), and IMD 5 (least deprived), and lowest in TDM IMD 1 (most deprived). The reported MVPA was higher for all TDM groups by deprivation except IMD 1 (Appendix H).

Figure 7.6: Minutes of MVPA total by TDM subgroup

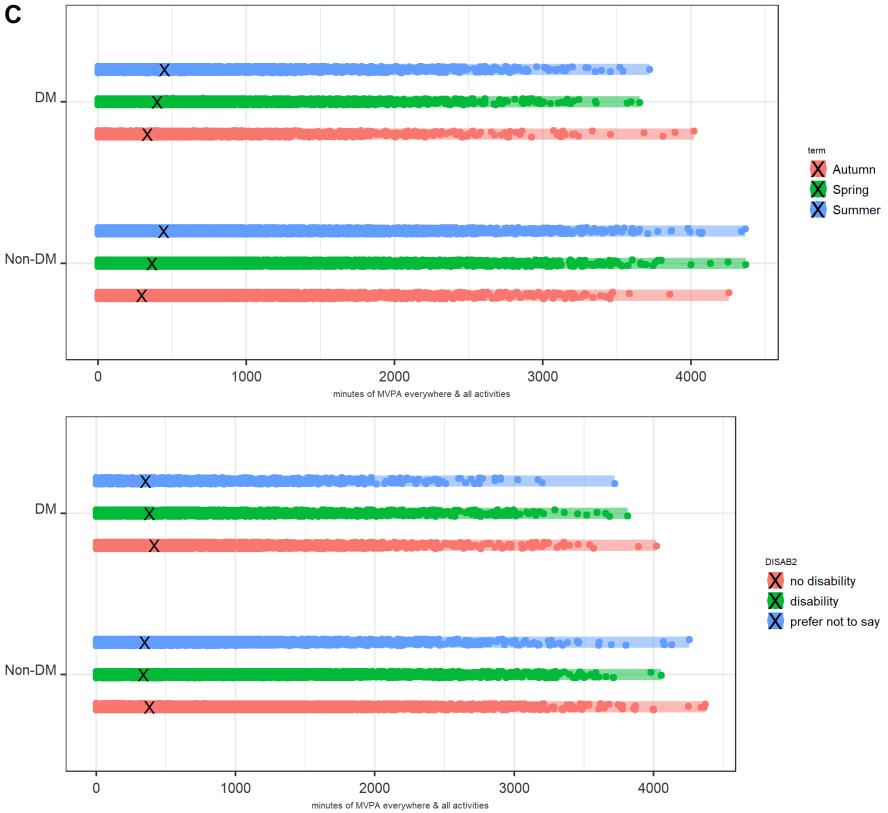




Median Minutes of MVPA from all activities everywhere by TDM Subgroups



Median Minutes of MVPA from all activities everywhere by TDM Subgroups



p<0.001 for differences in MVPA by TDM status and all confounders (all graphs above) in 2A, 2B, 2C, and 2D; MVPA: moderate to vigorous physical activity

7.3.6 Modelling Results

7.3.6.1 Registration to The Daily Mile and minutes of MVPA

In the fully adjusted models, registration to TDM in the logit model predicting excess zeroes was not significant in any setting (i.e., inside school, outside school, or overall). This implies that a child attending a TDM registered school was no more or less likely to report no activity than a child in a non-TDM school (Appendix I).

The results of the zero-inflated negative binomial models, including model coefficients are shown in Table 7.7. The first part of the model is the negative binomial portion, and this applies to children who have a chance of reporting more than zero minutes of MVPA. The baseline number of minutes on average during school hours and was 162 (95% CI 150 to 175) minutes/week. After adjustment, TDM was associated with an Incidence Rate Ratio (IRR) of 1.06 (95%CI 1.02–1.10). This is equivalent to an increase in MVPA from 162 to 172 minutes (95%CI 165–178). This equates to a 10-minute difference (95% CI 3–16 minutes) in the minutes of MVPA during school hours between children in TDM registered and non-TDM registered schools across the week.

When applying the same approach for minutes of MVPA for children outside school hours per week, the baseline number of minutes of MVPA on average outside school was 437 (95%CI 404 – 473) minutes per week. After adjustment, TDM was associated with an IRR of 1.06 (95% CI 1.01 – 1.10).) This is equivalent to an increase in MVPA from 437 to 463 minutes. This equates to a 26-minute difference (95% CI 4 – 44 minutes)) in the minutes of MVPA outside school hours between TDM and non-TDM registered children across the week. Finally, for minutes of total MVPA for children, which is a sum of in school and outside school MVPA, the baseline number of minutes of MVPA on average was 584 (95%CI 540 – 630). After adjustment, TDM registration was associated with an IRR of 1.06 (95% CI 1.02 – 1.10), equating to a 35-minute difference (95% CI 12 – 58 minutes) in weekly MVPA between children in TDM and non-TDM registered schools. For the full modelling results, please see Appendix I.

Table 7.7: Association between registration The Daily Mile and physical activity duration in and outside school hours and total activity***

	Negative Binomial Portion *(predicting minutes of MVPA)*			***Logit Portion*** *(predicts the odds of reporting zero)*		
Outcomes	***Adjusted IRR^^ (95% CI)***	***SE***	***p***	***Adjusted OR^^ (95% CI)***	***SE***	***p***
Minutes of MVPA in school hours						
Intercept	161.61 (149.54 – 174.66)	0.04	**<0.001**	0.18 (0.14 - 0.24)	0.14	**<0.001**
Daily Mile: No (Reference)						
Daily Mile Yes	1.06 (1.02 – 1.10)	0.02	**0.003**	0.95 (0.83 – 1.09)	0.07	0.46
ICC: 0.07						
Minutes of MVPA outside school hours						
Intercept	436.95 (403.58 - 473.08)	0.04	**<0.001**	0.03 (0.02 – 0.04)	0.17	**<0.001**
Daily Mile: No (Reference)						
Daily Mile Yes	1.06 (1.01 – 1.10)	0.02	**0.006**	0.94 (0.81 – 1.08)	0.07	0.35
ICC: 0.05						
Minutes of MVPA total (in + outside school)						
Intercept	583.67 (540.40 – 630.40)	0.04	**<0.001**	0.03 (0.02 – 0.04)	0.21	**<0.001**
Daily Mile: No (Reference)						
Daily Mile Yes	1.06 (1.02 – 1.10)	0.02	**0.003**	0.97 (0.81 - 1.16)	0.09	0.71
ICC: 0.06						

^^ adjusted for gender, age, deprivation (IMD), ethnicity, term of survey completion, rurality, Ofsted rating of school, disability
ICC: intraclass correlation coefficient
SE: Standard error
MVPA: moderate to vigorous physical activity
OR: odds ratio; **IRR:** incident rate ratio
p: p-value
***Multilevel multivariable zero-inflated negative binomial regression coefficients, clustered by school; (level-1 N=49561 children; level-2 N=1049 schools)

7.3.6.2 Registration to The Daily Mile and meeting the recommended levels of physical activity

After adjustment for potential confounders, children attending schools registered to TDM were 6% more likely to meet the recommended levels of physical activity compared to children attending non-TDM schools (RR 1.06 (95% CI (1.02, 1.11)) (Table 7.8).

Table 7.8 Association between Daily Mile Registration and Meeting the Recommended Levels of Physical Activity

Predictors	Adjusted Odds Ratios (95% CI)	Adjusted Relative Risk (95% CI)	SE	p-value
(Intercept)	1.30 (1.11, 1.52)	1.14 (1.06 – 1.23)	0.08	0.001
Daily Mile: No				
Daily Mile Yes	1.12 (1.04, 1.21)	1.06 (1.02 – 1.11)	0.04	**0.003**
ICC: 0.04				

^^ adjusted for gender, age, deprivation (IMD), ethnicity, term of survey completion, rurality, Ofsted rating of school, disability
ICC: intraclass correlation coefficient
SE: standard error
95%CI: 95% confidence interval
Recommended Levels of Physical Activity = average of 60 minutes of MVPA/day across the week; or >=420 minutes of MVPA/week
Multilevel multivariable logistic clustered by school (level-1 N=49561 children; level-2 N=1049 schools)

7.3.6.3 Sensitivity analysis results

Considering I was interested in determining if the potential impact of TDM was the same for different subgroups of the population, I added interaction terms to the model between the 3 key covariates identified and the treatment arm, i.e., TDM and gender, TDM and year group, and TDM and IMD (deprivation).

However, the results were inconclusive and nonsignificant, possibly because the reference groups were too small. Further, the trends and gradients observed were not clear and could not be interpreted meaningfully. The complexity underlying these models make it difficult to interpret the results correctly and extract potential trends. There was some evidence of a

potential interaction between TDM and girls, however, this was not clear; considering that there may be some reverse causality between TDM girls and physical activity levels. With age, there seemed to be some interaction between older primary school children (year 5-6) and TDM, where TDM participation in year 5-6 children seemed to have a greater effect than in year 1-2 children. However, this may be due to physical literacy of younger children, and the survey collects activity data for year 1-2 children from parents, which may also lead to underestimating activity levels in children in year 1-2. The results for the interaction between TDM and IMD were inconclusive. The results of all the models form the sensitivity analyses can be found in Appendix J. Because of the nature of the inconclusive results even after adding the interaction terms independently for the primary outcome, and the nature of the models (ZINB), I did not run individual interaction terms for the secondary outcomes: Minutes of MVPA outside school and Minutes of MVPA everywhere.

The results of the subgroup analyses for the secondary outcome that was binary, reaching the recommended levels of physical activity (yes/no), were also inconclusive (Appendix K). I tested for interactions between TDM participation and IMD, gender, and year group, in separate models. There were no significant interactions between TDM participation and gender, and year group. There was a significant interaction between IMD 3 and IMD 5 with TDM participation, however, there was no clear trend observed between deprivation groups and TDM and so this was not interpreted.

7.4 Part 2: To compare the variety of reported physical activity on primary school children attending schools registered to The Daily Mile compared to those who are not (Objective 5)

7.4.1 Measures

Exposure

As in Part 1 of this chapter, children attending schools officially registered to The Daily Mile Foundation's database on April 2019 were assigned to the TDM group, and all other children to the unexposed group (non-TDM).

Outcomes

The primary outcome was variety of activity reported in school. The secondary outcomes were variety of activity outside school, and the overall variety of activity reported.

The outcomes used in this study were derived by me using from the Active Lives Survey. The variety (number of activities) reported by a respondent was derived based on whether they had engaged in a specific pre-listed activity over the last week (binary). If they reported as having participated, they were given a score of 1. There was a total of 67 activities they could have participated in (list provided by Sport England). Thus, the maximum number of activities reported as participating could be 67. However, if a child (or parent) reported having participated in more than 36 activities in the preceding week, they were excluded from the dataset by Sport England as it seemed unlikely that they would have participated in more than 36 activities in any given week. Thus, the true maximum value for the number of activities reported as participating was 36.

Covariates

Inclusion of covariates into the models was theoretically informed *a priori*. These were the same as in Part 1. Covariates included adjustments for age (self-reported), gender (self-reported), ethnicity (self-reported), disability (self-reported), deprivation (matched on school location), season (term of survey completion), rurality (matched on school location), and Ofsted rating of the school (matched on school unique reference number). Data on the covariates were collected by Sport England as part of the Active Lives Survey (Table 7.1).

7.4.2 Methods

7.4.2.1 Statistical analysis

I first described the top 20 activities by setting – during school hours, outside school, and everywhere. I then described the 20 most popular activities by gender and, gender and registration status to TDM. I also examine the number of activities (variety) across different settings by registration status to TDM.

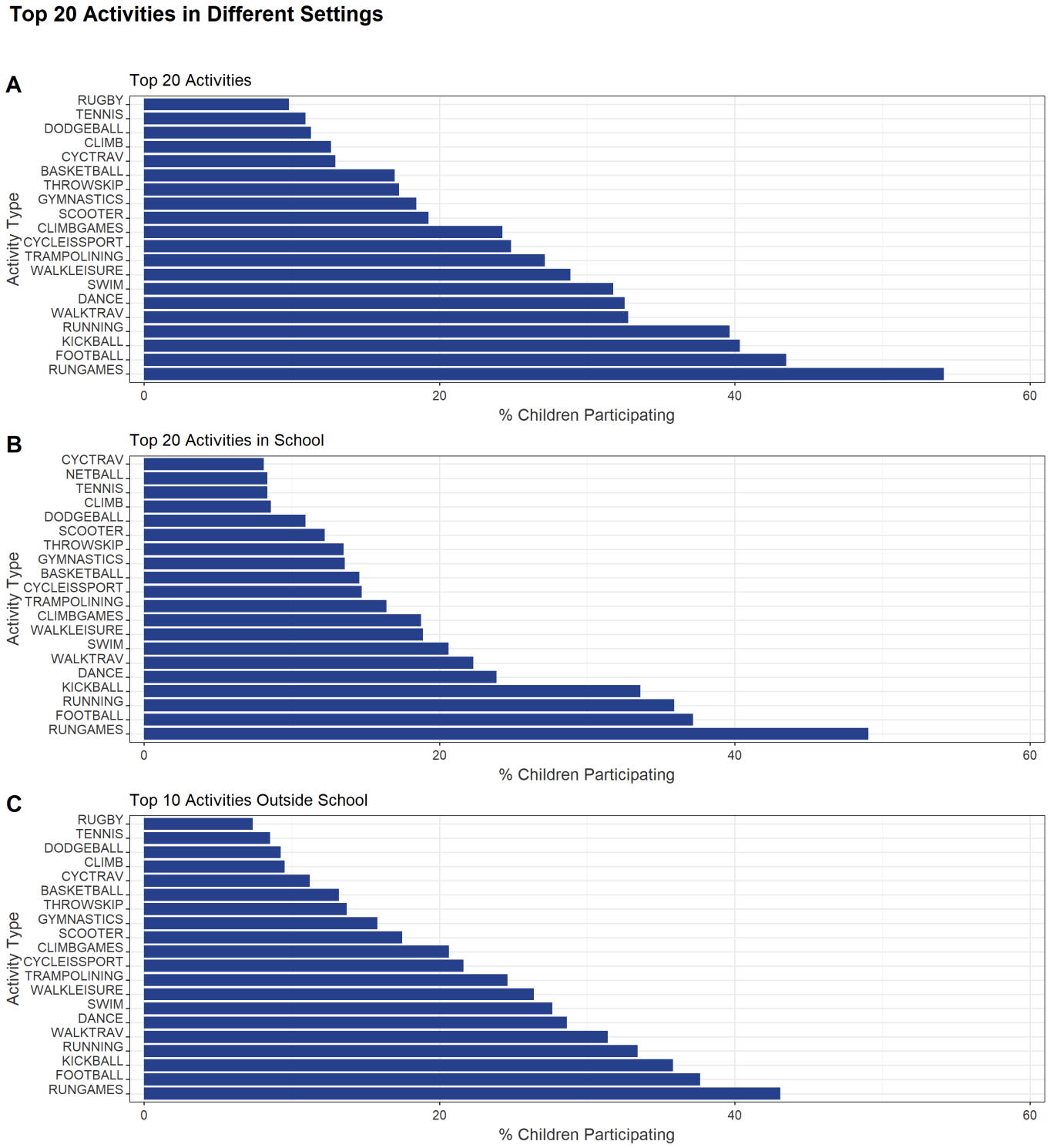
I checked for overdispersion in the outcomes (variety of activity in school, outside school and everywhere). To test the association between TDM and variety of activities during school hours, outside school, and total, I used negative binomial regressions. Since the data was over dispersed, I used a negative binomial model instead of a Poisson regression model. The models treated non-TDM registration as the reference category. The addition of covariates into the models was theoretically informed a priori and included the following variables: adjusted for age, gender, ethnicity deprivation, disability, term of survey completion (season).

7.4.3 Results

7.4.3.1 Descriptive statistics

The 3 most popular activities among all children did not change based on whether it was during or outside school hours during term time (Figure 7.7). The most popular activity remained running games, followed by football, and kickball or running. Other type of activities remained common to both settings (in and outside school), with varying levels of popularity (e.g., tennis was the 18th most popular activity inside school and the 19th most popular outside school). Rugby was the only activity not featured in the top 20 in both settings; it was the 20th most popular activity outside school (Figure 7.7).

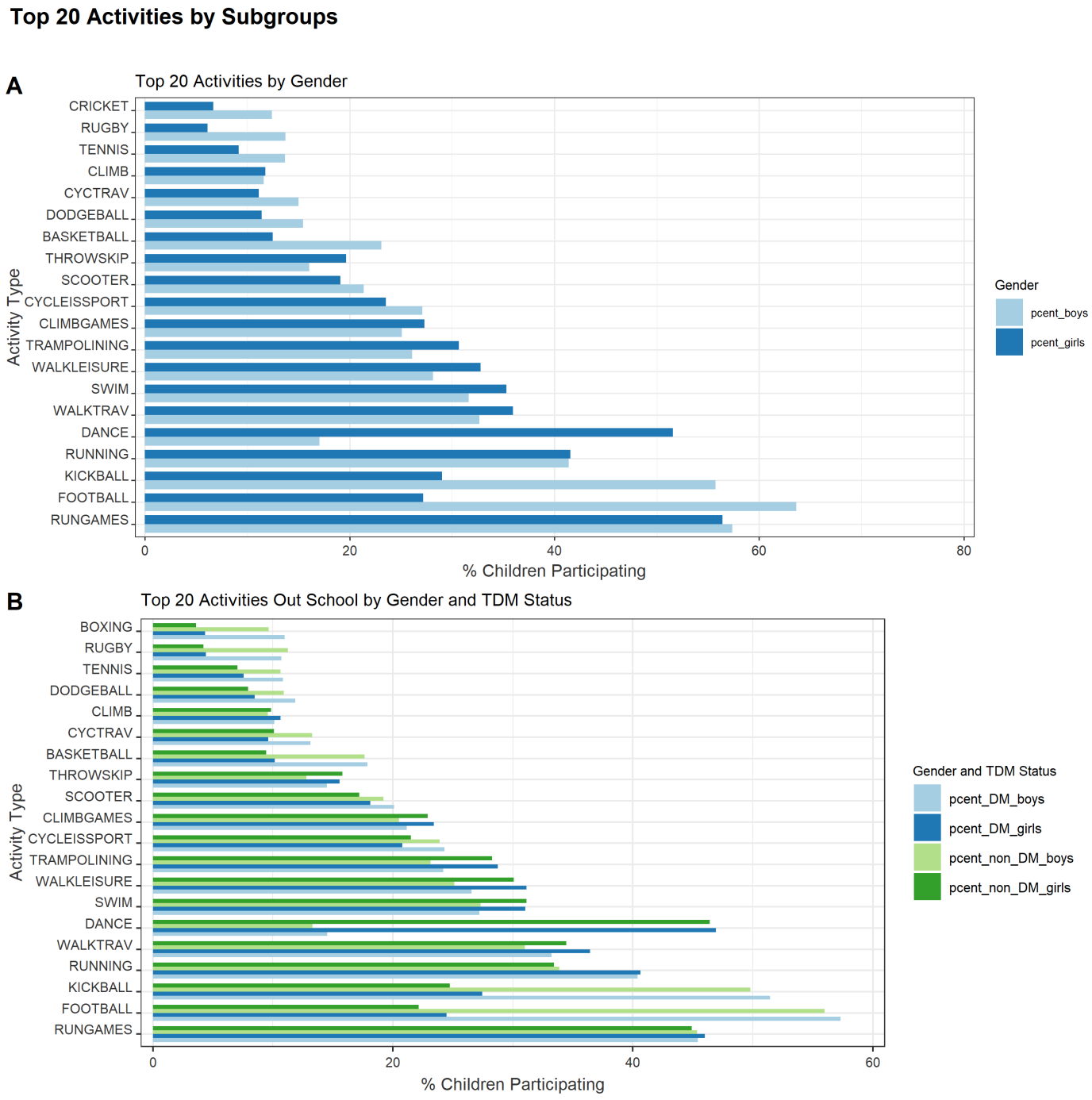
Figure 7.7: Top 20 activities in all primary school children in the Active Lives Children and Young People Survey 2018-2019



Children participated in a wide range of activities which often conformed to gender stereotypes. For instance, a greater proportion of girls reported dancing and trampolining compared to boys.

Similarly, a greater proportion of boys reported playing cricket, rugby and football compared to girls (Figure 7.8A). The popularity of the type of activitiy did not change for girls or boys children based on TDM status (Figure 7.8B).

Figure 7.8: Top 20 activities in subgroups of primary school children in the Active Lives Children and Young People Survey 2018-2019



7.4.3.2 Crude differences in variety of activity by The Daily Mile

Children attending TDM registered schools reported engaging in a significantly wider variety of activities across the week compared with those attending non-TDM registered school during school hours (5.0 vs 4.8), outside school hours (5.6 vs 5.3), and everywhere across the week (6.6 vs 6.3) (Table 7.9).

Table 7.9: Variety of activities (number) across different settings by registration to The Daily Mile

Variety of activities inside school				
	Mean	***sd***	**Median**	IQR
Daily Mile				
Non-DM (N=41535)	4.8	4.1	4	2-7
DM (N=10497)	5.0	4.2	4	2-7
Variety of activities outside school				
	Mean	***sd***	**Median**	IQR
Daily Mile				
Non-DM (N=41535)	5.3	4.1	5	2.0, 7.0
DM (N=10497)	5.6	4.2	5	2.0, 8.0
Variety of activities everywhere				
	Mean	***sd***	**Median**	IQR
Daily Mile				
Non-DM (N=41535)	6.3	4.4	6	3-9
DM (N=10497)	6.6	4.5	6	3-9

Non-DM: Non-Daily Mile
DM: Daily Mile
IQR: Interquartile range
Sd: standard deviation

7.4.3.3 Modelling results

After adjustment for potential confounders, children attending TDM registered schools consistently and significantly reported participating in a greater variety of activities during term time compared to children attending non-TDM registered schools. The intercept gives the baseline number of activities children reported as participating in and was 3.71 during school hours. For children attending TDM registered schools, this increased by 1.04 times (95% CI 1.00-1.08) which equals to 3.86 (95% CI 3.71-4.00) activities during school hours across the week during term time (Table 7.10).

Similarly, the baseline number of activities outside school hours was 4.96. For children attending TDM registered schools, this increased by 1.05 times (95% CI 1.01-1.08) which

equals 5.21 (95% CI 5.00-5.36) activities outside school hours across the week during term time (Table 7.10).

Lastly, the baseline number of activities outside school was 5.91. For children attending TDM registered schools, this increased by 1.05 times (95% CI 1.01-1.08) which equals 6.21 (95% CI 5.97-6.38) activities during term time (Table 7.10). The complete modelling results can be found in Appendix L.

Table 7.10: **Association between TDM and variety of activity across different settings*****

	In School				Outside School				Everywhere			
Predictors	**Incidence Rate Ratios**	**SE**	**95%CI**	**p**	**Incidence Rate Ratios**	**SE**	**95%CI**	**p**	**Incidence Rate Ratios**	**SE**	**95%CI**	**p**
(Intercept)	3.71	0.03		<0.001	4.96	0.03		<0.001	5.91	0.03		<0.001
Daily Mile: No												
Daily Mile Yes	1.04	0.02	1.00-1.08	0.037	1.05	0.02	1.01-1.08	0.006	1.05	0.02	1.01-1.08	0.004
Random Effects												
ICC	0.08				0.06				0.06			

Note: *All models adjusted for gender, age, deprivation (IMD), ethnicity, term of survey completion, rurality, and disability*
ICC: *Intraclass correlation coefficient;* ***SE****: standard error,* ***95%CI****: 95% confidence interval;* ***p****=p-value*
***Multilevel multivariable negative binomial regression coefficients, clustered by school; (level-1 N=47776 children; level-2 N=1013 schools)

7.5 Discussion

7.5.1 Summary of chapter findings

- This analysis found that children attending schools registered to TDM reported 10 additional minutes of MVPA per week during school hours, 26 additional minutes of MVPA per week outside school hours and 35 additional minutes of MVPA in total per week compared to children in non-TDM registered schools.
- Children attending TDM registered schools were 6% more likely to meet the recommended levels of physical activity compared to those who were not in TDM registered schools.
- Children attending TDM registered schools reported a marginally larger variety of types of activities in and outside school per week compared to those who were not in TDM registered schools.

7.5.2 Strengths and limitations

The study strengths include its size and representativeness of the national sample. I also adjusted for important differences in characteristics between schools highlighted in previous work in Chapter 5 and 6, which showed that that schools that take up TDM are inherently different – more likely to be in urban areas and have a higher proportion of disadvantaged pupils. Further, this is the first study reporting national data in England on children's physical activity.

Another strength of this work is that I have used a robust model to consider zero-inflation observed. There has been limited prior interest in methods for modelling skewed and zero-inflated physical activity count data.[468] However, in some epidemiological disciplines (e.g., HIV trials) and ecology, where data is frequently highly right skewed with a preponderance of zeros, zero-inflated models are considered the best fit.[469–474] I hypothesised that zeros in the Active Lives Survey are a result of mainly three events; structural zeros related to restrictions in children's ability to engage in physical activity; random zeros are the result of the sampling variability; and false zeros occur due to errors in the survey design. Ignoring overdispersion and/or zero inflation can lead to biased and serious errors in the interpretation of the results.[472] Additionally, I did not only rely on amount of activity, measured as MVPA to investigate the differences in levels of physical activity; I also investigated the variety in reported types of activity. Finally, while the Active Lives Survey is real-world data, there is no reason to suggest it is any different from research-grade data.

However, there are some important limitations. The Active Lives Survey data are cross-sectional, and I cannot confirm that differences observed in activity (MVPA and variety) are after implementation of TDM, making any causal inference more challenging. Self-report questionnaires to measure physical activity are a more feasible and cost-effective method when evaluating physical activity in large studies across time, than for instance accelerometer derived objective measures.[158,159] However, these questionnaires rely on an individual's recall ability, and therefore one's cognitive ability. This is especially problematic for children who have cognitive immaturity.[156,158] This increases the risk of recall bias, leading to measurement errors of the 'dose' of physical activity. For instance, self-report questionnaires are more likely to capture physical activity that can be easily recalled from the 'retrievable memory'[160]. The Active Lives Survey only captures structured activity – activities that the survey explicitly lists those children may have engaged in over the preceding week; it is more of a measure of engagement in specific activities rather than a measure of time in specific physical activity intensities. It unfortunately fails to capture incidental activity (that would otherwise be captured by objectively measured physical activity) and is especially true for primary school children who engage in small bouts of incidental activity.[156,161] This is problematic when assessing the duration and intensity of activity (as done in Part 1), but is a strength of this study when evaluating the differences in the varieties of activities reported as done in Part 2 (e.g., it is easier to remember that one played football in the preceding 7 days than how active they were while playing football).

Further, social desirability pressures may lead to respondents overestimating their levels of physical activity.[156,158,161] This may particularly be true in the context of the active lives survey where children fill in the survey in schools, and among their peers which may create an enhanced socially pressured environment that may lead children to overestimate their physical activity levels. However, there is no reason to assume that these issues systematically differ among subgroups of the population or in the "intervention" and "non-intervention" groups. Lastly, TDM status is based on official school registration to TDM and has not been validated. However, I considered registration to be an intention to implement TDM rather than a proxy measure of participation in the intervention. The detail provided by Sport England on the validation of the survey is limited. Further evaluation of the validity and reliability of the Active lives Survey would be helpful to allow for some of the bias observed in self-report data to be calibrated and the data can provide a more complete understanding of the physical activity levels and perceptions of children in England.

7.5.3 Possible explanations and comparison of findings with previous literature

Previous evidence has suggested an approximate 10 minute increase in device-measured MVPA on days children performed one session of TDM compared to non-TDM days.[356,374] I found a difference of 10 minutes of reported MVPA per week during school hours for children in TDM schools and 26 minutes of MVPA outside school per week. Although this difference is small relative to the recommended 60 minutes of MVPA per day, it is worth noting that we measured MVPA from all activities across the week, whereas TDM is only a 15-minute running-jogging intervention in schools. Further, the gender stereotypes observed within the Active Lives Survey for activity types has been previously found in English primary school children.[466]

The results from the Active Lives Survey indicated that there was likely no compensation in activity among children attending schools registered to TDM, both in terms of duration of activity (minutes of MVPA) and variety. This compensatory effect in children for duration of activity has previously been observed across the day and the week in other intervention evaluations [228,303,475] where an increase in MVPA was measured during the school day, yet total MVPA remained unchanged.[303,476] Though evidence from evaluations of other active mile initiatives such as Marathon Kids have found that active miles can also be an avenue to promote activity outside schools indicating that there might not be a compensation of activity.[477] I found children attending TDM registered schools reported more MPVA both in and outside school hours suggesting that that school TDM involvement may in fact, have an additional benefit outside school. Further, this trend was reflected for the variety of activities children reported participating in, where children registered to TDM reported engaging in a marginally higher number of activities during school hours, outside school hours and everywhere compared to children attending non-TDM registered schools. This is important as the United Kingdom CMO and WHO guidelines for children's physical activity state that children should engage in a variety of activities to help them achieve the recommended average of at least 60 minutes MVPA a week and engage in activities that strengthen muscle and bone. Running in isolation, which is the type of activity that TDM is, is not sufficient to enable this. Further, there are non-physical health related benefits from participating in a wider variety of activities beyond running. For instance, team sports show improved psychological and social health in children compared to individual sports.[478] Importantly, it should be noted however that I cannot conclude that this is a direct effect of TDM as TDM registration may act as a proxy for generally more activity promoting schools. This is a preliminary finding and compensation of activity must be thoroughly investigated using measures of adherence and indicators of the dose of TDM against activity outcome measures before any substantial claims can be made.

Other interventions such as classroom activity breaks,[479] physically active learning,[480] and after-school clubs[282] have shown to increase weekday, weekend and total MVPA. Given that that the lack of sustainable and feasible interventions is one of the reasons for poor implementation of school-based physical activity interventions,[21] simple, already widely taken up initiatives such as TDM along with other promising interventions can create an active school environment that does not solely rely on single element interventions to solve the inactivity crisis facing children. TDM can be seen as an activity that enhances and expands children's physical activity opportunities.[481] This is because it can provide an "inclusion of a new occasion to be active" (*expansion*) within the school system by offering 15-minutes a day of MVPA and because it is "designed to increase physical activity above routine practice"(*enhancement*), and must be done in addition to curriculum PE. A recent systematic review[304] found that interventions that focus on *expansion* of opportunities, including classroom physical activity breaks (such as TDM), are the most promising to address shortfalls in children's physical activity. Similarly, Daly-Smith et *al*'s framework for creating active schools puts non-curricular physical activity such as exercise breaks at the centre of opportunities to increase overall activity in children, whilst also noting that individual behaviour change to enhance activity is fragile and high-level factors at the school, local authority, and system level are crucial.[85,108,482] Active miles in schools alone as single-element interventions are unlikely to be sufficient to enable all children in England to meet physical activity guidelines. Nevertheless, the results of this study show that they can contribute to a whole systems-based approach.[185]

7.6 Conclusions

Children attending schools registered to TDM report more minutes of moderate to vigorous physical activity, and a larger variety of activities per week both during school and outside school hours than children attending non-TDM schools. This suggests that TDM may be one potential avenue to support increases in primary school children's physical activity as part of a wider suite of school- and non-school-based physical activity promotion initiatives.

8. Fidelity to The Daily Mile

Overview

In Chapter 5 and 6, I assessed the Reach and Equity of TDM across England respectively. Thereafter, in Chapter 7, I evaluated the Impact of TDM; where I assessed the differences in reported physical activity outcomes in children attending TDM registered schools compared with those in non-registered schools. Fidelity of implementation of school-based physical activity interventions is a known issue. Often, poor fidelity translates to poor effectiveness of interventions, and evidence shows a large drop in effectiveness of physical activity interventions when scaled from controlled to real-world settings.[22] *In this chapter, I address the final aspect of the evaluation – fidelity to TDM based on its core running criteria. It is vital to note that "fidelity", as I refer to throughout this chapter and thesis, is a simplified definition, as "fidelity" is more than just doing running, jogging for 15 minutes, 3 times per week, in school. True fidelity includes the core running criteria along with the other core principles of TDM (e.g., during curriculum time, done in all weathers) (Section* ***Error! Reference source not found.****). Due to data limitations and my assessment of the most important "active ingredient" of TDM, I defined fidelity only based on the core running criteria using self-reported measures of running in school.*

The relevant thesis objectives are – ***Objective 6: and Objective 7:***

This chapter is divided into 2 parts.

- ***Part 1 - Objective 6 To assess if children in TDM registered schools report doing a daily mile by adhering to its core running criteria of 15 minutes running (MVPA) outdoors in school at least three times a week***
- ***Part 2 - Objective 7. To examine the association between TDM registration and within school variation of self-reported activity - using de-facto daily mile as a case study.***

8.1 Study design, data source, and study population

This is a cross-sectional study using data on children in England from the Active Lives Survey from 2018 - 2019. The Active Lives Survey is a publicly funded survey commissioned by Sport England that collects physical activity data on children aged 5 to 16 years from schools (every year, since 2017). The sample included all children from primary school year groups 1 (aged 5-6 years) to 6 (aged 10-11 years) in the survey. For more information on the Active Lives Survey and how respondents are assigned TDM status, refer to Section 4.3.4.

8.2 Part 1: To assess if children in TDM registered schools report doing a daily mile by adhering to its core running criteria of 15 minutes (MVPA) running outdoors in school at least three times a week (Objective 6)

8.2.1 Measures

Exposure

Children attending schools officially registered to The Daily Mile Foundation's database on April 2019 were assigned to the TDM group, and children attending all other schools to the unexposed group. TDM data linkage to the Active Lives Survey was done by Sport England.

Outcomes

The primary outcome was reporting doing a de-facto daily mile (yes or no). A de-facto daily mile was defined as whether children reported adhering to TDM's core running criteria of 15-minutes running/jogging in school at least 3-times a week. They were given a non-de-facto daily mile status if they didn't report the above. De-facto daily mile can also be thought of as the 'true dose of TDM'. The secondary outcome was a breakdown of fidelity into varying levels of adherence: no adherence, low adherence, medium adherence, high adherence, and very high adherence. For the derivation of these outcomes, please see the next section.

8.2.2 Methods

8.2.2.1 Variable Derivation

Primary Outcome: Reporting a de-facto daily mile

A specific variable within the Active Lives Survey – 'Time spent in doing MVPA at school from running, jogging, cross-country, and the Daily Mile' on each weekday was used to derive 'de-facto daily mile' as a binary variable. Based on their responses, children were then assigned to two groups:

- **De-facto daily mile (true dose of TDM):** Children reporting adhering to TDM's core running criteria were given a de-facto daily mile status (i.e., reporting 3 or more days >=15 minutes spent in doing MVPA at school from running, jogging, cross-country, and the Daily Mile)
- **Not de-facto daily mile:** Children reporting not adhering to TDM's core running criteria were given a not de-facto daily mile status (i.e., not reporting 3 or more days >=15 minutes spent in doing MVPA at school from running, jogging, cross-country, and the Daily Mile)

Secondary Outcome: Levels of adherence

The secondary outcome was a breakdown of fidelity into varying levels of adherence to TDM's running criteria: no adherence, low adherence, medium adherence, high adherence, and very high adherence. Exploring different levels of adherence provides an opportunity to understand what might be happening at a more granular level than by merely creating two groups.

These levels were split as:

- **1** = no adherence (reported 1 day running/jogging for at least 15 minutes in school)
- **2** = low adherence (reported 2 days running/jogging for at least 15 minutes in school)
- **3** = medium adherence (reported 3 days running/jogging for at least 15 minutes in school)
- **4** = high adherence (reported 4 days running/jogging for at least 15 minutes in school)
- **5** = very high adherence (reported 5 days running/jogging for at least 15 minutes in school)

8.2.2.2 Statistical Analysis

This part of this chapter was restricted to descriptive analyses. To evaluate the fidelity of TDM's core running criteria by official registration status, I analysed the in-school running patterns of children by TDM registration. I assessed the fidelity to TDM's core running criteria by comparing registration to TDM by de-facto daily mile status. I then delved deeper into understanding the subgroups that drive fidelity by assessing the levels of adherence to TDM's core running criteria by TDM registration. I further examined the differences in adherence by registration status and specific strata (specifically gender and age). This allowed me to investigate whether there were any specific differences reporting a de-facto daily mile by registration status and gender or age. For instance, does fidelity to TDM's core running criteria differ by gender and registration status, i.e., are TDM registered boys more likely to adhere to TDM's core running criteria compared to girls,

and how does this difference compare to non-TDM registered boys and girls. This also enabled me to understand whether some subgroups were more adherent to TDM's running criteria.

8.2.3 Results

8.2.3.1 Registration to TDM and reporting a de-facto daily mile

A higher proportion of children in TDM registered schools reported doing a de-facto daily mile across the week (27% vs 21%) (running 3 times a week in school for at least 15 minutes) (Table 8.1). While this is unsurprising given that children in TDM registered schools would be doing TDM, less than 30% of children in registered schools reported doing a TDM, suggesting low fidelity.

Table 8.1: Registration to The Daily Mile and de-facto daily mile proportions

	Registered Non-DM (N=41535)	**Registered DM (N=10497)**
Not reporting a de-facto daily mile	32289 (78.6%)	7527 (72.6%)
Reporting a de-facto daily mile	8805 (21.4%)	2841 (27.4%)

8.2.3.2 Registration to TDM and levels of adherence

Table 8.2 illustrates the levels of adherence to TDM's core running criteria against official registration to TDM. A higher proportion of children attending TDM registered schools report medium, high and very high adherence to TDM's core running criteria compared to children in non-registered schools (Table 8.2). Most of the children in the de-facto daily mile category (Table 8.1) were comprised of children from the 'very high' category (Table 8.2).

There was a high proportion of children in both registered and not registered schools who report zero minutes of MVPA attributable to running in school every weekday. The proportion was higher in non-registered children (give %) This was foreseeable given that this was observed in Chapter 7 of this thesis where zero-inflation was a key issue when assessing minutes of MVPA in the Active Lives Survey.

I investigated the children who report 0 minutes of MVPA in school attributable to running/jogging/cross-country/The Daily Mile (n=32439). Of 32439 children, only 1586 children report 0 minutes of all intensity (including low) activity everywhere across the week. Which means, these children are the inherently inactive children. Of 32439 children, only 2831 children report 0

minutes of all intensity (including low) activity in school across the week. Which means, these children aren't active in school. Further, of these 2831 children, only 1586 report 0 mins all intensity activity outside school across the week. Which means, 1245 children still do some activity outside school.

Table 8.2: Adherence to The Daily Mile's core running criteria by official registration status

	Non-Daily Mile (N=41535) (N%)	Daily Mile (N=10497) (N%)	Total (N=54447) (N%)
Adherence			
Zero MVPA reported	26516 (63.8)	5878 (56.0)	32439 (59.6)
No	4471 (10.8)	1245 (11.9)	5723 (10.5)
Low	1302 (3.1)	404 (3.8)	1708 (3.1)
Medium	930 (2.2)	260 (2.5)	1192 (2.2)
High	855 (2.1)	300 (2.9)	1155 (2.1)
Very high	7020 (16.9)	2281 (21.7)	9314 (17.1)
Missing	441 (1.1)	129 (1.2)	2916 (5.4)

Zero: reported 0 minutes of MVPA in school attributable to running/jogging/The Daily Mile in school every weekday
No: Once a week
Low: 2 times a week
Medium: 3 times a week
High: 4 times a week
Very high: 5 times a week
Missing: NA

8.2.3.3 De-facto daily mile by TDM subgroups

When examining the differences seen in reporting de facto daily mile (Table 8.1) by subgroups, specifically gender and age, a slightly lower proportion of TDM registered girls report doing a de-facto daily mile compared to TDM boys (26.5% and 28.7% respectively; approximately a 2.2% difference). This difference in reporting a de-facto daily mile is also reflected between non-TDM girls and boys (19.9% and 22.6% respectively, a 2.7% difference). The difference between girls and boys reporting de facto daily mile is similar in both TDM and non-TDM schools (Table 8.3).

Table 8.3: Registration to The Daily Mile and de-facto daily mile proportions by Gender

	Not reporting a de-facto daily mile	Reporting a de-facto daily mile
Not Registered Boy (N=18950)	14495 (77.4)	4241 (22.6)
Not Registered Girl (N=19560)	15530 (80.1)	3868 (19.9)
Registered Boy (N=4858)	3413 (71.3)	1373 (28.7)

Registered Girl (N=4930)	3597 (73.5)	1294 (26.5)
Not Registered Other (N=1835)	1359 (75.7)	436 (24.3)
Registered Other (N=444)	321 (73.6)	115 (26.4)

With respect to age and registration, and reporting a de-facto daily mile, a slightly lower proportion of children in Year 1 and 2 report doing a de-facto daily mile in both registered and not-registered school compared to older children (Table 8.4). As age increases, across both registered and non-registered children, a higher proportion report doing a de-facto daily mile. However, the biggest differences occur at Years 3 and 4 where the jump from Year 1-2 is quite large in registered and not-registered children (approximately 11% and 13% respectively). At year 3, 8% more TDM children report a de-facto daily mile compared to not-registered children, and this is a 5% difference for children in Year 4.

Table 8.4: Registration to The Daily Mile and de-facto daily mile proportions by school year

	Not reporting a de-facto daily mile N (%)	**Reporting a de-facto daily mile N (%)**
Not Registered		
1 (N=1652)	1525 (92.4)	126 (7.6)
2 (N=1598)	1460 (91.5)	136 (8.5)
3 (N=8910)	7159 (81.1)	1665 (18.9)
4 (N=8838)	6609 (75.9)	2104 (24.1)
5 (N=10733)	8185 (77.0)	2439 (23.0)
6 (N=9804)	7351 (75.9)	2335 (24.1)
Registered		
1 (N=467)	400 (85.8)	66 (14.2)
2 (N=549)	467 (85.5)	79 (14.5)
3 (N=2041)	1480 (73.5)	534 (26.5)
4 (N=2194)	1532 (70.7)	635 (29.3)
5 (N=2568)	1793 (70.9)	735 (29.1)
6 (N=2678)	1855(70.1)	792(29.9)

8.2.3.4 Physical activity levels by TDM registration and reporting a de-facto daily mile

Table 8.5 outlines the activity levels of children by their registration status and whether they report doing a de-facto daily mile. The highest median minutes of MVPA across the week is reported by children who are not registered to TDM but are reporting a de-facto daily mile (820 minutes (IQR: 480-1340)) followed by children registered to TDM and reporting a de-facto daily mile (770 (IQR: 450-1270). Children reporting a de-facto daily mile are substantially more active compared to those

not reporting a daily mile, regardless of whether they attend a school registered to TDM. This indicates that children reporting a de-facto daily mile are inherently more active and it might not a result of TDM registration itself.

Table 8.5: Activity levels by registration and de-facto TDM status

	Not reporting a de-facto daily mile		**Reporting a de-facto daily mile**	
	Not registered- (N=32289)	**Registered** (N=7527)	**Not registered** (N=8805)	**Registered** (N=2841)
Total minutes MVPA across week				
Median	280	300	820	770
IQR	125, 560	130, 595	480, 1340	450, 1270
Minutes MVPA inside school across week				
Median	75	80	240	232
IQR	30, 150	30, 150	160, 355	155, 345
Minutes MVPA outside school across week				
Median	190	200	560	515
IQR	70, 415	75, 440	282, 1010	260, 945
Meeting CMO/WHO recommendations				
No	20855 (64.6%)	4714 (62.6%)	1764 (20.0%)	641 (22.6%)
Yes	11434 (35.4%)	2813 (37.4%)	7041 (80.0%)	2200 (77.4%)
IQR: Interquartile range				

8.2.4 Summary:

Adherence to TDM's core running criteria was higher among children attending registered schools compared to non-registered schools, however it remains low, with only 30% fidelity.

Initially, I had planned to re-run the analysis on *Impact* done for in Chapter 7 (Objective 4) of this thesis. Instead of using TDM registration as the exposure, I was to use de-facto daily mile as the exposure. The outcomes I have analysed in Chapter 7 of this thesis were minutes of MVPA during school hours, MVPA outside school hours, and total MVPA. However, after much thought, I came to realise that the outcomes (minutes of MVPA) were differentially distributed across the exposure status (de-facto); wherein I would be comparing more physically active children (de-facto yes) with less physically active children (de-facto no) for minutes of MVPA, which would not be a fair comparison. This assumption is reflected in Table 8.5 where regardless of registration status, children reporting a de-facto daily mile were considerably more active than those not reporting one. If I did re-run these models using de-facto daily mile as the new exposure (instead of registration), the question I would be answering is whether children who report more running in school (de-facto daily mile derivation) are more active overall. Considering re-running the models

from objective 4 of this thesis using a new exposure status of de-facto daily mile was no longer meaningful, this part, Part 1, addressing objective 6, was used descriptive statistics and has informed the analysis for objective 7 of this thesis which is addressed in the Part 2 of this chapter.

8.3 Part 2: To examine the association between TDM registration and within school variation of self-reported activity - using de-facto daily mile as a case study (Objective 7)

8.3.1 Underlying Rationale

If adherence to TDM is high, all children in TDM schools would report doing a de-facto daily mile (i.e., running or jogging for 15 minutes at least three times a week in school). This can be examined by assessing within school variation of doing a de-facto daily mile and can be contextualised by comparing it with non-TDM registered schools. By examining within school variation in reporting a de-facto daily mile, it is possible to assess within school agreement. If there is very strong agreement in children reporting a de-facto daily mile, we would observe very low variation within schools. This is because high fidelity in TDM schools would mean limited variation in how children respond to doing a de-facto daily mile, meaning, they would agree with each other.

If within school variation for reporting a de-facto daily mile is lower in registered schools than non-registered schools, then we could hesitantly conclude that the Active Lives Survey is a useful tool for measuring activity attributable to TDM in school. We could also hesitantly conclude that TDM registered schools are participating in TDM in some way as TDM is a whole-school initiative. Therefore, if the whole school is indeed participating and reporting the core running 'dose', which is a de-facto daily mile, then the variation within the school would be low. If within school variation for reporting a de-facto daily mile is the same or higher in TDM registered schools compared to non-registered schools, then we cannot conclude the above.

8.3.2 Methods

8.3.2.1 Descriptive methods

To visually describe the variation observed in reporting a de-facto daily mile, first, I calculated the proportion of children in each school doing a de-facto daily mile and mapped that by registration status. I then plotted the plotted the proportion of children reporting doing a de-facto daily mile by the number of schools and TDM registration.

8.3.2.2 Statistical analysis: A Multilevel Analysis of Active Partnership, School, Year Group, and Individual-Level Variation in reporting a de-facto daily mile

Physical activity is a complex behaviour influenced by individual, inter-personal, environmental and policy level factors. TDM while being a 'simple intervention' (not a complex multi-component

intervention), is implemented in schools – a dynamic and complex setting. Multilevel models have been increasingly used to explicitly model complex hierarchical structures, where children within year group are nested within schools' local authorities. Multilevel or hierarchical models are common with school-based cluster study designs, where children are nested within schools, with no cross classification, as it adjusts standard errors to account for clustering. However, such models also allow description and comparison of the amount of variability at the different levels. A multilevel model combines fixed effects, which are known covariates at different levels that explain physical activity, and random effects that partition the residual variation (that is, the variability due to unknown factors) into variability at the different levels.

8.3.2.3 Measures

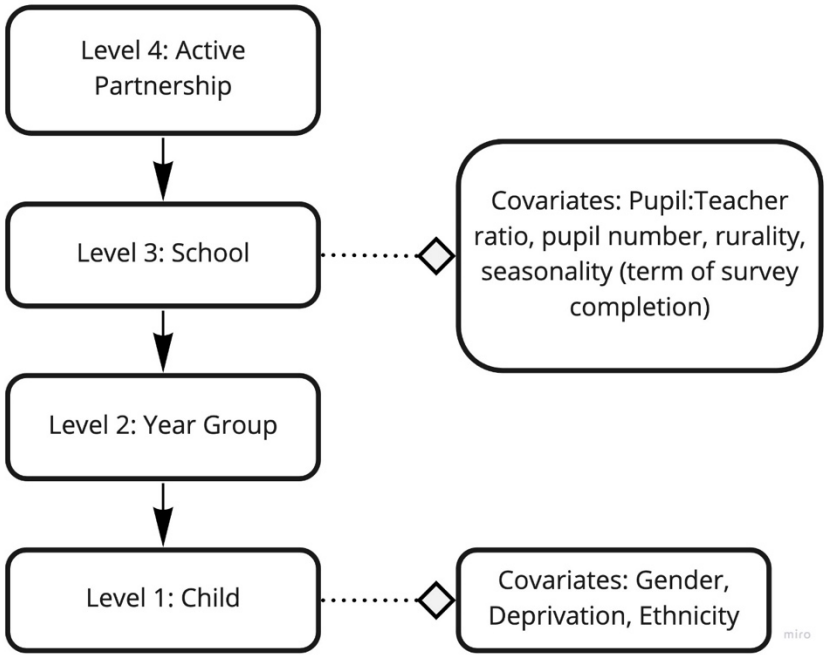
Outcome: De-facto daily mile. This variable was binary and was derived from the 'Time spent in a week doing MVPA at school from running, jogging, cross-country, and the Daily Mile' in the Active Lives Survey. I chose to use de-facto TDM (binary) instead of the 'raw' continuous form of the original variable because of overdispersion and zero-inflation issues for minutes of MVPA in the Active Lives Survey.

Exposure: There was no exposure of interest here. Instead, the focus was on understanding the variation in reporting a de-facto daily mile (adherence) at different levels, what characteristics might explain some of that variation; and how this differs based on official registration status to TDM.

Clustering Levels (Random Effects)

To compare the variation in physical activity outcomes at different levels, I used multilevel models. This statistical approach allowed me to include all four sources of variability in a single multilevel model with four levels, summarised in the classification diagram in Figure 8.1 where children (level 1) were nested within one year group (level 2) nested within schools (level 3) and Active Partnerships (level 4). It was of interest to identify how much of the variation observed in reporting a de-facto daily mile could be explained by these levels (random effects) or other characteristics at the respective level (covariates). Further, by splitting the population by TDM registration status, it enabled me to assess whether the factors that explained the variation differed. The reasons and hypotheses for the inclusion of covariates and clustering levels has been explained below:

Figure 8.1: **Classification diagram for the multilevel model. An arrow indicates a nested relationship; a diamond arrow indicates covariates included in the model at that level**



1. **Child** – Data in the Active Lives Survey in at the individual child level. The Active Lives Survey does not include any parent level covariates that might explain some of the variation observed (e.g., parental education level). However, there are some child level characteristics that might explain some of the variation.

   Covariates:

   i. **Gender** – There are known gender differences in physical activity where boys tend to be more physically active than girls

   ii. **Deprivation** – There are differences in physical activity by deprivation status where children from more affluent backgrounds tend to be more physically active than those from more deprived backgrounds. In the Active Lives Survey, the only child level variable for deprivation is the Family Affluence Scale Score that was part of the questionnaire and was self-reported. Score for family affluence created from standard questions about household items or spending and then grouped into high, medium, low. The other more common measures of deprivation such as the Index for Multiple Deprivation (IMD) could not be used here as a child's IMD value in the survey was matched on school postcode, not the child's home postcode.

iii. **Ethnicity** – Children of certain ethnic minorities (e.g. Asian – specifically Bangladeshi and Pakistani) are less physically active compared to White British children.

2. **Year Group –** Year Group was selected as a clustering level (random effect) as there are differing educational pressures and responsibilities for different year groups. For instance, in England, children in Year 6 (aged 10-11 years) sit exams known as SATS – Standardised Assessments Tests. The grades obtained by Year 6 children in these tests are reflected on the teachers' and schools' performance. Thus, I believed that children in higher year groups might not be as encouraged to take part in running programmes like TDM compared to younger children. Further, there are known problems with implementation fidelity of school-based physical activity programmes,[21] and although TDM is a whole school intervention, some of the variation observed in doing a de-facto daily mile might arise from the year group level. Additionally, it is well founded that children's physical activity declines with age, where there is an average decrease of 4% in total physical activity with each additional year of age.[178] In this case, year group can be considered a proxy measure for age. This is also why age is not included as a fixed effect at the child level.

3. **School:** The Active Lives Survey design is school-based (detail in chapter X), where sampling is conducted at the school level, and the questionnaire is completed in schools. Further, registration to TDM is at the school level where children are given TDM registered status based on whether they attend a school officially registered for TDM or not. By adding these covariates at level 3, we are interested in whether these covariates can explain level 3 (school) variation.

Variables that might explain level 3 variation.

Covariates*:*

i. **Rurality** – I found that registration to TDM was associated with the rurality of a school, where schools in urban major conurbations were more likely to register compared to schools in cities and towns (Section 5.2). The rurality of the school

might explain some of the variation in children reporting a de-facto daily mile, especially when registered and non-registered children are analysed separately.

Rurality was a categorical variable based on the Office for National Statistics Classification – Rural: Hamlets and Isolated Dwellings, Town and Fringe, and Village; Urban: Urban city and town, Major Conurbation, and Minor Conurbation. It was Matched on geography based on school location.

ii. **Pupil Number (size of the school)** – The number of pupils in a school (or school size) might explain some of the variation in children reporting a de-facto daily mile, especially when registered and non-registered children are analysed separately. For instance, schools with large pupil numbers that are registered to TDM might be less likely to implement TDM even though they are registered because of additional pressures of coordinating activities for a larger number of pupils. Further, TDM is supposed to be a whole school intervention, thus, schools with higher pupil numbers might not have the means to implement it for all year groups at least 3 times a week (de-facto daily mile definition). In this case, for registered children, the random effect for Year Group might explain some of the variation.

This was a categorical variable divided into 5 categories = Up to 100 pupils

101 to 200 pupils; 201 to 300 pupils; 301 to 500 pupils; 501 pupils and over. It was matched on school level information.

iii. **Pupil to teacher ratio** – Pupil to teacher ratio was considered an important characteristic of the school to explain the variation in children reporting a de-facto daily mile since TDM is implemented by teachers. Therefore, if the pupil to teacher ratio is large, it implies that 1 teacher has more children in her care compared to when the ratio is small, consequently making it less likely for the teacher to implement TDM. This was a categorical variable divided into 5 categories – Fewer than 15:1; 15:1 to 19:1; 20:1 to 24:1; 25:1 to 29:1; 30:1 or more. It was matched on school level information.

iv. **Seasonality** (term of survey completion) – The Active Lives Survey is completed in schools during the spring, summer and autumn terms. Physical activity differs in children by season, where children in the warmer months with longer hours of daylight like spring and summer are more likely to be physically active than compared to the winter months. Season may explain some of the variation in

reporting a de-facto daily mile, especially in TDM registered children, as TDM might not be implemented regularly through the colder and wetter months as compared to the warmer ones.

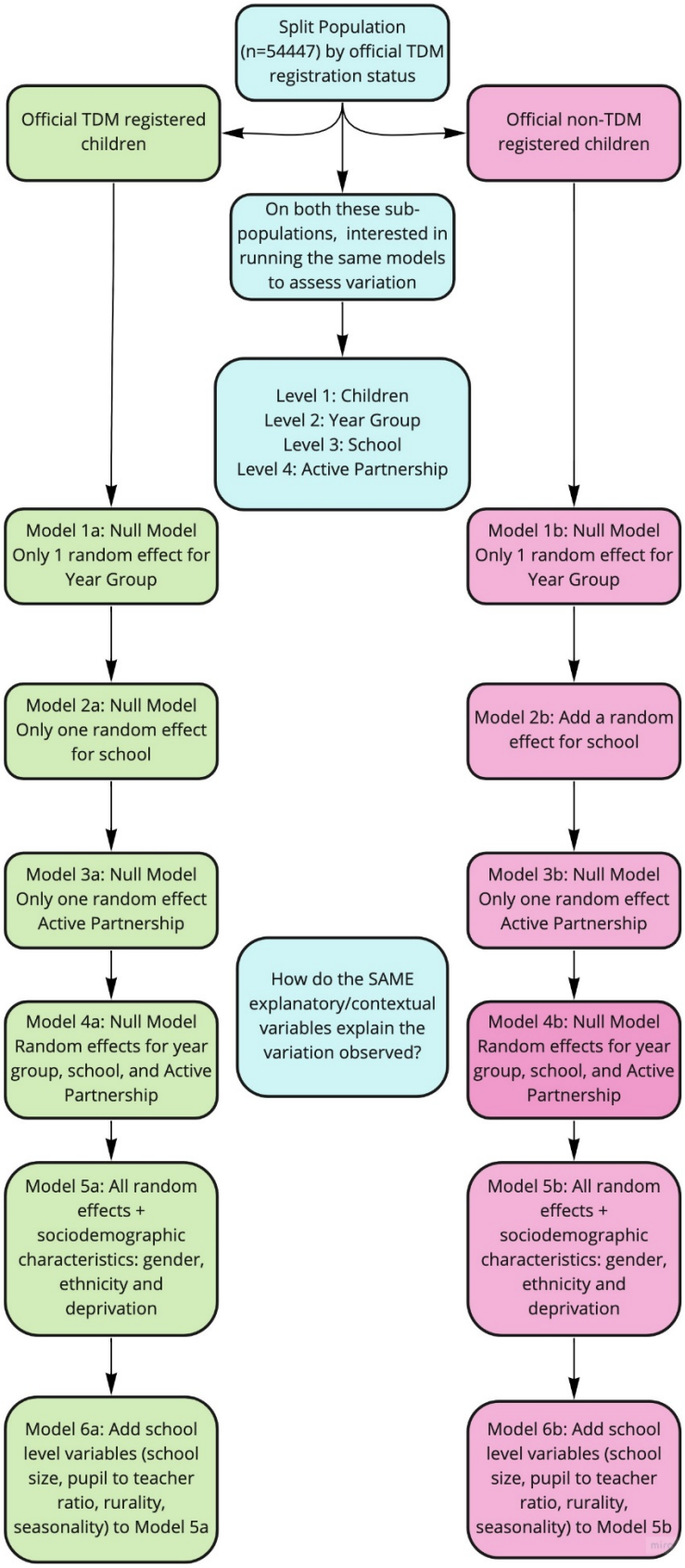
4. **Active Partnerships:** Active Partnerships are locally based strategic organisations that are partly funded by Sport England which is a non-departmental public body under the UK's Department for Digital, Culture, Media and Sport. There are a total of 43 Active Partnerships that, between them, cover every part of England. Active Partnerships are strategic organisations that work at the grassroots levels to understand the needs of the local community and engaging with the local community to share learning of what works best locally and in context specific situations.[483] They are focussed on growing grassroots sport and physical activity. Further The Daily Mile Foundation has partnered with Active Partnerships via Sport England and London Marathon Events to put in place 13 coordinators to encourage primary schools to sign up and deliver The Daily Mile. The 13 coordinators are currently based in Active Essex, Active Gloucestershire, GreaterSport, Herts Sport Partnership, Kent Sport, Living Sport, London Sport, MSP (Merseyside), Rise (North Tyneside), Sport Birmingham, Wesport (Bristol), and Yorkshire Sport Foundation.[484] Considering some Active Partnerships have specific coordinators designated towards increasing uptake and implementation of TDM, they might explain some of the variation in children reporting a de-facto daily mile, especially when analysed separately based on registration status.

8.3.2.4 Model Building

I analysed reporting a de-facto daily mile by official TDM registration and non-registration. I considered five models that explore different fixed and random effects. Fixed effect terms explain differences in reporting a de-facto daily mile in terms of known covariates, similar to standard regression models, and may explain variation at any or all levels of the multilevel structure. For example, school rurality may explain school variation in physical activity and reporting a de-facto daily mile. Similarly, a child's socioeconomic status, as measured by IMD may explain variation in their physical activity and reporting a de-facto daily mile given that schools with a higher proportion of disadvantaged pupils are more likely to register to TDM compared to those with a

lower proportion (as observed in study 1, *Reach,* of this thesis, Section 5.2). Random effect terms describe the structure of any remaining variation which is unaccounted for by the fixed terms and can thus identify clustering at different levels. Considering I was interested in knowing the difference in the variation accounted for by the random and fixed effects by official registration status, I split the population by TDM registration status and ran identical models on both sub-populations (Figure 8.2)

Figure 8.2: Model Building



The five models as illustrated in Figure 8.2 were as follows:

Model 1: This model describes the percentage of total variation in reporting a de-facto daily mile explained by year group. I fitted a variance component model which included an intercept term only in the fixed effects, and a random effect term for year group. This allowed me to assess the variation in reporting a de-facto daily mile at the year group level, and how this differed in TDM registered (Model 1a) and not-registered children (Model 1b).

Model 2: This model describes the percentage of total variation in reporting a de-facto daily mile explained by school. I fitted a variance component model which included an intercept term only in the fixed effects, and a random effect term for school. This allowed me to assess the variation in reporting a de-facto daily mile at the school level, and how this differed in TDM registered (Model 2a) and not-registered children (Model 2b).

Model 3: This model describes the percentage of total variation in reporting a de-facto daily mile explained by Active Partnerships. I fitted a variance component model which included an intercept term only in the fixed effects, and a random effect term for Active Partnership. This allowed me to assess the variation in reporting a de-facto daily mile at the Active Partnership level, and how this differed in TDM registered (Model 3a) and not-registered children (Model 3b).

Model 4: This model describes the percentage of total variation in reporting a de-facto daily mile explained by year group, school and Active Partnerships. I fitted a variance component model which included an intercept term only in the fixed effects, and a random effect term for year group, school, and active Partnership. This allowed me to assess the variation in reporting a de-facto daily mile at the year group, school and Active Partnership levels, and how this differed in TDM registered (Model 4a) and not-registered children (Model 4b).

Model 5: I investigated how much of the variation at different levels was explained by child characteristics (gender, deprivation, ethnicity) by adding them as fixed effects to year group, school and active partnerships as random effects. The random effects included described how much of the residual variation is attributable to each level. This model was run on both sub-populations TDM registered (Model 5a) and not-registered children (Model 5b).

Model 6 Final Model: I investigated how much of the variation at different levels was explained by school characteristics (school size, teacher to pupil ratio and rurality and seasonality), by adding

them to Model 4 as fixed effects. The child characteristics and random effects were the same as in Model 4. This model was run on both sub-populations TDM registered (Model 6a) and not-registered children (Model 6b) to evaluate the differences and contextualise the variation observed in both sub-populations.

8.3.2.5 Sensitivity analysis

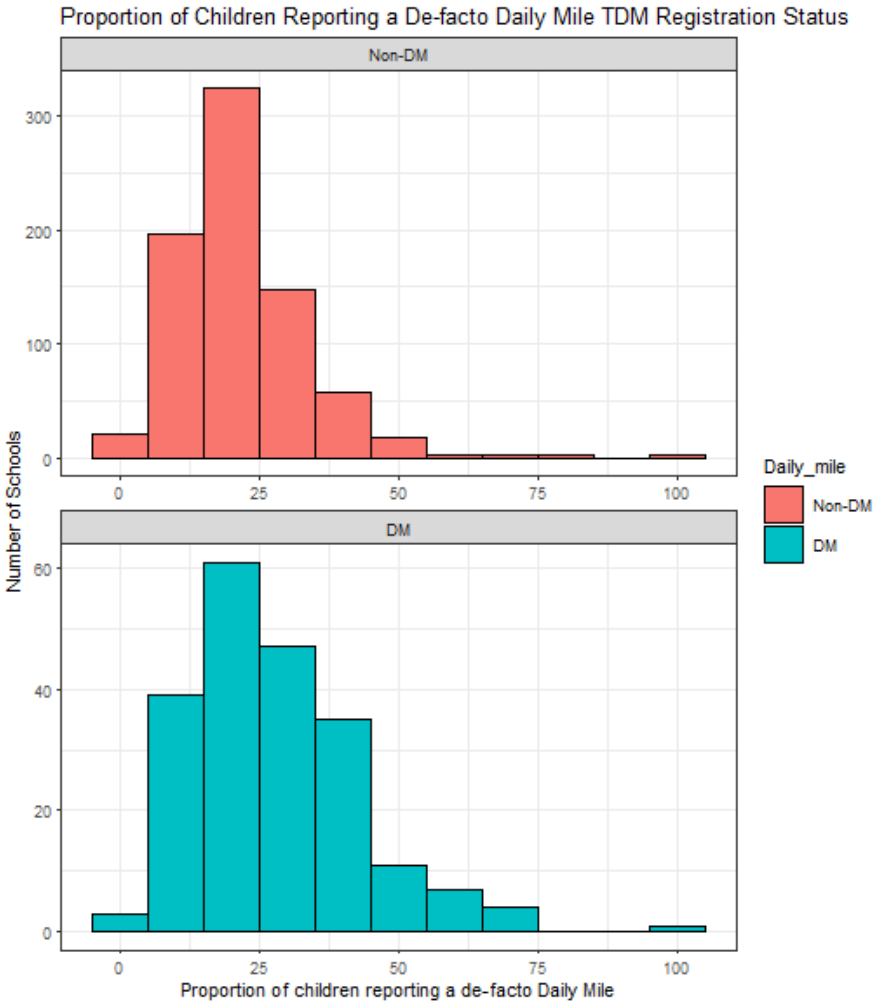
Considering model 4a, 5a, 6a did not converge, most likely due to the model being overfitted – that is, the random effects structure being too complex to be supported by the data, I removed the highest clustering level (Active Partnership) from models 4a, 5a, and 6a, and re-ran them. That is, Model 4a was identical to 4b, 5a identical to 5b, and 6a identical to 6b, except that they did not include a random effect for Active Partnership.

8.3.3 Results

8.3.3.1 Descriptive Results

Figure 8.3 illustrates the variability in reporting a de-facto daily mile by officially registration status. Among non-TDM registered schools, there is spread in the proportion of children reporting a de-facto daily mile. This was expected given that children in non-registered schools are not doing the structured activity that TDM provides, and so there is a more 'evened-out' spread. There was no evidence of greater variability in reporting a de-facto daily mile in non-registered schools than registered schools. However, non- registered schools are slightly more skewed, that is, there are more schools with higher proportion reporting a de-facto daily mile in registered schools.

Figure 8.3: Comparing the variation in the proportion of children reporting de-facto daily mile by official registration status



Initial descriptive analysis suggests that 4% more boys reported doing a de-facto daily mile compared to girls (48% vs 44% respectively), implying that boys were slightly more active in terms of running/jogging in school compared to girls. Most children (in both groups) reported a medium family affluence score, though a slightly larger proportion of children reporting a de-facto daily mile belonged to high family affluence grade (Table 8.6).

Table 8.6: **Individual and school characteristics by reporting a de-facto daily mile**

	No de-facto daily mile reported (N=39870) N(%)	**De-facto daily mile reported (N=11661) N(%)**
Gender		
Boy	17925 (45.0)	5621 (48.2)
Girl	19157 (48.0)	5169 (44.3)

Other	1682 (4.2)	551 (4.7)
Missing	1106 (2.8)	320 (2.7)
Ethnicity		
White British	25421 (63.8)	7589 (65.1)
White Other	1509 (3.8)	429 (3.7)
Asian	2039 (5.1)	590 (5.1)
Black	1154 (2.9)	328 (2.8)
Mixed	2736 (6.9)	821 (7.0)
Other	1560 (3.9)	448 (3.8)
Prefer Not to Say	4477 (11.2)	1211 (10.4)
Missing	974 (2.4)	245 (2.1)
Family Affluence Score		
low 0-6	7737 (19.4)	1776 (15.2)
medium 7 -9/10	21617 (54.2)	6171 (52.9)
high 10/11-12/13	8963 (22.5)	3327 (28.5)
Missing	1553 (3.9)	387 (3.3)
Pupil to teacher Ratio		
Fewer than 15:1	764 (1.9)	199 (1.7)
15:1 to 19:1	9793 (24.6)	2950 (25.3)
20:1 to 24:1	23961 (60.1)	6892 (59.1)
25:1 to 29:1	4151 (10.4)	1243 (10.7)
30:1 or more	266 (0.7)	108 (0.9)
Missing	935 (2.3)	269 (2.3)
School Size		
Up to 100 pupils	1250 (3.1)	478 (4.1)
101 to 200 pupils	10956 (27.5)	3117 (26.7)
201 to 300 pupils	8524 (21.4)	2562 (22.0)
301 to 500 pupils	16144 (40.5)	4570 (39.2)
501 pupils and over	2996 (7.5)	934 (8.0)
Rurality		
Rural	8011 (20.1)	2479 (21.3)
Urban	31859 (79.9)	9182 (78.7)

8.3.3.2 Multilevel modelling results

In the descriptive and visual analysis shown above, there was evidence of a larger than expected variability in reporting a de-facto daily mile by official TDM registration status. The variability in the proportion of children reporting a de-facto daily mile was almost identical in registered and not-registered schools. The modelling results investigate the overall variation and sources of variation in detail (Table 8.7). The full modelling results can be found in Appendix M.

Random effects only

Table 8.7 shows the proportion of the total variation in reporting a de-facto daily mile attributable to known covariates (fixed effects) and random variation at the different levels for TDM registered and non-registered children.

Model 1 included a random effect for Year Group only. The between year group variance for reporting a de-facto daily mile for children in non-TDM registered schools was double that of children in registered schools (0.32 vs 0.16 respectively). The ICC of this null model for registered children was 0.05. This can be interpreted as meaning that 5% of the variance in children in registered schools reporting a de-facto daily mile were due to year group-to-year-group variation also known as within year group variation. For non-registered children, the ICC of the same model was 0.09. This implies that 9% of the variance in children in non-registered schools reporting a de-facto daily mile are due to within year group variation. In this case, year group explains a higher proportion of the total variance in non-registered schools compared to registered schools.

Model 2 included a random effect for school only. The between school variance for reporting a de-facto daily mile for children in registered schools was almost 1.5 times that of children in non-registered schools (0.40 vs 0.29 respectively). The ICC of this null model for registered children was 0.11. This can be interpreted as meaning that 11% of the variance in children in registered schools reporting a de-facto daily mile were due to school-to-school variation also known as within school variation. For non-registered children, the ICC of the same model was 0.08. This implies that 8% of the variance in children in non-registered schools reporting a de-facto daily mile were due to within school variation. In this case, schools explain a higher proportion of the total variance in registered schools compared to non-registered schools.

Model 3 included a random effect for Active Partnerships only. The between Active Partnerships variance for reporting a de-facto daily mile for children in registered schools was 0.18 compared to 0.02 for those in non-registered schools. The ICC of this null model for registered children was 0.05. This can be interpreted as meaning that 5% of the variance in children in registered schools reporting a de-facto daily mile were due to Active Partnerships-to-Active Partnerships variance, also known as within Active Partnerships variation. For non-registered children, the ICC of the same model was 0.01. This implies that 1% of the variance in children in non-registered schools reporting a de-facto daily mile were due to within school variation. In this case, Active Partnerships explain a higher proportion of the total variance in registered schools compared to non-registered schools.

Model 4 included random effects for year group, school, and Active Partnerships. For registered children, the model 4a did not converge when including all three random effects. This is most likely due to the model being overfitted – that is, the random effects structure is too complex to be supported by the data. To rectify this, I removed the highest clustering level (Active Partnership), and the model converged. Model 4a presented in Table 8.7 is identical to 4b except that it did not include a random effect for Active Partnership.

The random intercept variances were higher for school in registered compared to non-registered schools (0.40_{school} vs 0.27_{school} respectively) and were lower for year group in registered compared to non-registered schools ($0.18_{\text{Year Group}}$ vs $0.34_{\text{Year Group}}$ respectively). This means that schools explain a greater amount of the total variation attributable to the random effects for children in registered schools compared to those in non-registered schools; and that year group explain a lesser amount of the total variation attributable to the random effects for children in registered schools compared to those in non-registered schools. This implies that for children in registered schools, the year group is playing a bigger role in the variation for children reporting a de-facto daily mile, and for children in non-registered schools, the school itself is playing a bigger role in the variation for children reporting a de-facto daily mile. For children in not-registered schools, Active Partnerships in this model do not have a substantial role to play in explaining variation. The ICC for model 4a (registered children) was 0.152. This infers that ≈15.2% of the total variance in children reporting a de-facto daily mile in TDM registered schools is explained by year group and school effects. The ICC for model 4b (non-registered children) was 0.157. This infers that ≈15.7% of the total variance in children reporting a de-facto daily mile in non-TDM registered schools is explained by year group, school, and Active Partnership effects. While the ICCs were similar for registered and non-registered schools (models 4a and 4b respectively), as seen from the random intercept variances, the random effects contribute distinctly to the ICC in registered and non-registered schools.

Table 8.7: Variation in reporting a de-facto daily mile by official registration status to The Daily Mile

	Registered to The Daily Mile	**Not Registered to The Daily Mile**
Model 1: Year Group Random Effect only	**Model 1a**	**Model 1b**
τ_{00}	$0.16_{\text{Year Group}}$	$0.32_{\text{Year Group}}$

ICC	0.05	0.09
Model 2: School Random Effect only	**Model 2a**	**Model 2b**
τ_{00}	0.40 $_{\text{school}}$	0.29 $_{\text{school}}$
ICC	0.11	0.08
Model 3: Active Partnership Random Effect only	**Model 3a**	**Model 3b**
τ_{00}	0.18 $_{\text{Active Partnership}}$	0.02 $_{\text{Active Partnership}}$
ICC	0.05	0.01
Model 4: All random effects **Model 4a: registered children, random effects for year group and school** **Model 4b: Non-registered children, random effects for year group and school, and Active Partnership**	**Model 4a**	**Model 4b**
τ_{00}	0.40 $_{\text{school}}$	0.27 $_{\text{school}}$
	0.19 $_{\text{Year Group}}$	0.004 $_{\text{Active Partnership}}$
		0.34 $_{\text{Year Group}}$
ICC	0.152	0.157
Model 5: Model 4 + Child Characteristics	**Model 5a**	**Model 5b**
τ_{00}	0.39 $_{\text{school}}$	0.26 $_{\text{school}}$
	0.18 $_{\text{Year Group}}$	0.00 $_{\text{Active Partnership}}$
		0.33 $_{\text{Year Group}}$
Variance attributable to the fixed effects	0.02	0.03
ICC	0.148	0.153
Marginal R^2 / Conditional R^2	0.006 / 0.152	0.007 / 0.160
Model 6: Model 5 + school characteristics	**Model 6a**	**Model 6b**
τ_{00}	0.35 $_{\text{school}}$	0.25 $_{\text{school}}$
	0.17 $_{\text{Year Group}}$	0.01 $_{\text{Active Partnership}}$
		0.33 $_{\text{Year Group}}$
Variance attributable to the fixed effects	0.06	0.05
ICC	0.138	0.151
Marginal R^2 / Conditional R^2	0.016 / 0.152	0.012 / 0.161

τ_{00}: random intercept variance/between subject variance
ICC: Intraclass correlation coefficient
N: level-2, level-3, level-4 units which were the number of year groups (level-2), number of schools (level-3) and number of Active Partnerships (level-4) used in the model
Observations: number of children (observations at level-1) used in the model
Marginal R^2 / Conditional R^2: Marginal R2 provides the variance explained only by fixed effects and conditional R2 provides the variance explained by the entire model, i.e., both fixed effects and random effects.

Random effects and fixed effects

Model 5 included children's socio-demographic characteristics as fixed effects in addition to the random effects in model 4. The ICC for model 5a (registered children) is 0.148, dropping only very marginally from model 4a (ICC: 0.152), even after adding children's sociodemographic characteristics, suggesting that children's gender, ethnicity and deprivation account for only ~0.4% of the variation seen in children reporting a de-facto daily mile in registered schools. Similarly, the ICC for model 5b was 0.153, dropping only very slightly from model 4b (0.157), also suggesting that children's gender, ethnicity and deprivation account for only ~0.4% of the variation seen in children reporting a de-facto daily mile in non-registered schools. This is also reflected in the Marginal R^2 / Conditional R^2. The Marginal R2 provides the variance explained only by fixed effects and conditional R2 provides the variance explained by the entire model, i.e., both fixed effects and random effects. For model 5a (registered), the Marginal R^2 / Conditional R^2 is 0.006 / 0.152 and for model 4b (non-registered), the Marginal R^2 / Conditional R^2 is 0.007 / 0.160. Children's socio-demographic characteristics (fixed effects) explain minimal variation in the models and were almost identical for children in registered and non-registered schools.

Model 6 was an updated model from model 5 that also included school characteristics as fixed effects. As with model 5, the random intercept variances were higher for school in registered compared to non-registered schools (0.35_{school} vs 0.25_{school}) and were lower for year group in registered compared to non-registered schools ($0.17_{\text{Year Group}}$ vs $0.33_{\text{Year Group}}$). This implies that for children in registered schools, the year group is playing a bigger role in the variation for children reporting a de-facto daily mile, and for children in non-registered schools, the school itself is playing a bigger role in the variation for children reporting a de-facto daily mile. The ICC for model 6a (registered children) is 0.138, dropping slightly from model 4a (ICC: 0.148), even after adding school characteristics, suggesting that a schools' size, pupil to teacher ratio and rurality and seasonality account for ~1% of the variation seen in children reporting a de-facto daily mile in registered schools. The ICC for model 6b was 0.151, dropping very marginally from model 5b (0.153), suggesting that school characteristics account for ~0.2% of the variation seen in children reporting a de-facto daily mile in non-registered schools. The drop in the ICC by adding school characteristics to the models was far greater (a difference of approximately 0.8%) for registered children compared to non-registered; suggesting that school characteristics play a bigger role in explaining variation in reporting a de-facto daily mile in those registered than those who were not. The Marginal R^2 / Conditional R^2 for model 6a was 0.016 / 0.152 compared to 0.006 / 0.152 for

model 5a, suggesting that school characteristics were more important at explaining variation in reporting a de-facto daily mile in registered children compared to children's characteristics.

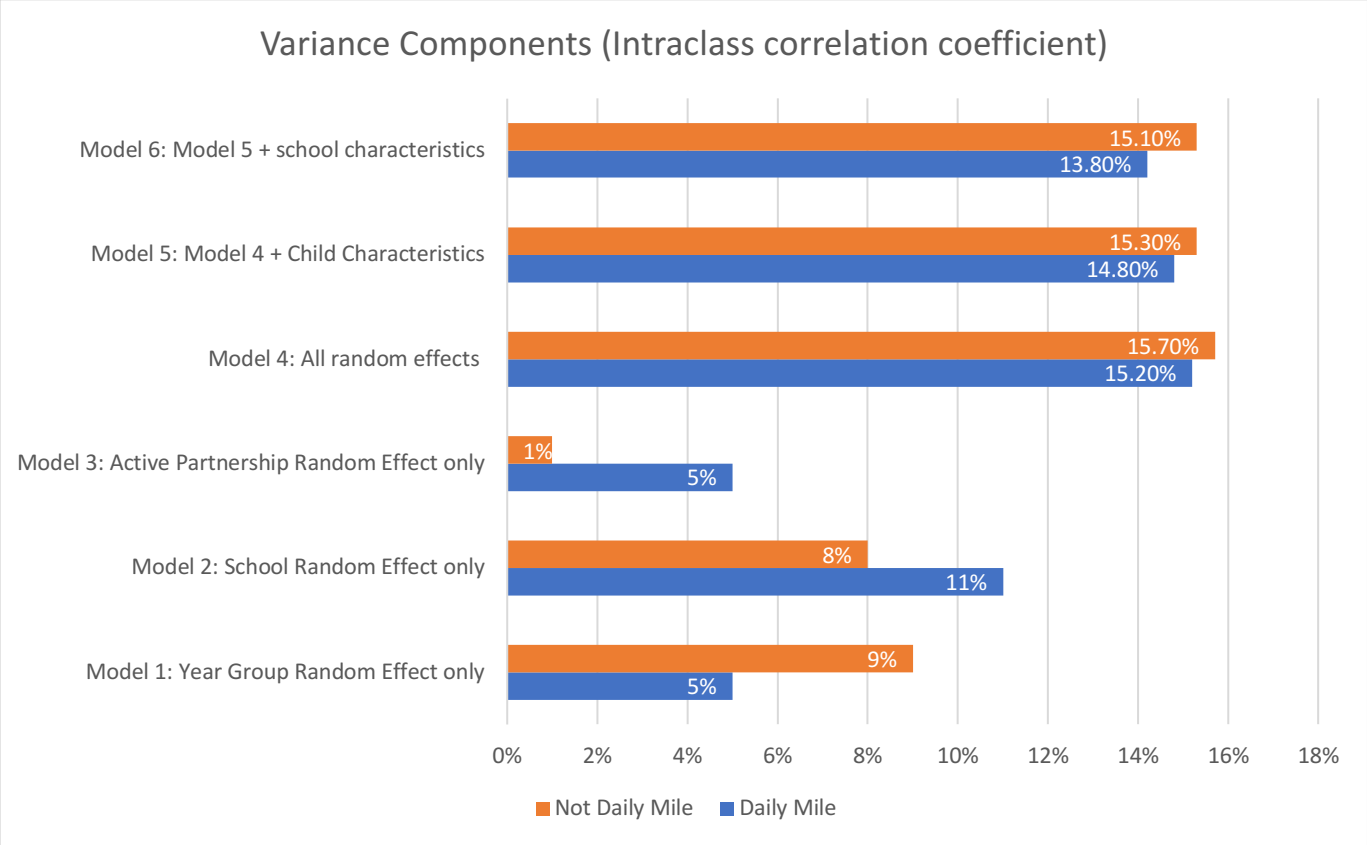
Key message for modelling results

The ICCs were very similar in the TDM and non-TDM registered sub populations in models 4, 5, and 6, which include all the random effects. However, models 1, 2 and 3, which were null models for each random effect separately, suggest that the specific random effects contribute differently to each sub population (

Figure 8.4). For instance, there is evidence that year group is more important in non-TDM schools than TDM schools, schools itself seem to play a greater role in explaining variation in TDM schools compared to non-TDM, and Active Partnerships seem to play almost no role in explaining the variation of reporting a de-facto daily mile in non-TDM schools but play a meaningful role in explaining variation in TDM schools.

Figure 8.4 illustrates these phenomena, where the contribution of each random effect is illustrated by their differential contribution based on registration status.

Figure 8.4: Variance components of the multilevel models



8.4 Discussion

8.4.1 Summary of chapter findings

- Fidelity to TDM's core running criteria is higher in registered schools compared to non-registered schools, but still falls significantly short (30% fidelity).
- There is evidence that the main subgroup that is driving adherence in registered schools is the 'very adherent group' – those that report doing TDM every day.
- There was no difference in variation in reporting a de-facto daily mile by registration status by visual assessment.
- Multilevel models showed that fixed effects at the individual child level (i.e., gender, deprivation and ethnicity) and at the school level (i.e., pupil to teacher ratio, pupil number, and rurality) do not play a big role in explaining variation in reporting a de-facto daily mile in both registered and non-registered schools.
- Multilevel models also showed that year group explained lesser variation for registered schools than for non-registered, schools account for more variation for registered schools than for non-registered, and Active Partnerships were only important for registered schools.

8.4.2 Strengths and limitations

A strength of this study is the scale of schools included in the assessment of fidelity to TDM's core running criteria. The implementation and fidelity of school-based physical activity interventions are often assessed via process evaluations.[319] However, conducting process evaluations can be costly and is often limited to a smaller sample[120] than what is possible with routinely collected data. In this study I propose a novel method of assessing fidelity to public health interventions using routinely available data. Another strength of this study is the use of multilevel models to assess the sources of variation in implementation. This approach facilitated an assessment of what might be contributing to adherence to TDM, but also what is not known about adherence to TDM which is represented in the residual unaccounted variance. By including random effects for different clustering levels, I was able to assess the specific sources of variation for each clustering level individually and collectively. By adding the same individual child and school characteristics as fixed effects to the models, I was able to assess whether the same characteristics contribute to within school variation, and this aided understanding of potential mechanisms at a more granular level. Interestingly, the fixed effects included in the models, including gender and age,[178,200,202,441,485] known important covariates of children's physical activity, did not account for reporting a de-facto daily mile, and this did not change based on registration status. This suggests that there are potentially other mechanisms responsible for children adhering to

TDM's core running criteria that is unaccounted for in the variation. This may suggest limitations in modelling approach, and less that we can conclude that there is no relationship. Additionally, given a large amount of variance remained unaccounted for in this study, helping guide future research into what potential factors might explain variation in implementation. This type of hypothesis-generating research that leverages routinely collected data to assess core epidemiological and evaluation questions is essential to designing future studies and evaluations.

There are some important limitations to this study. I did not include all the core principles of TDM in my definition of "fidelity" and instead defined it only based on the core running criteria. Had I included other aspects of TDM, the results might have changed. However, due to data limitations as a result of relying on routine data, it was not possible to include data on the other core principles. I did not include some known psychosocial constructs that drive implementation of school-based physical activity interventions such as teacher and children's motivation and children's competence.[375,464] I also did not include any parental information as this was not available. There are other known facilitators and barriers to implementing TDM and other school-based running interventions that I have not been able to include in my analysis such as the style of delivery of TDM – when and where it was delivered; physical and built environment features – such as schools having a designated flat surface/running track that children could use to do TDM and whether the school had any weather policies (e.g., wet weather outdoor running prohibition); and additional children's characteristics such as excess weight status and their physical fitness and stamina might explain some of the residual variation.[120,126,343,375] I use self-reported data MVPA data to define de-facto daily mile and this might be subject to recall bias. However, I do not believe this was differentially distributed across TDM and non-TDM schools. My definition of de-facto daily mile included time spent in doing MVPA at school from running, jogging, cross-country, and the Daily Mile. This was not purely restricted to minutes of MVPA from running, and there could have been some misclassification of those reporting a de-facto daily mile (e.g., if they did >=15 minute of MPVA from cross-country at least three days in the preceding seven days and did not do TDM).

8.4.3 Possible explanations of findings and comparison to previous literature

Implementation is defined as "a specific set of activities designed to put into practice an activity or programme of known dimensions".[317] This encompasses all the processes of programme delivery, including fidelity, dose delivered and dose received, quality, responsiveness, differentiation and adaptation.[318]The United Kingdom Medical Research Council's (MRC)

guidance on process evaluations, a method commonly used to evaluate complex health interventions clearly outlines the need to understand the effect of implementation while trialling the intervention and post-evaluation scale up.[319] Further, for an intervention to prove successful, it will highly depend on the context and its multiple components such as skills, pre-existing circumstances, resources and attitudes.[319–322] Pre-existing circumstances and contexts that the intervention is delivered will have different causal pathways owing to the different populations and settings.

The descriptive analysis in this chapter found that fidelity to TDM's core running criteria was low among those registered. Most of the children in the de-facto daily mile category (Table 8.1) were comprised of children from the 'very high' category (Table 8.2); meaning that very adherent children (those who report running 5 times a week in school for at least 15 minutes) are the children driving adherence in TDM schools. While it would be beneficial to further analyse this, the numbers were too small in the 'medium' and 'high' categories to power such an analysis.

When assessing variation in reporting a de-facto daily mile visually (Figure 8.3), in TDM registered schools, the spread was evened out, and looked almost identical to the spread in non-registered schools; suggesting more variability in reporting a de-facto daily mile for registered children than initially hypothesised. This might be a result of implementation problems or might be a function of something to do with respondents filling in the survey. This warranted further investigation to inspect where the variation observed might be arising from and to understand what factors might explain some of it, leading to the modelling study.

In the modelling study, I found that different factors contribute to fidelity of TDM's core running criteria by registration status. For instance, year group explained lesser variation for registered children. This is possibly because given that in principle, TDM is a whole school intervention and if the school is registered and indeed participating, they do it as a whole school intervention and not just selected classes. In contrast, schools accounted for more variation in registered children compared to non-registered. This suggests that some schools that register do not in fact implement TDM and is in line with the descriptive statistics done in this chapter to address fidelity; where I found that only 30% of registered children reported doing a de-facto daily mile. This finding, coupled with the year group variance findings suggest that the focus should be to ensure that the schools who register must be supported to implement it, as when schools do implement TDM, they do so as a whole-school approach. Active Partnerships accounted for 5% of the variation in registered children compared to almost none among non-registered children. There are 43 Active

Partnerships across England who work collaboratively with local partners to create the conditions for an active nation, using the power of sport and physical activity to transform lives. These Active Partnerships are based all over England and their main goal is to increase physical activity in children. They also collaborate with TDM, and in some areas they do promote TDM. This could explain why they are important in explaining variation in fidelity to TDM's core running criteria among children who are registered.

Findings from this study using self-reported measures of running in school show that fidelity to TDM's core running criteria is considerably lower than other studies that have evaluated TDM's implementation.[120,357,486] Harris's process evaluation of one school [120] showed that key stage one children in the school did TDM 91.5% of days of the study and on average, 95.8% students received the intervention. For key stage 2 children, TDM was delivered 86.4% of the study period and on average, 94.6% of children received the intervention. Interestingly, of the days that children did participate in TDM, 95.7% key stage 1 and 92.7% key stage 2 students completed the recommended 15 minutes. These are considerably higher rates of adherence to TDM's running criteria than I found. However, implementation of interventions in real world settings is known to lower than study and trial settings.[22,324] Harris et al only included one school, as opposed to over 1000 schools included in my assessment of fidelity, suggesting higher internal validity. Additionally, Harris et al used direct observation to measure children's physical activity which can be subject to reactivity, where children modify their behaviour during the period of observation or measurement.[127,128] In Hanckel et al's rapid ethnographic study in South London,[126] teachers mostly reported implementing TDM two to four times a week, whereas implementing TDM every day was not common. Further, within the schools that were implementing TDM, predominantly, children in all year groups participated. This was also reported by Malden and Doi[375] in their qualitative study, where a several teachers stated that all classes at their school took part, often at the request of the head teacher, while others mentioned that only some classes did TDM, and that participation does not happen every day either due to teacher preferences or age/ability of the children. Hanckel,[126] and Malden and Doi's[375] findings are reflected in the results of the multi-level models in this chapter, where between year group (classes) variation in reporting a de-facto daily mile was lesser in TDM registered schools than for non-registered schools. Similarly, Ryde et al's[371] qualitative study showed that teachers would have liked to implement TDM every day, but in actuality, it was implemented only about three time a week, especially on days where PE was not scheduled. They also found that the logistics and risk assessment meant it could not be done every day. In this study, I use implementing (reporting a de-facto daily mile) three-times a week as the definition as this is the TDM 'dose' recommended by

TDM Foundation. In this analysis, I found that implementation based on a three-times a week dose was considerably lower than other studies, albeit, the approach was different; where I took a quantitative approach as opposed to a process evaluation[120,126] or qualitative approach.[357,371,375]

8.5 Conclusions

This study is hypothesis generating research that is crucial for future longitudinal research and study design. It demonstrates a novel and creative method of assessing variation in implementation to TDM's core running criteria using a large nationally representative dataset of self-reported physical activity data. Overall fidelity to TDM's core running criteria remains low, with a larger amount of variation in reporting a de-facto TDM attributable to school and active partnerships for registered children, and year group for non-registered children.

9. Discussion

Overview

This thesis aims to use routine data to evaluate a real-world public health intervention, TDM. It assesses the reach, equity, impact, and subsequently, the fidelity of TDM. The discussion sections of chapters 5, 6, 7 and 8 considered each studies' limitations and relations to existing literature and lists possible explanations. The current chapter provides a more general discussion of the thesis, its overall methodological considerations, key results and observations, and its relation to public health and policy. This chapter also concludes the thesis.

9.1 Summary of thesis findings

This thesis focussed on the use of routinely available data to investigate a public health intervention. It is evident that a vast amount of routine data, albeit with its limitations, is available in England and it can be leveraged to evaluate public health interventions. Its limitations should not undermine its relevance to both public health research and its subsequent influence on policy. TDM is an unusual public health intervention in that its specific aim and design was to improve children's fitness and increase their physical activity, but it has been adopted to solve a myriad of public health problems in children.

In study 1, *Reach of The Daily Mile,* one in five primary schools in England was shown to have registered with TDM since 2012. However, the distribution varied across the nine English regions. Registration was much higher in London and major urban conurbations, where over a third of primary schools are registered. After adjusting for school and local authority characteristics, larger primary schools in urban areas, compared to rural areas and schools with higher proportion of disadvantaged children, were more likely to have registered for TDM. In addition, there was no association between TDM registration and area-based physical activity or excess weight status, or schools' educational attainment. There was evidence of variation in registration of TDM in different local authorities that was not accounted for by characteristics of schools and their pupils, suggesting other factors not included in the model may explain variation in school registration to TDM.

Study 2 assessed the *Equity of The Daily Mile.* Across 123 local authorities, three distinct clusters of high, medium, and low need for physical activity interventions were identified. The three clusters of need were characterised by determinants of children's health and the need for physical activity interventions. The important drivers of need that determined the clusters included childhood deprivation, children's social, emotional and mental health needs, children's physical activity, and use of outdoor space for exercise and health reasons. Despite TDM not being a targeted intervention, schools located in the highest need cluster for physical activity interventions were 25% more likely to be registered to TDM than schools in the lowest need cluster; registration ranged from one in five schools in the low-need cluster to one in four in the high-need cluster. This suggests that TDM is being taken up by schools, particularly those whose children could potentially benefit from it the most.

An analysis of 49,561 children attending 1,049 primary schools in England (Study 3, *Impact of The Daily Mile)* showed that children attending schools registered to TDM reported 10 additional

minutes of MVPA per week during school hours, 26 additional minutes of MVPA per week outside school hours, and 35 additional minutes of MVPA in total per week compared to children in non-TDM registered schools. Children attending TDM registered schools were 6% more likely to meet the recommended physical activity levels compared to those who were not in TDM registered schools. In addition, children attending TDM schools reported participating in a greater variety of activities during school hours, outside school, and everywhere across the week, although the difference was small. These gains are relatively low considering TDM requires that children participate in a minimum of 45 minutes a week of MVPA in school. However, there was no evidence that children who attend schools registered to TDM compensate their activity across the week in terms of variety or duration.

Finally, in study 4, *Fidelity to The Daily Mile,* using children's self-reported activity*,* there was evidence of low fidelity to TDM's core running criteria. Only 30% of children attending TDM registered schools reported doing a de-facto daily mile (i.e., the prescribed 'dose' of TDM). Further, this 30% of children were driven primarily by strong followers of TDM and reported running or jogging in school for at least 15 minutes every day. Results from the multilevel models that aimed to quantify variation in reporting a de-facto daily mile suggested that individual children and school characteristics explained little variation in reporting a de-facto daily mile in both children at schools registered and not registered to TDM. Year group explained less variation for children at registered schools than at non-registered, suggesting that those schools that were registered and did implement TDM, implemented it across all year groups. Interestingly, schools accounted for more variation for registered schools than for those non-registered implying TDM may have a whole school effect, and Active Partnerships were only important for children at registered schools.

9.2 Methodological considerations

This section provides a summary of overall methodological considerations. Methodological considerations that are specific to each respective study and its analysis were outlined within each chapter.

To consider the importance of methodological issues, they are grouped in terms of internal and external validity.

- Internal validity refers to the extent to which conclusions drawn from the experimental data are free from confounding issues. Influences on the internal validity of this thesis are

considered across study design, confounding, chance, and measurement bias in exposures and outcomes.

- External validity refers to the extent to which findings can be applied to other populations or settings. Effects on external validity are addressed through the consideration of selection bias and the generalisability of the findings of this thesis.

9.2.1 Internal Validity

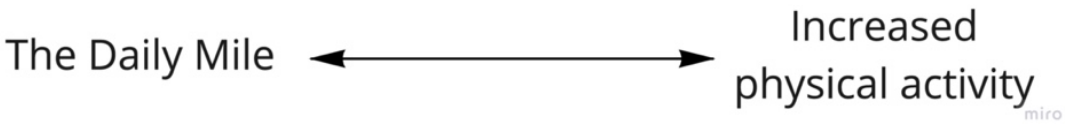
9.2.1.1 Study design, confounding, and chance

9.2.1.1.1 Study design

Cross-sectional nature

All four studies in this thesis are cross-sectional, making it difficult to make any causal claims or understand the mediators involved in the observed associations. Further, I cannot be certain of the processes behind the association, making reverse causality a possible explanation of some findings (Figure 9.1).

Figure 9.1: **Possible causal mechanism**



In study 3, I found that children attending TDM registered schools reported more activity than those at non-registered schools (Section 7.4.3.3). However, it is not possible from this study to ascertain whether it was indeed TDM that was increasing activity in children or whether children at schools registered to TDM had pre-existing high levels of activity. However, Studies 1 and 2 clearly show that schools in areas with the highest need for school-based physical activity interventions were more likely to register to TDM than those in low-need areas (Section 6.3.5 and 5.2.2). This strongly suggests that schools where children are already active were not the most likely to register to do TDM. Cross-sectional studies are often at risk of interpreting estimated associations as causal effects. This must be carefully considered when policymakers base policy on these studies. The need to extrapolate cross-sectional associations to make causal statements is a dangerous precedent to set, but one that all too often is required to provide absolute numbers that decision makers and governments can use. Rothman et al., and Greenland argue that this approach reduces the value that cross sectional studies provide to our understanding of population health.

Cross-sectional studies are relatively inexpensive to conduct, are important for generating hypotheses for population health and their findings can be used to design and plan further advanced studies such as longitudinal cohort studies.[487–489]

Further, cross-sectional studies, by their nature, are unable to account for longitudinal trends; results only indicate the status of health among the population at a specific point in time. For instance, in the analysis of clustering of health behaviours and determinants of children's physical activity in England (Study 2), the results only represent the geographical variation and clustering of health behaviours and its association with TDM registration at a point in time. Longitudinal studies would help determine the changing health needs of the population and help examine the implementation and sustainability of TDM over time. This need for longitudinal data goes beyond assessing the *Reach* and *Equity* of TDM. Longitudinal data would have been ideal for assessing both sustained uptake of TDM and changes of outcomes, especially when assessing TDM's potential impact on children's physical activity levels and variety across time. However, the Active Lives Survey is not a cohort, but a survey, meaning that the same children are not re-sampled, and so this type of longitudinal analysis would not be possible using that data.
Importantly, if time of registration to TDM and multiple years of data for the Active Lives Survey were available, even though the Active Lives Survey is not a cohort but a survey, these data could be used to conduct longitudinal analysis for understanding population trends such as Difference in Difference or Interrupted Time Series analyses.

With regard to the considerations highlighted above, I argue that the ecological fallacy is a concern. Ecological fallacy is the failure in reasoning that arises when an inference is made about an individual based on aggregate data for a group.[490] For instance, in study 2, *Equity,* I relied on local authority estimates of children's obesity and physical activity levels as a measure of all the individuals within a local authority. This aggregation of data can result in the loss or concealment of certain details. Statistically, a correlation tends to be larger when an association is assessed at the group level than when it is assessed at the individual level.[491,492] To determine whether the ecological hypotheses produced by group-level data are true for individuals, data is required on the individual level. This data can also aid in causal inference and population heterogeneity, and confounding bias can be accounted for.[491,492]

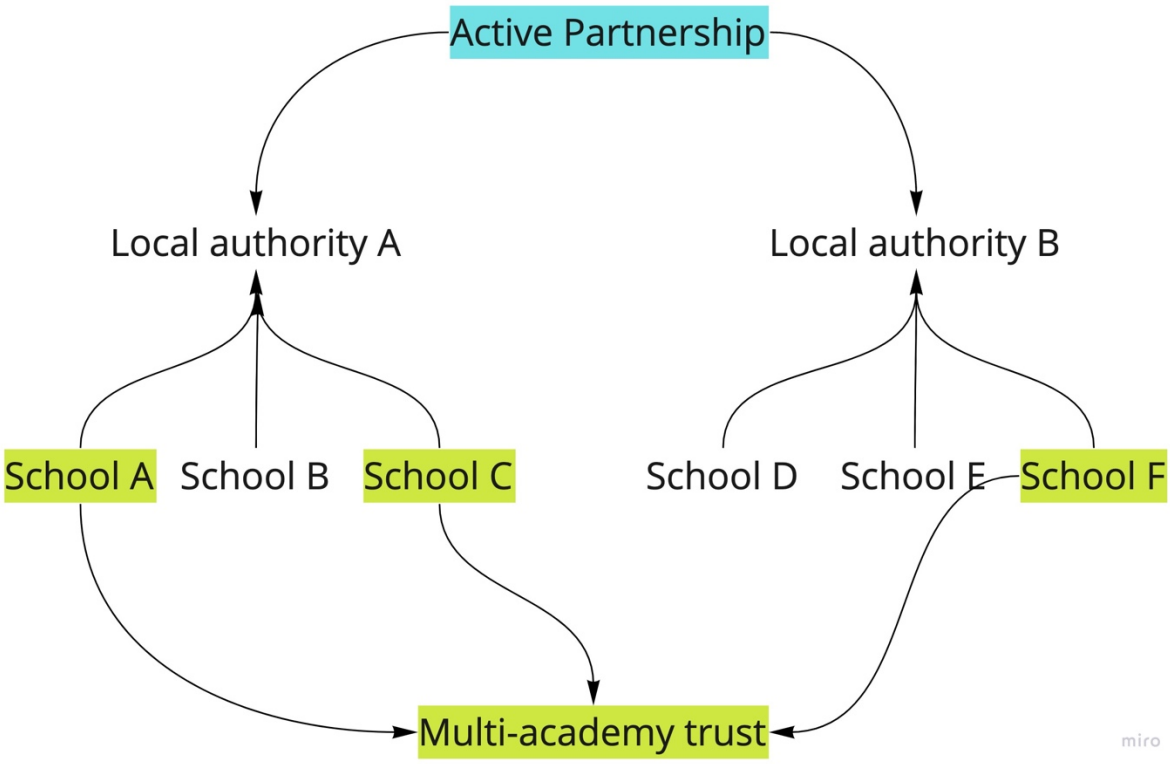
Clustering

A key strength of this work has been that all the studies within this thesis considered clustering by school and/or local authority, recognising that children are nested within schools and subsequently

that schools are nested within local authorities. For instance, relating to both study design and confounding for internal validity, I took into account clustering and the hierarchical nature of the data across the studies where appropriate (study 1, 3 and 4), reducing the confounding by clusters.[493]

In generalised linear models, a key assumption is that observations are independent. This is not the case for children within schools and schools within local authorities. Not taking this clustering into account can affect the confidence intervals and standard errors. The structure of education in England is highly complex; schools are within local areas, but may be under the umbrella of a local authority or a multi-academy trust (Figure 9.2)

Figure 9.2: Clustering and complex nesting of schools



When I examined the *Fidelity to The Daily Mile,* I found that Active Partnerships were an important factor to consider, especially for schools registered to TDM and children within those schools, as it explained more variation in children reporting doing a daily mile. Not including Active Partnerships as a clustering variable in earlier studies may have impacted the results. For instance, when I studied the characteristics of schools associated with TDM registration (Study 1), residual variation may have been explained by membership of Active Partnership. Clustering by both local

authority and Active Partnership would not be possible, partly due to the complex hierarchical nature of this model that the data would not be able to support. Local authorities in England drive a substantial amount of health and education policy in England, and some local authorities actively promote TDM.[126] In contrast, Active Partnerships are specifically responsible for promoting children's activity and sport in England. Further, they are under the control of Sport England, which in turn collaborate with TDM Foundation to increase uptake and implementation of TDM. However, I decided to use local authorities, as there are a larger number of local authorities than Active Partnerships in England. Further, even though I clustered by upper-tier local authorities in Study 2, *Equity*, instead of the more granular lower-tier local authorities, they were still split into 152 distinct areas of England (upper-tier) compared to just 15 Active Partnerships across England, implying it is far less granular. While local authorities are more specific and granular than Active Partnerships, both approaches have limitations and strengths. Further, I did not account for multi-academy trusts; this is important as some research shows that health promotion is organised at the school-level, not at the multi-academy trust level. However, these data were not routinely available and future research might benefit from exploring this further.[494]

Modelling process

Understanding underlying patterns in the data is key to a strong study design and using appropriate modelling approaches, and therefore generates more robust results. For example, within the Active Lives Survey, I did an in-depth examination of data and planned the subsequent data analysis accordingly. In this case, I selected the modelling approach based on whether there was evidence of zero inflation and/or overdispersion. I borrowed and applied knowledge from ecology and other epidemiology sub-disciplines to build the models and applied it to children's physical activity self-reported data.[469,472] I investigated in detail how the zeroes were generated in the self-reported physical activity data, and why certain methodological approaches might be superior for the data at hand (e.g., hurdle versus zero-inflated models). This in-depth data analysis and understanding of modelling assumptions leads to more rigorous results (Section 7.3.3). Similarly, in study 2, *Equity,* I allowed the data to tell its own story through the cluster analysis. Without forced or imposed arbitrary cut-offs for the clusters to be generated or without relying solely on statistical significance, this open approach to cluster analysis implies higher confidence in the results.

9.2.1.1.2 Confounding, assumptions, and unmeasured factors

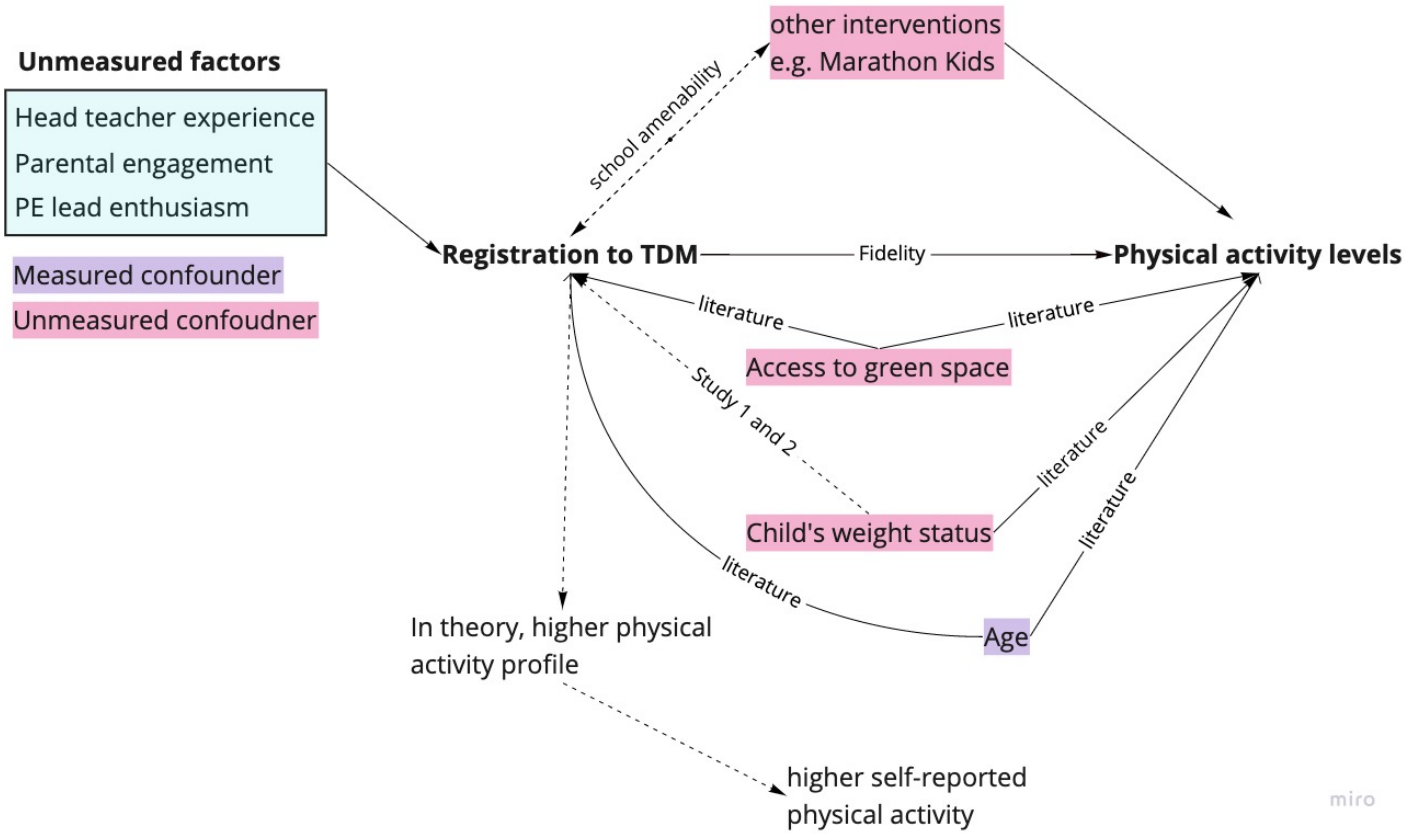
As with any secondary data analysis, the adjustments made to the models were restricted to variables collected during the process of data collection and data availability. Confounding is the distortion of the association between an exposure and an outcome by an extraneous, third variable

called a confounder. If confounders are not accounted for, they can cause an overestimate or underestimate of the observed association between exposure and health outcome, leading to false and misleading conclusions.[488] Confounding can be minimised at the design and the analysis phase.[488,495]

There is often unmeasured confounding and unknown variables that can be confounders in observational studies.[496] Adding to this, given that I have used routine data throughout this thesis, there were analyses in which I could have included additional adjustments if the data were available. At the design phase, I considered important confounders from the literature and tabulated those against what was available routinely. For instance, children's age is known to be associated with their physical activity levels and might be associated with registration and implementation of TDM given that certain age groups of children have additional academic pressures such as standardised assessment tests in Year Six.[178–180] Thus, I adjusted for age where appropriate (Study 3).

There have been instances where I became aware of a confounder that might distort a particular association, but due to lack of availability of data, I was unable to adjust for it. For instance, a child's weight status can confound the association between TDM and children's physical activity, based on the literature and the findings from *Equity (Section 6.3)* of this thesis (Figure 9.3).[81,82] Further, I did not have important data on other policies, initiatives, or interventions (national or local) that were ongoing at the same time. For instance, it was possible that children at schools registered to TDM were Marathon Kids.[342,344] This is important as children who were at schools registered to TDM could have been part of schools more amenable to adopting behaviour change interventions (e.g., Marathon Kids), which implies that TDM alone may not have been responsible for the higher levels of activity in those children. Had this information and data been available, I would have adjusted for it, strengthening the internal validity of this thesis.

Figure 9.3: **Example of unmeasured factors and confounders to consider**



I used multivariable models throughout the analyses. These enabled the adjustment and control of multiple variables simultaneously through mathematical modelling. I also standardised the data and variables for certain analyses (e.g., cluster analysis in study 2, and the multilevel models in study 1), to minimise the influence of different measurement scales of each of the variables and make the relative weight of each variable equal in the analyses (Section 5.1.5 and 6.2.4).

More traditional methods at the design phase to control for confounding are often preferred.[488,497] Through random assignment of participants, RCTs reduce the prospect of confounding. Randomisation with a sufficiently large sample enables all potential confounding variables (observed and unobserved) to have the same average value between different groups;[488] though trials are not always appropriate or feasible. It would not be possible to conduct an RCT on the same scale that I have demonstrated in this thesis. There can be ethical considerations to randomising children to interventions and control groups, especially if the health benefits of the intervention are potentially important. More importantly, an RCT design would not have been suitable for this thesis due to known issues of scaling efficacy from trials to real-world settings for school-based physical activity interventions,[22,324] and the national scope of this

thesis. Finally, I used national data, specifically in study 1 and 2, that is quality assured by the government and/or public health England; this increases the internal validity of the findings.

9.2.1.1.3 Chance

Chance is a random error appearing to cause an association between an exposure and an outcome. Erroneous results due to chance are inherent in all research and cannot be eradicated; this type of error can therefore influence results, even when biases have been properly controlled for.[498] I tested for null significance levels (p value) of 0.05. This p-value indicates the degree to which the data conform to the pattern predicted by the test hypothesis and all the other assumptions used in the test (the underlying statistical model); it is not the probability that the test hypothesis is true.[499] Comparing p-values to make definitive conclusions at an arbitrary level (usually α=0.05 or 0.01) is the most frequently used statistical method of establishing significance across epidemiology and public health.[488,499] However, this approach has been widely criticised in recent years.[489,499,500] In line with recent guidance and best practice, the results and consequent interpretations I presented in this thesis do not solely rely on statistical significance, but also examined the point estimates, and confidence intervals and their uncertainty.

In addition, the methodological rigour in the studies presented in this thesis uses large, representative samples, reducing the likelihood that chance alone is responsible for the effects and associations observed.[501] In study 1 and 2 (*Reach and Equity)*, I used data from the whole English population; while subject to ecological fallacy, the results are relevant and meaningful at the population level and have important public health implications. Specifically in study 2, where I assessed *Equity*, I used advanced unsupervised machine learning cluster algorithms to deduce differences in the clusters derived, not relying on statistical significance to reach the conclusions. In study 3 and 4 (*Impact and Fidelity)*, I used the Active Lives Survey, a nationally representative sample of approximately 50,000 children in England. These large sample sizes lead to less uncertainty in the results and smaller confidence intervals, ascertaining high methodological precision for the associations and results found.

9.2.1.2 Error and bias in measurement for the exposures and outcomes

Registration to TDM

In study 1 and 2, TDM registration was the outcome of interest, and in study 3 and 4, TDM registration was the exposure of interest. Throughout this thesis, I have used registration to TDM as an intention to adopt a behaviour change public health intervention, TDM, rather than a proxy measure for participation. This is also the same limitation as in any pragmatic RCT as the intention-

to-treat principle.[502] The intention-to-treat analysis is where all participants are analysed based on the original group they were assigned to, regardless of the treatment they received. This method reduces the bias in assessing the effectiveness of an intervention and maintains the benefits of randomisation.[502] Though I do consistently state through the thesis that I consider registration to TDM as an intention to adopt TDM rather than a proxy measure for participation in TDM, there are important nuances to consider. For instance, for a school to be considered registered via The Daily Mile Foundation website, it can be as a result of only one member of staff from a school who was interested enough to sign up to the website. This does not necessarily mean that they intended to participate (it could have merely been an interest) nor that they intended to implement it across the whole school (i.e., different year groups).

Registration was obtained from TDM Foundation who do not have a record on participation, date of registration, or sustained participation (i.e., whether those initially registered to TDM continued implementing it). This could lead to misclassification bias as it is not possible to determine if schools registered to TDM are implementing it, and if they are, to what degree, and whether they are also implementing another similar school-based running programme. If those registered are indeed participating, it increases this thesis' internal validity. Other studies have found high-fidelity to TDM's core running criteria. However, these have been either qualitative in nature or a process evaluation[120,357,371,375,384], none of which were able to quantify fidelity or make inferences for a large representative population. The results from the fourth study of this thesis, *Fidelity,* suggest that fidelity was low to the core running criteria among those registered (30%), and is more reflective of the overall literature on the implementation and fidelity of school-based physical activity interventions.[21,503] If those registered are not participating, it decreases this thesis' internal validity and could also attenuate the effect findings assuming that higher fidelity would be associated with higher effectiveness. Given the opposing conclusions of the specific implementation literature on TDM,[120,357,371,375,384] and the overall literature on implementation of school-based physical activity interventions[21,503] and the findings from *Fidelity,* questions remain about how significant these limitations are to reflect the validity of this thesis.

While it would have been ideal to have detailed data on TDM participation, there was a trade-off between sample size and data availability, and the acquisition and collection of more detailed data on TDM implementation. Registration data on TDM was provided by TDM Foundation, which could not provide data on the number of schools registered to do TDM, date of registration or information on the sustained implementation of TDM. While this might be standard, questions must be asked about why TDM Foundation is solely interested in the number of schools that have

registered to TDM; and subsequently, the implications of collecting data and knowing about sustained participation in TDM, for the business, INEOS, and the brand, TDM.[504] Additionally, for independent evaluation, it is important these data are collected and shared.

Self-reported physical activity data

It is important to mention that the Active Lives Survey, from where this physical activity data was obtained was not designed to be used for research purposes or for this particular study. Instead, it is used to monitor the physical activity and sporting trends at the population level of children in England. For that purpose, self-report data is appropriate due to its cost-effectiveness compared to device-based measures and the ability to collect data from a large representative sample of children (Section 1.7).[158,159]

As described in chapters 1 and chapter 7 (Section 1.7.3 and 7.5.2), there are limitations to using self-report data; these include errors in measurement due to over or underestimations of activity due to cognitive biases such as recall bias and social desirability bias.[124,129] While self-report data may be problematic for measuring the intensity and duration of activity, it has been shown to be particularly useful for measuring the type of activity completed – individuals are more likely to accurately report the type of activity rather than the duration.[117,124,129] In study 3, *Impact,* I assessed variety in addition to duration of activity, raising the internal validity of assessing the potential impact of TDM. Further, I assessed duration and variety of activity both during school hours and outside school hours. This increases the internal validity of the findings that higher activity during school hours (duration and variety) among children at schools registered to TDM are not compensated for by activity outside school hours.

Proxy measures

Due to my restriction to use only routine data in this thesis, I have had to rely on imperfect health measures. For instance, in study 2, *Equity*, I used the 'utilisation of outdoor space for exercise/health reasons' as an overall proxy measure of the built environment to include in my definition of 'need'. This might not be the most accurate and may conflate the propensity to use outdoor space with the design of the built environment. Additionally, when evaluating *Fidelity* in study 4, the main outcome was reporting a 'de-facto daily mile', which was the term given to children who reported doing the dose of TDM. This variable was derived from the Active Lives Survey where children reported the 'time spent doing MVPA at school from running, jogging, cross-country, and the Daily Mile' each weekday. This might include children doing any running

or jogging in school that is not attributable to TDM, reducing this study's internal validity. However, individuals are more likely to recall specific activities rather than general incidental activity attributable to running or jogging; children may accurately recall running or jogging during school hours as a result of TDM. Recall bias may therefore have been less influential for the specific research question addressed. Finally, it is important to mention that especially in study 3 and 4, I have used self-reported data in both the exposure (TDM) and the outcomes (MVPA, variety of activity, de-facto daily mile). However, this tends to be more problematic if both (TDM and MVPA) are reported by the same individual due to correlated error. In this case, only MVPA was reported by children whereas TDM status was based on registration data provided by TDM Foundation. While this is a limiting factor, its strength is in its size, and the analysis in assessing variation in self-reported outcomes (Study 4) makes a valuable public health contribution. Routine data is not designed to be used for research purposes which lends itself to certain internal validity concerns; however, its contribution to research is instrumental to the way in which policy is shaped.

9.2.2 External Validity

External validity refers to whether relationships and associations found can be generalised to different measures, persons, settings, and times.[505] Selection bias can affect external validity and "occurs in epidemiological studies when there is a systematic difference between the characteristics of samples selected for the study and the wider population".[506] In studies evaluating interventions, such as those included in this thesis, selection bias occurs when there are systematic differences between comparison groups in response to treatment, in this case, TDM. The external validity of the studies in this thesis owing to their large sample sizes is one of the biggest strengths of this work. All the studies presented in this thesis cover the whole population of England, either directly (study 1 and 2), or through representative samples (study 3 and 4), increasing their external validity. This provides a national overview and evaluation of TDM. This has not previously been done, to the best of my knowledge, when evaluating school-based physical activity interventions or TDM.[120,356,357,374,376] The Active Lives Survey used in study 3 and 4 is the largest survey of its kind in England, including physical activity data from almost 50,000 children. While there was a slight under-representation of younger children in the data, when comparing the profiles of children in TDM and non-TDM schools within the survey, they matched that of the profiles of schools I found in study 1, indicating high external validity of the findings. Lastly, representativeness can be different in data processing if participants who do or do not provide valid data differ characteristically. I have addressed this specifically within the study chapters where I

compared the characteristics of schools (study 1) and local authorities (study 2) in the analytic sample versus the excluded sample.

The extent to which the research findings can be considered generalisable and applicable to other populations is a central feature of external validity. The epidemiological findings in this thesis are strengthened by the fact that they are derived from large nationally representative samples or the whole population. This provides an argument for generalisability of the findings of this thesis across the United Kingdom and potentially across Europe and more widely to other high-income countries and contexts. However, these results cannot be applied more globally or to low- and middle-income countries owing to differing needs and contexts, such as cultural barriers and public health priorities.

9.3 Implications for public health and policy recommendations

The reach of TDM and lessons it provides

The findings from the first study, *Reach of The Daily Mile,* that TDM is potentially reaching over one million children in England is evidence of the intervention's appeal to schools. It appears to be a wide-reaching intervention. Small trials have shown the physical fitness benefits of TDM.[356,357,378] If these benefits are sustainable, then coupled with the findings that TDM is taken up by urban schools serving disadvantaged populations, it suggests an added value from TDM over other interventions that, when scaled, have failed to reach populations of children most in need.[507]

While TDM began as a grassroots movement via its founder and former head-teacher, Elaine Wiley, whether it can still be considered a grassroots movement is questionable. With a large petrochemicals company funding TDM,[352,504] its partnership with Sport England to increase uptake,[465] and the numerous ad and television campaigns run by TDM Foundation puts into question whether its grassroots nature is solely responsible for its popularity. If school-based physical activity interventions are embedded into the school curriculum, they are more likely to be effective and sustainable[508] and TDM could be a vehicle to help children achieve physical activity recommendations. TDM demonstrates that teacher-led interventions can reach populations that need it most with adequate funding (INEOS) and government endorsement (Section 1.15) and is a lesson for policymakers on how this can be achieved for other interventions. It can be argued that TDM is an example of the possible success, at least in terms of reach, of a public health intervention with sufficient funding. Policymakers must attempt to understand what drew teachers,

decision makers, and implementers to TDM that fed into its popularity and widespread adoption, especially during its grassroots phase. This, in turn, will allow those characteristics of TDM to be translated to other policies to increase their uptake and understand the needs and attitudes of the population, working in sync with the 'end users and implementers'.

Investigating clustering of health behaviours beyond TDM

The findings from study 2, *Equity,* show that local authorities across England have different need for children's physical activity interventions, and areas with higher need have higher uptake to TDM. I have demonstrated the potential for using clustering techniques to target interventions to populations most in need. Policy makers could consider adopting this technique in public health practice to improve efficiency of applying trial and other evidence. Identifying clusters of local authorities that share patterns of need for physical activity interventions may help to guide public health and other policy interventions. For example, successful interventions in one local authority might transfer more easily to other local authorities within the same cluster, as these areas may share similar challenges and contextual features. This study helps us to understand the geographic variation of health needs. There is a necessity for finetuning interventions to target combinations of underlying health behaviours that give rise to the clusters seen in this study and previously. Targeting single behaviours and determinants of children's physical activity in isolation is not sufficient or recommended.[461] Further, policymakers and practitioners need to ensure that interventions are designed and implemented to match need.

Should TDM be promoted?

Based on the results and interpretation of this thesis there is mixed evidence for promoting TDM. If the findings of this thesis are indeed accurate, whether TDM should be promoted is a crucial feature to consider as the political and public health interest in active miles and TDM continues to rise. Here I rationalise both approaches:

<u>Argument for promoting TDM</u>

Given that this thesis provides a national overview and includes all schools in the school census, the schools registered to TDM appear to be self-selecting to an extent. This suggests that there was an intention to change behaviour in schools that traditionally do not engage with physical activity interventions (high-need schools were shown to be more likely to register – Study 2).[507] It can be argued that those not registered to TDM are doing another type of activity or have a pre-existing robust physical activity curriculum where there is no need to introduce another intervention, i.e.,

the children are low need. If this is the case, then promoting TDM more widely may not have an impact. Based on study 3's findings, TDM only provides an extra 10 minutes of MVPA per week during school hours. While small, this may be particularly beneficial to children with high need who are less physically active as opposed to children in the general population. Further, it is important to note that note that the 10 minutes is an average from the modelling estimates and there is individual variation around that estimate; so, it may, in fact, be hugely beneficial for some.

Although immensely popular in England, based on study 3 and the wider literature,[374,378] TDM does not seem to be especially effective at improving children's health overall, and the improvements in physical activity are small. This may be due to low fidelity, as seen in study 4 and in the literature.[21] Therefore, my recommendation is that schools registered should continue to stay registered and implement TDM. In contrast, those not registered are likely not high need and might not significantly benefit from an extra 10 minutes of MVPA per week in school. Therefore, the results provide strong evidence that the focus should not be on expanding the TDM school base, but to ensure that fidelity is sustained in those already registered, who can benefit from it the most.

TDM can be seen as an activity that enhances and expands children's physical activity opportunities.[481] This is because it can provide an "inclusion of a new occasion to be active" (*expansion*) within the school system by offering 15-minutes a day of MVPA and because it is "designed to increase physical activity above routine practice"(*enhancement*), and must be done in addition to curriculum PE. A recent systematic review[304] found that interventions that focus on the *expansion* of opportunities, including classroom physical activity breaks (such as TDM), are the most promising to address shortfalls in children's physical activity. Similarly, Daly-Smith et al's framework for creating active schools puts non-curricular physical activity such as exercise breaks at the centre of opportunities to increase overall activity in children, while also noting that individual behaviour change to enhance activity is fragile and high-level factors at the school, local authority, and system level are crucial.[85,108,482] Given that that the lack of sustainable and feasible interventions is one of the reasons for poor implementation of school-based physical activity interventions,[21] simple initiatives such as TDM along with other promising interventions can create an active school environment that does not rely solely on single element interventions to solve the inactivity crisis facing children.

<u>Argument against promoting TDM</u>

Findings from study 3, *Impact,* showed a small difference in MVPA for children attending TDM registered schools compared to those in non-registered schools for activity during school hours, outside school hours, and in total across the week. This is in keeping with what was expected given that TDM is only a 15-minute physical activity intervention. However, the impact of TDM may be diluted if the implementation fidelity is low, as found in study 4, *Fidelity* (30% fidelity in those registered). The results from *Impact* indicated that the differences in physical activity between children in TDM and non-TDM schools were observed for activity in school and out of school hours and may even allay concerns that TDM reduces children's total activity.[228,374,398,509] However, findings from this thesis, given small effect sizes, suggest that it is not feasible to expect TDM in isolation to increase overall physical activity in children. Other interventions such as classroom activity breaks[479], physically active learning,[480] and after-school clubs[282] have been shown to increase weekday, weekend and total MVPA and may be better alternatives to TDM.

Despite its wide reach, there is insufficient evidence that TDM is the best potential intervention for children. Active miles in schools alone as single-element interventions are unlikely to be sufficient to enable all children in England to meet physical activity guidelines. Further, as described through this thesis, physical activity behaviour is very complex, consisting of many different behaviours undertaken in different physical and social contexts. Not every activity is liked by everyone, and there will be a significant group of children that do not like running and may even be deterred from activities by TDM. In addition, TDM in isolation is unlikely to have larger impacts such as reducing obesity, which is what the United Kingdom government is currently advocating it for. This is because public health issues such as obesity are complex problems driven by systemic factors and other individual behaviours like diet that require a whole-systems approach, with a focus needed on targeting upstream determinants.[19,85] TDM can certainly be part of a wider-systems-based approach but must be embedded within a suite of interventions aimed at increasing children's physical activity. More importantly, policymakers should deliberate the opportunity cost of TDM and consider other potential interventions that are likely to have a larger and more sustained impact on children's physical activity behaviours and consequently, on public health.

Fidelity and Implementation

Successful large-scale implementation of interventions is a known challenge. It has recently been shown that when obesity-reducing interventions (including school-based physical activity) are scaled up, the effect-sizes observed are 75% lower than those reported in trial settings.[22] TDM has the advantage of already being scaled up and wide-reaching with one in five primary schools in England already having registered,[416] and it reaching high-need populations;[449] though

evidence around its equitability and long-term effectiveness and sustainability at the individual level warrants further research before additional promotion by government and policymakers.

Previous studies that have focussed on evaluating TDM Foundation's claims on its effectiveness have thus far found no significant effects of TDM improving children's cognitive ability[374] or reducing obesity.[373,378] TDM Foundation claims that TDM makes children 'healthier, happier and concentrate more in class'. However, the science and evidence base does not support this. The literature review I conducted in chapter 3 and the latest Public Health England active-mile briefings[338] suggest that it is appealing to schools and can contribute to children's daily physical activity, but there is inadequate evidence for its effect on other health outcomes. By promoting unsubstantiated claims of TDM being more effective than it is, for instance, through its various associations with health (e.g., obesity) and academic outcomes, it can be detrimental to its own success and policymakers, researchers and TDM Foundation should contemplate this.

Schools seem to be taking it upon themselves to register to TDM, and this is particularly true for schools with high need, but there is no evidence nationally that they are implementing it. Findings from this thesis show that TDM is an intervention within reach of all, especially those who are most in need. However, from a policy perspective, there is a need to closely monitor TDM's implementation and effectiveness before both government and policymakers recommend wider implementation. While the literature shows the flexibility of TDM is one of the biggest drivers of uptake and implementation, and its appeal to schools and teachers, TDM Foundation has a strict list of what TDM entails via its core principles. Current evaluations of TDM, including the work in this thesis, have not specifically evaluated TDM against its core principles. Whether TDM can work and be sustained based on the core principles is a question that needs addressing, especially by policymakers. This is because there is a difference between TDM as the branded, prescribed, regimented intervention that is being widely promoted both via TDM Foundation via advertisements and campaigns and the government versus one that is merely the 'active ingredient' of 15-minutes of running or jogging a day during curriculum time.

9.4 Post Covid-19

To move forward in a post-Covid-19 world, simple and effective interventions will be vital to resume children's activity which has greatly suffered from the lockdowns.[510] TDM being easy to implement,[375] already widely adopted, and reaching those who need it most across England[416,449] can be in a unique position to do this as those most deprived and those from ethnic minorities were most affected by lockdowns and also have lower levels of physical activity.[511] TDM Foundation published a guide to "Social Distancing during The Daily Mile"

which can be used to ensure safety. However, as children go back to school, TDM must be part of a wider solution to increasing children activity. If the ultimate goal of physical activity and education programmes in schools is to increase amounts of lifelong activity post-school, across the life course, policy makers must question whether TDM is the right intervention to do that. Some suggest TDM might work based on SDT by promoting autonomy, competence and relatedness.[360,361] However, controlled compliance cannot be ruled out as a driver of implementation; for schools remain an environment where power dynamics between teachers (implementers) and children are present. In addition, TDM can be viewed as an enforced mile and might not address the inherent interest that children have in physical activity that is around play and recognising its value.[512,513] These nuanced experiences of children can only be explored through gathering their experiences (e.g., children who did TDM across primary school and their experiences and perceptions of it). Further, policymakers must also ask whether schools are truly the best place to implement TDM during curriculum time. Academic pressures, time, cost, and burden on teachers are important factors to consider, especially in a post-Covid19 world, where all the above are likely to become more acute.

The geographic inequalities observed in study 2, *Equity,* are likely to get more acute in a post-pandemic world, further disenfranchising those who are already disadvantaged. From a policy perspective, targeting policies that match the needs of the population is more equitable than blanket policies directed at the whole population with differing needs. From a practice perspective, learning must be shared between areas that have similar contextual factors and circumstances. This study provides a pre-Covid19 baseline of the geographical health disparities and differing needs for children's physical activity in England. In the future, studies similar to this will allow us to track the progress made in reducing the clustering of health inequalities, observe potential shifts in children's needs, and evaluate the impact of the government's new 'levelling-up' agenda.

9.5 Contribution of this thesis and recommendations

9.5.1 Using routinely available data to conduct public health intervention evaluations

This thesis demonstrates that the vast amount of routine data available in England can be used for research purposes and to evaluate public health interventions. For instance, the schools' database I created can be used as a research resource for other studies and research. The cluster analysis is an example of how this data can be used to conduct more complex and nuanced population health surveillance. The biggest strength and benefit of using routine data is that it can provide national overviews of real-world public health interventions.[42,43,52] It provides an opportunity to look

at population health intervention evaluations beyond small randomised clinical trials and must be embraced, especially in fields where the translation from intervention design to implementation remains poor, such as physical activity research.[21,43] In an age where studies are increasingly finding the lack of effectiveness of school-based physical activity interventions, using routine data can provide insight into the actual needs of the population with the understanding that there is no-one-size-fits-all approach to this. To my knowledge, this is the first study in England that has exclusively relied on using routine data to evaluate a school-based physical activity intervention.

While routine data has multiple benefits, its biggest limitation is it is often cross-sectional in nature. However, as I have demonstrated through this thesis, routine data can be used to inform further research, such as trials and process evaluations. The work done in study 4, *Fidelity,* is an example of this. I thought of a creative way of assessing fidelity to TDM's core running criteria among those registered. While there are limitations to my method, it is a resourceful way of evaluating fidelity and using the data available to inform further research as I have done in the designing of the iMprOVE cohort.[392] In this thesis I have thought innovatively about public health data to make the most use of it. I have applied non-traditional methods in epidemiology to understand data better, integrating public health, epidemiology, and novel complex statistical analyses. For instance, methodologically, using an unsupervised machine learning algorithm, the hierarchical cluster analysis in study 2, *Equity,* advances on previous research by accounting for the interaction of several determinants of children's physical activity. Similarly, for the in-depth investigation of zeros (zero-inflation and overdispersion) in study 3, the inspiration for the analysis came predominantly from ecology, where this is a common issue. By looking beyond traditional methods in public health and epidemiology, we can find a vast amount of data to be used and novel methods to be applied. The quality of routine data is one of its limitations. For instance, the need to rely on proxy measures might not be an accurate measure (Section 9.2.1.2) or surveys being filled by proxy. In the Active Lives Survey, parents of younger children, those in Year 1 and 2 are asked to complete the questionnaire on behalf of their children. However, it is not clear how much parents would know of their children's daily activity levels in school.

In terms of recommendations, there is an especially urgent need for the Active Lives Survey to make its data validation process transparent. Currently, the data validation information provided by Sport England of the self-reported data against the objective measurement study is ambiguous, and their data cleaning and imputation processes have limited detail. By being transparent about the processes and limitations of the data, policymakers and researchers can understand the constraints of the data and be more nuanced and circumspect about results and conclusions. Further,

Sport England could consider making device-based measurements public so as to strengthen the use and validity of the dataset, a method that has been recognised to improve the use of self-reported physical activity data.[174] This would also aid in developing new methods to calibrate self-reported measures of physical activity reported by young children (primary school aged) against what it is device measured. Further, these types of data must be used more widely for evaluating public health interventions.

Overall, the routine data available in England is dispersed in different locations and held by different data controllers. Streamlining this process will be a monumental task but a necessary one to enable the use and maximise the full potential of the data. Linkage can be done by large data controllers such as NHS Digital, by linking individual-level child data on health (e.g., NCMP), education (extracts of the National Pupil Database), demography (Census) and health behaviours (physical activity – Active Lives Survey). These could then also be linked to local authority and regional level data in the future. Identification of the data available and data access remain two of the most significant issues researchers working in this space face. Making these two procedures easier will be a remarkable feat that will benefit public health data in a big way.

9.5.1.1 Lessons from secondary use of routine data in England

During this PhD, I have outlined the routine data available in England relating to children's health, education, and wellbeing. While the specific studies and corresponding results only used a few of those data, I spent considerable time exploring data sources, access, and usage. Initially, I intended on using childhood obesity data from the NCMP. However, I was unsuccessful in obtaining this data. Although there is a willingness by NHS Digital and Public Health England, the main data controllers for the NCMP, to allow researchers to use the data, the ethics application processes and the application process (DARS) are ambiguous. My recommendation would be for the approvals process at the national level to be streamlined to enable researchers across the country to use the NCMP, which is an outstanding research resource. Practical recommendations include: 1) Having the right team, with all stakeholders involved 2) That everyone involved have a realistic attitude to the capabilities of the data 3) Clarity on the time needed for cleaning and linking data, which must be made upfront, and quality of the data should be acknowledged early in the research process. Additionally, it is important to consider that these public bodies are at the mercy of political will. Thus, it is important to have everyone committed from the beginning and for collaborations to exist between government, researchers, and other relevant stakeholders. For instance, in the case of my PhD, perhaps a supervisor from one of these national bodies would have been advantageous.

In terms of other data sources I have used in this thesis, such as data available from Public Health England's repository, Fingertips,[45], the data can be downloaded in multiple formats for use, with data dictionaries easily retrievable. The process is transparent and clear. Similarly, the Active Lives Survey data acquisition process was remarkable. The process was streamlined, quick to work, and allows researchers access to the vast amount of children's physical activity and sporting data in England.

9.5.2 Methodological recommendations

- The choice of models and analysis must be made after a thorough examination of the data. For instance, the zero-inflated models used in this thesis. This reduces the risk of making erroneous conclusions about the data.
- Cross-sectional observational studies have value without the need to make causal claims and assumptions about results derived from them.[487–489] There is a need to be cautious of causal messaging of cross-sectional studies which is something that is common with public health and physical activity literature.[514]
- Future methodological work recommended here is dependent on improved data availability, transparency, and access. For instance, Sport England making the objective measured data available from the Active Lives Survey will validate the self-report data. Analysis such as a Bland Altmann analysis[515] to assess children's self-report data against objectively measured data will facilitate important methodological research, such as whether the most active children (objectively measured) are the most likely to report reliable estimates of self-report data, increasing the validity of the data and its utility.
- Routine data must not be disparaged; its use to inform policy is tremendous.

9.5.3 Remaining research questions and future work

Overall, this large, nationwide cross-sectional work will allow for more detailed studies to take place on evaluating the impact and implementation of TDM. So far, studies assessing TDM have focussed on impact and been small, regional studies. My thesis analysed TDM across the whole intervention evaluation process, going systematically from reach to equity to impact to fidelity.

In terms of future research for TDM, important questions remain about the effect of TDM on the long-term engagement of physical activity among those who have participated. TDM has been ongoing since 2012 and is aimed at primary school-aged children. Thus, there is already a cohort

of children that have now gone through TDM from the beginning to the end of primary school. Understanding the long-term effect on these children's engagement will be critical to understanding its capacity to change behaviour. Further, qualitative research to understand the perspective of these children will enable differentiation of whether TDM indeed promotes autonomy in children or whether it is compliance-driven. As discussed in chapter 2, autonomous motivation is a key determinant of children's engagement and motivation to be active.[342,348] In contrast, the latter, compliance-driven activity and mandated activity, is unlikely to be sustainable and might facilitate negative experiences among children.[348,516,517]. Thus, understanding children's motivations behind engaging in TDM is vital. Further, future research that aims to understand how this engagement plays out across the life course will be valuable since a small increase in the propensity to engage in physical activity in early primary school years could translate to huge changes and benefits at the population level.

Certain subgroups of children might benefit more from physical activity, such as girls and those with differing weight status. Analysing the impact of TDM on children with differing weight status and other subgroups of children will be useful. Further, it is important to consider how these differential impacts play out across the life course and whether TDM engages everybody equally. Assessing the impact of TDM on other closely linked health behaviours such as dietary behaviours will also be beneficial.

Studies focussing on the variation in implementation of TDM in real-world settings and larger populations is important. It is also essential to assess what fidelity is in real-world settings to the other criteria and core principles of TDM and not just the 'dose' or 'active ingredient' of physical activity. Comparing fidelity to these other criteria with the running criteria will be helpful to assess which factors of TDM are most taken up, implemented, and important for sustainability. Research could also focus on having a more granular understanding of fidelity to TDM, where fidelity to TDM's core running criteria is assessed against outcomes such as levels of physical activity and fitness, extending this to evaluate whether it varies by subgroups (e.g., age, gender).

While I found that schools in areas with the greatest need register to TDM, it is imperative to study implementation over time, given that previous studies have found teacher buy-in to be crucial for long-term adherence to school-based running programmes.[125,375] It would also be of interest to include additional determinants of children's physical activity using methods similar to the cluster analysis, such as policy and behavioural determinants that are currently unavailable in routine data, to be able to understand the bigger upstream drivers of need.[518] Importantly, I recommend future

studies focus on achievable benefits that active miles might provide to children; such as increased activity attributable to running, psychological impacts of TDM (autonomy and competence), long-term sustainability of TDM in secondary schools, and children's perceptions and attitudes to active miles. This thesis makes a case for further analysing longitudinal data in children doing active miles in schools and school-based running programmes to measure in school and outside school activity. Longitudinal data will also facilitate answering valuable questions including but not limited to whether TDM has any influence on long-term engagement in physical activity among children and how this varies by subgroups; and whether engaging in bouts of MVPA via TDM has any wider impacts on physical activity due to adaptive responses by children, parents, schools, or other segments of society.

9.6 Thesis conclusion

Overall, this thesis reveals that routine data can be effectively used to evaluate real-world public health interventions. By evaluating TDM, I found that TDM is a wide-reaching, equitable intervention reaching those that need it most. Overall, 22% of all primary schools in England are registered to TDM, and this includes schools with both high and low educational attainment. In addition, schools in urban areas are more likely to register to TDM. Schools in local authorities of high need are also more likely to register, where one in four schools are registered compared to one in five in low need local authorities.

While TDM is being taken up widely, its potential impact on addressing inadequate levels of children's physical activity in England is limited. Children in schools registered to TDM report more activity (minutes of MVPA) and a greater variety of activity during school hours and outside school hours. However, these differences were small, a difference of 10 minutes of MVPA during school hours per week and 26 minutes of MVPA during school hours per week. Further, as expected, fidelity to TDM's core running criteria remained low among those registered. Fidelity was mainly driven by children who reported doing a daily mile every weekday. Additionally, factors that explained the variation in reporting doing the dose of TDM (de-facto daily mile) varied by TDM registration status.

Collectively, findings from this thesis suggest that TDM is an example of a public health intervention that can have abundant reach due to its early grassroots features, followed by plentiful monetary support, extensive promotion, campaigning, and advertising. It also indicates that vastly endorsed interventions might not be effective at changing complex behaviour at the population level, which needs whole systems- and school-based changes targeting upstream and downstream

determinants. Given TDM's large reach but relatively small impact, it must be part of a wider suite of school- and non-school-based physical activity.

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Appendices

Appendix A

Taken directly from https://www.sportengland.org/

QUESTIONNAIRE DESIGN

Versions

There are three versions of the questionnaire for:

- year 1-2 children
- year 3-6 children
- year 7-11 children

Parents of year 1-2 children also complete a questionnaire providing more detail for each child they have in the sampled class.

There is a further questionnaire to be completed by one of the teachers at each school. The year 1-2 questionnaire takes around 10 minutes to complete, the year 3-6 and 7-11 questionnaires around 20 minutes, and the parent and teacher questionnaires around 15 minutes.

As the year 3-6, year 7-11 and parent questionnaires are very similar, the overview for these has been shown in a single table below. The year 1-2 questionnaire and the teacher questionnaire overviews are shown in separate tables.

Document updated: October 2019

Text in red denotes questionnaire changes introduced for 2019-20 (year 3 of the survey) QUESTIONS - OVERVIEW (Year 3-11 survey)

QUESTION	FURTHER INFORMATION	AGE GROUPS
Introduction	**No response required**	**Yr 3-6, 7-11, parents**
Sex **Is your child a...**	**Boy** **Girl** **This allows the subsequent questions in the parent questionnaire to be worded as 'your son' or 'your daughter'.**	**Parents**
SchYr **Which school year are you in?**	**Years 1-11. Options displayed vary according to version of questionnaire being completed**	**Yr 3-6, 7-11, parents**

Event **Since [current month] last year, have you been to see any live sporting events?**	**Yes** **No** **Can't remember** **Respondents are asked to include both professional sport and watching friends or family compete but not events participated in by the respondent or watched on TV.**	**Yr 5-6, 7-11**
EventN **How many live sporting events have you been to see since [current month] last year?**	**(Asked if answered "Yes" to Event)** **One** **Two** **Three or more**	**Yr 5-6, 7-11**
Week **Which of these have you/has**	**Respondents are asked to select, from a list of 37 activities, all the exercise, sport and fitness activities done at school (including PE lessons), at home,**	**Yr 3-6, 7-11, parents.**

QUESTION	FURTHER INFORMATION	AGE GROUPS
your son/daughter done in the last seven days, since last [current day of the week]?	at clubs, or somewhere else. Option to add up to four other sports or physical activities not in the list, in text boxes, or to answer "None of these". Parents see the message "You may find it helpful to complete this question with your son/daughter"	
Wk4 Have you/Has your son/daughter done any of these activities in the last 4 weeks?	Asked if answer to Week (activities done in last seven days) = 'None of these'. Same response options as Week.	Yr 3-6, 7-11, parents
Wk4Oft How many times in the last 4 weeks have you/your son/daughter done any of these activities?	Asked if one or two activities selected at Wk4 Once Twice Three times or more	Yr 3-6, 7-11, parents
Grid (at school) Please tell us on which days you/he/she did each of these activities while at school, during normal school hours. • Include activities in PE lessons and break times. • Do not include activities at before and after school clubs, even if these took place at school	If one or more activities is selected at Week, a grid is presented with columns for each day of the school week (Monday-Friday) and rows based on the activities reported.	Yr 3-6, 7-11, parents

Grid (outside school) **Now please tell us on which days you/he/she did these activities outside school hours.** **Please include activities you/he/she did:** **• before you/he/she got to school and after you/he/she left school** **• at the weekend** **• on holiday days** **• at before and after school clubs, even if these took place at school**	**If one or more activities is selected at Week, a grid is presented with columns for each day of the week (Monday-Sunday) and rows based on the activities reported.**	**Yr 3-6, 7-11, parents**

QUESTION	FURTHER INFORMATION	AGE GROUPS
GridChk **You told us that your son/daughter did the following activity/activities in the last seven days, but you did not tell us when. For each activity please tell us whether this is because your son/daughter did the activity but you are not sure when, or because your son/daughter did not actually do the activity**	**If one or more activity chosen at week is not entered in either Grid, a further grid is presented asking why each activity was not entered.**	**Parents**
Time **For activities entered in Grid (outside school):** **You told us that on [day of the week], [X days ago], [you/your son/your daughter] did [activity] outside normal school hours.** **How long did you/your son/your daughter do this activity for?**	**Less than 10 minutes Less than half an hour About half an hour About three-quarters of an hour One hour More than an hour Yr 3-6 'Don't know' or Yr 7-11/parent 'Cannot give estimate'** **Only asked with respect to the most recent day each activity was done.**	**Yr 3-6, 7-11, parents**
Location **And did you do [activity] indoors, or outdoors?**	**Indoors Outdoors** **Not asked for activities which can be assumed to be outdoors (e.g. walking to school).** **Only asked with respect to the most recent day each activity was done.**	**Yr 5-6, 7-11**

WalkSch **How long does it usually take you/your son/daughter to walk to/home from school?**	**Asked if child has walked to or from school any day.** **Less than 10 minutes Less than half an hour About half an hour About three-quarters of an hour One hour More than an hour Yr 3-6 'Don't know' or yr 7-11/parent 'Cannot give estimate'**	**Yr 3-6, 7-11, parents**
CycleSch **How long does it usually take you/your son/daughter to cycle to/home from school?**	**Asked if child has cycled to or from school any day.** **Less than 10 minutes Less than half an hour About half an hour About three-quarters of an hour One hour More than an hour Yr 3-6 'Don't know' or yr 7-11/parent 'Cannot give estimate'**	**Yr 3-6, 7-11, parents**
BrFast **When you did [activity], did it make you breathe faster than sitting down reading?**	**Asked for each activity done in the last week.** **Yes** **No**	**Yr 3-6, 7-11**

QUESTION	FURTHER INFORMATION	AGE GROUPS
Hot When you did [activity], did it make you hot or tired?	Asked for each activity done in the last week. Yes No	Yr 3-6, 7-11
SchTrav_bcd How did you [your son/daughter] get to school today? Please choose all the ways you [your son/daughter] came to school today.	Walked Rode a bike Scooter Car Bus Train or tram or tube None of these (please type in how you [your son/daughter] came to school)	Yr 3-6, 7-11, parents
We would now like you to think about all types of exercise and sport. How much do you agree or disagree with the following statements? PLEnjoy I enjoy taking part in exercise and sports. PLConf I feel confident when I exercise and play sports. PLEasy I find exercise and sports easy. PLGdMe I understand why exercise and sports are good for me. PLKnow I know how to get involved and improve my skills in lots of different types of exercise and sports.	Strongly agree Agree Disagree Strongly disagree Can't say	Yr 3-6, 7-11 Yr 3-6, 7-11 Yr 3-6, 7-11 Yr 3-6, 7-11 Yr 7-11 only
SwmCan Can you/your son/daughter swim?	Yes No	Yr 3-6, 7-11, parents

Swm25Can **Can you/your son/daughter swim a length of a swimming pool (25 metres) without stopping?**	**Asked if SwmCan = "Yes"** **Yes** **No**	**Yr 3-6, 7-11, parents**
Swm200Can **Can you swim 200 metres (eight lengths of a standard sized swimming pool) without stopping?**	**Asked if Swm25Can = "Yes"** **Yes** **No**	**Yr 7-11**
SwmStk **Which of the following swimming strokes can you do?**	**Ask if SwmCan = "Yes"** **Front crawl** **Backstroke** **Breaststroke** **Butterfly**	**Yr 7-11**

QUESTION	FURTHER INFORMATION	AGE GROUPS
SwmTrd **Can you stay in one place in the pool and keep your head above the water without holding onto the side or a float, and without touching the bottom of the pool? This is sometimes called treading**	Yes No	**Yr 3-6, 7-11**
SwmTrd (parents' version) **Can your son/daughter tread water? This means staying in one place in the pool and keeping his/her head above the water without holding onto the side or a float, without touching the bottom of the pool and without being held by someone.**	Yes No	**Parents**
SwmOft **Would you like to swim more often?**	Yes No	**Yr 3-6, 7-11**
SwmLake **Imagine that tomorrow you fall into a large lake. The lake is deep and you can't touch the bottom. You have all your clothes on, and you are about five metres away from the land (this is about the length of a large car). Could you get back to the land without someone helping you?**	Yes No	**Yr 3-6, 7-11**

Vol (Yr 3-6 version) **Since [current month] last year, have you volunteered, or given your time to do any of the following activities? Think only about when you do them to help with sports, exercise or dance.**	**Raised money for sports or dance at school or a club** **Been a 'sports leader' or 'sports ambassador'** **Helped with setting up or clearing away** **Helped with refreshments (food or drink)** **Given any other help. Please tell us what you did.** **No, have not done any of these activities since [current month] last year**	**Yr 3-6**

QUESTION	FURTHER INFORMATION	AGE GROUPS
Vol (Yr 7-11 version) **Since [current month] last year, have you volunteered, or given your time to do any of the following activities?**	**Raised money for a sports club, organisation or event (Only include fundraising for sport, not fundraising by taking part in a sports event or activity)** **Been a 'sports leader' or 'sports ambassador'** **Coached or instructed an individual or team(s) in a sport, dance or fitness activity (other than solely for family members)** **Refereed or umpired at a sports match, competition or event** **Acted as a steward or marshal at a sports or dance activity or event** **Provided any other help for a sport, dance or fitness activity (e.g. helping with refreshments; setting up sports kit or equipment, scoring matches, first aid). Please tell us what you did.** **No, have not done any of these activities since [current month] last year**	**Yr 7-11**
VolN **If one activity selected at Vol: And have you done [activity] more than once since [current month] last year?** **If more than one activity selected at Vol:** **Think about all those sport, dance and fitness activities you have given your time to support. Have you given your time more than once since [current month] last year?**	**Yes** **No**	**Yr 3-6, 7-11**

WellHp **Overall, how happy did you feel yesterday?**	**Scale 0-10 where:** **0 = Not at all happy** **10 = Completely happy** **This is a standardised wellbeing question**	**Yr 3-6, 7-11**
WellHpU **Is this how you usually feel?**	**Ye** **s** **N** **o**	**Yr 3-6**
WellSt **Overall, how satisfied are you with your life nowadays?**	**Scale 0-10 where:** **0 = Not at all satisfied** **10 = Completely satisfied** **This is a standardised wellbeing question**	**Yr 7-11**

QUESTION	FURTHER INFORMATION	AGE GROUPS
WellWt **Overall, to what extent do you feel that the things you do in your life are worthwhile?**	**Scale 0-10 where:** **0 = Not at all worthwhile** **10 = Completely worthwhile** **This is a standardised wellbeing question**	**Yr 7-11**
Try **Thinking about all the things you do at school and at home, how much do you agree or disagree with the following statement:** **If I find something difficult, I keep trying until I can do it.**	**Strongly agree** **Agree** **Disagree** **Strongly disagree** **Can't say**	**Yr 3-6, 7-11**
Trust **How much do you feel you can trust people who are a similar age to you?**	**I can trust them a lot I can trust them a bit** **I can't trust them very much I can't trust them at all**	**Yr 3-6, 7-11**
Lonely_c **How often do you feel lonely?**	**Often/always, Some of the time, Occasionally, Hardly ever, Never** **Prefer not to say**	**Yr 7-11**
Sex **Are you a…**	**Girl** **Boy** **Other** **Prefer not to say**	**Yr 3-6, 7-11**
SexOth **You have not categorised yourself as a boy or a girl. How would you describe yourself?**	**Asked if Sex = "Other"** **Fill in text box or choose "Prefer not to say"**	**Yr 7-11**
Age **How old are you/is your son/daughter?**	**Different age options presented depend on questionnaire version 5-16**	**Yr 3-6, 7-11, parents**

DobDD, DobMM **When is your son's/daughter's Birthday? Please tell us the day and the month.**	**Select day and month**	**Parents**
Eth **Which one of these best describes your background or race?**	**White (British or English) White (not British or English)** **Mixed race** **Asian or British** **Asian Black or Black British** **Other** **Prefer not to say**	**Yr 3-6, 7-11**
Eth (parents' version) **What is your son's/daughter's ethnic group?**	**More detailed response options provided than those shown to children. Includes "Prefer not to say"**	**Parents**

QUESTION	FURTHER INFORMATION	AGE GROUPS
DisNew_bcd Do you/Does your son/daughter have a disability, special need or illness (e.g. autism, dyslexia, or asthma), which makes it difficult for you/him/her to do any of these things? (see list below)	Yes No Don't know Prefer not to say	Yr 3-6, Yr 7-11, parents
DisHwNew_bcd Which of these [do you /does your son/daughter] have difficulty with because of [your/ your son's/daughter's] disability, special need or illness? Tick all the boxes that apply	Asked if DisNew_bcd = "Yes" Concentrating and paying attention (includes ADHD) How you [he/she] behave[s] in a way which makes life difficult (includes anger problems) Reading or writing (includes dyslexia) Using numbers (e.g. putting numbers the wrong way round) Difficulty learning or understanding new things (includes finding it hard to remember things) How you [he/she] feel[s] [and your[his/her] mental health] (including feeling anxious or depressed) Co-ordination (includes balance problems) Moving around including walking and running Using your [his/her] hands for writing or to pick things up (includes difficulty holding a pen) Seeing and using your [his/her] eyes (includes colour blindness) Hearing and using your [his/her] ears Speaking and	Yr 3-6, Yr 7-11, parents Only refer to mental health for Y7-11 and parents)

	communicating Breathing (includes asthma) Gives you [him/her] pain (e.g. hypermobility) Affects your [his/her] health for a long time (includes conditions such as diabetes) Something else you have [he/she has] difficulty with because of your [his/her] disability, special need or illness [please type in] None of these Don't know Prefer not to say	

QUESTION	FURTHER INFORMATION	AGE GROUPS
DisEff_bcd Does this disability, special need or illness have a big effect on your [his/her] life? [Do any of these disabilities, special needs or illnesses have a big effect on your [his/her] life?]	Ask if any code except 'none/DK/PNTS' at DisHwNew_bcd Ye s N o Don't know Prefer not to say	Yr 3-6, Yr 7-11, parents
DisYear_bcd Do you think this disability, special need or illness will last for a year or more? [Do you think any of these disabilities, special needs or illnesses will last for a year or more?	Ask if any code except 'none/DK/PNTS' at DisHwNew_bcd Ye s N o Don't know Prefer not to say	Yr 3-6, Yr 7-11, parents
Eatlunch Where do you normally eat lunch on school days? If it varies from day to day, choose the option which applies on most days	I mainly eat school lunches (food served by the school) I mainly go outside of school and buy my lunch I mainly bring a packed lunch to school I mainly go home to have my lunch	Yr 7-11
SchM Do your parents have to pay if you have school meals? Or: You say that you do not usually have a school lunch, but if you had a school lunch (food served by the school), would your parents have to pay for it?	Ye s N o Don't know	Yr 7-11
We would now like to ask you some questions to understand more about you, your home and your family FASCar Does your family own a car, van or truck?	The final series of questions are taken from the Family Affluence Scale used by the World Health Organisation to estimate socio-economic status No Yes, one Yes, two or more	Yr 3-6, 7-11, parents

	For parents: if respondent tries to skip past this question, "Prefer not to say" option will appear	
FASBed **Do you/does your son/daughter have your/his/her own bedroom for your/his/herself?**	**Yes** **No** **For parents: if respondent tries to skip past this question, "Prefer not to say" option will appear**	**Yr 3-6, 7-11, parents**

QUESTION	FURTHER INFORMATION	AGE GROUPS
FASpc **How many computers does your family own (including laptops and tablets, but NOT including game consoles and smartphones)?**	**None** **One** **Two** **More than two** **For parents: if respondent tries to skip past this question, "Prefer not to say" option will appear**	**Yr 3-6, 7-11, parents**
FASHol **How many times did you and your family travel out of England for a holiday last year?**	**None** **Once** **Twice** **More than twice** **For parents: if respondent tries to skip past this question, "Prefer not to say" option will appear**	**Yr 3-6, 7-11, parents**
FASBth **How many bathrooms are in your home?**	**None** **One** **Two** **More than two** **For parents: if respondent tries to skip past this question, "Prefer not to say" option will appear**	**Yr 3-6, 7-11, parents**
FASDsh **Does your family have a dishwasher at home?**	**Yes** **No** **For parents: if respondent tries to skip past this question, "Prefer not to say" option will appear**	**Yr 3-6, 7-11, parents**
Final **Thank you! That is the end of the survey.**		**Yr 3-6, 7-11, parents**

QUESTIONS – OVERVIEW (year 1-2 survey)

QUESTION	FURTHER INFORMATION
AGE **How old are you?**	5 6 7
BDAYMTH **Which month is your birthday in?**	**Select month**
SCHYR **Which school year are you in?**	Year 1 Year 2
SEX **Are you a boy or a girl?**	Boy Girl
WEEKSP1 **Have you done any of these sports in the last week? Please choose all the sports you did**	Football Netball or Basketball Cricket Swimming Gymnastics Tennis Rounders Judo or Karate I did another sport I did no sport
PLLIKESP **Do you like playing sport?**	I love playing sport I like playing sport I don't like playing sport I hate playing sport
PLEASY **Do you find sport easy?**	Yes No I don't know
WEEKAC1 **Have you done any of these things in the last week? Please choose all the things you did**	Walking Riding a bike Scooter Running games Climbing frame Trampoline Dancing Roller skating I did other activities I did

	no activities
PLLIKEAC2 **Do you like being active?** **This includes things like running games, riding a bike or scooter,** **walking, and dancing.**	I love being active I like being active I don't like being active I hate being active
SWIMLK **Do you like swimming?**	I love swimming I like swimming I don't like swimming I hate swimming I don't know

QUESTION	FURTHER INFORMATION
TRAVEL **How did you get to school today?** **Please choose all the ways you came to school today**	**I walked** **I rode a bike** **I went on a scooter I went in a car** **I went on a bus** **I went on a train or tram or tube**
WELLHP4 **How do you feel today?**	**Choice of:** 

QUESTIONS – OVERVIEW (teachers' survey)

QUESTION	FURTHER INFORMATION
URN	Enter unique reference number
YRGROUP_E What school years does this school include? Select all that apply	Options displayed are based on type of school – primary/secondary/other. The answer to this determines which subsequent questions and response options are displayed. Reception – Year 13
~~TEACHYR~~ ~~Which year groups do you currently teach? Please only include year groups you teach regularly, including year groups you teach to cover other staff on a regular basis.~~	~~Options selected at YRGROUP_E are presented,~~ ~~plus "Do not teach any specific year group"~~
SPROLE_E Do you hold any PE or sport related roles in the school?	Response options shown depend on school phase (primary or secondary) Specialist PE teacher PE lead/PE and Sport Co-ordinator School sports co-ordinator Sports specialist trainee or apprentice Sports coach School Games Organiser/ Assistant School Games Organiser (SGO/ASGO) Other (please specify) None of these
ROLE_E Do you hold any of these leadership roles or responsibilities in the school?	Response options shown depend on school phase (primary or secondary) Head teacher Deputy Head Assistant Head Curriculum area lead/Department Head/Head of Faculty Phase leader e.g. Head of Early Years Lead for any non-

	curriculum areas (e.g. safeguarding, careers, co-curricular activities) SEN co-ordinator Other (please specify): text box None of these
PETRAINSCH Has the school offered any training specific to PE, sport or physical activity in the last year to either yourself or colleagues? Please check with colleagues if you are unsure.	Yes but just to PE teachers Yes to everyone No Don't know
SPORTFAC Which of the following facilities does the school have? Select all that apply	Select from a list of facilities, "other specialist of sports facilities (please specify)" or "none of these"

QUESTION	FURTHER INFORMATION
COMMUSE1 **Does the school make any of these facilities available for community use?** **By community use we mean any activity outside of school time or children's education where facilities are used predominantly by community groups (for instance local sports clubs, or for adult education). Sharing facilities with other primary or secondary schools should not be included.**	**Yes – for sport related reasons** **Yes – for non-sport related reasons** **Yes, for both sport and non-sport related reasons No** **Don't know**
COMMUSE2 **Which of these facilities does the school make available for community use?**	**Asked if COMMUSE1 = "Yes". Response options selected at SPORTFAC are shown again.**
EXTFAC **What extra facilities or equipment would help enhance your PE and Sport offer?**	**Same response options as SPORTFAC**
TRAVMON **Does your school monitor how pupils travel to school?**	**Ye s** **No** **Don't know**
WALK **Does the school participate in Walk to School week or other similar initiatives promoting active travel to school?**	**Asked if primary school Yes** **No** **Don't know**
ACTTRAV **Does the school do anything to promote active travel to school?**	**Asked if secondary school Yes** **No** **Don't know**
TIMEBT, TIMELT **How long are break and lunch time at the school?** **If the length varies, please tell us the longest time that any pupils have**	**Answers given in minutes for break time and lunch time**

TIMEBSC1, TIMELTC2, TIMEASC3 **Below are a number of school-based activities. For each one, please type in how many minutes a single session usually lasts at the school.** **Think only of activities involving sport and physical activity.** **Think of the time when pupils are doing the activities. Do not include changing time.**	**Answers given in minutes for:** **Before school sports or exercise clubs or training Lunch time sports or exercise clubs** **After school sports or exercise clubs or training**

QUESTION	FURTHER INFORMATION
TIMEPE ***For primary schools*:** **For each year group, how much time each week do pupils spend doing PE lessons in school (i.e. curriculum PE)?** **Please provide the time usually spent, including changing time.** ***For secondary, middle and all through schools*: For each year group, how much time each week do pupils spend doing PE or Games lessons in school (i.e. curriculum PE)? Please only think about core PE time, and ignore any additional time for those studying PE at GCSE. Please provide the time usually spent.**	**Answers in minutes per week for each year group selected at YRGROUP**
SESSPE_E **Still thinking about a typical week, how many PE sessions do pupils have?**	**Number of sessions per week**
SWIM1 **This year [year] which year groups, if any, will have (or have already had) swimming lessons provided by the school? Include swimming lessons arranged by the school, wherever they take place.**	**Year groups selected at YRGROUP shown plus** **"Swimming lessons are not offered".**
SWIM2 **How many school swimming sessions does each pupil get during the whole school year? Think only of standard class swimming lessons, not swimming clubs or team training.**	**Ask unless "swimming lessons not offered" at SWIM1** **Fewer than 10 (e.g. weekly sessions for half a term)** **10-19 (e.g. weekly sessions for a whole term) 20-29 (e.g. weekly sessions for two terms) 30 or more (e.g. weekly sessions for three terms) None of these**

SWIM3 **What is the length of the main swimming pool at the facility used by pupils for swimming lessons?**	**Ask unless "swimming lessons not offered" at SWIM1** **Less than 25 metres** **25 metres** **30-33 metres** **50 metres** **Other length – please specify**
SWIMNC **What would support you to better deliver the national curriculum requirement that all children are able to swim at least 25 metres by the end of key stage 2?**	**Additional teacher training in swimming and water safety** **Additional resources for teachers** **Having additional funding (to cover the costs of pool hire/ transport etc.)** **Better access to facilities** **Higher priority placed on swimming within the school** **Additional teacher available for swimming lessons** **Other (please specify)**

QUESTION	FURTHER INFORMATION
SPORTS **Which of the following activities are offered at the school during PE lessons? Include activities delivered by external providers if part of standard school lessons.**	**Select from a list of activities, with text boxes for "other team or ball sports (please specify)" and "other sports or exercise activities"**
SPORTSCLUBS **Which of the following activities are offered at the school before school, during lunchtime or at after school clubs? Include activities for pupils offered at school by outside providers. Include any clubs offered during this school year [year] even if not currently on offer.**	**Select from a list of activities, with text boxes for "other team or ball sports (please specify)" and "other sports or exercise activities"**
PEPREM **Has additional support been targeted at any of the following groups as a result of the PE and sport premium funding which all state- funded schools receive?**	**Asked if school is state-funded (not independent)** **Boys** **Girls** **Those less engaged/ least active in PE and sport** **Children lacking in PE skills, agility and confidence** **Overweight children** **Disadvantaged children (e.g. those eligible for free school meals** **Children with SEN Specific year groups** **Other (please specify): text box** **No targeting of specific groups**
TRANSIT1 (primary schools) **Does the school do any of the following activities to support the transition of pupils from primary to secondary school?**	**Offer an introduction to sports which are part of the secondary curriculum** **Teach children the fundamental skills needed to access the secondary PE curriculum Engage with local secondary schools to ensure a smooth transition for pupils** **Other (please specify): text box** **No, none**

TRANSIT2 (secondary schools) Does the school do any of the following activities to support the transition of pupils from primary to secondary school?	**School staff assist primary schools in delivering activities such as PE lessons, sports day or after school clubs** **School runs taster sessions or holiday sports camps or clubs open to primary pupils School runs sports competitions for primary schools to participate in** **Have a dialogue with your feeder primary schools** **Support primary schools to offer an introduction to secondary school sports for pupils** **Other (please specify):** **text box No, none**

QUESTION	FURTHER INFORMATION
INTROFOOD **Now there are two questions about school food, included because they relate to pupils' more general health and wellbeing. If necessary, please consult another member of staff in answering these questions.**	**No response options shown**
FOODED **How does the school provide food education for all pupils and develop their skills in preparing nutritious meals?**	**Response options shown depend on school phase (primary or secondary)** **Pupils are encouraged to support catering staff in the preparation and serving of school food School has some food grown on-site by students which is used for preparation of school meals** **School supports teaching staff in their professional development around food and nutrition** **School ensures healthy eating is a priority in the curriculum** **School ensures healthy eating is a priority in food technology or PSHE classes** **School routinely provides cooking lessons as part of the curriculum at Key Stage 4** **School runs an extracurricular cooking club at least once per month, open to all pupils Other initiatives ~~(please specify)~~** **None of these**

FOODSFS **How does the school ensure it is complying with the School Food Standards (SFS)?**	**School ensures SFS compliance is included in catering contract** **School gains at least annual assurance over SFS compliance from caterers / local authority** **School is part of a food or menu award, accreditation, audit or inspection scheme (such as Food for Life or Healthy Schools London)** **School ensures catering staff are trained and supported in providing meals that meet the school food standards** **School has nominated governor with specific responsibility for school food** **School complies with the SFS throughout the school day, including during school lunches, break-times and before or after school clubs** **School goes beyond SFS and has a school food policy which bans pupils from bringing in food or drink high in sugar, salt or fat** **Other initiatives ~~(please specify)~~ None of these** **Don't know**

Appendix B

Taken directly from https://www.sportengland.org/

Indoor outdoor assumptions from sport England
Location of activity assumptions:

If location was provided, then the answer was used. Where location was not provided then an assumption was made based on activity and whether in or out of school. For year 1-2 and year 3-4 pupil's location was always assumed.

Table A1: Location of activity assumption

Activity	OUTSIDE SCHOOL assumption	IN SCHOOL assumption
Walking to school	Outdoors	n/a
Walking home from school	Outdoors	n/a
Walking to get somewhere else (not to or from school)	Outdoors	Outdoors
Walking - type not specified (could be for travel or going on a walk)	Outdoors	Outdoors
Going on a walk (includes walking a dog)	Outdoors	Outdoors
Riding a scooter	Outdoors	Outdoors
Cycling to school	Outdoors	n/a
Cycling home from school	Outdoors	n/a
Cycling to get somewhere else (not to or from school)	Outdoors	Outdoors
Cycling - type not specified (could be for travel or fun)	Outdoors	Outdoors
Cycling for fun	Outdoors	Outdoors
Dancing	Indoors	Indoors
Kicking a ball about	Outdoors	Outdoors
Skateboarding, roller skating	Outdoors	Outdoors
Trampolining (including in a garden, at a trampoline centre, or as part of a club)	Outdoors	Indoors
Frisbee, throwing/catching, skipping	Outdoors	Outdoors
Playing it, tag, chase, sardines or other running game	Outdoors	Outdoors
Climbing or swinging in playground, garden or park	Outdoors	Outdoors
Swimming	Indoors	Indoors
Football	Outdoors	Outdoors
Netball	Outdoors	Outdoors
Hockey	Outdoors	Outdoors
Cricket	Outdoors	Outdoors
Rugby	Outdoors	Outdoors
Baseball, softball	Outdoors	Outdoors
Rounders	Outdoors	Outdoors
Basketball	Outdoors	Indoors
Dodgeball / benchball	Indoors	Indoors

Table tennis / ping pong	Indoors	Indoors
Badminton	Indoors	Indoors
Tennis	Outdoors	Outdoors
Gymnastics	Indoors	Indoors
Cheerleading	Indoors	Indoors
Running / jogging/ cross-country/ the daily mile	Outdoors	Outdoors
Sports day	Outdoors	Outdoors
Field athletics	Outdoors	Outdoors
Gym or fitness (fitness class e.g. yoga, or using exercise machines e.g. rowing machine, exercise bike, running machine)	Indoors	Indoors
Horse riding	Outdoors	Outdoors
Martial arts (Judo, karate, taekwondo and other martial arts)	Indoors	Indoors
Boxing	Indoors	Indoors
Climbing	Outdoors	Indoors
Ice skating	Indoors	Indoors
Water sports (e.g. canoeing, kayaking, sailing, rowing, surfing)	Outdoors	Outdoors
Volleyball	Indoors	Indoors
Archery	Outdoors	Outdoors
Fencing	Indoors	Indoors
Lacrosse	Outdoors	Outdoors
Water polo	Indoors	Indoors
Hula hooping	Outdoors	Outdoors
Karting	Outdoors	Outdoors
Golf	Outdoors	Outdoors
Handball	Indoors	Indoors
King ball	Indoors	Indoors
Korfball	n/a	n/a
Motorsports	Outdoors	Outdoors
Tai Chi	Indoors	Indoors
Roller hockey	Indoors	Indoors
Snow sports	Outdoors	Outdoors
Squash or racketball	Indoors	Indoors
Angling	Outdoors	Outdoors
Kick boxing, MMA or self defence	Indoors	Indoors
Acrobatics	Indoors	Indoors
Sledging	Outdoors	Outdoors
Orienteering	Outdoors	Outdoors
Other active play	Outdoors	Outdoors
Other team sport	Outdoors	Outdoors
Other racket sports	Indoors	Indoors
Other combat sport, martial art or target sport	Indoors	Indoors
Multi-sports	Indoors	Indoors
Adventure or outdoor sports	Outdoors	Outdoors
Leisure games: Snooker, pool, billiards, ten pin bowling, skittles, darts	Indoors	Indoors
Other fitness or gym	Indoors	Indoors
Other sport or fitness activity	Indoors	Indoors

Appendix C

Taken directly from https://www.sportengland.org/

Duration assumptions sport England

Minutes Assumption
Where minutes outside school were provided by the respondent these were used for number of minutes (with slight downward adjustment of reported time based on objective measurement study)

Questionnaire response	Coded value used in derivation
Less than 10 minutes	5 minutes
About quarter of an hour	10 minutes
About half an hour	25 minutes
About three-quarters of an hour	35 minutes
One hour	50 minutes
More than one hour	60 minutes but there are three exceptions - going on a walk (2), Running (27) and Golf (58) where coded as 75 if in this category
Don't know	CODE ACCORDING TO ACTIVITY AND AGE. See list below

Where minutes were not provided the minutes were imputed using the figures here which varied by school year and whether at or outside school. All at school activity was imputed.

Table A2: Minutes imputed

Activity	Imputed minutes outside school					Imputed minutes at school		
	Year 1-2 (parents)	Year 3-4	Year 5-6	Year 7-11		Year 1-2 (parents)	Year 3-6	Year 7-11
Walking to school	10	10	10	10		-	-	-
Walking home from school	10	10	10	10		-	-	-

Walking to get somewhere else (not to or from school) (pupil)	25	10	25	25		20	15	30
Walking to get somewhere else (not to or from school) (parent)	25	10	25	25		20	15	30
Going on a walk (includes walking a dog)	35	25	25	25		20	15	30
Riding a scooter	10	10	25	25		20	15	30
Cycling to school	10	10	10	10		-	-	-
Cycling home from school	10	10	10	10		-	-	-
Cycling to get somewhere else (not to or from school) (pupil)	25	25	25	25		20	15	30
Cycling to get somewhere else (not to or from school) (parent)	25	25	25	25		20	15	30
Cycling for fun	25	25	25	35		20	15	30
Dancing	25	25	35	35		20	15	30
Kicking a ball about	25	25	25	25		10	10	5
Skateboarding, roller skating	25	25	25	25		20	15	30
Trampolining (including in a garden, at a trampoline centre, or as part of a club)	25	25	25	25		20	15	30
Frisbee, throwing/catching, skipping	10	10	10	10		10	10	5
Playing it, tag, chase, sardines or other running game	25	25	25	25		10	10	5
Climbing or swinging in playground, garden or park	25	10	10	10		10	10	5
Swimming	25	25	35	50		20	15	30
Football	35	35	35	35		20	15	30
Netball	35	25	35	35		20	15	30
Hockey	35	25	35	35		20	15	30
Cricket	25	25	25	35		20	15	30
Rugby	50	35	35	50		20	15	30
Baseball, softball	25	25	10	25		20	15	30
Rounders	10	25	25	25		20	15	30
Basketball	25	25	25	35		20	15	30
Dodgeball / benchball	25	25	25	25		20	15	30
Table tennis / ping pong	10	10	10	25		20	15	30
Badminton	25	25	25	35		20	15	30
Tennis	35	25	25	35		20	15	30
Gymnastics	35	35	35	35		20	15	30

Cheerleading	35	25	35	35		20	15	30
Running / jogging/ cross-country/ the daily mile	10	25	25	25		20	15	30
Sports day	35	35	35	35		20	15	30
Field athletics	25	25	25	35		20	15	30
Gym or fitness (fitness class e.g. yoga, or using exercise machines e.g. rowing machine, exercise bike, running machine)	25	25	25	35		20	15	30
Horse riding	35	35	35	50		20	15	30
Martial arts (Judo, karate, taekwondo and other martial arts)	35	35	35	50		20	15	30
Boxing	35	25	35	35		20	15	30
Climbing	25	10	10	25		20	15	30
Ice skating	35	35	35	50		20	15	30
Water sports (e.g. canoeing, kayaking, sailing, rowing, surfing)	50	25	35	35		20	15	30
Volleyball	25	25	25	25		20	15	30
Archery	25	25	25	25		20	15	30
Fencing	25	25	25	25		20	15	30
Lacrosse	25	25	25	25		20	15	30
Water polo	25	25	25	25		20	15	30
Hula hooping	25	25	25	25		20	15	30
Karting	25	25	25	25		20	15	30
Golf	25	25	25	25		20	15	30
Handball	25	25	25	25		20	15	30
King ball	25	25	25	25		20	15	30
Korfball	25	25	25	25		20	15	30
Motorsports	25	25	25	25		20	15	30
Tai Chi	25	25	25	25		20	15	30
Roller hockey	25	25	25	25		20	15	30
Snow sports	25	25	25	25		20	15	30
Squash or racketball	25	25	25	25		20	15	30
Angling	25	25	25	25		20	15	30

Kick boxing, MMA or self defence	25	25	25	25		20	15	30
Acrobatics	25	25	25	25		20	15	30
Sledging	25	25	25	25		20	15	30
Orienteering	25	25	25	25		20	15	30
Other active play	25	25	25	25		10	10	5
Other team sport	25	25	25	25		20	15	30
Other racket sports	25	25	25	25		20	15	30
Other combat sport or martial art	25	25	25	25		20	15	30
Multi-sports	25	25	25	25		20	15	30
Adventure or outdoor sports	25	25	25	25		20	15	30
Leisure games: Snooker, pool, billiards, ten pin bowling, skittles, darts	25	25	25	25		20	15	30
Other fitness or gym	25	25	25	25		20	15	30
Other sport or fitness activity	25	25	25	25		20	15	30
Walking - type not specified (could be for travel or going on a walk)	25	10	25	25		-	-	-

Appendix D

Technical note on the Active Lives Children and Young People Survey 2018-2019.

Taken directly from https://www.sportengland.org/

Ipsos MORI
Social Research Institute

Technical note sport England
a



December 2019
ActiveLivesChildrenandYoung People Survey 2018/2019
Year 2 Technical Note
September 18 – July 19

IpsosMORI

The Active Lives Children and Young People Survey was conducted by Ipsos MORI on behalf of Sport England which commissioned the survey to inform both their own strategy and the strategies of the Department for Digital, Culture, Media and Sport (DCMS), the Department for Education (DfE) and the Department of Health and Social Care (DHSC).

The published data which this note accompanies are presented for Year 1 (academic year 2017/18) and Year 2 (academic year 2018/19). This document provides details about Year 2 of the survey, with differences from year 1 pointed out. Full details about Year 1 are provided in the Year 1 technical note.

Fieldwork and Survey Design

The new data presented here were collected during year 2 of the survey, between September 2018 and July 2019 (2018/19 academic year) in England. The data were collected using CAWI online questionnaires administered in schools. There were three types of questionnaire:

Short simple questionnaire for pupils in year 1-2 (age 5-7),

Questionnaires for pupils in year 3-11 (age 7-15/16) and parents of pupils in year 1-2,

Questionnaire for one teacher in each school (most often the PE lead but also heads, deputies and other teachers).

The table in the questionnaire content section shows which year groups and participant types were asked each type of question. The questionnaire content varied by age so as not to over-burden younger pupils.

Valid responses from sampled schools which could be used for analysis are shown below:

Number of valid responses from sampled schools used in analysis

School type	Year 1	Year 2
Year 1-2 pupils	25,927	23,587
Year 3-11 pupils and parents of pupils in year 1-2	109,503	113,728
Teachers	1,623	1,524

Pupils took part during school time using school computers or tablets. Teachers and parents took part at school or on their own computers or tablets at home. Information about the survey was provided to schools, class teachers, pupils and parents in advance of taking part in the survey.

Sample design

The survey design is schools based. The sample design was generally the same as the first year of the survey (2017/2018) to ensure comparability; any differences have been noted.

A sample of schools was drawn from the Department for Education list of schools (Edubase 2017/18)[1]. The database contained 24,281 schools, from which certain types of establishment were removed[2] before selection of the sample resulting in a sample frame of 21,351 schools. Of these 6,101 were selected as main sample and 2,003 as a reserve sample. The main sample was designed to include up to ten primary and ten secondary schools in each local authority and 370 independent schools across the country. The reserve sample comprised up to five primary and five secondary schools in each local authority but not every local authority had sufficient schools. State schools with a probability of selection of one or greater were automatically included in the sample. The remaining state schools were selected with a probability proportional to size. The sample of independent schools was stratified by local authority and pupil count. Reserve schools were only issued in local authorities where insufficient responses had been obtained from the main sample.

The main sample schools were allocated to a term using systematic random sampling. The sample was designed to include 35% of the schools in the autumn term, 35% in the spring term and 30% in the summer term (in year 1 this was 30%/ 40% /30%; the adjustment was made in order to achieve equal numbers in the Autumn and Spring terms). The main issued sample of schools was 2,136 in the autumn term, 2,136 in the spring term and 1,829 in the summer term. In the spring term 237 reserve schools in 95 local authorities were issued and in the summer term 207 reserve schools in 96 local authorities were issued.

For each school up to three year groups were selected (only two in schools which only had two eligible year groups). The sample was designed to ensure that where possible year groups affected by summer

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1 Since the sample was drawn, Edubase has changed and is now referred to as 'get information about schools' (GIAS).

2 Nurseries, Pupil Referral Units, Special schools, Technology and Technical colleges, Studio schools, Sixth form colleges, schools with fewer than 30 pupils or containing only one year group.

exams were oversampled in earlier terms (and even more so than in the 2017/18 survey). Schools could opt-in to take part in the survey if they had not been sampled. The data for these schools are not included as part of the national dataset and so are not included in this report.

The information about the selected schools and the selected year groups in each school was communicated to Active Partnerships (APs) who were responsible for asking schools to participate. They did this directly with schools or through third parties such as School Games Organisers. Once a school had agreed to take part they used a Kish Grid provided by Ipsos MORI to select one mixed ability class within each of their selected year groups. URLs for the online surveys were then provided to each school. There were unique URLs for each school but not each pupil or parent.

The table below shows the number of schools with any pupil responses included in the analysis dataset in each term by type of school. This includes schools with partial pupil responses in cases where the questionnaire was completed sufficiently to be included in the analysis. Cases were included in the analysis if pupils in year 3-11 and parents completed all the activity questions in the survey and if year 1- 2 pupils responded to the question which asked whether they like playing sport. This table excludes schools which opted into the survey but which are not used for national level analysis (of which there were 44). This also excludes schools where a teacher responded but there were no pupil responses (of which there were 81[3]). There were seven sampled schools for which responses were received in more than one term. In the table below the schools only appear in one term to avoid double counting.

[3] Of the 81 schools where a teacher responded but no pupils 37 were primary, 43 were secondary and 1 was independent. Among the 1,907 responding schools 465 had no teacher response.

Number of schools with partial or complete pupil responses in the 2018/19 academic year

School type	Autumn term	Spring term	Summer term	Total
State Primary	362	405	335	1,102
State Secondary	252	278	249	779
Independent	10	6	10	26
Total	624	689	594	1,907

Number of schools with partial or complete pupil responses in the 2017/18 academic year

School type	Autumn term	Spring term	Summer term	Total
State Primary	326	503	365	1,194
State Secondary	249	281	251	781
Independent	16	13	7	36
Total	591	797	623	2,011

Weighting

Weighting is required to reduce the risk of bias in survey estimates. Weights are produced to make the weighted achieved sample match the population as closely as possible. For the Active Lives Children and Young People Survey the weights correct for non-response by schools.

For state schools the weighting involved calibration to counts of school year by gender, counts of pupils in schools with more than 20% of pupils getting free school meals and counts of pupils in schools in a rural area. This was done separately for each region. It was not possible to adjust for local authority counts as there were two local authorities in which no schools participated. However, instead counts of pupils in NUTS2 (Nomenclature of Territorial Units for Statistics) geographical areas were used as there was at least one responding school in each area. Independent schools were calibrated by counts of school year and gender. We explored the possibility of calibrating by region for independent schools but there were several regions with no independent school pupils in year 3-6 or 7-11 responding to the survey. It should be noted that results by region include pupils in independent schools but the data for independent school pupils has not been weighted by region.

The population estimates for weighting are produced from DfE pupil population estimates from Edubase[4] (2017/18). The sample for year 2 (2018/19) was drawn from 2017/18 school data because the sample was selected during the previous academic year so that APs could contact schools in advance of the fieldwork term. For consistency, the weighting was carried out using the same data which had been used for sampling.

In year 2 we noted that a number of schools had substantially more responding pupils than the selected 30 per up to three selected classes. In some cases this appeared to be because schools which had opted in additional pupils (which is an option offered to schools) had asked these opted-in pupils to complete using the URLs for sampled pupils only. Therefore, the weighting for year 2 was designed to trim the number of weighted pupils to 40 per class in the school, to avoid these additional pupils affecting the national results.

Weights have been calculated for pupils and parents. There are no weights for teachers and any teacher analysis is carried out unweighted (though the year 2 report contains no teacher results). Some of the data reported in the wellbeing tables involves analysis of matched year 1-2 pupil data with parent data for those year groups. This is only done when an individual match can be made based on gender, date of birth, year group and school. For this analysis the parent weight was used.

Minimum base sizes

The data has been suppressed for certain cells in the data tables:

Where the unweighted number of respondents responding to the question overall or to an individual category is less than 30, results are not presented. The symbol * is used to indicate this
Where the number of schools contributing to the results for a local authority is 2 or fewer. The symbol ^ is used to indicate this
Where the unweighted base for a local authority is less than 150. The symbol ^ is used to indicate this

[4], Since the estimates were produced Edubase has changed its name and is now referred to as 'get information about schools' (GIAS).

Where there is a difference in school phase[5] for a local authority across survey years and one of the survey years has just one phase e.g. just years 3-6 in year 1 and all 3 phases in year 2. The symbol ^ is used to indicate this

Confidence Intervals

Confidence intervals for the measures presented in the report can be found in the linked report tables. Confidence intervals indicate that if repeated samples were taken and confidence intervals computed for each sample, 95% of the intervals would contain the true value. Confidence intervals vary for each measure and each demographic breakdown.

Confidence intervals have been calculated using the complex survey package in SPSS, which takes account of design effects. They are presented for rates (%) in the report tables. Confidence intervals would also apply to the population estimates presented in the report and report tables.
Sometimes confidence intervals cannot be provided, for example when the rate is 100%. In this case the symbol ^ is used. See the next section for more detail on the other circumstance in which confidence intervals cannot be calculated.

Design effects

For analysis by demography and large geography (region and Active Partnership) the calculation of confidence intervals takes account of strata (local authority) and clustering (school). Where there is only one school in a strata overall or for the demographic sub-groups being presented, confidence intervals cannot be calculated. The symbol ^ is used where confidence intervals cannot be calculated because only one school took part in each local authority covered by the particular demographic or geographic category being shown. For analysis by local authority, the confidence intervals take account of strata but not clustering because using the full design effects resulted in too many local authorities having missing confidence intervals.

[5] Where the three school phases are school years 1-2, 3-6 or 7-11

Significance Testing

The report and accompanying tables show data for the last two survey years (academic year 2017/18 and academic year 2018/19). This has allowed for analysis of the change in participation and activity levels over time. Note that analysis for year 1 has been carried out to ensure the categories being presented are comparable with year 2. For example, the local authorities presented for both years are the new, post-April 2019 local authorities. The same measures are presented in this report for both years, even if these differ from the measures presented in the Year 1 report in December 2018.

To compare data across the two survey years, significance testing has been applied to the report tables. This indicates whether changes observed across survey years are likely to be 'true' changes in the population, rather than just observed by chance. Comparisons are between year 2 (2018/19) and year 1 (20176/18).

Standard errors were generated using the complex samples module in SPSS: these were then applied to t-tests to assess statistical significance.

Only differences which are statistically significant are reported on as differences in the commentary. Where results are reported as being the same for two groups, this means there is no statistically significant difference.

Population estimates

These are estimates of the number of pupils in a particular group (for example, the number of pupils in the less active group, or the number of boys who have attended a live sports event at least twice in the last year).

These estimates have been calculated using the rate (%) and the 2018/19 DfE pupil population estimates, and therefore the true value would lie within a range around the estimates. The 2018/19 DfE pupil data was used so that the estimates would be based on the data for the academic year the survey took place. For sub-groups the population estimate is calculated from the share of the weighted responses for that category. The confidence intervals for the population estimates can be calculated by dividing the population estimate by the rate (%) and multiplying by the lower and upper confidence interval rates in

the report tables. In some cases a population estimate has not been provided. ** is used where a decision has been made not to publish population estimates. For example, for disability because the categorisation in the data does not match those provided in population data.

Questionnaire content

Owing to the wide age range covered by the survey, different questions were asked to different year groups. This reflected:
whether questions are relevant (e.g. volunteering is not relevant for most year 1-2 pupils),
whether children could be expected to understand and answer questions on that topic (e.g. younger pupils were not expected to answer questions about life satisfaction),
the time it took younger pupils to answer the questionnaire (questions were omitted for year 3-4 pupils to reduce questionnaire length and burden),
whether questions can be answered by parents on behalf of their child (e.g. parents were not asked about their child's wellbeing).

For comparability the questionnaire was kept broadly the same as the year 1 version although there were some changes. The table on the following page shows which year groups were asked each question for the questions included in the annual report and tables. This is also clearly indicated on each table.

For details about the development of the survey please refer to the Year 1 Technical Report available from the United Kingdom Data Service.

Details of the questions asked of respondents and presented in the 2018/19 report

Questions content by year group	Year 1-2 pupils	Year 1-2 parents	Year 3-4 pupils	Year 5-6 pupils	Year 7-11 pupils
Activities					
Participation in sport and physical activity in last week (activities in and out of school and time spent out of school) (time spent in school assumed)	No	Yes	Yes	Yes	Yes
Intensity of activity (whether made them breathe faster, whether made them hot or tired)	No	No – moderate intensity assumed	Yes but for some activities intensity assumed	Yes but for some activities intensity assumed	Yes but for some activities intensity assumed
Whether outside school activity done indoors or outdoors (NB indoor/outdoor is assumed for all at school activity)	No	No - location assumed based on Year 5-11 pupils responses	No – location assumed based on Year 5-11 pupils responses	Yes	Yes
Attitudes Extent to which enjoy sport and physical activity, feel confident taking part, find it easy (competence), understand why it is good for them, and know how to get involved or improve their skills	Yes but amended - only whether like playing/ being active/ find it easy	No	Yes apart from how to get involved / improve skills	Yes apart from how to get involved / improve skills	Yes
Swimming					
Whether can swim at all, 25m, tread water	No	Yes	Yes	Yes	Yes
Whether can swim 200m	No	No	No	No	Yes
Whether can self-rescue, would like to swim more often	No	No	Yes	Yes	Yes
Do you like swimming	Yes	No	No	No	No
Volunteering frequency and type (types vary between year 5-6 and 7-11 pupils so are presented separately)	No	No	No	Yes	Yes
Wellbeing and development					
Happiness	Smiley face	No	Yes	Yes	Yes
Life satisfaction and how worthwhile life is	No	No	No	No	Yes
Individual development (resilience)	No	No	Yes	Yes	Yes
Community development (trusting peers)	No	No	Yes	Yes	Yes
Live sporting events	No	No	No	Yes	Yes
Demographic and social questions					
Gender, age, year group	Yes	Yes	Yes	Yes	Yes
Ethnicity	No	Yes	Yes	Yes	Yes
Disability (different for year 3-6 and year 7-11 and parent)	No	Yes	Yes	Yes	Yes
Family affluence scale	No	Yes	Yes	Yes	Yes

Definitions used in the report

Activity data in the report

Activity questions

The data were collected by asking:

which activities from a list pupils had done in the last 7 days,
on which days they had done each activity in the last 7 days (separately for in and out of school),
how long they spent doing the activity the last time they did it (outside school), and
whether it made them breathe faster or made them hot or tired.

Respondents could also mention other activities which were not listed on the questionnaire and these were coded to the relevant activity.

Year 5-11 pupils were also asked whether they did each out of school activity indoors or outside (except for certain activities such as cycling for travel which were assumed). The indoor/outdoor location of all in school activities and all activities for year 1-4 pupils was assumed using a standard approach.

Moderate activity: This is defined as activity where you raise your heart rate and feel a little out of breath (pupils were asked whether it made them breathe faster).
Vigorous activity: This is defined as when you are out of breath or are sweating - you may not be able to say more than a few words without pausing for breath (pupils were asked whether it made them hot or tired)
In year 2 a change was introduced for half the pupils in year 3-11 (alternate pupils going into the survey across all three terms). Half were asked the same question about moderate intensity activity as in year 1 and half were asked a slight different question which asked 'breathe faster than sitting down reading'. By providing the comparison with sitting down reading, more of the activity done was classed as moderate intensity which has an impact on the amount of moderate plus intensity activity reported by pupils.
For year 1-2 pupils all activity has been assumed to be moderate intensity since parents were not asked about intensity for their children.

Deriving and cleaning activity data

Information on activities, time spent, intensity and location were combined and fed into the measures presented in the analysis (levels of activity and specific activities participated in). The following rules and edits were used in preparing the derived activity variables:

The questionnaire was set up such that people selected the activities they did. Any activity which was not selected was assumed not to have been done.

Where respondents provided duration information for an activity outside school, this was done as response groups (e.g. about half an hour, about three-quarters of an hour) and we allocated a set time for each for creating the derived activity variables (based on evidence from an objective measurement study[6], a standard duration falling within the band was applied). The data have been cleaned such that missing durations for outside school have been imputed using standard durations for that activity. Pupils were not asked about time spent on activities in school and so for all activities in school durations have been imputed using a standard set of times related to the year group and type of activity based on data for outside school, information from teachers on PE and break time durations and the results of the objective measurement study.

Where information on duration, location or intensity was missing, standard rules were used to impute the data so that activity variables could be calculated for every case in the dataset.

Where pupils mentioned an excessive number of activities over the previous week the case was dropped from the data. Data were dropped for cases with more than 25 activities per day on average, resulting in 418 cases being dropped from the data from sampled schools.

In Year 2 a change was made to the questionnaire so that for a small number of activities the level of intensity was assumed rather than asked. This does not affect the comparison with Year 1 because though intensity was asked for these activities in Year 1, intensity was assumed in the creation of derived variables. In the implementation of this change in Year 2 an error was introduced to the script which meant that intensity was not asked for walking and cycling for travel when it should have been. To rectify this issue, for the data collected during the first half of the survey year (to February 2019) when intensity was not asked, imputation was used for intensity. The table overleaf shows how this was applied, taking account of various factors including the intensity at which the participant reported going for a walk or cycle (for which intensity was asked), how long they walked or cycled for and the intensity of the other activities

[6] In the objective measurement study pupils used a wrist worn accelerometer and completed the questionnaire so that their objective data could be compared with the data collected in the questionnaire.

they reported. The imputation approach was based on information from Year 1, when intensity had been collected. The resulting figures showed similar levels of activity as in the equivalent term in Year 1.

Imputation assumptions for missing intensity for walking and cycling for travel

<table>
<tr><td>Walking for Travel</td><td></td><td colspan="4">% activities reported as moderate plus</td></tr>
<tr><td></td><td>Duration of their walking for travel</td><td><50%</td><td>50-74%</td><td>75%+</td><td>Missing</td></tr>
<tr><td rowspan="3">Going for a walk = light</td><td>< 30 mins</td><td colspan="4" rowspan="3">Set all to light</td></tr>
<tr><td>30-45 mins</td></tr>
<tr><td>60+ mins</td></tr>
<tr><td rowspan="3">Going for a walk = moderate plus</td><td>< 30 mins</td><td>Set to light</td><td colspan="3">Set 50% minutes light, 50% vigorous</td></tr>
<tr><td>30-45 mins</td><td colspan="4">Set 50% minutes light, 50% vigorous</td></tr>
<tr><td>60+ mins</td><td colspan="4">Set to vigorous</td></tr>
<tr><td rowspan="3">Did not report going for a walk</td><td>< 30 mins</td><td colspan="2" rowspan="3">Set to light</td><td colspan="2">Set to light</td></tr>
<tr><td>30-45 mins</td><td colspan="2" rowspan="2">Set 50% minutes light, 50% vigorous</td></tr>
<tr><td>60+ mins</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Cycling for Travel</td><td></td><td colspan="4">% activities reported as moderate plus</td></tr>
<tr><td></td><td>Duration of their cycling for travel</td><td><50%</td><td>50-74%</td><td>75%+</td><td>Missing</td></tr>
<tr><td rowspan="3">Overall</td><td>< 30 mins</td><td>Set to light</td><td colspan="3">Set 50% minutes light, 50% vigorous</td></tr>
<tr><td>30-45 mins</td><td colspan="4" rowspan="2">Set to vigorous</td></tr>
<tr><td>60+ mins</td></tr>
</table>

Levels of Activity

Data are presented for three categories for *overall activity in the last week*. Only activity of at least moderate intensity is included. The first category includes pupils who meet the Chief Medical Officer's (CMO) guidelines for young people of doing at least 60 minutes of activity on average per day across a week. The second category includes children who do an average of 30-59 minutes on average a day and the third category the children do less than 30 minutes a day. The categories are named:

Active (an average of 60 minutes or more a day)
Fairly active (an average of 30-59 minutes a day)
Less active (less than an average of 30 minutes a day)

The categorization has changed since the 2017/18 report which had 4 categories, bringing it in line with recently published CMO guidelines. In Year 1 the first category was split into Active every day (at least 60 minutes every day) and Active across the week (an average of 60 minutes or more a day but not every day). In year 2 the data for Active every day is shown in Table 5 as it is a School Sports Action Plan metric.

Government policy aims that children and young people should get 30 minutes of their daily physical activity through the school day and 30 minutes outside of school. Tables are also presented for *activity in school and outside school* Only activity of at least moderate intensity is included. For in school activity every day is five days (week days), for outside school activity every day is seven days. Where activity is shown for a specific location or setting these categories are used:

An average of 30 minutes or more a day
Less active (less than an average of 30 minutes a day

This differs slightly from the Year 1 report where the first category was split into two to distinguish between those who were active every day and those who did 30 minutes on average per day across the week.

A table is also included to show whether pupils participated in activity of *any intensity* (light, moderate or vigorous) *at least twice in the last 28 days* for any duration.

Activities

Information is presented on whether or not the pupil has done each activity for any duration with at least moderate intensity in the last week for groups of activities and specific activities. The table on the next page shows the specific activities which are included under each of the composite activity groupings used in the report. Where relevant, the wording or description given in the questionnaire is also included for reference.

Activities which are included under each of the composite activity groupings used in the report

Broad activity group	Activity group	Activities
Sporting activities	Team sports	Football, Netball, Hockey, Cricket, Rugby, Baseball, Softball, Rounders, Basketball, Dodgeball, Benchball, Volleyball*, Lacrosse*, Handball*, King ball*, Korfball*, Roller hockey*, Other team sport*
	Running, athletics or multi- sports	Running, jogging, cross-country, the Daily Mile, Track and Field athletics, Sports day events, Multi-sports*
	Gymnastics, trampolining or cheerleading	Gymnastics, Trampolining (including in a garden, at a trampoline centre, or as part of a club), Cheerleading, Acrobatics including aerial, aerial hoop*
	Swimming, diving and water polo	Swimming (and diving), Water polo*
	Racket sports	Table tennis/ping pong, Badminton, Tennis, Squash or racketball*, Other racket sports*
	Combat sports, martial arts or target sports	Boxing, Judo, karate, taekwondo and other martial arts, Archery*, Fencing*, Tai Chi*, Other combat sport or martial art*
	Adventure or outdoor sports	Climbing (including indoors), Snow sports*, Angling*, Sledging*, Orienteering*, Other adventure or outdoor sports*
	Ice skating	Ice skating
	Water sports	Water sports (canoeing, kayaking, sailing, rowing, surfing)
	Horse riding	Horse riding
	Golf	Golf*
	Karting and motorsports	Motorsports*, Karting*
	Othersportorfitnessactivity	Leisure games: Snooker, pool, billiards, ten pin bowling, skittles, darts*, Other sport or fitness activity*
Active play and informal activities	Active play and informal activities	Kicking a ball about, Skateboarding, roller skating/blading, Frisbee, throwing and catching or skipping, Playing it, tag, chase, sardines or other running games, Climbing or swinging in the playground, garden or park, Other active play*, Hula hooping*
Walking	Walking for travel	Walking to get to school or other places
	Walking for leisure	Going on a walk
		Walking - type not specified (could be for travel or going on a walk)*
Dance	Dance	Dancing
Cycling	Cycling for travel	Cycling to get to school or other places
	Cycling for fun/fitness	Cycling/riding a bike for fun or fitness
		Cycling - type not specified (could be for travel or fun)*
Scooter	Riding a scooter	Riding a scooter
Fitness activities	Gym or fitness	Gym or fitness (fitness class e.g. yoga, or using exercise machines e.g. rowing machine, exercise bike, running machine), Other fitness or gym*
Active Travel	Walking for travel	Walking to get to school or other places
	Cycling for travel	Cycling to get to school or other places
	Riding a scooter	Riding a scooter

* These activities were not included in the questionnaire but were backcoded from other answers.

Activities continued

In addition, information on *swimming* has been included. This covers swimming confidence and capability as reported by pupils in year 3-11 and year 1-2 parents, and attitudes to swimming reported by year 1-2 pupils (see previous table for age ranges covered by each question).

Volunteering

This is defined as volunteering at least twice in the last 12 months to support sport and physical activity. Examples of volunteering activities include being a sports leader or ambassador, coaching, refereeing, umpiring and stewarding, helping with set up and clearing away, helping with refreshments and any other activities which support sport and physical activity. Activities which only help family members are not included. Activities which involve sport and activity to raise money for sport are not included in the measure, although pupils were asked about them.

These questions were asked to pupils in year 5-11. Pupils in year 5-6 and year 7-11 were asked about a different range of activities (appropriate to their age) and so information on roles is presented in separate tables for these two year groups.

Pupils were asked whether they had 'volunteered or given your time to do any of the following activities'. The question for pupils in years 5-6 included the clarification: 'Think only about when you do them to help with sports, exercise or dance'. Pupils could report on other activities not on the list. These were subsequently backcoded and ineligible activities such as helping at Brownies or running cake sales were excluded. All pupils who had reported that they helped with at least one type of activity were asked whether they had given their time for these activities more than once in the last year. Only those who had done so more than once were included in the measure. Note that while 'coached or instructed' is a separate category for year 7-11, for year 5-6 any back coded answers for coaching are included in other and 'setting up or clearing away is a separate category for year 5-6 but for year 7-11 any back coded answers of this type are included in other. The results for year 5-6 and 7-11 are presented separately because of the differences in codes.

Wellbeing and individual and community development

Three dimensions of mental wellbeing are presented: *happiness, life satisfaction* and the extent to which they feel the things they do in their life are *worthwhile*. For year 1-2 a smiley face question was used which is expressed as three categories in the tables: happy, neither happy nor sad, sad. For year 3-6 the standard ONS happiness yesterday question was used. For year 7-11 the standard ONS happiness yesterday, life satisfaction and worthwhile questions were used.
Happiness: "How happy did you feel yesterday?" (year 3-11)

Life Satisfaction: "How satisfied are you with life nowadays?" (year 7-11)

Feeling your life is Worthwhile: "To what extent are the things you do in your life worthwhile" (year 7-11)

These three questions are answered on an 11 point scale from 0 to 10 where 0 is not at all and 10 is completely. The results are presented as mean scores. The standard ONS wellbeing question about anxiety was not included as it is not recommended for use in children under 14 years old.
Individual and community development was captured from year 3-11 pupils through a question about trying difficult things and a question about trusting peers. Each question is asked on a 5-point scale from strongly agree (5) to strongly disagree (1) and agree and strongly agree. The questions asked were:
Individual Development: Using the resilience question "If I find something difficult, I keep trying until I can do it" (year 3-11)
Community development: Using the trust question "How much do you feel you can trust people who are a similar age to you?" (year 3-11)
In year 2 the results for strongly agree are shown, which differs from the Year 1 report when combined agree and strongly agree results were shown. The tables show the wellbeing and development indicators by demographic characteristics as well as split by level of activity and volunteering behaviour. See previous sections for activity and volunteering definitions. The findings for these variables can be found in other table sets. Here they are just used to look at levels of wellbeing and development split by level of activity and volunteering. The means for wellbeing tables are the mean calculated across the groups to which the answer relates from the scores of 0-10 which were used as answers to the questions.

Attitudes questions

There were five questions about attitudes included in the year 3 to 11 questionnaire. These were based on the concept of physical literacy[7]. Year 3-6 pupils were asked the first four and year 7-11 pupils were asked all of them. Pupils were asked to respond on a scale with the following categories: strongly agree, agree, disagree, strongly disagree, can't say.

I enjoy taking part in exercise and sports *(enjoyment)*

I feel confident when I exercise and play sports *(confidence)*

I find exercise and sports easy *(competence)*

I understand why exercise and sports are good for me *(understanding)*

I know how to get involved and improve my skills in lots of different types of exercise and sport *(knowledge)*

Year 1-2 pupils were asked about their attitudes in a short questionnaire. They were asked:

Do like playing sport? (I love, I like, I don't like, I hate… recoded into yes/no) *(enjoyment)*

Do you find sport easy? (yes, no, don't know recoded into yes/no) *(competence)*

Do you like being active? This includes things like running games, riding a bike or scooter, walking, and dancing. (I love, I like, I don't like, I hate… recoded into yes/no) *(enjoyment)*

Do you like swimming? (I love, I like, I don't like, I hate…, I don't know recoded into yes/no) *(enjoyment)* but included under swimming in reporting

Sports spectating

This is measured as having watched two or more live sports events, whether professional or amateur, over the previous 12 months.

Pupils were asked:

Have you done this activity (attended a live sports event) in the past 12 months?
How many live sporting events have you been to see since last year?

[7] 'Whitehead, M. (2016) Physical Literacy', *International Physical Literacy Association*

Additional information provided was: Include all matches and competitions, including professional sports as well as watching family and friends compete. Please do not include any events that you took part in yourself, or events you watched on TV.
Answers of 'twice' or 'three or more' were included in this measure.

Key demographic variables

Year group and gender

The report contains breakdowns by *year group and gender*. Gender includes the category 'other'. Year 7-11 pupils were asked to give more details. Where answers did not appear to indicate a gender other than male or female they were coded as prefer not to say or gender uncodeable. Year group is the answer reported by the pupil or their parent. In some cases this was inconsistent with the age given but we took the year group as given and did not recode.

Ethnicity

Parents of year 1-2 pupils were asked about their child's ethnicity using the full ONS standard question with a breakdown of ethnic groups (an additional code of 'prefer not to say' was added for the 2018/19 survey. These have been grouped into broader categories for analysis. Ethnicity for year 3-11 pupils was self-reported and used a simplified question which offered these categories: White (British or English), White (nor British or English), Mixed race, Asian or British Asian, Black or Black British, Other, Prefer not to say (in year 2017/18 of the survey 'none of these' was presented rather than other and prefer not to say). For year 1-2 data reported by the parents Chinese has been coded into other.
A derived variable of gender and ethnicity combined has been included. The ethnic breakdown for the gender category 'other' has not been shown because of small base sizes.

Family Affluence Scale

This is a standard scale developed for the Health Behaviour in School Aged Children Survey (an international study of 11-15 year olds). The updated version of the scale was used which asks the following questions. Minor modifications were made to the questions to make them suitable for parents and for younger children for whom the scale was not originally designed.
We would now like to ask you some questions about your home and your family. Does your family own a car, van or truck?

Do you have your own bedroom for yourself?

How many computers does your family own (including laptops and tablets/iPads, but NOT including game consoles and smartphones)?
How many times did you and your family travel out of England for a holiday last year?

How many bathrooms (room with a shower/ bath or both) are in your home?

Answers to these questions were scored according to the answers given, resulting in an overall score between 0 and 13. Scores of 0-6 =low, 7-10=medium, 11-13=high. Note that in the autumn term of Year 1 the car question only had yes/ no categories when it should have had none, one, two or more. This means that scores in the autumn term have a maximum of 12. Adjustments have been made to the groupings to allow for this in the Year 1 data. In Year 2 the correct question was asked throughout the survey year

Disabilities and number of impairments

The questions asked about disability varied by age. Year 3-6 pupils were asked a simpler question about whether they need extra help with a list of tasks which included things like 'moving around including walking and running', 'using your hands for writing or to pick things up'. Parents of year 1-2 and pupils in year 7-11 were asked 'Do you[8] have a disability, or a special educational need (e.g. dyslexia) which means you need extra help to do things'. If the answer was 'yes' they were asked 'Does this disability or special educational need affect you in any of the following areas?' A similar list was provided but with more categories and detail than for year 3-6 pupils.

Those who reported they needed help with anything (year 3-6) or said yes to the initial question (year 7-11) were defined as having a disability. The number and type of impairment was derived from the information given about specific things they needed help with. The number of limiting impairments was derived from the question which asked about types of impairment. It should be noted that this is the number of impairments from a set list.

Those in the no disability category are those who reported no need for extra help or no to the disability question. Note that because of the different questions for the two age groups, breakdown by disability

[8] Or your son or your daughter in parent questionnaire

is not presented for overall findings, only for findings for specific year groupings. Population estimates are also not presented for disability groups.

Summary of pupil questionnaire changes from year 1 to 2

In year 2 the walking to get to school or other places and walking for travel included a new clarification that it (excludes walking around school but includes school trips/walking to offsite games fields or buildings etc).

Half the sample in year 2 had a changed wording to the question about moderate intensity activity 'did it make you breathe faster than sitting down reading' while half the sample retained the old wording 'did it make you breathe faster'.

Ethnicity question in Year 2 replaced 'none of these' with 'other' and added 'prefer not to say'. Changes to wording of disability categories to add more examples or explanations in Year 2. Addition of 'prefer not to say' as an answer option for the disability questions in Year 2.

Addition of 'concentrating and paying attention' as a disability category in Year 2 when in Year 1 it had been back coded from other answers for year 7-11 only.

Amended wording for a question about whether school meals have to be paid for to make it easier for children who do not usually eat school lunches to answer (not presented in published data) in Year 2.

Note on Terminology

In the report tables, the term "respondents" is used as the heading for the unweighted base for each column. The term respondents have been used because the term participant which is usually used to refer to people who take part in a survey is confusing in the context of a survey about sports participation where participation has a different meaning.

The term rate (%) means the weighted percentage of respondents who gave that answer.

The term share (%) means the weighted percentage of respondents who gave a given answer who are in that demographic category.

For more information

3 Thomas

About Ipsos MORI's Social Research Institute

The Social Research Institute works closely with national governments, local public services and the not-for-profit sector. Its c.200 research staff focus on public service and policy issues. Each has expertise in a particular part of the public sector, ensuring we have a detailed understanding of specific sectors and policy challenges. This, combined with our methods and communications expertise, helps ensure that our research makes a difference for decision makers and communities

THE ACTIVE LIVES CHILDREN AND YOUNG PEOPLE SURVEY – QUESTIONNAIRE CONTENT

INTRODUCTION

Data collection for the Active Lives Children and Young People Survey started in September 2017 - administered by Ipsos MORI - and results will be published on an annual basis. It will provide a broad and deep understanding of children and young people's participation in, and attitudes towards, sport and physical activity. The aim is that 100,000 children from around 2,000 schools will participate in the survey each year. This is the first survey of this scale ever to be carried out among children and young people on an annual basis anywhere in the world.

SURVEY DESIGN

Methodology

The survey covers England only and will be carried out in state-funded maintained schools and some independent schools, meaning that around 96% of all children in school years 1 to 11 will be eligible to participate.

Schools are selected at random within each Local Authority. Within each school up to three year groups are randomly chosen and within these year groups, a single mixed-ability class is randomly selected.

The survey is completed online during classroom-based sessions. Active Partnerships are playing a key role in contacting sampled schools to encourage and help them to participate.

Summary of content

The questionnaire captures information about the type and amount of physical activity that children and young people have done in the last seven days, to help us establish how many children are

meeting the Chief Medical Officer's guidelines of an average of at least 60 minutes per day across the week and how many are less active. It asks how much activity was done in school and outside of school and, for older children, whether this was done indoors or outdoors.

There are questions on attendance at live sporting events and volunteering in sport but these will only be asked of children in Year 5 and above (age 9+). There is also a brief section on swimming proficiency and water safety.

There are further questions on attitudes towards physical activity, physical literacy (i.e. motivation, confidence, perceived competence and knowledge & understanding), mental wellbeing (e.g. levels of happiness), self-efficacy and levels of social trust.

The demographic information captured for each child includes age, gender, ethnicity, disability and socio-economic status.

Appendix E

Ethics form from Imperial College London Research Ethics Committee

Imperial College London

Imperial College Research Ethics Committee
Imperial College London
Room 221
Medical School Building
St Marys Campus
London
W2 1PG
Tel: +44 (0)207 594 1872

researchethicscommittee@imperial.ac.uk

19 June 2019

Dear Sonia Saxena

Study Title:. Evaluating the potential impact of The Daily Mile

ICREC reference: 19IC5320

The above study was approved by your Head of Department on 28/05/19 and by the Joint Research Compliance Office on 19/06/19.

Under the Imperial College Research Ethics Committee process, a study that has been reviewed by the Joint Research Compliance Office and Head of Division/Department (or Principal), where no significant ethical issues have been identified in the protocol or ethics application, can be approved without requiring it to go to full committee.

Documents
The documents reviewed were:

- ICREC Application form (v5 10/06/19)
- Protocol (v4 10/06/19)
- End user agreement
- TDMF Letter

Yours sincerely,

Ruth Nicholson,
Head of Research Governance and Integrity,
Imperial College London

Appendix F

Table A3: Missing data for variables included in the definition of 'need' by local authority

Local authority name	Excess Weight Status at Age 5-6 (%)	Children Physical Activity (%)	Excess Weight Status at Age 11/12 (%)	Adult Physical Activity (%)	Adolescent Sedentary Time (%)	Use of Outdoor Space (%)	Adult Excess Weight (%)	Children on Free School Meals (%)	School pupils with social, emotional and mental health needs (%)
Blackpool	28.58	59.59	38.58	54.36	79.9	NA	66.51	25.26	3.08
Bracknell Forest	19.44	NA	28.39	73.87	68.6	NA	62.52	6.64	1.9
Camden	20.69	NA	36.4	71.65	68.1	17.11	46.47	24.96	2.67
City of London	NA	NA	NA	73.17	NA	NA	45.43	11.27	4.23
Hackney	24.01	42.17	40.24	69.95	70.7	NA	49.21	27.73	3.38
Halton	26.64	NA	40.31	62.85	76.9	17.55	74.41	26	3.06
Hammersmith and Fulham	19.06	NA	35.8	68.25	64.6	17.42	48.98	20.73	2.13
Herefordshire	23.65	50.08	34.69	66.81	65.1	NA	64.51	8.22	2.9
Hounslow	23.21	NA	38.93	63	70	18.34	60.44	14.59	3.26
Isles of Scilly	NA	NA	NA	78.62	NA	NA	63.51	4.43	NA
Kensington and Chelsea	19.3	45.87	35.35	72.79	69.6	NA	49.97	18.9	2.13
Lewisham	21.31	NA	37.3	71.63	73.4	17.69	55.6	16.14	1.98
Liverpool	27.77	NA	39.53	66.42	78.1	17.36	62.45	24.02	2.99
NA	NA	NA	NA	NA	NA	NA	NA	10.74	2.72
NA	NA	NA	NA	NA	NA	NA	NA	9.8	3.11
NA	NA	NA	NA	NA	NA	NA	NA	12.74	2.48

Newham	23.73	NA	42.66	53.12	69.9	18.82	62.97	13.58	2.03
North Somerset	24.8	47.06	26.86	71.11	65.7	NA	66.41	8.08	2.32
Rutland	22.81	56.25	29.85	68.12	68.7	NA	62.94	4.69	1.41
South Tyneside	24.66	46.98	38.13	60.27	77.8	NA	71.66	19.17	2.72
Southend-on-Sea	22.41	NA	33.23	62.97	73.9	15.11	67.98	11.63	2.08
St. Helens	28.16	NA	36.63	61.75	78.3	21.2	72.55	15.78	2.77
Thurrock	22.31	NA	37.9	60.91	76	36.9	68.97	11.43	2.33
Tower Hamlets	21.44	NA	41.49	67.19	67.6	15.7	49.11	33.58	3.02
Waltham Forest	21.75	NA	38.01	63.01	69.5	14.33	54.49	13.96	2.6
Wandsworth	17.46	NA	32.87	72.29	64.5	19.76	55.22	15.43	3.62
Westminster	21.75	NA	37.97	68.83	66	20.07	47.98	21.99	3.19
Wirral	24.05	NA	34.04	62.1	69.8	23.39	62.48	16.95	3.55
Wokingham	18.75	45.27	25.85	73.49	62.9	NA	50.94	5.3	1.91

Appendix G

Table A4: Clusters and local authorities

Highest need areas (Cluster 1)	**Medium-need areas (Cluster 2)**	**Lowest need areas (Cluster 3)**
Barking and Dagenham	Bedford	Barnet
Barnsley	Bexley	Bath and North East Somerset
County Durham	Birmingham	Brighton and Hove
Coventry	Blackburn with Darwen	Bromley
Darlington	Bolton	Buckinghamshire
Doncaster	Bradford	Cambridgeshire
Dudley	Brent	Central Bedfordshire
Gateshead	Bristol	Devon
Hartlepool	Bury	Essex
Kingston upon Hull	Calderdale	Hertfordshire
Knowsley	Cheshire East	Kingston upon Thames
Luton	Cheshire West and Chester	Leicestershire
Medway	Cornwall	Northamptonshire
Middlesbrough	Croydon	Oxfordshire
North East Lincolnshire	Cumbria	Richmond upon Thames
North Lincolnshire	Derby	South Gloucestershire
North Tyneside	Derbyshire	Suffolk
Redcar and Cleveland	Ealing	Surrey
Rotherham	East Riding of Yorkshire	Trafford
Salford	East Sussex	West Berkshire
Sandwell	Enfield	West Sussex
Sefton	Gloucestershire	Wiltshire
Stockton-on-Tees	Greenwich	Windsor and Maidenhead
Stoke-on-Trent	Hampshire	York
Sunderland	Haringey	
Tameside	Harrow	
Wakefield	Havering	
Walsall	Hillingdon	
Wigan	Isle of Wight	
Wolverhampton	Islington	
	Kent	
	Kirklees	
	Lambeth	

	Lancashire	
	Leeds	
	Leicester	
	Lincolnshire	
	Manchester	
	Merton	
	Milton Keynes	
	Newcastle upon Tyne	
	Norfolk	
	North Yorkshire	
	Northumberland	
	Nottingham	
	Nottinghamshire	
	Oldham	
	Peterborough	
	Plymouth	
	Portsmouth	
	Reading	
	Redbridge	
	Rochdale	
	Sheffield	
	Shropshire	
	Slough	
	Solihull	
	Somerset	
	Southampton	
	Southwark	
	Staffordshire	
	Stockport	
	Sutton	
	Swindon	
	Telford and Wrekin	
	Torbay	
	Warrington	
	Warwickshire	
	Worcestershire	

Appendix H

Table A5: Physical activity levels across different settings by registration status to The Daily Mile

	Registered to The Daily Mile			Not Registered to The Daily Mile			P value*
	Max N	**Median minutes MVPA**	IQR	**Max N**	**Median minutes MVPA**	IQR	
In school	10368	115	50, 215	41094	105	45,200	<0.001
Outside school	10368	267	105, 580	41094	245	95, 540	<0.001
Total	10368	395	175, 795	41094	360	160, 735	<0.001
*p-values obtained by Kruskal Wallis test for medians IQR: Interquartile range							

Table A6: Physical activity from all activities total across subgroups

	N	Median minutes MVPA from all activities total	IQR	p-value
The Daily Mile				<0.001
Registered	10368	395	175, 795	
Not registered	41094	360	160, 735	
Gender				<0.001
DM Boy (N=4858)	4786	470	190, 915	
Non-DM Boy (N=18950)	18736	410	175, 835	
DM Girl (N=4930)	4891	360	170, 680	
Non-DM Girl (N=19560)	19398	325	150, 640	
DM Other (N=79)	73	430	155, 1020	
Non-DM Other (N=348)	333	445	150, 1010	
Ethnicity				**<0.001**
DM white british (N=6549)	6489	415	190, 805	
non-DM white british (N=26717)	26469	377	170, 750	
DM white other (N=391)	384	388.5	180, 820.5	
non-DM white other (N=1572)	1552	365	170, 810	
DM asian (N=666)	658	395	155, 795	
non-DM asian (N=1992)	1971	330	135, 705	
DM black (N=355)	348	335	153.750, 795	
non-DM black (N=1149)	1133	355	130, 705	
DM mixed (N=781)	766	390	170, 817.5	
non-DM mixed (N=2832)	2789	375	165, 775	
DM other (N=422)	411	360	155, 775	
non-DM other (N=1621)	1595	340	132.5, 733.5	
DM prefer not to say (N=1105)	1088	335	135, 716.250	

non-DM prefer not to say (N=4651)	4595	290	115, 640	
School year				<0.001
DM 1 (N=467)	466	477.5	275, 730	
non-DM 1 (N=1652)	1651	445	275, 695	
DM 2 (N=549)	546	470	270, 775	
non-DM 2 (N=1598)	1596	455	280, 695	
DM 3 (N=2041)	2014	335	155, 685	
non-DM 3 (N=8910)	8824	290	130, 625	
DM 4 (N=2194)	2167	395	165, 766	
non-DM 4 (N=8838)	8713	350	145, 745	
DM 5 (N=2568)	2528	380	160, 820	
non-DM 5 (N=10733)	10624	360	160, 775	
DM 6 (N=2678)	2647	440	190, 913.5	
non-DM 6 (N=9804)	9686	400	175, 815	
term/season				<0.001
DM Autumn (N=2850)	2825	335	130, 687	
non-DM Autumn (N=13917)	13802	295	120, 625	
DM Spring (N=4114)	4062	400	185, 799.250	
non-DM Spring (N=15624)	15459	365	165, 735	
DM Summer (N=3533)	3481	450	210, 875	
non-DM Summer (N=11994)	11833	445	210, 865	
deprivation IMD				<0.001
DM 1 (N=831) most deprived	820	330	140, 691.250	
non-DM 1 (N=2029) most deprived	2006	321	125, 705	
DM 2 (N=810)	801	345	135, 775	
non-DM 2 (N=2673)	2647	375	150, 785	
DM 3 (N=1263)	1245	375	172, 740	
non-DM 3 (N=3706)	3667	330	135, 700	
DM 4 (N=1165)	1149	375	155, 810	
non-DM 4 (N=4536)	4489	375	165, 762	
DM 5 (N=773)	760	472.5	210, 886.250	
non-DM 5 (N=3749) least deprived	3699	365	160, 760	
non-DM 10 (N=4623) least deprived	4569	390	180, 777	
Disability				<0.001
DM no disability (N=4938)	4882	420	200, 790	
Non-DM no disability (N=19659)	19494	385	180, 740	
DM disability (N=3722)	3675	385	155, 805	
Non-DM disability (N=14659)	14486	340	140, 730	
DM prefer not to say (N=1553)	1531	357	155, 795	
Non-DM prefer not to say (N=5978)	5892	350	145, 740	
Rurality				<0.001
DM Urban: Major Conurbation (N=3427)	3379	390	165, 790	
Non-DM Urban: Major Conurbation (N=8277)	8178	370	155, 755	
DM Urban: Minor Conurbation (N=570)	562	431	175, 818.8	

Non-DM Urban: Minor Conurbation (N=746)	741	335	145, 755	
DM Urban: Town/City (N=4781)	4730	385	175, 780	
Non-DM Urban: Town/City (N=23637)	23382	355	155, 735	
DM Rural: Town / Fringe (N=724)	710	491	215, 903.8	
Non-DM Rural: Town / Fringe (N=5801)	5754	387	175, 754.3	
DM Rural: Village (N=779)	772	405	200, 746.3	
Non-DM Rural: Village (N=2522)	2493	375	170, 705	
DM Rural: Hamlets / Isolated Dwellings (N=216)	215	420	207.5, 830	
Non-DM Rural: Hamlets / Isolated Dwellings (N=552)	546	335	190, 633.8	
Note: p-values derived from Kruskal Wallis test for medians **DM = Daily Mile** **Non-DM = Non-Daily Mile**				

Appendix I

Complete Modelling Results for Chapter 8 – Impact of The Daily Mile

Primary outcome: Minutes of MVPA in school

Table A7: Multivariable Zero-inflated negative binomial regression coefficients for the number of minutes of moderate to vigorous physical activity in school

	Negative Binomial Portion					**Logit Portion**				
Predictors	***Incidence Rate Ratios***^^	***SE***	***CI low***	***CI high***	***p***	***Odds Ratio***^^	***SE***	***CI low***	***CI high***	***p***
(Intercept)	161.61	0.04	149.54	174.66	**<0.001**	0.18	0.03	0.14	0.24	**<0.001**
Daily Mile: No										
Daily Mile Yes	1.06	0.02	1.02	1.10	0.003	0.95	0.07	0.83	1.09	0.463
Rurality: Rural										
Urban	1.00	0.02	0.96	1.04	0.852	1.22	0.09	1.06	1.40	0.005
Ofsted: Outstanding										
Good	0.96	0.02	0.92	1.01	0.092	1.14	0.09	0.98	1.33	0.093
Requires improvement	0.94	0.03	0.88	1.00	0.063	1.14	0.14	0.91	1.44	0.254
Inadequate	0.85	0.07	0.72	0.99	0.040	1.42	0.40	0.82	2.45	0.211
Ofsted Missing	0.92	0.03	0.87	0.99	0.016	1.15	0.13	0.92	1.45	0.215
Year Group: 1 and 2										
3 and 4	1.00	0.02	0.97	1.04	0.777	0.38	0.02	0.33	0.43	<0.001
5 and 6	1.03	0.02	1.00	1.07	0.048	0.43	0.03	0.38	0.48	<0.001
Ethnicity: White British										
White other	1.04	0.02	1.00	1.08	0.066	1.15	0.10	0.96	1.37	0.126
Asian	0.98	0.02	0.94	1.02	0.309	1.01	0.09	0.85	1.20	0.882

Black	1.00	0.02	0.95	1.05	0.988	0.99	0.11	0.80	1.23	0.942
Mixed	1.05	0.02	1.02	1.09	0.001	0.93	0.07	0.81	1.08	0.366
Other	0.99	0.02	0.95	1.03	0.690	1.17	0.11	0.98	1.40	0.091
Prefer not to say	0.94	0.01	0.91	0.96	<0.001	1.29	0.07	1.15	1.44	<0.001
Gender: Boy										
Girl	0.84	0.01	0.83	0.85	<0.001	0.96	0.04	0.89	1.03	0.252
Other	1.02	0.02	0.98	1.06	0.406	1.25	0.11	1.06	1.47	0.008
IMD Quintiles: 1 (most deprived)										
2	0.97	0.03	0.92	1.03	0.353	1.03	0.10	0.85	1.25	0.729
3	0.96	0.03	0.91	1.02	0.163	0.98	0.10	0.81	1.20	0.868
4	0.95	0.03	0.90	1.01	0.096	0.95	0.09	0.78	1.15	0.587
5 (least deprived)	0.95	0.03	0.90	1.01	0.108	0.84	0.09	0.69	1.02	0.086
IMD missing	0.95	0.04	0.88	1.03	0.249	0.95	0.14	0.71	1.27	0.715
Disability: No disability										
Yes	1.00	0.01	0.98	1.01	0.615	1.17	0.05	1.08	1.27	<0.001
Prefer not to say	1.00	0.01	0.97	1.02	0.766	1.16	0.06	1.04	1.29	0.008
Term/Season: Autumn										
Spring	1.08	0.02	1.04	1.12	0.000	0.53	0.03	0.47	0.60	0.000
Summer	1.21	0.02	1.16	1.26	0.000	0.33	0.02	0.29	0.38	0.000
Random Effects										
σ^2	0.57									
τ_{00}	0.04 $_{xcluster}$									
ICC	0.07									
N	1049 $_{xcluster}$									
Observations	49561									
Marginal R^2 / Conditional R^2	0.025 / 0.092									
AIC	576893.491									

^^ adjusted for gender, age, deprivation (IMD), ethnicity, term of survey completion, rurality, Ofsted rating of school, disability

σ^2 = residual variance (within individual residual variance)

τ_{00} = random intercept variance/between subject variance (how much groups or subjects differ)
ICC: Intraclass correlation coefficient - Proportion of variance explained by between-person differences
N: number of schools (level-2) used in the model
Observations: number of children (observations at Level-1) used in the model
Marginal R2 provides the variance explained only by fixed effects and conditional R2 provides the variance explained by the entire model, i.e., both fixed effects and random effects.

Secondary outcome: Minutes of MVPA outside school

Table A8: Multivariable Zero-inflated negative binomial regression coefficients for the number of minutes of moderate to vigorous physical activity outside school

	Negative Binomial Portion					**Logit Portion**				
Predictors	***Incidence Rate Ratios^^***	***SE***	***CI low***	***CI high***	***p***	***Odds Ratio^^***	***SE***	***CI low***	***CI high***	***p***
(Intercept)	436.95	0.04	403.58	473.08	**<0.001**	0.03	0.17	0.02	0.04	**<0.001**
Daily Mile: No										
Daily Mile Yes	1.06	0.02	1.02	1.10	0.006	0.94	0.07	0.81	1.08	0.353
Rurality: Rural										
Urban	1.01	0.02	0.97	1.05	0.510	1.25	0.09	1.08	1.44	0.003
Ofsted: Outstanding										
Good	0.96	0.02	0.91	1.00	0.037	1.20	0.10	1.02	1.41	0.024
Requires improvement	0.94	0.03	0.88	1.01	0.074	1.14	0.14	0.89	1.45	0.303
Inadequate	0.87	0.07	0.74	1.03	0.101	1.64	0.46	0.95	2.83	0.076
Ofsted Missing	0.93	0.03	0.87	0.99	0.034	1.13	0.14	0.90	1.44	0.296
Year Group: 1 and 2										
3 and 4	0.90	0.02	0.87	0.94	<0.001	3.08	0.37	2.44	3.89	<0.001
5 and 6	1.05	0.02	1.01	1.09	0.009	3.17	0.38	2.51	4.00	<0.001
Ethnicity: White British										
White other	1.06	0.03	1.01	1.11	0.015	1.16	0.12	0.96	1.41	0.130
Asian	0.92	0.02	0.88	0.96	<0.001	1.20	0.10	1.02	1.42	0.032
Black	0.91	0.03	0.86	0.96	0.001	1.16	0.12	0.94	1.42	0.171
Mixed	1.03	0.02	0.99	1.07	0.104	1.09	0.08	0.95	1.26	0.220
Other	1.01	0.02	0.96	1.06	0.743	1.16	0.11	0.97	1.39	0.111
Prefer not to say	0.89	0.01	0.86	0.92	<0.001	1.46	0.08	1.31	1.63	<0.001
Gender: Boy										
Girl	0.77	0.01	0.75	0.78	<0.001	0.80	0.03	0.74	0.86	<0.001
Other	0.96	0.02	0.92	1.01	0.110	1.25	0.10	1.07	1.46	0.005

IMD Quintiles: 1 (most deprived)										
2	1.01	0.03	0.95	1.07	0.799	1.02	0.10	0.84	1.23	0.856
3	1.02	0.03	0.96	1.07	0.596	0.87	0.09	0.71	1.06	0.171
4	1.04	0.03	0.98	1.10	0.215	0.84	0.08	0.69	1.02	0.078
5 (least deprived)	1.04	0.03	0.98	1.10	0.214	0.75	0.08	0.61	0.91	0.005
IMD missing	0.98	0.04	0.90	1.06	0.566	0.90	0.14	0.67	1.21	0.499
Disability: No disability										
Yes	0.98	0.01	0.96	1.00	0.023	1.22	0.05	1.13	1.33	<0.001
Prefer not to say	1.00	0.01	0.97	1.02	0.734	1.21	0.07	1.09	1.35	0.001
Term/Season: Autumn										
Spring	1.14	0.02	1.10	1.18	<0.001	0.51	0.03	0.45	0.58	<0.001
Summer	1.30	0.03	1.25	1.35	<0.001	0.29	0.02	0.25	0.33	<0.001
Random Effects										
σ^2	0.70									
τ_{00}	0.04 $_{xcluster}$									
ICC	0.05									
N	1049 $_{xcluster}$									
Observations	49561									
Marginal R^2 / Conditional R^2	0.047 / 0.096									
AIC	673445.363									

^^ adjusted for gender, age, deprivation (IMD), ethnicity, term of survey completion, rurality, Ofsted rating of school, disability

σ^2 = residual variance (within individual residual variance)

τ_{00} = random intercept variance/between subject variance (how much groups or subjects differ)

ICC: Intraclass correlation coefficient - Proportion of variance explained by between-person differences

N: number of schools (level-2) used in the model

Observations: number of children (observations at Level-1) used in the model

Marginal R2 provides the variance explained only by fixed effects and conditional R2 provides the variance explained by the entire model, i.e., both fixed effects and random effects.

Secondary outcome #2: Total minutes of MVPA (in school + outside school)

Table A9: Multivariable Zero-inflated negative binomial regression coefficients for the number of minutes of moderate to vigorous physical activity everywhere

	Negative Binomial Portion					Logit Portion				
Predictors	***Incidence Rate Ratios***^^	***SE***	*CI low*	*CI high*	***p***	***Odds Ratio***^^	***SE***	*CI low*	*CI high*	***p***
(Intercept)	583.67	0.00	540.40	630.40	<0.001	0.03	0.21	0.02	0.04	<0.001
Daily Mile: No										
Daily Mile Yes	1.06	0.02	1.02	1.10	0.003	0.97	0.09	0.81	1.16	0.711
Rurality: Rural										
Urban	1.00	0.02	0.96	1.04	0.919	1.21	0.11	1.00	1.45	0.049
Ofsted: Outstanding										
Good	0.95	0.02	0.91	0.99	0.028	1.24	0.13	1.01	1.53	0.039
Requires improvement	0.94	0.03	0.88	1.00	0.054	1.22	0.19	0.89	1.66	0.223
Inadequate	0.86	0.07	0.73	1.01	0.060	2.01	0.71	1.01	4.02	0.047
Ofsted Missing	0.93	0.03	0.87	0.99	0.025	1.28	0.20	0.95	1.73	0.101
Year Group: 1 and 2										
3 and 4	0.93	0.02	0.90	0.96	<0.001	1.90	0.25	1.48	2.45	<0.001
5 and 6	1.05	0.02	1.02	1.09	0.003	2.33	0.30	1.82	2.99	<0.001
Ethnicity: White British										
White other	1.05	0.02	1.00	1.09	0.034	1.08	0.14	0.85	1.38	0.527
Asian	0.93	0.02	0.89	0.97	<0.001	1.08	0.12	0.87	1.35	0.465
Black	0.93	0.02	0.89	0.98	0.006	1.06	0.14	0.81	1.38	0.657
Mixed	1.04	0.02	1.00	1.07	0.032	1.09	0.10	0.92	1.31	0.324
Other	1.00	0.02	0.95	1.04	0.844	1.09	0.13	0.87	1.37	0.454
Prefer not to say	0.89	0.01	0.87	0.92	<0.001	1.47	0.10	1.29	1.69	<0.001
Gender: Boy										
Girl	0.79	0.01	0.78	0.80	<0.001	0.81	0.04	0.74	0.89	<0.001
Other	0.97	0.02	0.93	1.01	0.132	1.21	0.12	0.99	1.47	0.058

IMD Quintiles: 1 (most deprived)										
2	0.99	0.03	0.94	1.05	0.812	0.95	0.12	0.74	1.22	0.702
3	1.00	0.03	0.95	1.06	0.971	0.86	0.11	0.66	1.11	0.248
4	1.01	0.03	0.96	1.07	0.647	0.83	0.11	0.65	1.07	0.150
5 (least deprived)	1.02	0.03	0.96	1.07	0.600	0.70	0.09	0.54	0.91	0.007
IMD missing	0.97	0.04	0.89	1.05	0.487	0.90	0.17	0.62	1.31	0.589
Disability: No disability										
Yes	0.98	0.01	0.96	1.00	0.015	1.22	0.06	1.10	1.35	<0.001
Prefer not to say	0.99	0.01	0.97	1.02	0.620	1.26	0.09	1.10	1.44	0.001
Term/Season: Autumn										
Spring	1.13	0.02	1.09	1.17	<0.001	0.38	0.03	0.32	0.44	<0.001
Summer	1.29	0.03	1.24	1.34	<0.001	0.15	0.02	0.12	0.18	<0.001
Random Effects										
σ^2	0.63									
τ_{00}	0.04 $_{xcluster}$									
ICC	0.06									
N	1049 $_{xcluster}$									
Observations	49561									
Marginal R^2 / Conditional R^2	0.044 / 0.100									
AIC	710415.223									

^^ adjusted for gender, age, deprivation (IMD), ethnicity, term of survey completion, rurality, Ofsted rating of school, disability
σ2 = residual variance (within individual residual variance)
τ00 = random intercept variance/between subject variance (how much groups or subjects differ)
ICC: Intraclass correlation coefficient - Proportion of variance explained by between-person differences
N: number of schools (level-2) used in the model
Observations: number of children (observations at Level-1) used in the model
Marginal R2 provides the variance explained only by fixed effects and conditional R2 provides the variance explained by the entire model, i.e., both fixed effects and random effects.

Appendix J

Sensitivity Analysis Results for interaction terms

Table A10*:* Zero-inflated negative binomial regression coefficients for the number of minutes of moderate to vigorous physical activity in school with all interaction terms (TDM*Year group + TDM*Gender + TDM*IMD)

	Negative Binomial Portion					**Logit Portion**				
Predictors	*Incidence Rate Ratios*	*SE*	*CI*	*CI*	*p*	*Odds Ratio*	*SE*	*CI*	*CI*	*p*
(Intercept)	**168.54**	**0.04**	**155.60**	**182.56**	**<0.001**	**0.11**	**0.15**	**0.08**	**0.14**	**<0.001**
Rurality: Rural										
Urban	1	0.02	0.96	1.04	0.949	1.23	0.07	1.06	1.42	**0.007**
Ofsted: Outstanding										
Good	0.97	0.02	0.92	1.01	0.112	1.1	0.08	0.94	1.29	0.222
Requires improvement	0.95	0.03	0.89	1.02	0.141	1.15	0.12	0.90	1.47	0.248
Inadequate	0.9	0.11	0.73	1.12	0.351	1.58	0.36	0.78	3.20	0.202
Ofsted Missing	0.93	0.03	0.87	0.99	**0.021**	1.1	0.12	0.87	1.38	0.427
Daily Mile: No										
Daily Mile Yes	0.9	0.06	0.81	1.01	0.079	1.16	0.2	0.78	1.73	0.467
Year Group: 1 and 2										
3 and 4	1.08	0.06	0.96	1.21	0.203	0.44	0.19	0.31	0.65	**<0.001**
5 and 6	0.99	0.03	0.95	1.04	0.816	0.58	0.09	0.48	0.69	**<0.001**
Ethnicity: White British										
White other	1.04	0.02	0.99	1.08	0.091	1.11	0.09	0.93	1.34	0.253
Asian	0.99	0.02	0.95	1.03	0.516	0.96	0.09	0.80	1.14	0.626
Black	1	0.02	0.95	1.05	0.991	0.97	0.11	0.78	1.21	0.8
Mixed	1.05	0.02	1.02	1.09	**0.001**	0.91	0.08	0.79	1.06	0.235
Other	0.99	0.02	0.95	1.03	0.687	1.11	0.09	0.93	1.33	0.253

Prefer not to say	0.93	0.01	0.91	0.96	**<0.001**	1.22	0.06	1.09	1.37	**0.001**
Gender: Boy										
Girl	0.84	0.01	0.82	0.85	**<0.001**	0.9	0.04	0.83	0.98	**0.016**
Other	1.03	0.02	0.99	1.08	0.142	1.09	0.1	0.90	1.31	0.388
IMD Quintiles: 1 (most deprived)										
2	0.88	0.07	0.77	1.00	**0.047**	1.83	0.22	1.20	2.79	**0.005**
3	0.92	0.03	0.86	0.98	**0.015**	1.47	0.13	1.15	1.89	**0.002**
4	0.94	0.03	0.88	1.00	0.061	1.35	0.13	1.06	1.74	**0.017**
5 (least deprived)	0.93	0.03	0.87	0.99	**0.029**	1.23	0.13	0.96	1.57	0.109
IMD missing	0.91	0.14	0.69	1.21	0.527	4.02	0.36	1.97	8.22	**<0.001**
Disability: No disability										
Yes	0.99	0.01	0.98	1.01	0.573	1.05	0.04	0.97	1.14	0.226
Prefer not to say	0.99	0.01	0.97	1.02	0.567	1.05	0.06	0.94	1.17	0.403
Term/Season: Autumn										
Spring	1.08	0.02	1.04	1.12	**<0.001**	0.52	0.07	0.46	0.59	**<0.001**
Summer	1.22	0.02	1.17	1.27	**<0.001**	0.33	0.07	0.29	0.39	**<0.001**
Interactions										
Daily Mile Yes * Boy										
Daily Mile Yes * Girl	1.01	0.02	0.97	1.05	0.649	1.22	0.1	1.01	1.47	**0.042**
Daily Mile Yes * Other	0.95	0.05	0.86	1.05	0.322	1.61	0.2	1.08	2.40	**0.02**
Daily Mile Yes * IMD 1										
Daily Mile Yes * IMD 2	1.32	0.15	0.99	1.76	0.06	0.74	0.48	0.29	1.89	0.525
Daily Mile Yes * IMD 3	1.19	0.07	1.03	1.37	**0.016**	0.7	0.27	0.42	1.18	0.184
Daily Mile Yes * IMD 4	1.04	0.07	0.91	1.18	0.591	0.91	0.25	0.56	1.48	0.706
Daily Mile Yes * IMD 5	1.12	0.07	0.96	1.29	0.142	0.83	0.27	0.49	1.41	0.491
Daily Mile Yes * IMD missing	1.2	0.32	0.64	2.25	0.576	0.29	0.88	0.05	1.64	0.162
Daily Mile Yes * Year 1-2										
Daily Mile Yes * Year 3-4	0.89	0.13	0.68	1.16	0.381	1.18	0.44	0.50	2.81	0.702
Daily Mile Yes * Year 5-6	1.1	0.05	0.99	1.22	0.07	0.79	0.19	0.55	1.14	0.201

*Table A11: Zero-inflated negative binomial regression coefficients for the number of minutes of moderate to vigorous physical activity outside school with all interaction terms (TDM*Year group + TDM*Gender + TDM*IMD)*

	Negative Binomial Portion					**Logit Portion**				
Predictors	*Incidence Rate Ratios*	*SE*	*CI*	*CI*	*p*	*Odds Ratio*	*SE*	*CI*	*CI*	*p*
(Intercept)	447.57	0.04	412.46	485.68	**<0.001**	0.05	0.16	0.04	0.07	**<0.001**
Rurality: Rural										
Urban	1.02	0.02	0.98	1.06	0.346	1.3	0.08	1.12	1.52	**0.001**
Ofsted: Outstanding										
Good	0.95	0.02	0.91	1.00	**0.034**	1.23	0.08	1.04	1.45	**0.014**
Requires improvement	0.95	0.03	0.89	1.02	0.169	1.16	0.13	0.90	1.50	0.24
Inadequate	0.88	0.11	0.71	1.09	0.239	2.19	0.36	1.07	4.47	**0.032**
Ofsted Missing	0.94	0.03	0.88	1.00	**0.044**	1.2	0.12	0.94	1.52	0.135
Daily Mile: No										
Daily Mile Yes	0.97	0.06	0.86	1.09	0.57	0.98	0.23	0.62	1.54	0.927
Year Group: 1 and 2										
3 and 4	0.96	0.06	0.85	1.08	0.477	2.8	0.39	1.31	5.98	**0.008**
5 and 6	0.96	0.03	0.91	1.01	0.092	1.85	0.13	1.44	2.39	**<0.001**
Ethnicity: White British										
White other	1.06	0.02	1.01	1.11	**0.017**	1.16	0.1	0.95	1.41	0.153
Asian	0.93	0.02	0.89	0.98	**0.003**	1.19	0.09	1.00	1.42	**0.047**
Black	0.91	0.03	0.86	0.96	**0.001**	1.17	0.11	0.94	1.44	0.156
Mixed	1.02	0.02	0.98	1.06	0.328	1.07	0.08	0.92	1.24	0.372
Other	1	0.02	0.95	1.05	0.885	1.18	0.09	0.98	1.42	0.078
Prefer not to say	0.87	0.02	0.84	0.90	**<0.001**	1.49	0.06	1.33	1.67	**<0.001**
Gender: Boy										
Girl	0.77	0.01	0.75	0.79	**<0.001**	0.78	0.04	0.71	0.85	**<0.001**
Other	0.98	0.03	0.93	1.03	0.397	1.23	0.09	1.03	1.46	**0.022**
IMD Quintiles: 1 (most deprived)										
2	1.01	0.07	0.88	1.16	0.895	0.49	0.4	0.22	1.08	0.077

3	1.01	0.04	0.94	1.08	0.795	0.68	0.13	0.52	0.88	**0.003**
4	1.04	0.04	0.97	1.12	0.217	0.62	0.13	0.47	0.80	**<0.001**
5 (least deprived)	1.04	0.04	0.97	1.11	0.283	0.55	0.13	0.42	0.71	**<0.001**
IMD missing	0.93	0.14	0.71	1.22	0.594	0.02	3.48	0.00	18.43	0.262
Disability: No disability										
Yes	0.96	0.01	0.94	0.98	**0.001**	1.3	0.04	1.19	1.41	**<0.001**
Prefer not to say	0.98	0.01	0.96	1.01	0.226	1.3	0.06	1.17	1.45	**<0.001**
Term/Season: Autumn										
Spring	1.13	0.02	1.09	1.18	**<0.001**	0.52	0.07	0.46	0.59	**<0.001**
Summer	1.31	0.02	1.26	1.36	**<0.001**	0.28	0.08	0.24	0.33	**<0.001**
Interactions										
Daily Mile Yes * Boy										
Daily Mile Yes * Girl	0.99	0.02	0.95	1.04	0.783	1.01	0.1	0.82	1.23	0.952
Daily Mile Yes * Other	0.93	0.06	0.83	1.05	0.235	1.13	0.2	0.76	1.67	0.55
Daily Mile Yes * IMD 1										
Daily Mile Yes * IMD 2	1.1	0.16	0.81	1.49	0.533	0.47	1.27	0.04	5.64	0.553
Daily Mile Yes * IMD 3	1.14	0.07	0.99	1.32	0.068	0.66	0.28	0.38	1.15	0.146
Daily Mile Yes * IMD 4	1.05	0.07	0.91	1.20	0.496	0.95	0.26	0.57	1.58	0.852
Daily Mile Yes * IMD 5	1.13	0.08	0.97	1.31	0.115	0.97	0.29	0.55	1.69	0.905
Daily Mile Yes * IMD missing	1.25	0.32	0.67	2.32	0.486	26.01	3.69	0.02	36034.09	0.377
Daily Mile Yes * Year 1-2										
Daily Mile Yes * Year 3-4	0.99	0.14	0.75	1.32	0.967	2.15	1.25	0.19	24.66	0.539
Daily Mile Yes * Year 5-6	1.02	0.06	0.92	1.14	0.689	1.05	0.26	0.63	1.77	0.849
Random Effects										
σ^2	0.71									
τ_{00}	0.04 $_{xcluster}$									
ICC	0.05									
N	1012 $_{xcluster}$									

Observations	47266
Marginal R^2 / Conditional R^2	**0.042 / 0.090**
AIC	643014.3

*Table A12: Zero-inflated negative binomial regression coefficients for the number of minutes of moderate to vigorous physical activity everywhere with all interactions terms (TDM*Year group + TDM*Gender + TDM*IMD)*

	Negative Binomial Portion					**Logit Portion**				
Predictors	*Incidence Rate Ratios*	*SE*	*CI*	*CI*	*p*	*Odds Ratio*	*SE*	*CI*	*CI*	*p*
(Intercept)	602.67	0.04	556.66	652.48	**<0.001**	0.04	0.2	0.03	0.06	**<0.001**
Rurality: Rural										
Urban	1.01	0.02	0.97	1.05	0.713	1.27	0.1	1.05	1.55	**0.015**
Ofsted: Outstanding										
Good	0.95	0.02	0.91	0.99	**0.026**	1.25	0.11	1.01	1.54	**0.041**
Requires improvement	0.95	0.03	0.89	1.01	0.129	1.24	0.17	0.90	1.71	0.195
Inadequate	0.87	0.11	0.71	1.07	0.193	2.4	0.46	0.97	5.94	0.057
Ofsted Missing	0.93	0.03	0.87	0.99	**0.032**	1.34	0.15	0.99	1.81	0.056
Daily Mile: No										
Daily Mile Yes	0.95	0.06	0.85	1.06	0.37	1.21	0.29	0.69	2.11	0.51
Year Group: 1 and 2										
3 and 4	0.99	0.06	0.88	1.11	0.825	1.83	0.4	0.84	4.03	0.131
5 and 6	0.97	0.03	0.92	1.02	0.222	1.79	0.16	1.30	2.46	**<0.001**
Ethnicity: White British										
White other	1.05	0.02	1.00	1.09	**0.042**	1.06	0.13	0.82	1.37	0.651
Asian	0.94	0.02	0.91	0.98	**0.005**	1.07	0.11	0.86	1.34	0.553
Black	0.93	0.03	0.89	0.98	**0.007**	1.06	0.14	0.81	1.40	0.651
Mixed	1.03	0.02	1.00	1.06	0.093	1.08	0.09	0.90	1.29	0.413
Other	0.99	0.02	0.95	1.03	0.578	1.11	0.12	0.88	1.39	0.392
Prefer not to say	0.88	0.01	0.86	0.91	**<0.001**	1.47	0.07	1.28	1.69	**<0.001**
Gender: Boy										
Girl	0.79	0.01	0.77	0.81	**<0.001**	0.79	0.05	0.71	0.88	**<0.001**
Other	0.98	0.02	0.93	1.03	0.417	1.06	0.12	0.85	1.33	0.61

IMD Quintiles: 1 (most deprived)										
2	0.97	0.06	0.85	1.10	0.61	0.68	0.43	0.29	1.56	0.36
3	0.98	0.03	0.91	1.05	0.548	0.72	0.17	0.51	1.00	**0.049**
4	1.01	0.03	0.95	1.08	0.745	0.64	0.17	0.46	0.90	**0.009**
5 (least deprived)	1.01	0.03	0.94	1.08	0.862	0.55	0.17	0.39	0.77	**0.001**
IMD missing	0.88	0.13	0.68	1.14	0.326	0	21.98	Did not converge	Did not converge	0.747
Disability: No disability										
Yes	0.97	0.01	0.95	0.99	**0.001**	1.25	0.05	1.13	1.39	**<0.001**
Prefer not to say	0.98	0.01	0.96	1.01	0.198	1.31	0.07	1.14	1.50	**<0.001**
Term/Season: Autumn										
Spring	1.12	0.02	1.08	1.17	**<0.001**	0.38	0.08	0.33	0.45	**<0.001**
Summer	1.3	0.02	1.25	1.35	**<0.001**	0.15	0.11	0.12	0.18	**<0.001**
Interactions										
Daily Mile Yes * Boy										
Daily Mile Yes * Girl	0.99	0.02	0.95	1.04	0.805	1.02	0.13	0.79	1.31	0.886
Daily Mile Yes * Other	0.95	0.05	0.85	1.05	0.318	1.67	0.24	1.04	2.68	**0.033**
Daily Mile Yes * IMD 1										
Daily Mile Yes * IMD 2	1.15	0.15	0.87	1.53	0.322	0.5	1.17	0.05	4.93	0.552
Daily Mile Yes * IMD 3	1.16	0.07	1.01	1.33	**0.039**	0.58	0.37	0.28	1.18	0.134
Daily Mile Yes * IMD 4	1.05	0.07	0.92	1.19	0.507	0.91	0.33	0.48	1.74	0.779
Daily Mile Yes * IMD 5	1.12	0.07	0.97	1.30	0.116	0.81	0.37	0.39	1.66	0.558
Daily Mile Yes * IMD missing	1.29	0.3	0.71	2.34	0.399	758.42	22.02	Did not converge	Did not converge	0.763
Daily Mile Yes * Year 1-2										
Daily Mile Yes * Year 3-4	0.97	0.13	0.75	1.26	0.833	1.95	1.14	0.21	18.07	0.555
Daily Mile Yes * Year 5-6	1.04	0.05	0.94	1.16	0.416	0.85	0.33	0.45	1.62	0.628
Random Effects										
σ^2	0.63									

τ_{00}	0.04 $_{xcluster}$
ICC	0.06
N	1012 $_{xcluster}$
Observations	47266
Marginal R^2 / Conditional R^2	0.040 / 0.096
AIC	678162.04

*Table A13: Zero-inflated negative binomial regression coefficients for the number of minutes of moderate to vigorous physical activity in school for an interaction term between TDM*Gender*

	Negative Binomial Model			**Logit Model**		
Predictors	***Incidence Rate Ratios***	***SE***	***p***	***OR***	***SE***	***p***
(Intercept)	162.22	0.04	**<0.001**	0.12	0.14	**<0.001**
Rurality: Rural						
Urban	1	0.02	0.986	1.22	0.07	0.007
Ofsted: Outstanding						
Good	0.96	0.02	0.108	1.11	0.08	0.195
Requires improvement	0.94	0.03	0.075	1.18	0.12	0.176
Inadequate	0.9	0.11	0.315	1.63	0.36	0.176
Ofsted Missing	0.93	0.03	0.024	1.1	0.12	0.427
Daily Mile: No						
Daily Mile Yes	1.06	0.02	0.008	0.86	0.09	0.081
Year Group: 1 and 2						
3 and 4	1.05	0.05	0.328	0.46	0.17	<0.001
5 and 6	1.01	0.02	0.517	0.55	0.08	<0.001
Ethnicity: White British						
White other	1.04	0.02	0.095	1.11	0.09	0.255
Asian	0.99	0.02	0.525	0.96	0.09	0.637
Black	1	0.03	0.982	0.97	0.11	0.82
Mixed	1.05	0.02	0.001	0.91	0.08	0.236
Other	0.99	0.02	0.664	1.11	0.09	0.25
Prefer not to say	0.93	0.01	<0.001	1.22	0.06	0.001
Gender: Boy						
Girl	0.84	0.01	<0.001	0.9	0.04	0.016
Other	1.03	0.02	0.153	1.09	0.1	0.377
IMD Quintiles: 1 (most deprived)						
2	0.93	0.06	0.237	1.7	0.19	0.006
3	0.95	0.03	0.13	1.38	0.11	0.004

4	0.95	0.03	0.078	1.32	0.11	0.012
5 (least deprived)	0.95	0.03	0.093	1.19	0.11	0.131
IMD missing	0.95	0.13	0.702	3.16	0.33	0.001
Disability: No disability						
Yes	0.99	0.01	0.575	1.05	0.04	0.22
Prefer not to say	0.99	0.01	0.565	1.05	0.06	0.404
Term/Season: Autumn						
Spring	1.08	0.02	<0.001	0.52	0.07	<0.001
Summer	1.22	0.02	<0.001	0.33	0.07	<0.001
Interactions						
Daily Mile Yes * Boy						
Daily Mile Yes * Girl	1.01	0.02	0.659	1.22	0.1	0.042
Daily Mile Yes * Other	0.95	0.05	0.344	1.59	0.2	0.023
Random Effects						
σ^2	0.57					
τ_{00}	0.04 $_{xcluster}$					
ICC	0.07					
N	1012 $_{xcluster}$					
Observations	47266					
Marginal R^2 / Conditional R^2	0.026 / 0.092					
AIC	550573.584					

*Table A14: Zero-inflated negative binomial regression coefficients for the number of minutes of moderate to vigorous physical activity in school for an interaction term between TDM*YearGroup*

	The Daily Mile*Year Group Interaction Term					
	Negative Binomial Model			**Logit Model**		
Predictors	***Incidence Rate Ratios***	***SE***	***p***	***OR***	***SE***	***p***
(Intercept)	165.01	0.04	**<0.001**	0.11	0.14	**<0.001**
Rurality: Rural						
Urban	1	0.02	0.995	1.22	0.07	**0.007**
Ofsted: Outstanding						
Good	0.97	0.02	0.121	1.1	0.08	0.216
Requires improvement	0.94	0.03	0.087	1.18	0.12	0.188
Inadequate	0.9	0.11	0.322	1.62	0.36	0.178
Ofsted Missing	0.93	0.03	**0.026**	1.1	0.12	0.442
Daily Mile: No						
Daily Mile Yes	0.98	0.04	0.674	1.09	0.15	0.581
Year Group: 1 and 2						
3 and 4	1.04	0.05	0.492	0.46	0.18	**<0.001**
5 and 6	0.99	0.02	0.742	0.58	0.09	**<0.001**
Ethnicity: White British						
White other	1.04	0.02	0.092	1.11	0.09	0.264
Asian	0.99	0.02	0.526	0.96	0.09	0.617
Black	1	0.03	0.991	0.97	0.11	0.802
Mixed	1.05	0.02	**0.001**	0.91	0.08	0.221
Other	0.99	0.02	0.665	1.11	0.09	0.249
Prefer not to say	0.93	0.01	**<0.001**	1.22	0.06	**0.001**
Gender: Boy						
Girl	0.84	0.01	**<0.001**	0.94	0.04	0.093

Other	1.02	0.02	0.25	1.19	0.09	**0.043**
IMD Quintiles: 1 (most deprived)						
2	0.93	0.06	0.234	1.7	0.19	**0.006**
3	0.95	0.03	0.134	1.36	0.11	**0.006**
4	0.95	0.03	0.077	1.31	0.11	**0.014**
5 (least deprived)	0.95	0.03	0.104	1.17	0.11	0.172
IMD missing	0.95	0.13	0.695	3.18	0.33	**0.001**
Disability: No disability						
Yes	0.99	0.01	0.571	1.05	0.04	0.223
Prefer not to say	0.99	0.01	0.569	1.05	0.06	0.403
Term/Season: Autumn						
Spring	1.08	0.02	**<0.001**	0.52	0.07	**<0.001**
Summer	1.22	0.02	**<0.001**	0.33	0.07	**<0.001**
Interactions						
Daily Mile Yes * Year 1-2						
Daily Mile Yes * Year 3-4	1.07	0.06	0.244	1.06	0.2	0.769
Daily Mile Yes * Year 5-6	1.11	0.05	**0.026**	0.8	0.16	0.167
Random Effects						
σ^2	0.57					
τ_{00}	0.04 $_{xcluster}$					
ICC	0.07					
N	1012 $_{xcluster}$					
Observations	47266					
Marginal R^2 / Conditional R^2	0.026 / 0.092					
AIC	550573.589					

*Table A15: Zero-inflated negative binomial regression coefficients for the number of minutes of moderate to vigorous physical activity in school for an interaction term between TDM*IMD*

	The Daily Mile*IMD Interaction Term					
	Negative Binomial Model			**Logit Model**		
Predictors	*Incidence Rate Ratios*	*SE*	*p*	*OR*	*SE*	*p*
(Intercept)	167.07	0.04	**<0.001**	0.11	0.15	**<0.001**
Rurality: Rural						
Urban	1	0.02	0.945	1.23	0.07	**0.006**
Ofsted: Outstanding						
Good	0.96	0.02	0.1	1.11	0.08	0.203
Requires improvement	0.95	0.03	0.135	1.16	0.12	0.239
Inadequate	0.9	0.11	0.344	1.58	0.36	0.201
Ofsted Missing	0.93	0.03	**0.021**	1.1	0.12	0.429
Daily Mile: No						
Daily Mile Yes	0.95	0.05	0.304	1.18	0.18	0.359
Year Group: 1 and 2						
3 and 4	1.05	0.05	0.331	0.46	0.17	**<0.001**
5 and 6	1.02	0.02	0.48	0.55	0.08	**<0.001**
Ethnicity: White British						
White other	1.04	0.02	0.092	1.11	0.09	0.255
Asian	0.99	0.02	0.524	0.96	0.09	0.619
Black	1	0.02	0.978	0.97	0.11	0.787
Mixed	1.05	0.02	**0.001**	0.91	0.08	0.223
Other	0.99	0.02	0.696	1.11	0.09	0.256
Prefer not to say	0.93	0.01	**<0.001**	1.22	0.06	**0.001**
Gender: Boy						
Girl	0.84	0.01	**<0.001**	0.94	0.04	0.09

Other	1.02	0.02	0.243	1.19	0.09	**0.042**
IMD Quintiles: 1 (most deprived)						
2	0.91	0.06	0.105	1.73	0.2	**0.006**
3	0.91	0.03	**0.005**	1.51	0.12	**0.001**
4	0.93	0.03	**0.025**	1.4	0.12	**0.007**
5 (least deprived)	0.92	0.03	**0.011**	1.26	0.12	0.061
IMD missing	0.92	0.14	0.57	3.96	0.36	**<0.001**
Disability: No disability						
Yes	0.99	0.01	0.571	1.05	0.04	0.222
Prefer not to say	0.99	0.01	0.555	1.05	0.06	0.404
Term/Season: Autumn						
Spring	1.08	0.02	**<0.001**	0.52	0.07	**<0.001**
Summer	1.22	0.02	**<0.001**	0.33	0.07	**<0.001**
Interactions						
Daily Mile Yes * IMD 1						
Daily Mile Yes * IMD 2	1.12	0.06	0.071	0.96	0.23	0.848
Daily Mile Yes * IMD 3	1.24	0.07	**0.001**	0.63	0.25	0.062
Daily Mile Yes * IMD 4	1.08	0.06	0.195	0.81	0.23	0.346
Daily Mile Yes * IMD 5	1.16	0.07	**0.033**	0.74	0.26	0.25
Daily Mile Yes * IMD missing	1.15	0.32	0.669	0.31	0.88	0.186
Random Effects						
σ^2	0.57					
τ_{00}	0.04 $_{xcluster}$					
ICC	0.07					
N	1012 $_{xcluster}$					
Observations	47266					
Marginal R^2 / Conditional R^2	0.027 / 0.092					
AIC	550576.374					

Appendix K

Sensitivity Analyses results for secondary outcome: meeting the recommended levels of physical activity

Table A16: Multilevel multivariable logistic regression of Daily Mile Registration on Meeting the Recommended Levels of Physical Activity in England clustered by school with interaction terms

	TDM* Gender only			**TDM*year group only**			**TDM*IMD only**			**TDM*gender + TDM*year group +**		
Predictors	***Odds Ratios***	***SE***	***p***	***Odds Ratios***	***SE***	***p***	***Odds Ratios***	***SE***	***p***	***Odds Ratios***	***SE***	***p***
(Intercept)	1.05	0.08	0.544	1.08	0.08	0.335	1.13	0.08	0.149	1.12	0.08	0.159
Rurality: Rural												
Urban	0.95	0.04	0.185	0.95	0.04	0.176	0.94	0.04	0.122	0.94	0.04	0.121
Ofsted: Outstanding												
Good	0.85	0.04	**<0.001**	0.85	0.04	**<0.001**	0.85	0.04	**<0.001**	0.85	0.04	**<0.001**
Requires improvement	0.86	0.07	**0.032**	0.86	0.07	**0.036**	0.89	0.07	0.077	0.89	0.07	0.078
Inadequate	0.75	0.22	0.192	0.75	0.22	0.197	0.77	0.22	0.224	0.77	0.22	0.224
Ofsted Missing	0.81	0.07	**0.002**	0.82	0.07	**0.002**	0.81	0.07	**0.002**	0.81	0.07	**0.002**
Daily Mile: No												
Daily Mile Yes	1.16	0.05	**0.002**	1.01	0.09	0.928	0.89	0.1	0.239	0.89	0.12	0.33
Year Group: 1 and 2												
3 and 4	0.68	0.12	**0.001**	0.68	0.12	**0.001**	0.68	0.12	**0.001**	0.68	0.13	**0.003**
5 and 6	0.73	0.05	**<0.001**	0.71	0.05	**<0.001**	0.74	0.05	**<0.001**	0.73	0.06	**<0.001**
Ethnicity: White British												
White other	0.95	0.05	0.354	0.96	0.05	0.364	0.96	0.05	0.37	0.96	0.05	0.367
Asian	0.88	0.05	**0.004**	0.88	0.05	**0.004**	0.88	0.05	**0.004**	0.87	0.05	**0.004**
Black	0.94	0.06	0.316	0.94	0.06	0.321	0.94	0.06	0.334	0.94	0.06	0.329
Mixed	1.02	0.04	0.62	1.02	0.04	0.604	1.02	0.04	0.597	1.02	0.04	0.61
Other	0.91	0.05	0.063	0.91	0.05	0.063	0.91	0.05	0.066	0.91	0.05	0.065
Prefer not to say	0.77	0.03	**<0.001**	0.77	0.03	**<0.001**	0.77	0.03	**<0.001**	0.77	0.03	**<0.001**
Gender: Boy												

Girl	0.69	0.02	**<0.001**	0.68	0.02	**<0.001**	0.68	0.02	**<0.001**	0.69	0.02	**<0.001**
Other	0.93	0.05	0.152	0.89	0.05	**0.022**	0.89	0.05	**0.022**	0.93	0.05	0.159
IMD Quintiles: 1 (most deprived)												
2	1.29	0.13	**0.048**	1.29	0.13	**0.049**	1.23	0.13	0.109	1.23	0.14	0.145
3	1.2	0.06	**0.004**	1.2	0.06	**0.004**	1.07	0.07	0.365	1.07	0.07	0.328
4	1.28	0.06	**<0.001**	1.29	0.06	**<0.001**	1.23	0.07	**0.003**	1.24	0.07	**0.003**
5 (least deprived)	1.33	0.06	**<0.001**	1.34	0.06	**<0.001**	1.22	0.07	**0.005**	1.23	0.07	**0.004**
IMD Missing	0.94	0.26	0.815	0.94	0.26	0.805	0.91	0.29	0.734	0.9	0.29	0.724
Disability: No disability												
Yes	0.88	0.02	**<0.001**	0.88	0.02	**<0.001**	0.88	0.02	**<0.001**	0.88	0.02	**<0.001**
Prefer not to say	0.9	0.03	**0.001**	0.9	0.03	**<0.001**	0.9	0.03	**<0.001**	0.9	0.03	**<0.001**
Term/Season: Autumn												
Spring	1.36	0.04	**<0.001**	1.35	0.04	**<0.001**	1.36	0.04	**<0.001**	1.36	0.04	**<0.001**
Summer	1.83	0.04	**<0.001**	1.83	0.04	**<0.001**	1.83	0.04	**<0.001**	1.83	0.04	**<0.001**
Interactions												
Daily Mile Yes * Boy												
Daily Mile Yes * Girl	0.95	0.05	0.308							0.95	0.05	0.313
Daily Mile Yes * Other	0.84	0.12	0.142							0.83	0.12	0.128
Daily Mile Yes * Year 1-2												
Daily Mile Yes * Year 3-4				1.03	0.12	0.791				1.02	0.3	0.946
Daily Mile Yes * Year 5-6				1.17	0.1	0.112				1.06	0.11	0.621
Daily Mile Yes * IMD 1												
Daily Mile Yes * IMD 2							1.18	0.13	0.218	1.18	0.32	0.6
Daily Mile Yes * IMD 3							1.68	0.14	**<0.001**	1.64	0.15	**0.001**
Daily Mile Yes * IMD 4							1.15	0.13	0.269	1.12	0.14	0.413
Daily Mile Yes * IMD 5							1.5	0.14	**0.005**	1.46	0.15	**0.013**
Daily Mile Yes * IMD Missing							1.13	0.65	0.851	1.15	0.65	0.828
Random Effects												
σ^2	3.29			3.29			3.29			3.29		
τ_{00}	0.15 $_{xcluster}$			0.15 $_{xcluster}$			0.14 $_{xcluster}$			0.14 $_{xcluster}$		
ICC	0.04			0.04			0.04			0.04		
N	1012 $_{xcluster}$			1012 $_{xcluster}$			1012 $_{xcluster}$			1012 $_{xcluster}$		
Observations	47266			47266			47266			47266		
Marginal R^2 / Conditional R^2	0.034 / 0.076			0.034 / 0.076			0.035 / 0.076			0.035 / 0.076		
AIC	63336.386			63335.601			63325.512			63330.499		

Appendix L

Table A17: Negative binomial regression coefficients examining the association between TDM and variety of activity across different settings

	In School				Outside School				Everywhere			
Predictors	**Incidence Rate Ratios**	**SE**	**CI**	**p**	**Incidence Rate Ratios**	**SE**	**CI**	**p**	**Incidence Rate Ratios**	**SE**	**CI**	**p**
(Intercept)	3.71	0.03		<0.001	4.96	0.03		<0.001	5.91	0.03		<0.001
Daily Mile: No												
Daily Mile Yes	1.04	0.02		0.037	1.05	0.02		0.006	1.05	0.02		0.004
Rurality: Rural												
Urban	0.98	0.02		0.44	0.96	0.02		0.012	0.95	0.02		0.001
Year Group: 1 and 2												
3 and 4	1.56	0.05		<0.001	0.91	0.04		0.028	0.97	0.04		0.412
5 and 6	1.37	0.02		<0.001	0.88	0.02		<0.001	0.91	0.02		<0.001
Ethnicity: White British												
White other	1.02	0.02		0.222	1.02	0.02		0.224	1.02	0.02		0.198
Asian	1.01	0.02		0.468	0.97	0.02		0.083	0.97	0.02		0.072
Black	1.03	0.02		0.178	0.96	0.02		0.081	1	0.02		0.797
Mixed	1.05	0.01		<0.001	1.01	0.01		0.55	1.01	0.01		0.26
Other	1	0.02		0.851	0.98	0.02		0.344	0.97	0.02		0.113
Prefer not to say	0.95	0.01		<0.001	0.91	0.01		<0.001	0.92	0.01		<0.001
Gender: Boy												
Girl	0.92	0.01		<0.001	0.97	0.01		<0.001	0.96	0.01		<0.001
Other	1.03	0.02		0.086	1.01	0.02		0.643	1.03	0.02		0.037
IMD Quintiles: 1 (most deprived)												
2	0.74	0.06		<0.001	1.06	0.05		0.232	1.01	0.04		0.85
3	0.85	0.03		<0.001	1.12	0.03		<0.001	1.09	0.02		<0.001
4	0.85	0.03		<0.001	1.14	0.02		<0.001	1.11	0.02		<0.001
5 (least deprived)	0.87	0.03		<0.001	1.17	0.03		<0.001	1.14	0.02		<0.001
IMD missing	0.64	0.12		<0.001	0.95	0.1		0.576	0.89	0.09		0.219
Disability: No disability												

Yes	1.04	0.01	<0.001	0.98	0.01	0.009	0.99	0.01	0.362
Prefer not to say	1.05	0.01	<0.001	0.99	0.01	0.284	0.99	0.01	0.56
Term/Season: Autumn									
Spring	1.12	0.02	<0.001	1.12	0.02	<0.001	1.12	0.01	<0.001
Summer	1.26	0.02	<0.001	1.29	0.02	<0.001	1.27	0.02	<0.001
Random Effects									
σ2	0.49			0.45			0.37		
τ00	0.04 xcluster			0.03 xcluster			0.03 xcluster		
ICC	0.08			0.06			0.06		
N	1013 xcluster			1013 xcluster			1013 xcluster		
Observations	47776			47776			47776		
Marginal R2 / Conditional R2	0.038 / 0.116			0.029 / 0.085			0.029 / 0.092		
AIC	246475.7			254232.2			263435.8		

Appendix M

Chapter 9, Fidelity full modelling results

Table A18: Variation in reporting a de-facto daily mile by official registration status to The Daily Mile

	Registered to The Daily Mile	**Not Registered to The Daily Mile**
Model 1: Year Group Random Effect only	**Model 1a**	**Model 1b**
τ_{00}	0.16 $_{\text{Year Group}}$	0.32 $_{\text{Year Group}}$
ICC	0.05	0.09
N	6 $_{\text{Year Group}}$	6 $_{\text{Year Group}}$
Observations	10368	41094.00
Marginal R^2 / Conditional R^2	0.000 / 0.046	0.000 / 0.089
AIC	12093.17	42189.78
Model 2: School Random Effect only	**Model 2a**	**Model 2b**
τ_{00}	0.40 $_{\text{school}}$	0.29 $_{\text{school}}$
ICC	0.11	0.08
N	223 $_{\text{school}}$	831 $_{\text{school}}$
Observations	10368	41094.00
Marginal R^2 / Conditional R^2	0.000 / 0.109	0.000 / 0.081
AIC	11758.38	41798.43
Model 3: Active Partnership Random Effect only	**Model 3a**	**Model 3b**
τ_{00}	0.18 $_{\text{Active Partnership}}$	0.02 $_{\text{Active Partnership}}$
ICC	0.05	0.01
N	42 $_{\text{Active Partnership}}$	45 $_{\text{Active Partnership}}$
Observations	10368	41094.00
Marginal R^2 / Conditional R^2	0.000 / 0.051	0.000 / 0.006
AIC	12054.05	42637.86
Model 4: All random effects **Model 4a: registered children, random effects for year group and school** **Model 4b: Non-registered children, random effects for year group and school, and Active Partnership**	**Model 4a**	**Model 4b**
τ_{00}	0.40 $_{\text{school}}$	0.27 $_{\text{school}}$
	0.19 $_{\text{Year Group}}$	0.004 $_{\text{Active Partnership}}$
		0.34 $_{\text{Year Group}}$
ICC	0.152	0.157
N	6 $_{\text{Year Group}}$	6 $_{\text{Year Group}}$

	223 school	831 school
		45 Active Partnership
Observations	10368	41094
Marginal R^2 / Conditional R^2	0.000 / 0.152	0.000 / 0.157
AIC	11681.121	41373.795
Model 5: Model 4 + Child Characteristics	**Model 5a**	**Model 5b**
τ_{00}	0.39 school	0.26 school
	0.18 Year Group	0.00 Active Partnership
		0.33 Year Group
Variance attributable to the fixed effects	0.02	0.03
ICC	0.148	0.153
N	6 Year Group	6 Year Group
	222 school	826 school
		45 Active Partnership
Observations	9934	39201
Marginal R^2 / Conditional R^2	0.006 / 0.152	0.007 / 0.160
AIC	11228.226	39365.302
Model 6: Model 5 + school characteristics	**Model 6a**	**Model 6b**
τ_{00}	0.35 school	0.25 school
	0.17 Year Group	0.01 Active Partnership
		0.33 Year Group
Variance attributable to the fixed effects	0.06	0.05
ICC	0.138	0.151
N	6 Year Group	6 Year Group
	217 school	799 school
		45 Active Partnership
Observations	9752	38230
Marginal R^2 / Conditional R^2	0.016 / 0.152	0.012 / 0.161
AIC	11024.940	38373.295

τ_{00}: random intercept variance/between subject variance
ICC: Intraclass correlation coefficient
N: level-2, level-3, level-4 units which were the number of year groups (level-2), number of schools (level-3) and number of Active Partnerships (level-4) used in the model
Observations: number of children (observations at level-1) used in the model
Marginal R^2 / Conditional R^2: Marginal R2 provides the variance explained only by fixed effects and conditional R2 provides the variance explained by the entire model, i.e., both fixed effects and random effects.

Table A19: Full Results for Model 1a and 1b

	TDM registered - null model year group (1a)			**Non-TDM registered - null model year group (1b)**		
Predictors	*Odds Ratios*	*SE*	*p*	*Odds Ratios*	*SE*	*p*
(Intercept)	0.3	0.17	**<0.001**	0.2	0.23	**<0.001**
Random Effects						
σ^2	3.29			3.29		
τ_{00}	0.16 $_{\text{Year Group}}$			0.32 $_{\text{Year Group}}$		
ICC	0.05			0.09		
N	6 $_{\text{Year Group}}$			6 $_{\text{Year Group}}$		
Observations	10368			41094		
Marginal R^2 / Conditional R^2	0.000 / 0.046			0.000 / 0.089		
AIC	12093.172			42189.778		

Table A20: Full Results for Model 2a and 2b

	TDM registered - null model school (2a)			**Non-TDM registered - null model school (2b)**		
Predictors	*Odds Ratios*	*SE*	*p*	*Odds Ratios*	*SE*	*p*
(Intercept)	0.34	0.05	**<0.001**	0.25	0.02	**<0.001**
Random Effects						
σ^2	3.29			3.29		
τ_{00}	0.40 $_{\text{school}}$			0.29 $_{\text{school}}$		
ICC	0.11			0.08		
N	223 $_{\text{school}}$			831 $_{\text{school}}$		
Observations	10368			41094		
Marginal R^2 / Conditional R^2	0.000 / 0.109			0.000 / 0.081		
AIC	11758.375			41798.426		

Table A21: Full Results for Model 3a and 3b

	TDM registered - null model Active Partnership (3a)			**Non-TDM registered - null model Active Partnership (3b)**		
Predictors	*Odds Ratios*	*SE*	*p*	*Odds Ratios*	*SE*	*p*
(Intercept)	0.37	0.07	**<0.001**	0.27	0.03	**<0.001**
Random Effects						
σ^2	3.29			3.29		
τ_{00}	0.18 $_{\text{Active Partnership}}$			0.02 $_{\text{Active Partnership}}$		

ICC	0.05	0.01
N	42 Active Partnership	45 Active Partnership
Observations	10368	41094
Marginal R^2 / Conditional R^2	0.000 / 0.051	0.000 / 0.006

Table A22: Full Results for Model 4a and 4b

	TDM registered - null model year group + school			**Non-TDM registered - null model year group + school + Active Partnership**		
Predictors	*Odds Ratios*	*SE*	*p*	*Odds Ratios*	*SE*	*p*
(Intercept)	0.28	0.19	**<0.001**	0.18	0.24	**<0.001**
Random Effects						
σ^2	3.29			3.29		
τ_{00}	0.40 school			0.27 school		
	0.19 Year Group			0.00 Active Partnership		
				0.34 Year Group		
ICC	0.15			0.16		
N	6 Year Group			6 Year Group		
	223 school			831 school		
				45 Active Partnership		
Observations	10368			41094		
Marginal R^2 / Conditional R^2	0.000 / 0.152			0.000 / 0.157		
AIC	11681.121			41373.795		

Table A23: Full Results for Model 5a and 5b

	TDM registered - null model year group + school + child characteristics			**Non-TDM registered - null model year group + school + Active Partnership + child characteristics**		
Predictors	***Odds Ratios***	***SE***	***p***	***Odds Ratios***	***SE***	***p***
(Intercept)	0.27	0.19	**<0.001**	0.16	0.24	**<0.001**
Gender: Boy (Ref)						
Girl	0.88	0.05	**0.008**	0.84	0.03	**<0.001**
Other	0.83	0.12	0.128	1.06	0.06	0.35
Ethnicity: White British (Ref)						
White Other	1.1	0.13	0.45	0.96	0.07	0.504
Asian	0.99	0.11	0.93	0.95	0.06	0.387
Black	0.84	0.14	0.207	0.97	0.08	0.685
Mixed	0.89	0.09	0.219	1	0.05	0.98

Other	0.85	0.12	0.186	0.94	0.07	0.355
Prefer not to say	0.95	0.08	0.558	0.84	0.04	**<0.001**
Family Affluence Score: Low 0-6 (Ref)						
medium 7 -9/10	1.09	0.06	0.168	1.21	0.04	**<0.001**
high 10/11-12/13	1.39	0.08	**<0.001**	1.49	0.04	**<0.001**
Random Effects						
σ^2	3.29			3.29		
τ_{00}	0.39 $_{xcluster}$			0.26 $_{xcluster}$		
	0.18 $_{SCHYR_11}$			0.00 $_{CSP_name}$		
				0.33 $_{SCHYR_11}$		
ICC	0.15			0.15		
N	6 $_{SCHYR_11}$			6 $_{SCHYR_11}$		
	222 $_{xcluster}$			826 $_{xcluster}$		
				45 $_{CSP_name}$		
Observations	9934			39201		
Marginal R^2 / Conditional R^2	0.006 / 0.152			0.007 / 0.160		
AIC	11228.226			39365.302		

Table A24: Full Results for Model 6a and 6b

	TDM registered - null model year group + school + child and school characteristics			**Non-TDM registered - null model year group + school + Active Partnership + child and school characteristics**		
Predictors	*Odds Ratios*	*SE*	*p*	*Odds Ratios*	*SE*	*p*
(Intercept)	0.27	0.5	**0.009**	0.16	0.3	**<0.001**
Pupil to Teacher Ratio: Fewer than 15:1 (Ref)						
15:1 to 19:1	1.19	0.41	0.676	1.27	0.17	0.162
20:1 to 24:1	1.19	0.4	0.669	1.23	0.17	0.229
25:1 to 29:1	1.13	0.42	0.778	1.25	0.18	0.227
30:1 or more	0.91	0.61	0.871	1.45	0.32	0.248
School Size: Up to 100 pupils (Ref)						
101 to 200 pupils	0.71	0.26	0.181	0.75	0.12	**0.017**
201 to 300 pupils	0.82	0.29	0.487	0.78	0.12	**0.049**
301 to 500 pupils	0.72	0.27	0.22	0.72	0.13	**0.01**
501 pupils and over	0.75	0.33	0.382	0.84	0.15	0.237
Season: Autumn (Ref)						
termSpring	1.38	0.12	**0.009**	1.14	0.06	**0.021**
termSummer	1.55	0.13	**0.001**	1.27	0.06	**<0.001**

Rurality: Rural (Ref)						
Urban	0.86	0.15	0.301	0.97	0.06	0.631
Gender: Boy (Ref)						
Girl	0.89	0.05	**0.015**	0.84	0.03	**<0.001**
Other	0.84	0.12	0.145	1.06	0.06	0.347
Ethnicity: White British (Ref)						
White Other	1.1	0.13	0.462	0.95	0.07	0.45
Asian	1.01	0.11	0.938	0.96	0.06	0.514
Black	0.85	0.14	0.251	0.98	0.08	0.788
Mixed	0.9	0.09	0.237	1	0.05	0.981
Other	0.85	0.13	0.206	0.93	0.07	0.261
Prefer not to say	0.97	0.08	0.714	0.84	0.04	**<0.001**
Family Affluence Score: Low 0-6 (Ref)						
medium 7 -9/10	1.08	0.06	0.26	1.21	0.04	**<0.001**
high 10/11-12/13	1.36	0.08	**<0.001**	1.49	0.04	**<0.001**
Random Effects						
σ^2	3.29			3.29		
τ_{00}	0.35 $_{xcluster}$			0.25 $_{xcluster}$		
	0.17 $_{SCHYR_11}$			0.01 $_{CSP_name}$		
				0.33 $_{SCHYR_11}$		
ICC	0.14			0.15		
N	6 $_{SCHYR_11}$			6 $_{SCHYR_11}$		
	217 $_{xcluster}$			799 $_{xcluster}$		
				45 $_{CSP_name}$		
Observations	9752			38230		
Marginal R^2 / Conditional R^2	0.016 / 0.152			0.012 / 0.161		
AIC	11024.94			38373.295		