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# Development of Inequalities in Fruit and Vegetable Intake through Early Adulthood: Insights from Household Panel Surveys in the United Kingdom and Australia.

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**Article**

**Keywords:**

**Posted Date:** September 27th, 2024

**DOI:** https://doi.org/10.21203/rs.3.rs-4324934/v1

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**Additional Declarations:** There is **NO** conflict of interest to disclose.

## Abstract

# Background

Adequate fruit and vegetable intake is important for preventing chronic disease. The transition from adolescence to early adulthood involves significant life changes that may determine lifelong dietary patterns. Dietary habits in early adulthood often fail to meet recommended guidelines, particularly in less affluent groups, setting the foundation for long-term health inequalities. This study examined the trajectories of fruit and vegetable intake among young adults in the United Kingdom (UK) and Australia, analysing variations by sex and socioeconomic position (SEP).

# Methods

We analysed data from young adults aged 16–30 years from the UK Household Longitudinal Study (UKHLS) (n = 5,132) and the Household, Income and Labour Dynamics in Australia (HILDA) Survey (n = 2,981). Hybrid mixed-effect regression models were fitted to assess trajectories of fruit and vegetable intake, exploring differences by sex and SEP.

# Results

As young adults aged, fruit intake decreased while vegetable intake increased in both countries. Age-related trajectories of vegetable intake differed between females and males in Australia, but not in the UK. Parental education was a significant predictor of vegetable intake trajectories in both cohorts, with inequalities widening with age.

# Conclusions

The differing trajectories of fruit and vegetable intake among young adults in the UK and Australia emphasise the importance of understanding contrextual influences to effectively tailor public health strategies. Our study highlights early adulthood as a critical period for establishing dietary patterns that could influence long-term health outcomes. Addressing inequalities is essential when developing policies aimed at improving diet among young adults and reducing the prevalence of chronic disease.

## 1. Introduction

Fruit and vegetables are major components of a healthy diet, and their intake has been associated with a lower risk of chronic disease[1–5] and obesity[6–8]. Globally, the prevalence of overweight and obesity is growing among adolescents and young adults[9–11] and adequate fruit and vegetable intake is particularly important during adolescence in contributing to overall diet quality and risk of future chronic disease[1,3–

[5,12–16]. For example, poorer diet quality in adolescence has shown to be associated with higher fat mass[17,18], adiposity[19], cardiometabolic risk factors[20] and elevated body mass index[21], which, in turn, are linked with chronic disease[22].

The transition from late adolescence to early adulthood is a period of change, characterised by increased independence and the establishment of lifestyle habits, such as dietary patterns[23]. Despite the importance of dietary patterns in this age group, there have been few studies covering this longitudinally, limiting our understanding of the nuances across this transitional period[24]. In the present study, the age group of interest includes individuals aged 16–30 years, to capture this period of early adulthood[25,26] and we refer to this popuplation as 'young adults'. This period is particularly crucial for examining trajectories in fruit and vegetable intake as it encompasses a time when individuals often experience changes in living situations, educational environments, and employment status, all of which can influence dietary patterns and habits.

The UK and Australia share social and cultural overlaps, for example, access to healthcare through their universal healthcare systems[27,28], as well as language, political and economic similarities[29,30]. Both of these countries face comparable health challenges including overweight and obesity rates around 65%[31] for individuals aged 15 years and older, and difficulties in meeting fruit and vegetable consumption guidelines, despite public health efforts[32–34]. The World Health Organization (WHO) advises a minimum intake of 400g or five portions per day of fruits and vegetables[35,36], informing the UK's 5-a-day recommendation[2]. The National Health and Medical Research Council (NHMRC) 2013 Australian Dietary Guidelines build on this, recommending a minimum of two portions of fruit and five portions of vegetables per day[37], also known as the '2&5 campaign'. Despite minor variations in the recommendations, the overarching goal remains the same: to boost the intake of fruits and vegetables. Whilst there are a number of similarities between the UK and Australia, there may be contextual factors that drive fruit and vegetable intake, such as cost, availability, family food culture and school food policies[38]. Taking a comparative approach across both countries, as we do in this paper, not only facilities a broader understanding of dietary trends in this age group, but also aids in the identification of universally applicable interventions as well as country-specific strategies.

Previous research in countries such as Australia, Norway and the United States has underscored the significance of late adolescence and early adulthood as a period of dietary and life transitions. These studies collectively highlight the role of healthy diets during adolescence in setting the stage for long-term dietary habits. Notably, the evidence suggests that poor dietary habits established during this period tend to persist or worsen as individuals enter adulthood, with males shown to be especially prone to experiencing a deterioration in diet quality[39]. Life events, such as moving out of the family home or leaving education, have been identified as contributors to a decline in fruit and vegetable intake[40] and beginning full-time employment and becoming a parent have been associated with increased fast food

intake[41]. These studies underscore the concerning trend that many individuals struggle to maintain a healthy diet through early adulthood.

Early adulthood marks a period for the establishment of adult dietary patterns as well as the potential emergence of dietary inequalities. Evidence suggests this timeframe may be particularly pivotal in the development of diverging dietary patterns between females and males[42], with females typically consuming more fruits and vegetables than their male counterparts[32,43–45]. These differences may be attributed to varying health beliefs, knowledge about nutrition, and societal norms. Moreover, socioeconomic factors, including parental education and household income, play a significant role in shaping dietary behaviours[45–51]. Typically, a higher parental socioeconomic position (SEP) is associated with greater access to a variety of healthy foods, increased nutritional knowledge, and a higher likelihood of adhering to dietary guidelines. These are likely to lead to differential trends in intake between SEPs and contribute to the known inequalities in related health outcomes. Understanding these influences on dietary trajectories could help identify where public health efforts and interventions can be most effective, thus highlighting the need to focus on this age range to better understand the dietary trajectories and the roots of health disparities.

Building on these findings, our study uses nationally representative, longitudinal household panel data from the UK and Australia to analyse the dietary trajectories of young adults. The key objective of our study was to provide a nuanced analysis of how fruit and vegetable intake changes across early adulthood, considering the influence of sex and SEP. Analysis of multiple timepoints of panel data allows us to distinguish within-individual from cohort-level dietary changes, for a deeper understanding of diet trajectories during this critical period of development. Including both UK and Australian data allowed us to explore which findings may be replicable across contexts and begin to understand which aspects of each context may be driving intake. These findings could, in turn, help identify key moments for future interventions and which subgroups face the most pronounced dietary inequalities, thereby contributing to the reduction of chronic disease risk and addressing public health priorities.

Our objective was achieved through answering the following research questions:

1. What are the trajectories of fruit and vegetable intakes, across early adulthood (16–30 years), in UK and Australian populations?

## 2) How do these trajectories differ by sex and SEP?

## 2. Methods

# 2.1. Study design and population

Data for this analysis were drawn from the UK Household Longitudinal Study (UKHLS)[52] and the Household, Income and Labour Dynamics in Australia (HILDA) Survey[53], both up-to-date household-

based nationally representative panel surveys that have collected data in the UK since 2009 and Australia since 2001. In UKHLS, households were selected to participate in the general population sample based on a proportionately stratified, equal probability, randomly selected sample of residential addresses in the UK. In HILDA, households were included using a multi-staged approach, first selecting Census Collection Districts, followed by dwellings within those based on expected response and occupancy, and finally up to three household per dwelling were selected to participate. Further details on the UKHLS and HILDA sampling and survey methods can be found elsewhere[52,54–56].

In UKHLS, data for fruit and vegetable intake for adult household members aged 16 years and older were collected in waves 7 (2015–2016), 9 (2017–2019), 11 (2019–2021) and 13 (2021–2023). In HILDA, fruit and vegetable intake for adult household members aged 15 years and older were collected in waves 7 (2007), 9 (2009), 13 (2013), 17 (2017) and 21 (2021). This analysis included young adults aged 16–30 years at the time of data collection in wave 7 in both cohorts.

## 2.2. Survey and Measures

*Exposures: age and sociodemographic groupings*

Age, in completed years, was derived based on reported date of birth and interview date. To explore differences in sociodemographic groups, sex and parental education were explored. Sex was reported by a household member and checked for consistency across all previous waves by UKHLS during data collection.

Due to the household-based sampling method, parental education was self-reported by parents and updated at every wave to include their most recent qualification. “Parents” were defined as biological, adoptive or step-parents. In the present study, the highest achieved educational qualification of parents at the baseline wave (wave 7) was linked back to the young adults through cross-wave identifiers. If data from more than one parent was available, only the highest qualification was retained to derive a single variable. A binary variable was created for parental education from the six possible answers (degree, other higher degree, A-level etc, GCSE etc, Other, None) in UKHLS and eight possible answers in HILDA (postgrad – masters or doctorate, grad diploma or grad certificate, bachelor or honours, advanced diploma or diploma, cert III or IV, Year 12, Year 11 and below) to include 1) degree level and above and 2) no degree (any other qualification below degree level, including no qualification), dividing the populations into roughly equal groups.

*Outcome: young adult fruit and vegetable intake (portions per day)*

In both datasets, the questionnaire included self-reported intake of fruit and vegetable frequency (days/week) and amount (portions/day) (described in Table 1). In UKHLS, a numerical average value was assigned to each frequency category as follows: never = 0 days, 1–3 days = 2 days, 4–6 days = 5 days, and every day = 7 days. In HILDA, the reported frequency was retained. Frequency was multiplied by the reported amount (in portions) to obtain portions per week of fruit and vegetables. Portions per day were calculated by dividing this value by seven.

# 2.3. Statistical Methods

R statistical software[57] (2023.12.1 + 402) was the primary software used for statistical analysis. Python 3[58] was used for data pre-processing. Descriptive statistics were computed for outcomes (fruit or vegetable intake) and exposure variables (age, sex, and parental education), using frequency/percentage and mean/standard deviation, as appropriate (see Table 2).

*Multilevel models*

Data from the UK and Australia were analysed separately as multilevel linear regression models with measurement waves nested within individuals. Chi-squared Wald tests were run for all models to test whether the within-person effects of age differed significantly from the between-person effects. As these were shown to be significantly different, hybrid mixed effects models were used to model the relationship between both fruit and vegetable intakes separately and age, disaggregating overall effect of age by within- and between-person effects. Our analysis focusses on within-person effects to answer the research questions on trajectories of dietary intake.

We tested a non-linear term ($age^2$) for the relationship but this was not significant and did not improve model fit, so we assumed a linear relationship between age and both fruit and vegetable intake. In addition, we tested the use of robust standard errors because of heteroscedasticity found in the datasets, however, these did not improve the models. We proceeded without robust standard errors as linear mixed-effects models have been shown to be robust to violation of distributional assumptions[59].

For each dataset, Models 1a and 1b looked at the association between age and daily fruit or vegetable intake, respecitvely. Models 2a and 2b built on Models 1a and 1b to additionally include sex and its interaction with age to investigate whether there are differences in trajectories of intake between females and males. Similarly, Models 3a and 3b built on Models 1a and 1b to include parental education and its interaction with age to investigate whether there were differences in trajectories of intake of fruit and vegetables between individuals with parents with a degree versus those with no degree.

All models were fitted using the *lme4* package in the R statistical environment[60]. Confidence intervals at 95% were computed using the *confint.merMod* method[61] for multilevel models. The original survey weights were rescaled using the *rescale_weights* method from the *'datawizard'* package[62], allowing for the grouping structure to be accounted for when applying to survey weights to all models.

*Missing values and outliers*

We included young adult participants aged 16–30 years in UKHLS (n = 8,908) and HILDA (n = 3,357), that appeared in the baseline wave (Wave 7). Outliers were assessed and data removed for values that were greater than three times the interquartile range of intake for fruit or vegetables. This was done using separately for fruit and vegetable intake values, for example, if a outlier for fruit was removed, the non-outlier value would be retained for vegetables. A total of 176 data points for fruit or vegetable intake

were excluded in UKHLS using this method. In HILDA, no intake outliers were removed. These were checked using the same method as UKHLS but because the 'amount' variable was limited to six pre-defined options, these were less likely than in UKHLS where a free text box was used.

Not all participants had complete parental data for various reasons (e.g. parents were not part of the original sample). There were 888 (17%) and 1,179 (39%) missing values for parental education values in UKHLS and HILDA, after imputing missing values using a last observation carried forward method from previous waves. These participants were excluded only from Models 3a and 3b.

Longitudinal survey weights provided by each dataset were applied according to their user manuals[56,63]. These were based on Wave 7 being assigned as the 'baseline' wave for both datasets. The sample size for both datasets was reduced after applying survey weights due to some participants being assigned a weight of zero. Flow charts detailing sample sizes can be found in Fig. 1.

# 3. Results

## 3.1. Weighted sample characterises and descriptive statistics

At the baseline wave (Wave 7), the weighted analytical sample included 5,118 (UKHLS) and 2,981 (HILDA) young adults aged 16–30 years. Mean fruit intake was comparable between both populations (1.34 daily portions in UKHLS and 1.25 daily portions in HILDA). Mean vegetable intake was slightly lower in UKHLS at 1.60 daily portions, compared to HILDA at 2.03 daily portions. The mean age at Wave 7 was 22.1 years (SD: 4.4) in UKHLS and 22.5 years (SD: 4.3) in HILDA. Both populations had a fairly even split of female and male participants (55% and 52% females in UKHLS and HILDA, respectively). The proportion of parents with a degree was higher in UKHLS (47% vs 31% in HILDA). Table 2 shows the details of these characteristics.

## 3.2. Change in Fruit and Vegetable Intake with Age (Models 1a and 1b)

In UKHLS, for each year increase in age, individual fruit intake decreased by 0.02 portions per day [95% Confidence Interval (CI): -0.03, -0.01]. HILDA did not show any age-related change in fruit intake. On the other hand, both populations showed a consistent trajectory in vegetable intake: as they aged, young adults increased their vegetable intake by 0.03 portions per day per year [UKHLS 95% CI: 0.02, 0.04], [HILDA 95% CI: 0.02, 0.03]. Details of all model estimates can be found in Supplementary Table S1.

## 3.3 Change in Fruit and Vegetable Intake with Age by Sex (Models 2a and 2b) and Parental Education (Models 3a and 3b)

At baseline in both cohorts, females consumed more fruit and more vegetables than males (range: 0.10–0.22 more portions per day). There was no difference in intake trajectories between females and males in either population for fruit intake. In HILDA, sex moderated the relationship between age and daily vegetable intake (β = -0.02, 95% CI: -0.04, -0.01], however, this difference was not seen in UKHLS. Figure 2 displays how the difference in intake trajectories between females and males widened with age in HILDA, where females had a steeper increase in vegetable intake with age than males.

At baseline in both cohorts, individuals with parents who had a degree consumed more fruit and more vegetables than those with parents educated below degree level (range: 0.11–0.40 more portions per day). Parental education moderated the relationship between age and vegetable intake in both UKHLS (β = -0.02, 95% CI: -0.04, -0.00) and HILDA (β = -0.02, 95% CI: -0.04, -0.00), however, this was not the case for fruit intake. The difference in intake trajectories between those with parents with a degree and those without widened with age in both populations, as illustrated in Fig. 3.

# 4. Discussion

## 4.1. Principle findings

This is the first study to compare fruit and vegetable intake trajectories through ages 16–30 years in the UK and Australia, comparing differences by sex and SEP. Overall, females and individuals whose parents had a degree consumed more fruit and more vegetables in both countries. The trajectory of intake for fruit decreased with age in the UK, but there was no change observed in the Australian cohort. Conversely, vegetable intake trajectories increased in both countries. Notably, the increase in vegetable intake was more pronounced among females than males in Australia (but not the UK) exacerbating inequalities in dietary habits. Furthermore, our analysis showed the impact of SEP on diet, with individuals with a higher parental education having a more substantial increase in vegetable intake with age compared to their lower parental education counterparts.

## 4.2. Strengths and limitations of the study

The strengths of our study include the use of weighted, nationally representative samples and harmonized datasets, allowing for robust comparisons across the UK and Australia. The inclusion of parental-reported education enhances the reliability of the socioeconomic indicator, compared to if parental education had been reported by young adults. Our analytical approach of employing hybrid mixed effects models allowed for the disaggregation of between- and within-person effects, providing details on the effect of age on dietary intake to evaluate changes across early adulthood.

The reliance of self-reported fruit and vegetable intake and simplicity of the dietary questions introduce potential bias, with a risk of overreporting due to social desireability[64]. Although the dietary questions were comparable in both datasets, there are differing definitions of ‘portion’ in the UK and ‘serve’ in Australia, which may complicate comparisons. In Australia, a standard serve is 75g for vegetables and 150g for fruit and according to UK guidelines, a standard portion for both fruit and vegetables is 80g.

However, we analysed countries separately, comparing trajectories of intake rather than absolute intake, therefore, this did not affect our interpretation. Although our analysis demonstrated variations in trajectories between different sociodemographic groups, the groupings explored were limited by the comparability of available data, leaving other potentially important variables unexplored, such as geographical location, area deprivation, ethnicity or indigenous status.

The Covid-19 pandemic's impact on dietary habits adds an additional layer of complexity to our interpretation. Shifts in fruit and vegetable intake patterns could be attributed to pandemic-related factors, as our study included data collected since March 2020. The UK experienced an increase in home food preparation time[65,66], potentially leading to the observed increase in vegetable intake, as vegetables frequently require cooking. Qualitative findings from Australia suggested a mix of both positive and negative impacts on food preparation and consumption of the pandemic[66,67]. However, we conducted a sensitivity analysis by excluding data points collected from March 2020 onward, and there were no significant changes to the findings (data not shown).

## 4.3. Implication of findings

Young adults continue to have lower than recommended intakes of fruit and vegetables in both the UK and Australia. Our findings indicate only slight variations in intake with age, suggesting that dietary patterns established in adolescence tend to persist into early adulthood, with only minimal changes as individuals mature from age 16 to 30 years. Future research efforts could focus on trajectories through early adulthood and into late adulthood, to examine long-term dietary habits and whether these dietary patterns persist.

The observed difference in fruit and vegetable intakes between females and males has been previously documented[43,44,68,69]. Psychosocial frameworks, such as the Theory of Planned Behaviour, suggest that women exhibit higher perceived behavioural control and more positive attitudes towards consuming fruits and vegetables, which are predictors of their higher self-reported intake[43]. To mitigate these sex-differences in intake, interventions could aim to improve men's perceptions and attitudes towards fruits and vegetables. A healthy lifestyle intervention pilot aimed at young men aged 18–25 years in Australia demonstrated the feasibility, acceptability and potential efficacy of such interventions, with recommendations for specific recruitment, retention and research procedures to address specific motivators and barriers for this population[70]. In addition to overall sex-differences in intake, we found a widening difference with age between females and males in Australia but not in the UK. Research on marketing and advertising has shown that the UK has implemented regulations that control harmful gender stereotyping[71], while Australia has yet to establish similar restrictions[72]. This difference in regulatory approach could help explain why our study observed a greater polarisation with age between the sexes in Australia than in the UK. As young adults age, they become increasingly exposed to and aware of gendered attitudes, which may influence their dietary choices.

The relationship between parental SEP and dietary intake examined in the present study highlights a widening socioeconomic divide as participants aged, particularly in vegetable intake. The observed average difference amounts to around half a portion (~ 40 grams) per day in combined fruit and vegetable intake between young adults from higher and lower parental SEPs. A comprehensive systematic review of observational studies has demonstrated an inverse dose-response association between fruit and vegetable intake and the risk of cardiovarscular disease-related mortality and morbidity. Specifically, an increase of 50 grams/day in fruit and vegetable intake was associated with a reduction in all-cause mortality and various disease outcomes[1]. Therefore, prioritising intiatives that not only increase intake of fruit and vegetables across all demographics, but also focus on individuals from lower SEPs to boost intake up to the same level as those from a higher SEP could significantly improve public health outcomes and reduce health inequalities. The observed disparity demonstrates the importance of parental SEP in influencing diet quality, aligning with existing literature linking parental SEP with dietary trajectories throughout life[38,73,74]. Childhood SEP, predicted via parental education, has been shown to be critical in predicting young adult diet quality[74,75], with individuals in a lower SEP during childhood showing lower intakes of fruit and vegetables and higher intakes of fast food during early adulthood. These indicate the lasting effect of parental SEP on dietary habits, suggesting that a higher SEP earlier in life is conducive to healthier dietary patterns later in life. As adolescents gain independence and control over their food choices during early adulthood, they may begin to improve their diet by increasing fruit and vegetable intake. These would require considerations relating to resources available to them in terms of time, money, skills or facilities. However, if they are in a lower SEP, they may not have these resources are their disposal and would therefore struggle to increase their intake at the same rate as those that would have these resources (higher SEP individuals). The differences seen in vegetable intake as opposed to fruit is potentially due to the preparation effort involved, indicating that as young adults age, those from a higher SEP might have better opportunities to develop and use their cooking skills. The widening gap as young adults age emphasises the need for interventions tailored to address these inequalities, such as enhancing accessibility to healthy foods. For example, population level interventions such as subsidisation of healthier foods have shown to reduce inequalities, whereas person-centred approaches such as health education are more likely to widen inequalities[76]. Research suggests that the difference in diet quality among adolescents from a lower SEP may be worsened by limited availability of fruit and vegetables at home, suggesting that the home food environment also contributes to inequalities between the groups[77]. The development and maintenance of food planning skills from adolescence into early adulthood may also enhance the socioeconomic gap, as these skills are required for improved diet quality and are often influenced by parental education, making them less likely to be acquired in households of a lower SEP[78,79]. These factors should be considered when designing and implementing interventions and policy to improve diet quality. Such measures will benefit individuals from distinct SEPs differentially, thereby having consequential impacts on health inequalities.

# 5. Conclusion

Overall, fruit intake trajectories decreased with age and vegetable intake trajectories increased with age in 16–30 year olds in the UK and Australia. There were sex and SEP inequalities in fruit and vegetable intake such that females and those with parents with greater educational attainment consumed more of both. Vegetable intake trajectories by age differed by sex (in Australia only) and by parental education, widening with age. These findings highlight the need for targeted interventions and policies that not only promote increased fruit and vegetable intake among young adults but also address dietary inequalities, which could, in turn, improve long-term health outcomes and reduce the burden of diet-related chronic diseases.

## Declarations

# Ethical Approval

The University of Essex Ethics Committee has approved all data collection on Understanding Society main study, COVID-19 surveys and innovation panel waves, including asking consent for all data linkages except to health records.

# Competing Interests

The authors declare that they have no known competing interests.

# Funding

This work was supported by the MRC Epidemiology Unit, University of Cambridge [grant numbers MC_UU_00006/5, MC_UU_00006/7]. TB is funded by the Cambridge MRC Doctoral Training Partnership (grant number MR/N013433/1) and the Elizabeth McDowell Studentship at Newnham College, Cambridge. EMW is funded by a Career Development Award from the UK Medical Research Council [grant number MR/T010576/1]. KML is supported by a National Health and Medical Research Council Emerging Leadership Investigator Grant [APP1173803].

# Acknowledgements

We would like to acknowledge the contributions of Stephen Sharp for guidance on statistical methods for this analysis, as well as thank the study participants from the UK and Australia for their contribution in providing the data used in this analysis. In addition, we would like to thank Dr Yinhua Tao for reviewing the analysis code in R.

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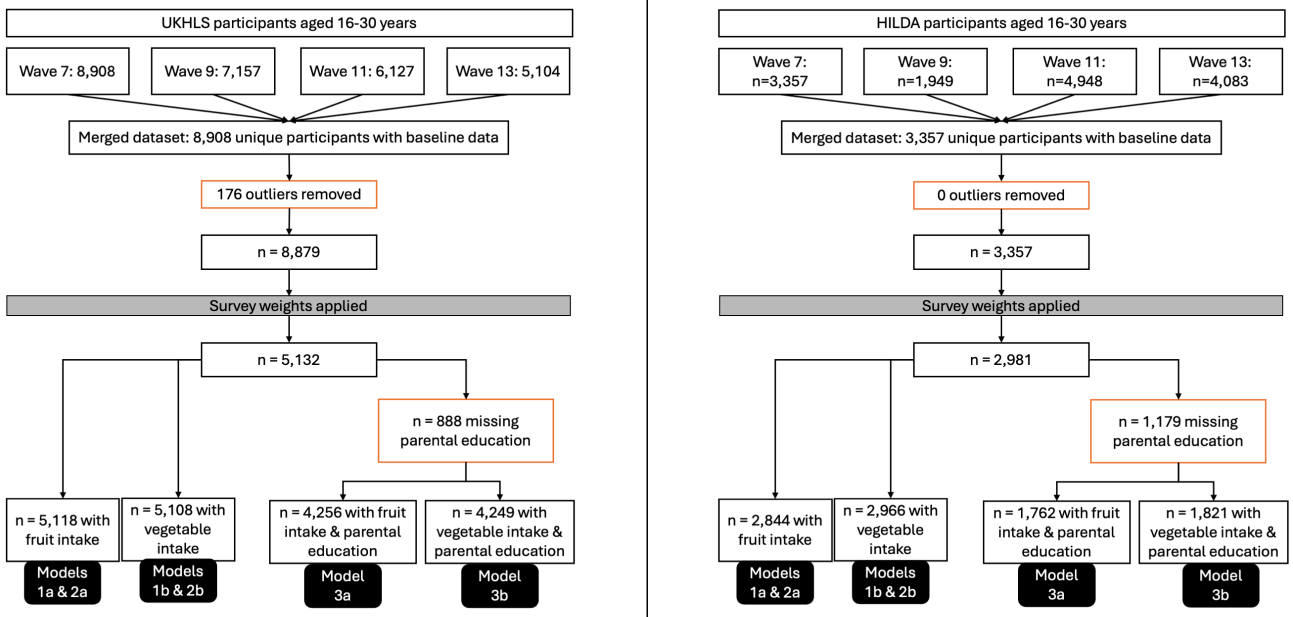
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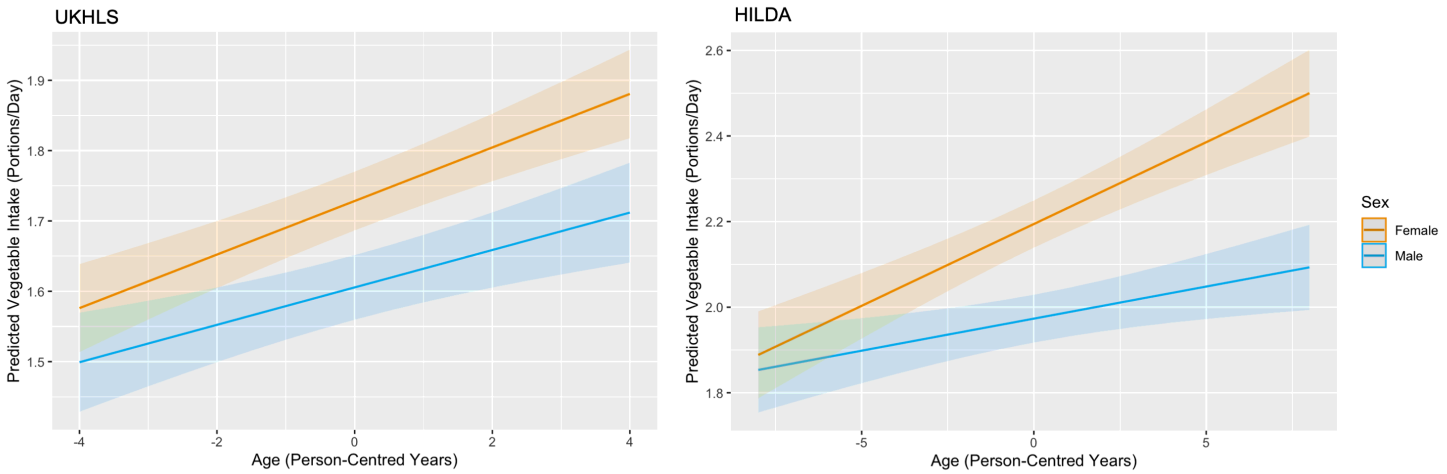
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# Figures



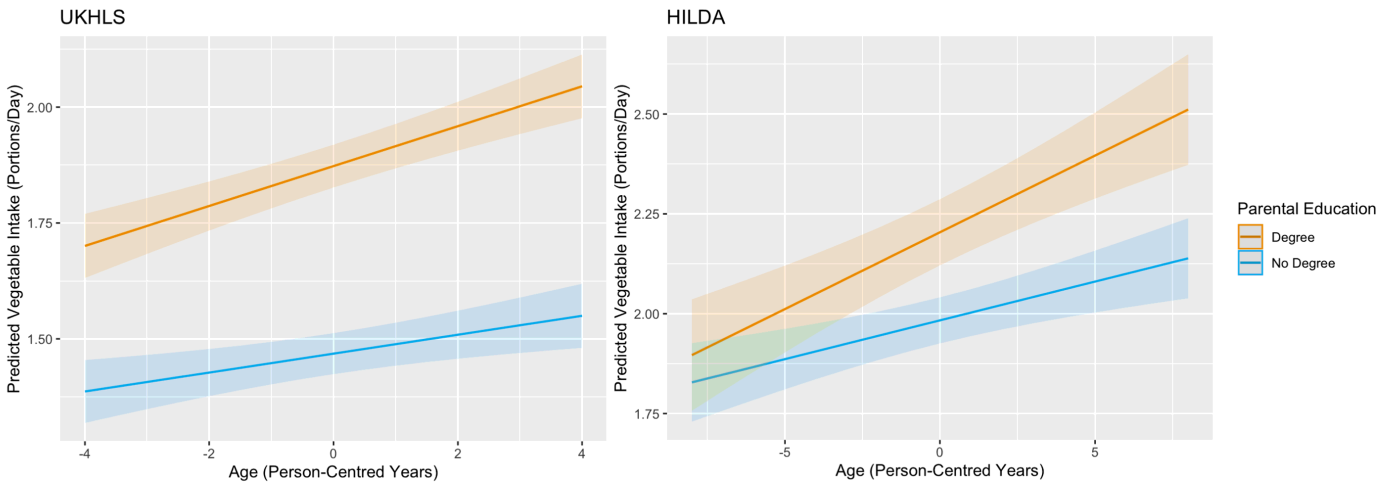

## Figure 1

UKHLS and HILDA Sample Size Flow Charts



### Figure 2

Predicted Vegetable Intake (portions per day) by sex in UKHLS and HILDA in young adults aged 16-30 years. Graphs include 95% Confidence Intervals. Note: Person-centred age is calculated for each individual and refers to the deviation from each individual's mean age across all waves to estimate within-person effects of age on intake.




### Figure 3

Predicted Vegetable Intake (portions per day) by parental education in UKHLS and HILDA in young adults aged 16-30 years. Graphs include 95% Confidence Intervals. Note: Person-centred age is calculated for each individual and refers to the deviation from each individual's mean age across all waves to estimate within-person effects of age on intake.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryTableTableS1.xlsx