SALT CONSUMPTION OF AUSTRALIAN ADULTS: A SYSTEMATIC REVIEW AND META-ANALYSIS

Mary-Anne Land[1-2], Bruce Neal[1-2,3], Claire Johnson[1-2], Caryl Nowson[4], Claire Margerison[4], Kristina S Petersen[1-2]

[1] The George Institute for Global Health, Sydney Australia, [2]The University of Sydney, Sydney Australia, [3]Royal Prince Alfred Hospital, Sydney Australia,[4]Deakin University, Geelong Australia

Corresponding Author:

Mary-Anne Land

The George Institute for Global Health

PO BOX M201 Missenden Road

Camperdown, NSW, AUSTRALIA

2050.

E: maland@georgeinstitute.org.au

WORD COUNT: 2657

TABLES: 1

FIGURES: 3

SUMMPLMENTARY: 3

ABSTRACT

Background

Salt reduction is a public health priority since it is a leading contributor to global disease burden. In Australia, there is uncertainty about current intake levels and trends in consumption. This review sought to estimate current intake levels.

Method

Electronic databases MEDLINE via Ovid and EMBASE were searched up to August 2016 to identify studies that examined salt intake in Australian adults using 24-hour urinary sodium excretion or dietary assessment methods. Random effects meta-analysis was used to obtain summary estimates.

Results

The review included data from 32 studies, which dated from 1989 to 2015, and included 16836 individuals. Mean weighted salt consumption measured by 24-hour urine collections was 8.7g/day (95% CI 8.39-9.02). Further adjustment for non-urinary loses makes the best estimate of salt intake for Australia 9.6g/day. Subgroup analysis by sex showed that mean weighted intake in males was 10.07g/day (95% CI 9.68-10.46g/day) and 7.34g/day (95% CI 6.98-7.70g/day) in females. When salt intake was measured by self-reported intake mean weighted consumption was 6.49g/day (95% CI 5.94-7.03g/day;) when diet diaries were used, 6.76g/day (95% CI 5.48-8.05g/day) when food frequency questionnaires were used and 6.69g/day (95% CI 6.30-7.08) when dietary recalls were used. There was no evidence of a decrease in salt intake over time (p=0.XX).

Conclusion

Salt intake in Australian adults is likely to be well above the World Health Organization's recommended maximum of 5g/day and does not appear to be falling. These data highlight the need for ongoing action on salt reduction in Australia.

Key words: Australia, salt, sodium, hypertension, systematic review, meta-analysis

INTRODUCTION

Despite steady improvement over the last three decades, cardiovascular disease remains the leading cause of death in Australia (1) and around the world (2). High dietary salt intake raises blood pressure, which increases the risk of cardiovascular disease (3). The World Health Organization recommends a maximum salt intake of 5g/day (4). However, in most countries salt intake levels far exceed this, and average salt intake worldwide is estimated to be 10g/day (5). Since population salt reduction is projected to be one of the most cost effective strategies to reduce rates of premature death and disability due to high blood pressure and vascular disease (6), all Member States of the World Health Organization have agreed to a global target to reduce mean population salt intake by 30% by 2025 (7).

Surveillance is a key component of salt reduction strategies (8). A recent review of salt reduction in Australia found that a number of activities are currently being implemented but additional efforts and more robust national monitoring mechanisms are required (9). To date, the only nationally representative survey of Australian adults suggested that average salt consumption was 6.2g/day (10). This survey used 24-hour dietary recalls and is likely to be an under-estimation of salt intake because incomplete reporting is a well described limitation of this assessment method (11, 12). Other ways of estimating salt intake include: food frequency questionnaires (FFQ), multiple dietary recalls and urine collections including spot, timed and 24-hour assessments. The measurement of 24-hour urinary sodium excretion is considered the 'gold standard' because approximately 90% of ingested salt is excreted in the urine (13). However, 24-hour urine collections are burdensome for participants to complete and therefore response rates are typically low (13). In addition, incomplete sample collection and cost can impact upon utility and as a consequence 24-hour urine collections are often not used in large population studies (14).

Australia has over the last few years implemented a number of programs targeting dietary salt intake but there has been no corresponding robust assessment of national intake levels against which success

or failure can be quantified. We undertook this systematic review and meta-analysis to obtain the best possible estimate of mean population salt consumption in Australian adults using all available data.

METHODS

Search strategy

A systematic search of peer-reviewed, published articles was performed to identify articles that reported, salt/sodium consumption obtained with 24-hour urine collections and/or dietary questionnaire methods in Australian adults aged 18 years and older. All articles published before August 2016 were included. Relevant articles were identified by searching MEDLINE via Ovid and EMBASE using relevant search words sodium or salt and Australia (supplementary material). Reference lists from identified articles were manually scanned to identify any other relevant articles. National experts were also consulted to identify additional research that may have been overlooked through the literature search.

Inclusion and Exclusion Criteria

Included studies reported mean/median sodium consumption in Australian adults (+18 years). Where data were extracted from intervention studies only baseline data were included. The primary analyses were based on data from 24-hour urine samples. Where a study reported both urinary analysis and dietary methods, all the results were included in the systematic review. There were no exclusion criteria based on date of publication, language, age, sex, study design or sample size. In addition, all studies were included regardless of the representativeness of the sample.

Data Extraction

The following study characteristics were extracted from each paper: population type, salt intake assessment method, sample size, sex, mean age, mean body mass index (BMI), study location, mean salt intake (standard deviation). If sodium intake (mg/d) was reported, it was converted to salt (g/d) by dividing by 1000 and multiplying by 2.54. Titles and abstracts of retrieved articles were

independently evaluated by two investigators (M-A.L and C.J). Reviewers were not blinded to authors, institutions, or manuscript journals. Abstracts that did not provide enough information regarding the inclusion and exclusion criteria were retrieved for full-text evaluation. Reviewers independently evaluated full-text articles and determined study eligibility. Disagreements were solved by consensus and if disagreement persisted, by a third reviewer (K.S.P). To avoid possible double counting of patients included in more than one report by the same authors or working groups, patient recruitment periods were evaluated and if necessary, authors were contacted for clarification. Furthermore, the corresponding author was contacted as needed to obtain data not included in the published report.

Outcomes

The primary analyses were based on salt intake measured by 24-hour urine collections. Subgroup analyses were conducted to determine differences in salt intake by sex, and population type. In addition, the association between salt intake, and age, publication date, and BMI was investigated. Secondary analyses were conducted to determine mean salt consumption estimated by dietary assessment methods.

Data Analysis

In the primary analysis, mean salt intake (95% confidence interval) was estimated based on 24-hour urine collections using inverse variance random effects meta-analysis. In the secondary analyses, mean salt intake was estimated based on dietary questionnaires. Where a study reported salt intake measured using a 24-hour urine collection and dietary methods, the results of the 24-hour urine collection were used in the primary analyses and data from the dietary analyses were also included in the subgroup analysis for measurement method. The I^2 statistic was used to explore the percentage of variability due to heterogeneity between studies rather than sampling error. To explore sources of heterogeneity subgroup analyses were performed for method of salt intake measurement, sex (male, female, mixed) and health status. Random effects meta-regression was performed to determine the relationship between salt intake and mean BMI, mean age cohort and year of publication. Sensitivity

analyses were conducted to determine if removal of any individual study altered estimated mean intake. The risk of publication bias was assessed by examination of a funnel plot of salt intake against the standard error of salt intake. Statistical analysis was completed using Stata (StataCorp, version 13, USA). P values of <0.05 were considered unlikely to have arisen by chance.

RESULTS

Data from 30 studies and 2 unpublished datasets were included in this meta-analysis (Figure 1). Characteristics of these studies and datasets are included in Table 1. Salt intake was measured by 24-hour urine collections in 26 studies, six studies used FFQs, five studies used dietary recalls and eight studies used dietary diaries. Of the 26 studies that measured salt intake using a 24-hour urine collection 10 also measured salt intake using a dietary questionnaire or diary. These studies were conducted between 1989 and 2015, and included random or volunteer general population samples, as well as populations with specific disease states including hypertension, metabolic syndrome and type 1 or type 2 diabetes.

The analysis of salt intake measured by 24-hour urine collection included data from 3896 individuals. Mean weighted salt intake was 8.7g/day (95% CI 8.39-9.02; τ^2=0.55; I^2= 91.3% p<0.001) (Figure 2). Inflation of salt intake by 10% to account for known non-urinary sodium excretion provides a best estimate of daily salt intake of 9.6g/day (15). Removal of each individual study did not substantially alter the mean estimate. Mean weighted intake in males was 10.07g/day (95% CI 9.68-10.46g/day; τ^2=0.32; I^2=72.4% p<0.001; 13 studies n=1381) and in females was 7.34g/day (95% CI 6.98-7.70g/day; τ^2=0.40; I^2=81.5% p<0.001; 16 studies n= 1708) (Figure 3). Analysis according to the health status of the sampled population showed weighted mean salt intake was 8.36g/day (95% CI 7.95-8.77g/day; τ^2= 0.58; I^2= 89.3% p<0.001; 15 studies n=2956) in random or volunteer populations, 8.82g/day (95% CI 7.88-9.77; τ^2= 1.11; I^2= 91.7% p<0.001; 6 studies n=486) in individuals with hypertension, 9.66g/day (95% CI 9.07-10.26; τ^2=0.20; I^2= 54% p=0.09; 4 studies n=355)) in those with type 1 or type 2 diabetes,

and 10.40g/day (95% CI 8.96-11.84g/day; τ^2=0.64; I^2=56.5%; p=0.13; 1 study n=99) in subjects with metabolic syndrome (Figure 3).

The secondary analyses showed that salt intake was 6.49g/day (95% CI 5.94-7.03g/day; τ^2=0.55; I^2= 87.2% p<0.001; 8 studies n= 503) when intake was measured using a diet diary, 6.75g/day (95% CI 5.48-8.05g/day; τ2=2.5; I^2=96.9% p<0.001; 6 studies n=504) when a FFQ was used and 6.69g/day (95% CI 6.30-7.08g/day; τ2=0.21; I^2=85.9 p<0.001; 5 studies n=12830) when a 24-hour recall was used (Figure 3).

Meta-regression showed salt intake measured by 24-hour urine collections was significantly associated with BMI (supplementary material) but there was no association with either year of publication or mean age of the cohort. Examination of the funnel plot showed some evidence of publication bias (supplementary material).

DISCUSSION

These analyses show that salt consumption in Australian adults is well above the recommended maximum of 5g/day. While variation existed in the salt intake estimates based on the method used to measure consumption, all estimates were in excess of the World Health Organization's recommended maximum. Our best estimate of 9.6g/day, which is based on 24-hour urine collections after inflation for non-urinary sodium loses is almost double the recommended maximum. The subgroup analysis by sex showed that mean weighted intake in males was 10.07g/day and 7.34g/day in females, which would be anticipated based on known lesser caloric intake in females. These data reinforce the need for implementation of salt reduction strategies in Australia.

Salt reduction has been on the agenda in Australia for many years although it is unclear what impact these strategies have had due to the lack of population monitoring of salt intake in Australia (9). The

Australian Health Survey conducted in 2011-12 has been the only attempt to measure salt intake in a large representative sample of the population, albeit using 24-hour dietary recalls. In this meta-analysis we did not observe any relationship between publication date and salt intake, suggesting there has been no change in consumption since 1989. However, this analysis of change over time is limited by the data available which are not based on repeat representative samples of the population and it is possible that real temporal changes in salt intake could have been concealed as a consequence.

Significant variation existed in the salt intake estimates made by the individual studies included but the significance of this heterogeneity is limited because the prediction interval (16) suggests that salt intake lies between 7.22 and 12.9g/day. Even the lower end of this range is well in excess of the World Health Organization's recommended maximum providing for a high likelihood that salt intake in Australia is excessive and needs to be reduced. This heterogeneity is not unexpected due to the between study variation in sample characteristics, methods used to measure salt intake and study design. Salt intake is known to vary significantly with characteristics such as age, BMI, and disease state and in meta-analysis based on aggregate data it is not possible to effectively control for such factors. The meta-regression analysis showed a relationship between BMI and salt intake, which is expected based on the relationship between caloric intake and salt intake. However, no relationship was observed between salt intake and age.

A review conducted in 2015 showed that the majority of salt reduction efforts in Australia have been led by non-government organisations and there is a need for stronger government intervention (9). One of the key Federal Government Initiatives was The Food and Health Dialogue introduced in 2009. As part of this initiative voluntary salt reduction targets were set for a number of food categories. These targets resulted in appreciable reductions in sodium content of breads (9%, 39mg/100g), ready-to-eat breakfast cereals (25%, 79mg/100g) and processed meats (8%, 101mg/100g) (17). The Food

and Health Dialogue has now been replaced by The Healthy Food Partnership and at present it is unclear what the objectives of this initiative will be. However, the results of the present meta-analysis show that salt reduction should remain a priority.

Worldwide the United Kingdom (UK) has implemented one of the most successful salt reduction strategies, which has had a significant impact on population consumption levels. Salt intake in the UK decreased from 9.5g/day in 2001 to 8.6g/day in 2008, and by a further 0.5g (6%) to 8.1g/day in 2011 (18). It has been estimated that the salt reduction campaign in the UK cost £15 million to implement but every year there are 9,000 fewer cardiovascular deaths and a cost saving of £1.5 billion as a result (19). In Australia, a community-based salt reduction intervention in a rural population showed that reducing population salt intake is possible using a multifaceted approach, which included education, community engagement, a smartphone application, provision of salt substitute and advertising. Salt intake was reduced by 0.8g/day between 2011 and 2014 in that study (20). The study provides a framework for implementation of a community based salt reduction strategy, however it is unlikely this type of intervention could be scaled throughout Australia and alternative approaches will be required.

In this study, there was considerable variation in salt intake estimates based on the measurement method. Estimates based on diet diaries (-2.21g/day), FFQs (-1.94g/day) and dietary recalls (-2.01g/day) were substantially lower than salt intake estimated using 24-hour urine collections. This is consistent with previous research, which documents under-reporting of salt intake when dietary survey methods are used (11). Salt intake is highly correlated with total energy intake, and under-reporting of energy intake is common and has been shown to be greater for those with higher body mass index (21, 22). There are also challenges relating to the quantification of dietary sodium in recipes for both processed and home-cooked foods, and discretionary salt use. These factors are difficult to overcome and therefore if dietary methods are used to estimate salt intake then the results

of this meta-analysis suggest that 24-hour urine samples should be completed in a sub-sample to enable calibration. Further, this research highlights the need for careful interpretation of results when using different methodologies for assessing salt intake.

This meta-analysis comprises the first effort to combine all of the salt consumption data collected in Australia to estimate population consumption. While this is a novel investigation, these analyses are limited by the significant heterogeneity observed between the studies. In addition, most of the included studies had small sample sizes. In addition, the majority of studies had criteria for excluding incomplete 24-hour urine collections or implausible dietary intake data, although these were not consistent across the studies

CONCLUSION

This systematic review and meta-analysis shows that salt consumption in Australian adults is almost certainly well above the World Health Organization's recommended maximum of 5g/day, reaffirming the need for action on salt reduction in Australia. It also highlights the need for systematic, standardised and repeated assessments of a national sample to determine whether implemented programs are achieving the 30% reduction targeted.

ACKNOWLEDGEMENTS

We thank the national experts who provided additional research papers and data.

CONFLICTS OF INTEREST

None

SOURCES OF FUNDING

B.N is supported by an NHMRC Principal Research Fellowship. He holds an NHMRC Centre for Research Excellence (APP1117300) and an NHMRC Program Grant (APP1052555).

AUTHOR'S CONTRIBUTIONS

All authors fulfil the ICMJE guidelines for authorship and have approved the final version of the manuscript submitted to Medical Journal of Australia.

M-A.L contributed to the review concept and design, completed the literature search, contacted national experts, completed initial data analysis and drafted the manuscript. C.J completed the literature search and contributed to the final version of the manuscript. C.N contributed to the review concept and design, revised the manuscript critically and contributed to the final version of the manuscript. B.N contributed to the review concept and design, data analysis, revised the manuscript critically and contributed to the final version of the manuscript. C.M contributed to the literature search and contributed to the final version of the manuscript. K.S.P contributed to the review concept and design, data analysis, drafted and contributed to the final version of the manuscript.

REFERENCES

1. Australian Institute of Health and Welfare. Cardiovascular disease: Australian facts 2011. Canberra: AIHW, 2011.
2. Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380(9859):2095-128.
3. Micha R, Peñalvo JL, Cudhea F, Imamura F, Rehm CD, Mozaffarian D. Association between dietary factors and mortality from heart disease, stroke, and type 2 diabetes in the united states. Jama. 2017;317(9):912-24.
4. World Health Organization. Guideline: Sodium intake for adults and children: World Health Organization; 2012. Available from: http://apps.who.int/iris/bitstream/10665/77985/1/9789241504836_eng.pdf?ua=1&version=meter+at+null&module=meter-Links&pgtype=article&contentId=&mediaId=&referrer=&priority=true&action=click&contentCollection=meter-links-click.
5. Mozaffarian D, Fahimi S, Singh GM, Micha R, Khatibzadeh S, Engell RE, et al. Global sodium consumption and death from cardiovascular causes. The New England journal of medicine. 2014;371(7):624-34.
6. Asaria P, Chisholm D, Mathers C, Ezzati M, Beaglehole R. Chronic disease prevention: health effects and financial costs of strategies to reduce salt intake and control tobacco use. The Lancet. 2007;370(9604):2044-53.
7. World Health Organization. Global Status Report on noncommunicable diseases 2014 Geneva, Switzerland World Health Organization; 2014. Available from: http://apps.who.int/iris/bitstream/10665/148114/1/9789241564854_eng.pdf?ua=1.
8. World Health Organization. SHAKE the salt habit - Technical package for salt reduction Geneva, Switzerland2016.
9. Webster J, Trieu K, Dunford E, Nowson C, Jolly KA, Greenland R, et al. Salt reduction in Australia: from advocacy to action. Cardiovasc Diagn Ther. 2015;5(3):207-18.
10. Australian Bureau of Statistics. 4364.0.55.001 - Australian Health Survey: First Results, 2011-12. 2012.
11. Freedman LS, Commins JM, Moler JE, Willett W, Tinker LF, Subar AF, et al. Pooled results from 5 validation studies of dietary self-report instruments using recovery biomarkers for potassium and sodium intake. American journal of epidemiology. 2015;181:473-87.
12. Rhodes DG, Murayi T, Clemens JC, Baer DJ, Sebastian RS, Moshfegh AJ. The USDA Automated Multiple-Pass Method accurately assesses population sodium intakes. Am J Clin Nutr. 2013;97(5):958-64.
13. Brown IJ, Tzoulaki I, Candeias V, Elliott P. Salt intakes around the world: implications for public health. International journal of epidemiology. 2009;38(3):791-813.
14. Ji C, Sykes L, Paul C, Dary O, Legetic B, Campbell NR, et al. Systematic review of studies comparing 24-hour and spot urine collections for estimating population salt intake. Revista panamericana de salud publica = Pan American journal of public health. 2012;32(4):307-15.
15. Lerchl K, Rakova N, Dahlmann A, Rauh M, Goller U, Basner M, et al. Agreement Between 24-Hour Salt Ingestion and Sodium Excretion in a Controlled Environment. Hypertension (Dallas, Tex : 1979). 2015;66(4):850-7.
16. Borenstein M, Higgins J, Hedges LV, Rothstein HR. Basics of meta-analysis: I2 is not an absolute measure of heterogeneity. Research Synthesis Methods. 2017.
17. Trevena H, Neal B, Dunford E, Wu J. An Evaluation of the Effects of the Australian Food and Health Dialogue Targets on the Sodium Content of Bread, Breakfast Cereals and Processed Meats. Nutrients. 2014;6(9):3802.
18. Sadler K, Nicholson S, Steer T, Gill V, Bates B, Tipping S, et al. Assessment of Dietary Sodium Levels Among Adults (aged 19-64) in England, 2011. Department of Health, 2012.

19. He FJ, Brinsden HC, MacGregor GA. Salt reduction in the United Kingdom: a successful experiment in public health. Journal of human hypertension. 2014;28(6):345-52.
20. Land MA, Wu JH, Selwyn A, Crino M, Woodward M, Chalmers J, et al. Effects of a community-based salt reduction program in a regional Australian population. BMC public health. 2016;16:388.
21. Freedman LS, Commins JM, Moler JE, Arab L, Baer DJ, Kipnis V, et al. Pooled results from 5 validation studies of dietary self-report instruments using recovery biomarkers for energy and protein intake. American journal of epidemiology. 2014;180(2):172-88.
22. Mendez MA, Popkin BM, Buckland G, Schroder H, Amiano P, Barricarte A, et al. Alternative methods of accounting for underreporting and overreporting when measuring dietary intake-obesity relations. American journal of epidemiology. 2011;173(4):448-58.
23. Fall in blood pressure with modest reduction in dietary salt intake in mild hypertension. Australian National Health and Medical Research Council Dietary Salt Study Management Committee. Lancet. 1989;1(8635):399-402.
24. Beard TC, Eickhoff R, Mejglo ZA, Jones M, Bennett SA, Dwyer T. Population-based survey of human sodium and potassium excretion. Clin Exp Pharmacol Physiol. 1992;19(5):327-30.
25. Beard TC, Woodward DR, Ball PJ, Hornsby H, von Witt RJ, Dwyer T. The Hobart Salt Study 1995: few meet national sodium intake target. Med J Aust. 1997;166(8):404-7.
26. Jones G, Beard T, Parameswaran V, Greenaway T, von Witt R. A population-based study of the relationship between salt intake, bone resorption and bone mass. Eur J Clin Nutr. 1997;51(8):561-5.
27. Bao DQ, Mori TA, Burke V, Puddey IB, Beilin LJ. Effects of dietary fish and weight reduction on ambulatory blood pressure in overweight hypertensives. Hypertension. 1998;32(4):710-7.
28. Mori TA, Bao DQ, Burke V, Puddey IB, Beilin LJ. Docosahexaenoic acid but not eicosapentaenoic acid lowers ambulatory blood pressure and heart rate in humans. Hypertension. 1999;34(2):253-60.
29. Hodge A, Patterson AJ, Brown WJ, Ireland P, Giles G. The Anti Cancer Council of Victoria FFQ: relative validity of nutrient intakes compared with weighed food records in young to middle-aged women in a study of iron supplementation. Aust N Z J Public Health. 2000;24(6):576-83.
30. Nowson CA, Morgan TO, Gibbons C. Decreasing dietary sodium while following a self-selected potassium-rich diet reduces blood pressure. J Nutr. 2003;133(12):4118-23.
31. Nowson CA, Worsley A, Margerison C, Jorna MK, Frame AG, Torres SJ, et al. Blood pressure response to dietary modifications in free-living individuals. The Journal of nutrition. 2004;134(9):2322-9.
32. Ward NC, Rivera J, Hodgson J, Puddey IB, Beilin LJ, Falck JR, et al. Urinary 20-hydroxyeicosatetraenoic acid is associated with endothelial dysfunction in humans. Circulation. 2004;110(4):438-43.
33. Hodgson JM, Burke V, Beilin LJ, Puddey IB. Partial substitution of carbohydrate intake with protein intake from lean red meat lowers blood pressure in hypertensive persons. The American journal of clinical nutrition. 2006;83(4):780-7.
34. Margerison C, Nowson CA. Dietary intake and 24-hour excretion of sodium and potassium. Asia Pacific journal of clinical nutrition. 2006;15(Suppl 3).
35. Brinkworth GD, Wycherley TP, Noakes M, Clifton PM. Reductions in blood pressure following energy restriction for weight loss do not rebound after re-establishment of energy balance in overweight and obese subjects. Clin Exp Hypertens. 2008;30(5):385-96.
36. Keogh JB, Brinkworth GD, Noakes M, Belobrajdic DP, Buckley JD, Clifton PM. Effects of weight loss from a very-low-carbohydrate diet on endothelial function and markers of cardiovascular disease risk in subjects with abdominal obesity. Am J Clin Nutr. 2008;87(3):567-76.
37. Dickinson KM, Keogh JB, Clifton PM. Effects of a low-salt diet on flow-mediated dilatation in humans. The American journal of clinical nutrition. 2009;89(2):485-90.
38. Nowson CA, Wattanapenpaiboon N, Pachett A. Low-sodium Dietary Approaches to Stop Hypertension-type diet including lean red meat lowers blood pressure in postmenopausal women. Nutr Res. 2009;29(1):8-18.

39. Lassale C, Guilbert C, Keogh J, Syrette J, Lange K, Cox DN. Estimating food intakes in Australia: validation of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) food frequency questionnaire against weighed dietary intakes. Journal of Human Nutrition and Dietetics. 2009;22(6):559-66.
40. Ekinci EI, Cheong KY, Dobson M, Premaratne E, Finch S, Macisaac RJ, et al. High sodium and low potassium intake in patients with Type 2 diabetes. Diabetic medicine : a journal of the British Diabetic Association. 2010;27(12):1401-8.
41. Charlton K, Yeatman H, Houweling F, Guenon S. Urinary sodium excretion, dietary sources of sodium intake and knowledge and practices around salt use in a group of healthy Australian women. Aust N Z J Public Health. 2010;34(4):356-63.
42. Ireland DM, Clifton PM, Keogh JB. Achieving the salt intake target of 6 g/day in the current food supply in free-living adults using two dietary education strategies. Journal of the American Dietetic Association. 2010;110(5):763-7.
43. Keogh JB, Lange K, Syrette J. Comparative analysis of two FFQ. Public Health Nutr. 2010;13(10):1553-8.
44. Huggins CE, O'Reilly S, Brinkman M, Hodge A, Giles GG, English DR, et al. Relationship of urinary sodium and sodium-to-potassium ratio to blood pressure in older adults in Australia. The Medical journal of Australia. 2011;195(3):128-32.
45. Villani AM, Clifton PM, Keogh JB. Sodium intake and excretion in individuals with type 2 diabetes mellitus: a cross-sectional analysis of overweight and obese males and females in Australia. J Hum Nutr Diet. 2012;25(2):129-39.
46. Australian Bureau of Statistics. 4324.0.55.002 - Microdata: Australian Health Survey: Nutrition and Physical Activity, 2011-12. Canberra2013.
47. Petersen KS, Torpy DJ, Chapman IM, Guha S, Clifton PM, Turner K, et al. Food label education does not reduce sodium intake in people with type 2 diabetes mellitus. A randomised controlled trial. Appetite. 2013;68:147-51.
48. Land MA, Webster J, Christoforou A, Praveen D, Jeffery P, Chalmers J, et al. Salt intake assessed by 24 h urinary sodium excretion in a random and opportunistic sample in Australia. BMJ open. 2014;4(1):e003720.
49. Blanch N, Clifton PM, Petersen KS, Willoughby SR, Keogh JB. Effect of high potassium diet on endothelial function. Nutr Metab Cardiovasc Dis. 2014;24(9):983-9.
50. Turner KM, Clifton PM, Keogh JB. Sodium and potassium excretion are related to bone mineral density in women with coeliac disease. Clinical Nutrition. 2015;34(2):265-8.
51. Nowson C, Lim K, Grimes C, O'Halloran S, Land MA, Webster J, et al. Dietary Salt Intake and Discretionary Salt Use in Two General Population Samples in Australia: 2011 and 2014. Nutrients. 2015;7(12):10501-12.
52. Petersen KS, Smith JM, Clifton PM, Keogh JB. Dietary intake in adults with type 1 and type 2 diabetes: validation of the Dietary Questionnaire for Epidemiological Studies version 2 FFQ against a 3-d weighed food record and 24-h urinalysis. Br J Nutr. 2015;114(12):2056-63.
53. Petersen KS, Clifton PM, Blanch N, Keogh JB. Effect of improving dietary quality on carotid intima media thickness in subjects with type 1 and type 2 diabetes: a 12-mo randomized controlled trial. Am J Clin Nutr. 2015;102(4):771-9.
54. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol. 2009;62(10):1006-12.

TABLE 1: SALT INTAKE IN THE AUSTRALIAN ADULT POPULATION FROM 1989 TO 2015.

Author	Year of publication	Method of assessment	Population	n	% male	State[a]	Salt g/d (Mean±SD)			Mean age (years)	Mean BMI (kg/m²)
							All	Males	Females		
Chalmers (23)	1989	24-hour urine	Diastolic blood pressure 90-100mmHg	108	83	NSW	8.1±0.4	-	-	58.4	-
Beard (24)	1992	24-hour urine	Random sample	54	41	TAS	8.3±4.6[c]	-	-	49	-
Beard (25)	1997	24-hour urine	Random sample	194	45	TAS	8.4±2.7	9.9±3.0	6.9±2.5	18-70	-
Jones (26)	1997	24-hour urine	Random and volunteer sample	154	22	TAS	-	10.7±2.3[c]	8.6±3.2[c]	46.9	-
Bao (27)	1998	24-hour urine	Overweight non-smoking men and postmenopausal women, taking antihypertensive medication ≥3 months	63	67	WA	10.5±8.0[c]	-	-	51.1	31.6
		3-day diet diary					7.7±6.3[c]	-	-		
Mori (28)	1999	24-hour urine	Mildly hyperlipidaemic volunteers	56	100	WA	10.2±4.2[c]	10.2±4.2[c]	-	48.8	28.8
		3-day diet diary					8.6±0.6[c]	8.6±0.6[c]	-		
Hodge (29)	2000	7-day diet diary	Iron deficient volunteers	63	0	VIC	5.9±1.4		5.9±1.4	33.3	-
		FFQ					5.4±1.6		5.4±1.6		
Nowson (30)	2003	24-hour urine	Twins (normotensive and	108	41	VIC	8.1±3.1	-	-	47	26.1

			hypertensive)								
Nowson (31)	2004	24-hour urine	Treated hyper and normotensive volunteers	94	60	VIC	8.8±2.9	-	-	55.6	29.0
Ward (32)	2004	24-hour urine	Untreated hypertensive and normotensive volunteers	66	56	WA	11.3±7.5[c]	-	-	54.1	26.7
Hodgson (33)	2006	24-hour urine	Hypertensive volunteers	60	63	WA	9.7±3.9	-	-	58.5	27.7
Margerison (34)	2006	24-hour urine 24-hour dietary recall	Healthy volunteers	144	55	VIC	8.6±3.2	9.9±2.8 8.0±3.3	7.0±2.9 6.2±0.9	55.2	29.2
Brinkworth (35)	2008	24-hour urine	Overweight and obese volunteers	208	33	SA	8.6±4.5[c]	10.6±5.5[c]	7.9±3.6[c]	52.4	33.6
Keogh (36)	2008	24-hour urine	Overweight and obese volunteers with ≥1 additional risk factor for metabolic syndrome	99	-	SA	11.3±5.8 9.8±3.7	-	-	50	33.7
Dickinson (37)	2009	24-hour urine	Overweight and obese volunteers	29	24	SA	9.0±4.0	-	-	52.7	31.6
Nowson (38)	2009	24-hour urine	Post-menopausal women with normal to high blood pressure	95	0	VIC	6.3±3.4[c]	-	6.3±3.4[c]	59.2	29.6

Lassale (39)	2009	24-hour urine 4-day diet diary FFQ	Healthy volunteers	62	0	SA	7.4±2.5 6.3±1.7 7.6±3.0	- - -	7.4±2.5 6.0±1.7 7.6±3.0	49.2	27.6
Ekinci (40)	2010	24-hour urine	Patients with Type 2 diabetes attending an outpatient clinic	122	52	VIC	10.1±3.6	9.9±3.1	8.3±3.0	68.6	30.4
Charlton (41)	2010	24-hour urine 3-day diet diary	Healthy volunteers	76	0	NSW	6.5±2.7 6.9±4.4	- -	6.5±2.7 6.9±4.4	38.3	24.0
Ireland (42)	2010	24-hour urine 24-hour dietary recall	Healthy volunteers	43	23	SA	7.3±3.0 7.9±2.6 -	7.2±3.8 9.4±1.8 8.7±3.9 7.2±2.8	6.9±3.0 7.0±2.4 7.0±4.2 7.8±3.8	56	-
Keogh (43)	2010	FFQ 1[d] FFQ 2	Healthy volunteers	159	100	SA	9.4±3.4[c] 7.8±3.2[c]	9.4±3.4[c] 7.8±3.2[c]	- -	55	27.4
Huggins (44)	2011	24-hour urine	Random sample	783	48	VIC	9.1±3.7[c]	10.4±3.8[c]	7.8±2.9[c]	64	28.4
Villani (45)	2012	24-hour urine 4-day diet diary	Overweight and obese volunteers with type 2 diabetes	88	59	SA	9.8±3.3 -	11.4±4.4 7.2±1.6	8.4±2.4 5.8±1.3	M=61.9 F-59.4	M=34.5 F=35.9
Australian Bureau of Statistics [Australian Health Survey] (46)	2011-12	24-hour dietary recall	Random sample	12153	47	ALL	6.0±3.4	6.8±3.8	5.2±2.9	40	25.7
Petersen (47)	2013	24-hour urine 24-hour dietary recall	Volunteers with type 2 diabetes	78	63	SA	9.9±4.6 7.0±3.2	11.0±4.4 7.3±2.7	7.4±3.6 6.3±2.7	63	34.1
Land (48)	2014	24-hour urine		419	45	NSW	8.8±3.6	10.2±3.7	7.6±3.0	55	29.3

Unpublished		24-hour dietary recall	Random and volunteer sampling	412	44		6.5±2.9	7.5±3.1	5.6±2.4		
Blanch (49)	2014	FFQ	Healthy volunteers	35	26	SA	5.6±2.1	-	-	31	21.7
Turner (50)	2015	24-hour urine	Volunteers with coeliac disease	28	0	SA	6.3±3.0	-	6.3±3.0	51	25
		3-day diet diary					5.0±1.7	-	5.0±1.7		
Nowson (51)	2015	24-hour urine	Random sample	598	46	VIC	8.1±3.1	9.2±2.6	6.7±2.7	57	26.6
		24-hour dietary recall					6.8±3.12[c]	6.1±3.2[c]	7.7±3.38[c]		
Petersen (52)	2015	24-hour urine	Volunteers with type 1 and type 2 diabetes	67	57	SA	8.6±4.1	9.0±4.0	8.1±4.2	56	31
		3-day diet diary					6.3±2.9	7.0±3.2	5.3±2.2		
		FFQ					6.2±2.5	6.4±2.3	6.0±2.8		
Petersen (53)	2015	FFQ	Volunteers with type 1 and type 2 diabetes	118	63	SA	6.4±2.9	7.2±3.1	5.1±1.7	57.5	32.6

[a]NSW- New South Wales, SA – South Australia, TAS – Tasmania, VIC –Victoria, WA – Western Australia; [b]ALL States includes those listed in addition to ACT- Australian Capital Territory, NT – Northern Territory and QLD – Queensland; [c]Calculated standard deviation; Conversion of mmol sodium to g/day salt = mmol x23 =sodium mg /1000 x 2.54

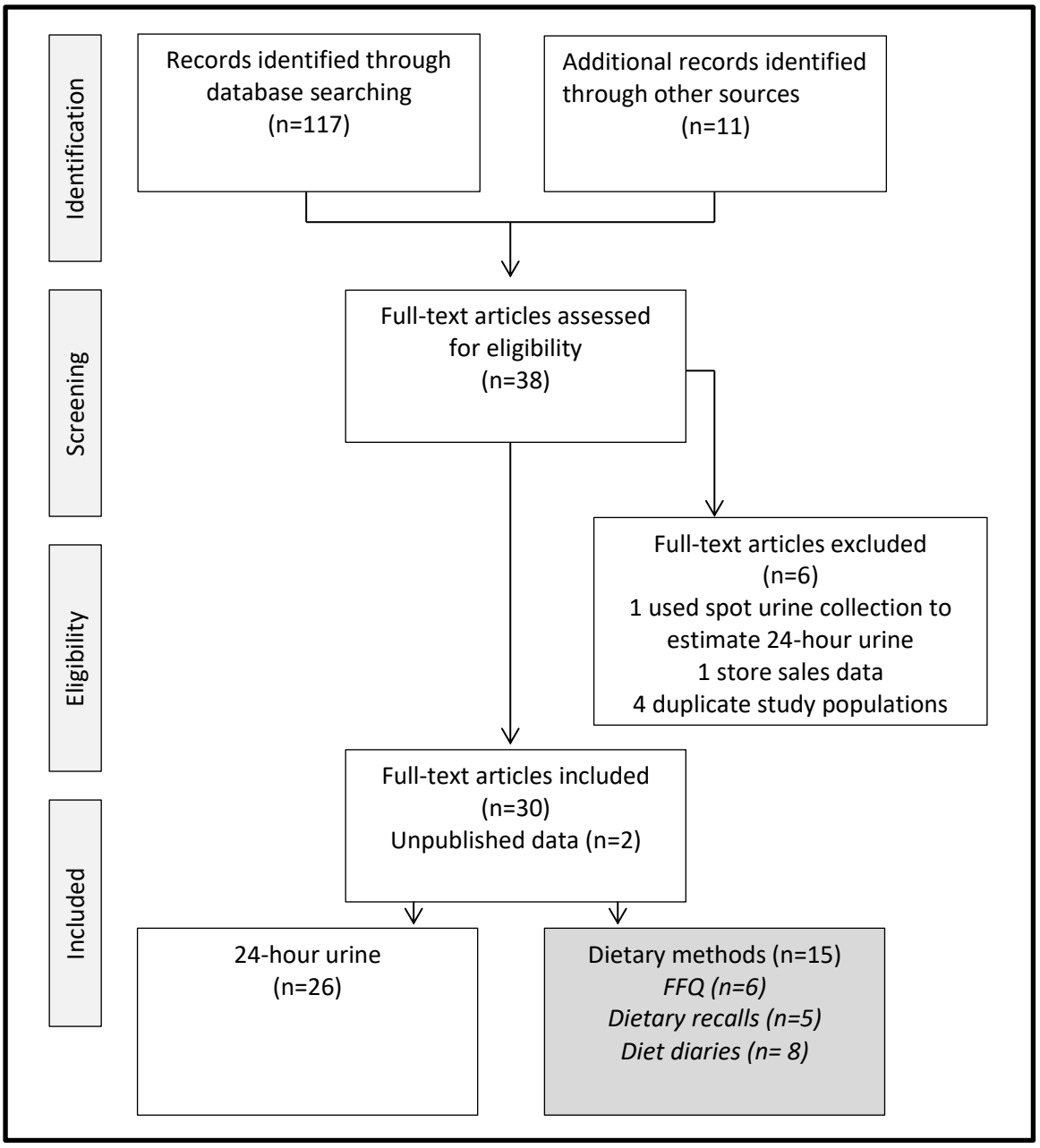

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Flow Diagram showing inclusion and exclusion of identified papers (54).

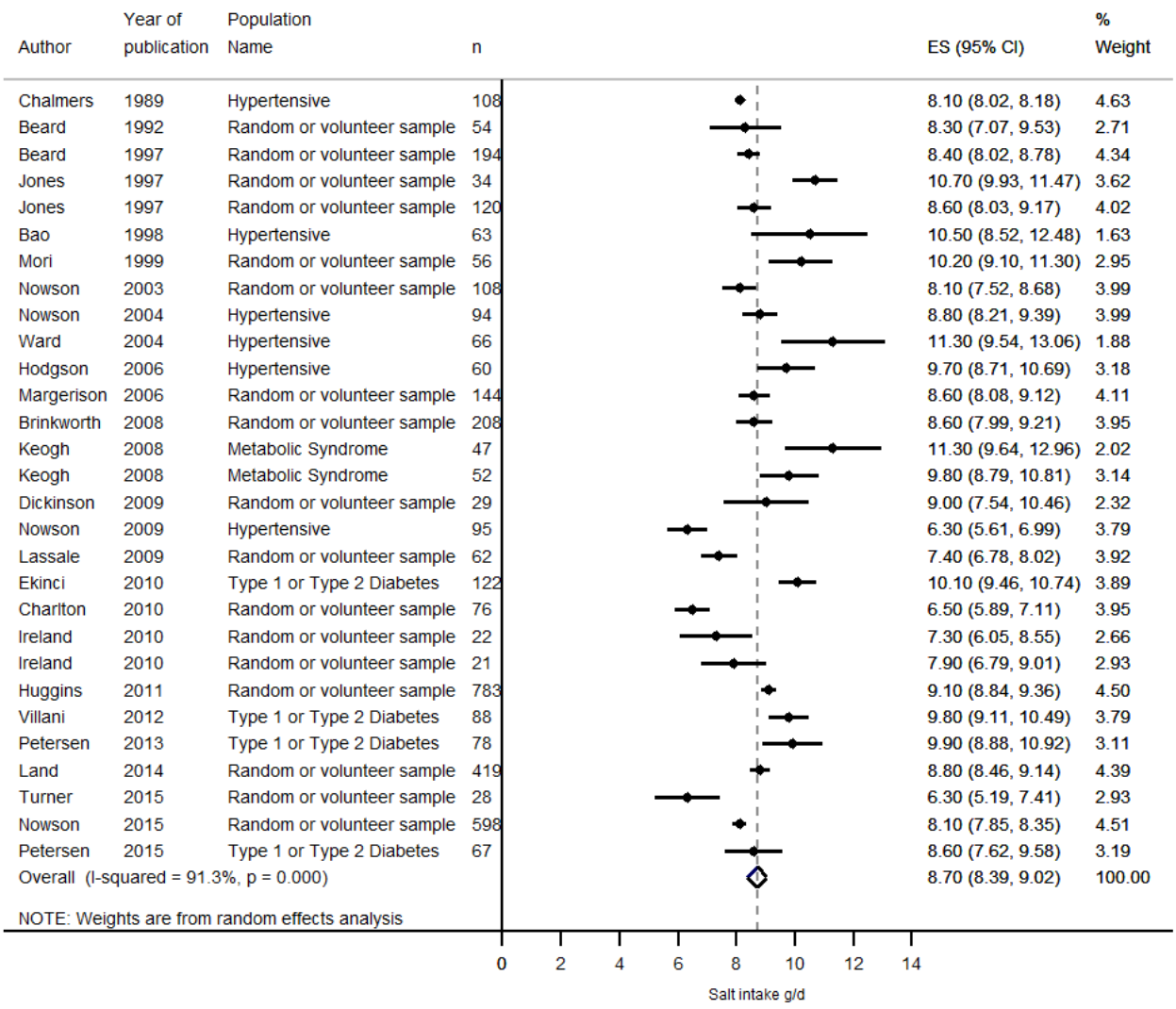

Figure 2: Random effects meta-analysis of overall salt intake, measured by 24-hour urine collection only, in Australia from 1989 until 2015

Subgroups	n	Salt g/day	95% CI
Measurement method			
24-hour urine collection	3896	8.70	8.37 - 9.03
Diet Diary	503	6.49	5.94 - 7.03
FFQ	504	6.76	5.48 - 8.05
Dietary Recall	13428	6.73	6.34 - 7.11
Population (24-hour collection only)			
Random or Volunteer Sample	2956	8.36	7.95 - 8.77
Hypertensive	486	8.82	7.88 - 9.77
Metabolic Syndrome	99	10.4	8.96 - 11.84
Type 1 or Type 2 Diabetes	355	9.66	9.07 - 10.26
Sex (24-hour collection only)			
Mixed	681	9.23	8.61 - 9.85
Male	1381	10.07	9.68 - 10.46
Female	1708	7.34	6.98 - 7.70

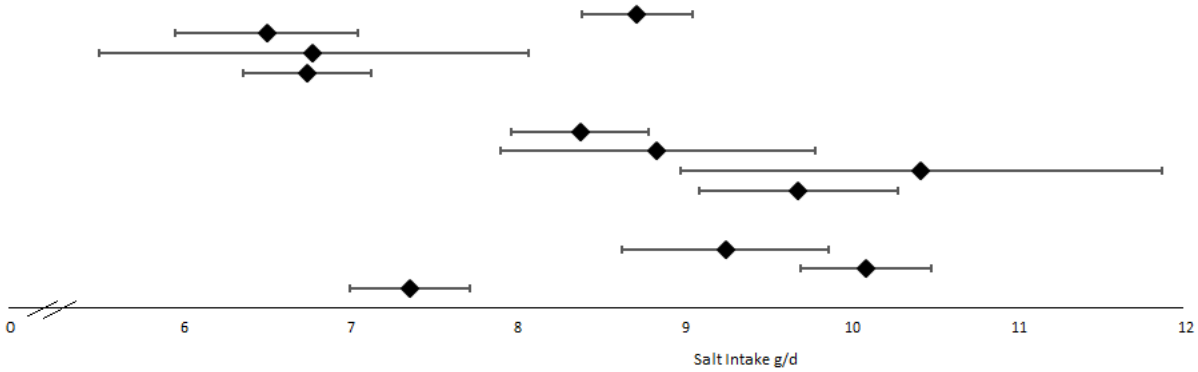

Figure 3: Summary of random effects meta-analysis of salt intake, by measurement method, population and sex

SUPPLEMENTARY MATERIAL

Search Strategy

Ovid MEDLINE 1946 - present

1. Australia/
2. salt or sodium or Na
3. intake or ingest* or eat* or consum* or diet* or urin* or excret*
4. 1 and 2 and 3

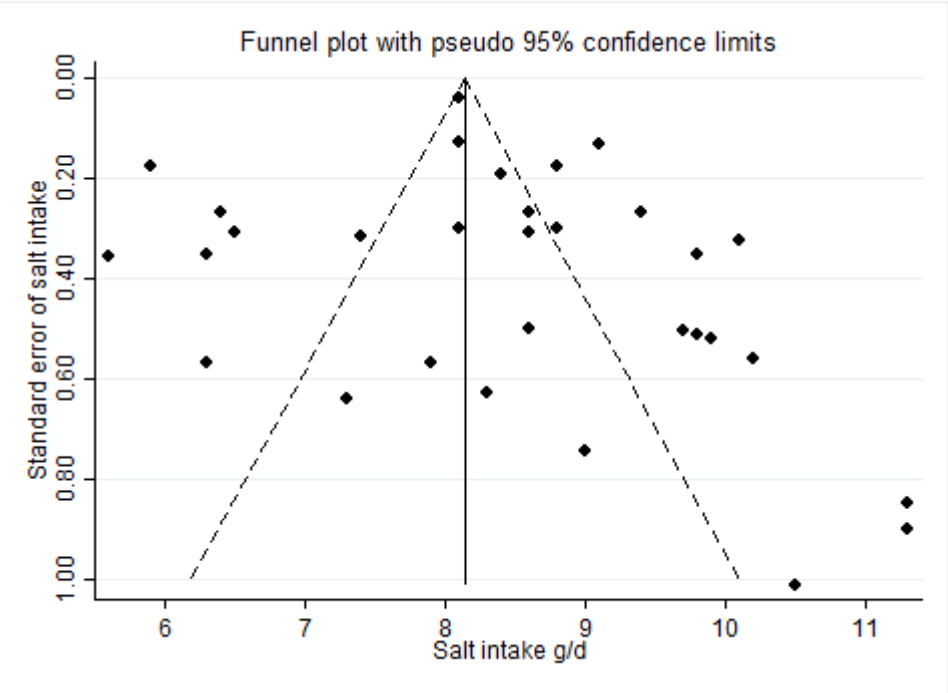

Figure 1: Funnel plot

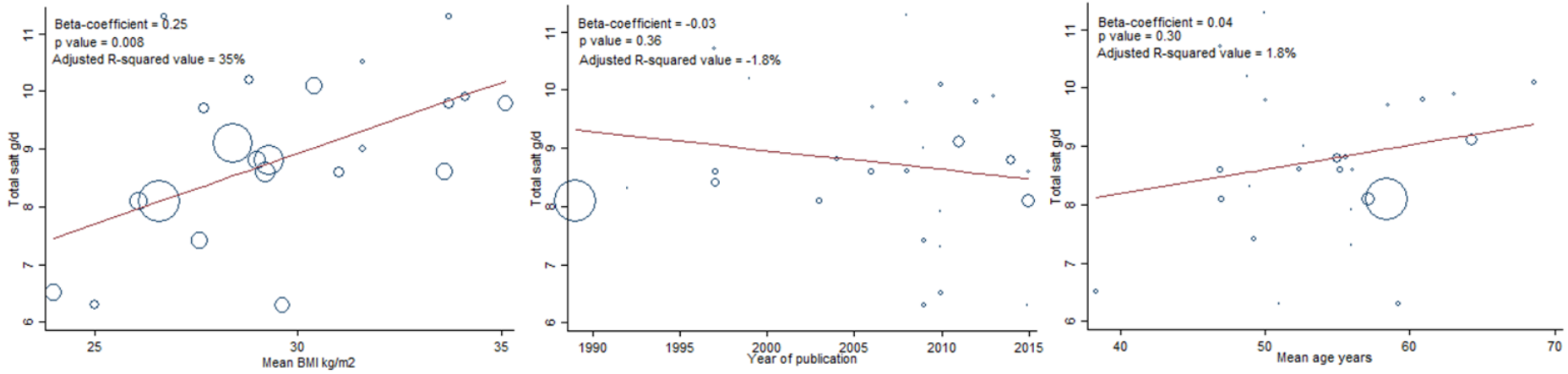

Figure 2: Random effects meta-regression of BMI and salt intake measured by 24-hour urine collections