Comparison of 24 hour urine and 24 hour diet recall for estimating dietary sodium intake in populations: Systematic Review and Meta-analysis

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Comparison of 24 hour urine and 24 hour diet recall for estimating dietary sodium intake in populations: Systematic Review and Meta-analysis

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Conflicts of Interest: Norm Campbell was a paid consultant to the Novartis Foundation (2016-2017) to support their program to improve hypertension control in low to middle income countries which includes travel support for site visits and a contract to develop a survey. NRCC has provided paid consultative advice on accurate blood pressure assessment to Midway Corporation (2017) and is an unpaid member of World Action on Salt and Health (WASH). Nancy Cook was an expert panel member for Jazz Pharmaceuticals (2019). Mark Woodward is a consultant for Amgen and Kyowa Hakko Kirin.

Keywords: dietary sodium, diet surveys, urine specimen collection

Abstract:

This systematic literature review and meta-analysis examined whether 24 hour diet recall is a valid way to measure mean population sodium intake compared with the gold standard 24 hour urinary assessment. We searched electronic databases Medline, Embase, and Scopus using pre-defined terms Studies were eligible for inclusion if they assessed adult humans in free-living settings, and if they included group means for 24 hour diet recall and 24 hour urinary collection of sodium intake in the same participants. Studies that included populations with an active disease state that might interfere with normal sodium metabolism were excluded. Results of 28 studies are included in the meta-analysis. Overall, 24 hour diet recall under-estimated population mean sodium intake by an average of 607 mg per day compared to the 24 hour urine collection. The difference between measures from 24 urine and 24 hour diet recall was smaller in studies conducted in high income countries, in studies where multipass methods of 24 hour diet recall were reported and where urine was validated for completeness. Higher quality studies also reported smaller differences between measures than lower quality studies. Monitoring of population sodium intake with 24 hour urinary excretion remains the most accurate method of assessment. Twenty-four hour diet recall tends to under-estimate intake, although high quality 24h diet recall improves accuracy, and may be used if 24 hour urine is not feasible.

Background

Non-communicable diseases (NCD) are responsible for over 70% of global deaths (1). The World Health Organization (WHO) *Global Action Plan for the reduction of non-communicable disease 2013-2020* has identified reducing mean population salt intake by 30% by 2025 as one of nine priority voluntary global targets for NCD reduction(2). This is due to the well documented positive association between sodium intake and blood pressure(3), as well as the evidence that links high salt intakes directly with cardiovascular outcomes including stroke and myocardial infarction(3-6).
WHO recommends a mean population sodium intake for adults of <2000mg/day (equivalent to 5 grams salt per day), with lower intakes for children proportional to energy intake(3). Recent estimates of intakes around the world are substantially higher. For example in 2010 global mean sodium intake was estimated to be 3950 mg/day (95% uncertainty interval: 3,890 to 4,010 mg/day)(7).

Essential to the WHO recommendation, is the measurement and monitoring of population sodium intake over time. Countries must assess population sodium intake in representative samples of adults, with sufficient numbers to ensure precision of estimates across the population, and in population sub-groups. Sodium intakes may vary by age and sex,(8, 9) and other population groups may have different levels due to different dietary patterns(10). Once a baseline has been established, monitoring to assess progress against the WHO target is also essential to assess effectiveness of public health sodium reduction interventions. While some countries have measured intakes in representative samples using 24 hour urine collections (9, 11-13), many countries conduct regular health and nutrition surveys using 24 hour diet recall to assess dietary intakes.

To assess average sodium intake in a population, it is recommended to use of single 24-hour urine collections in randomly selected individuals over a series of days that reflect the usual population dietary pattern(14). Many surveys also use repeat assessments in a sub-sample to assess day-today variability in individuals. On average, around 90% of ingested sodium is excreted in a 24 hr urine (15). Our previous systematic review indicates that 24-hour diet recall is not an accurate measure of usual sodium intake for individuals, compared to 24-hour urine collection(16). Here, we aim to describe the degree to which 24-hour diet recall is suitable for estimating population mean sodium intakes compared to 24-hour urinary assessment for population evaluation and monitoring purposes.

This paper was commissioned by the TRUE (International Consortium for Quality Research on Dietary Sodium/Salt) consortium. The mandate of the TRUE consortium is to develop minimum standards for clinical and epidemiological research on dietary salt. Member organizations of the TRUE consortium include the American Heart Association, the British and Irish Hypertension Society, the Chinese Regional Office of the World Hypertension League, Hypertension Canada, the International Association of National Public Health Institutes, the International Council of Cardiovascular Prevention and Rehabilitation, the International Society of Hypertension, the International Society of Nephrology, the *Journal of Clinical Hypertension*, the World Health Organization Collaborating Centre for Population Salt Reduction, the Technical Advisory Group to mobilize cardiovascular disease prevention through dietary salt control policies and interventions of the Pan American Health Organization/World Health Organization, the World Hypertension League, and the World Stroke Organization.

Methods

Search strategy

The electronic databases Medline (1946 to Present) Embase (1947 to present) and Scopus were searched in July 2018, using pre-defined terms: 384 duplicates were removed. Two authors (RM and EB) independently reviewed the titles and abstracts of all 3187 articles identified and matched these with pre-defined eligibility criteria (see below). Any discrepancies were discussed and either consensus achieved or articles were included in the full text review. Both reviewers then independently reviewed the full text of potentially eligible articles. Titles abstracts and full-text articles published in languages other than English were translated. Discrepancies were discussed with a third author (CC) and consensus achieved for final eligible studies. Reference lists of included studies were hand searched for additional articles not identified in the database search, and enquiries were made with co-authors and academic colleagues to identify further potentially eligible studies.

Eligibility criteria

Studies were eligible for inclusion if they were available in full text and assessed dietary sodium intake in adult humans in free-living settings. Eligible studies included both 24 hour urine collection and 24 hour diet recall in the same participants in the same time period. Studies that collected urine samples for less than 24 hours were excluded. Also, the studies needed to report mean (and standard deviation) sodium for 24 hour urine and 24 hour diet recall or measures that could be converted to a mean and standard deviation.

Feeding studies and studies where diet was controlled by investigators were excluded. There were no restrictions on language or study sample size. Studies that included children or participants who were pregnant (without separate analysis) were excluded, as were studies including participants with an active disease state likely to interfere with normal sodium metabolism (e.g. renal failure, heart failure).

Data Extraction

A data extraction form was developed and piloted by RM and CC. The data extracted were author name, country, publication year, study design (cross-sectional or intervention), age of participants, sex of participants, health status of participants, whether the urine was validated for completeness, number of days urine collected, mean urine sodium (mg), number of people measured for urine, whether a conversion factor was used to convert measured 24h urine excretion into estimate of intake(15), number of days diet collected, mean dietary sodium (mg), number of people measured for diet and whether discretionary salt measured during the diet recall. Measures of variability of data (such as standard deviation, standard error and 95% confidence intervals) for urine and diet were also extracted. Where data from more than one study were included in a single manuscript, data from individual studies were extracted separately where possible. Supporting articles outlining methods of data collection in more detail were also reviewed. If data originated from an intervention study, only baseline data were extracted. If discretionary salt estimates were reported separately from that in food, measures were combined. If multiple days of urine collection or dietary assessment were made, they were recorded as concurrent (assessed over the same 24 hour period) if there was ≥ 1 concurrent day.

CC and RM extracted the data independently and discussed any discrepancies. Data were entered by a third author (NO) into two separate excel spreadsheets, which were then merged to identify discrepancies or data entry errors. Any discrepancies were checked by two authors (RM and NO) and consensus achieved by referring back to the original papers. For the meta-analysis, we required a single mean (and standard deviation) sodium level (in mg) for each of the dietary measure and the 24hr urine measure. In order to achieve this, we made the following decisions:

- Where the means and standard deviations were reported for separate categories (for example by sex or ethnicity), the results were combined. We used the formula presented by Cochrane (section 7.7.3.8) for combining the categories (Table 7.7a in the handbook)(17). When there were more than two categories, the calculations were done sequentially as recommended by Cochrane.
- Where only the confidence intervals were reported, the standard deviations were calculated from the known formula for a confidence interval, assuming a normal distribution.
- Seven of the studies reported geometric means and their confidence intervals. We used the approach of Higgins et al (2008)(18) to transform this information into means and standard deviations consistent with the raw means presented in the other studies. In the present study, this avoids discarding 25% of the studies available in the pooled analysis.

Quality was scored on a scale of 0-7, using a scoring system developed for evaluating quality in validation studies of dietary intake methods.(19)(see Appendix B) Studies are rated as very good to excellent if the score ≥ 5.0; good ($3.5 \leq$ score < 5); acceptable/reasonable ($2.5 \leq$ score < 3.5) or poor if the score < 2.5.

This study was registered with PROSPERO (registration number: CRD42019118618)

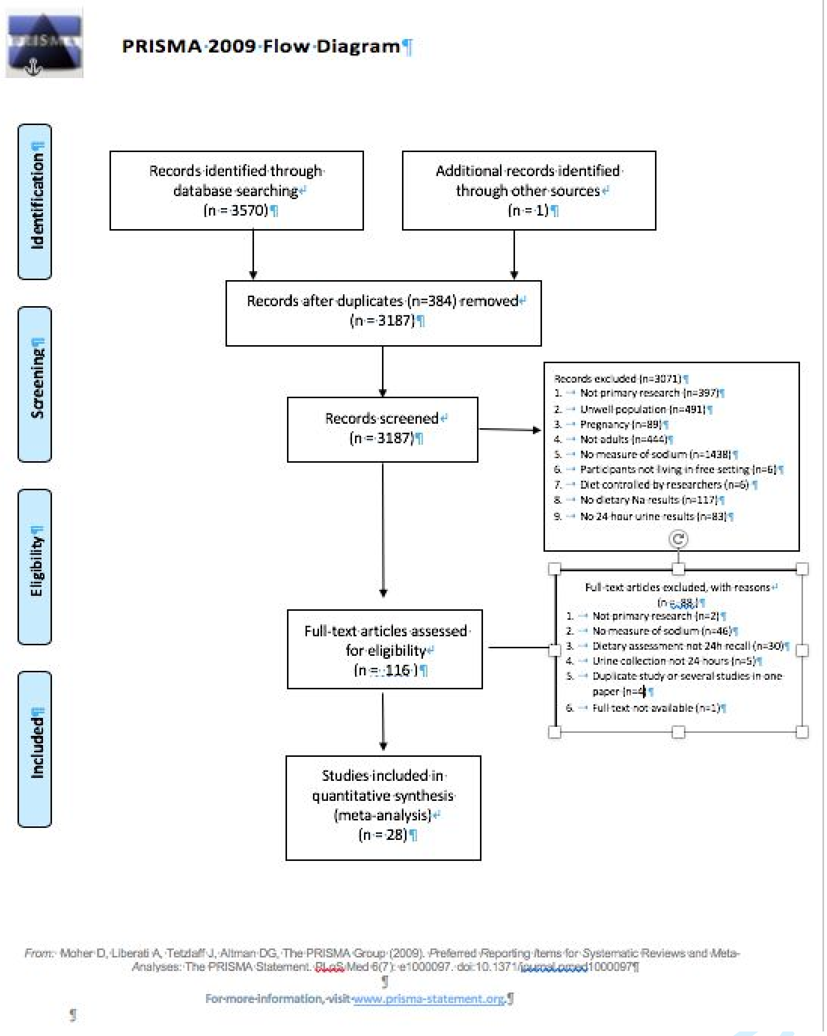
Statistical Analysis

Random effect meta-analyses were used to pool the individual results because of the observational nature of the studies. We conducted subgroup analyses for whether the authors stated the urine samples were validated, whether they stated the use of a multiple-pass (multipass) method to collect the dietary measure, whether they stated that they allowed for discretionary salt and whether the studies took place in an upper middle or high income country according to the World Bank country grouping for 2018/2019 tables(20). To examine potential sources of heterogeneity, sensitivity analyses were performed by (1) comparing studies where we transformed the geometric means and confidence intervals with others (2) comparing small studies (with fewer than 100 subjects) with larger studies and (3) comparing studies by quality. Meta regression was used to determine differences between groups. All analyses were performed using Stata Release 15 (StataCorp. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC. 2017). In cases where the mean and standard deviation were presented as mmol, we use the conversion 1 mmol Na = 1 mEq Na = 23 mg Na. Where salt was reported and not sodium we used the conversion 1 g Na = 2.54 g NaCl = 2.54 g salt.

Results

The initial search of three databases identified 3570 potentially eligible articles, and 1 article was identified through other sources. After 384 duplicates were removed, 3187 titles and abstracts were screened and 116 articles were assessed for eligibility (see Figure 1). Twenty-eight eligible studies are included in this review (see Table 1). Five of the 28 papers had the means and standard deviations (in mg) as required.

Figure 1 Prisma flow diagram



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement.* PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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Qualitative synthesis

Studies were published between 1992 and 2018, and included two intervention and 26 cross-sectional studies (Table 1). Most studies were conducted in high income countries, with 5 studies conducted in Middle Income Countries (Turkey(21), Brazil (22, 23) and South Africa(24) and India(25)). No studies were from Low Income Countries. Only one study(26) included fewer than 50 participants, the number recommended as a minimum for validation studies which include biomarkers.(19) Twenty-one studies reported that they used measures to validate 24 hour urine collections for completeness, including use of self-report, Para-amino benzoic acid (PABA), creatinine concentration, and/or urine volume. Thirteen studies reported the use of multiple pass (multi-pass) methods of 24 hour dietary recall assessment, and 13 studies reported methods that assessed discretionary salt: salt added in cooking and at the table. Fifteen studies included at least one day when 24 hour urine collection and 24 hour diet recall were concurrent. Conversion factors were 0.86 (n=8), 0.9 (n=2) or 0.95 (n=1) and are used to account for incomplete excretion of ingested sodium in urine (see Table 1).

Table 1: Description of studies included in qualitative synthesis.

First Author, publication year	**Name of study**	**Country/ies**	**Study design**	**sample size**	**age of participants (years) mean and/or (range)**	**(% female)**	**urine validated for completeness- paba, creat or .**	**maximum number of days urine collected**	**maximum number of days diet collected**	**Multiple pass methods used in 24h diet recall**	**Discretionary salt measured in 24h diet recall**	**concurrent (urine and diet)**
Campino 2016(27)		Chile	cross-sectional	135	41.2	51.9	Creatinine	1	1	Not stated	Yes	Yes
Charlton 2005(24)		South Africa	cross-sectional	325	(20-65)	50	PABA, creatinine, urine volume	3	3	No	No	Yes
Cornejo 2014(28)		Chile	cross-sectional	70	35	51.4	No	1	3	Not stated	Not stated	Yes
De Keyzer 2015(3)	European Food consumption Validation (EFCOVAL)	Belgium, Norway, Czech Republic	cross-sectional	365	(45-65)	50	PABA	2	2	Not stated	Yes	Yes
Dennis 2003(29, 30)	International Population Study on Macronutrients and Blood Pressure (INTERMAP)	China, Japan, UK, USA	cross-sectional	4680	(40-59)	49.6	Urine volume, other method and self report	2	4	Yes	Yes	Yes

Dhemla 2016(25)		India	cross-sectional	60	(25-45)	50	Not stated	1	4	Not stated	Yes	Not stated
Erdem 2017(21)	SALTURK II	Turkey	cross-sectional	464	47.6	53.1	Creatinine	1	1	Yes	Yes	Yes
Espeland 2001(31)	Trial of Nonpharmacologic Interventions in the Elderly (TONE)	USA	cross-sectional	800	(60-79)	54	Urine volume and self report	1	1	Not stated	Yes	No
Ferreira-Sae 2009(22)		Brazil	cross-sectional	132	55.5 (18-85)	62.9	Not stated	1	1	Not stated	Yes	No
Freedman 2015(32, 33)	Observing Protein and Energy Nutrition (OPEN)	USA	cross-sectional	484	53.4 (40-69)	46	PABA	2	2	Yes	Not stated	No
Freedman 2015 (32, 34)	Energetics	USA	cross-sectional	263	37.8 (21-69)	64	Not stated	2	3	Yes	Not stated	Not stated
Freedman 2015(32, 35)	Nutrition and Physical Activity Assessment Study (NPAAS)	USA	cross-sectional	450	70.5 (50-79)	100	PABA	1	3	Yes	No	Yes
Freedman 2015 (32, 36)	Nutrient Biomarker Study of Womens Health Initiative Strategy	USA	cross-sectional	544	70.9 (50-79)	100	PABA and self report	1	2	Yes	No	Yes

Johansson 1992 (26, 37)		Sweden	intervention	20	44 (27-61)	80	Other method	1	4	Not stated	Not stated	Yes
Kelly 2015(37)		Ireland	cross-sectional	50	(18-64)	36	PABA	1	2	Yes	Yes	Yes
Kong 2018 (38)		South Korea	cross-sectional	640	(19-69)	50	Creatinine and urine volume	2	2	Not stated	Not stated	Not stated
Lassale 2015 (39)	Nutri Net Santé	France	cross-sectional	193	(23-83)	48	PABA, creatinine and self report	2	3	Yes	Yes	Yes
Mann 1987 (40)		Canada	intervention	56	48.5 (20-78)	62.5	Creatinine	2	1	Not stated	Not stated	No
Mercado 2015 (41)		USA	cross-sectional	402	(18-39)	54	Creatinine , urine volume and self report	2	2	Yes	No	Yes
Nam 2017 (42)		South Korea	cross-sectional	640	(19-69)	50	Creatinine, urine volume	2	2	Not stated	Not stated	No
Perin 2013 (23)		Brazil	cross-sectional	108	56.7	51.9	Not stated	1	1	Not stated	Yes	No
Reinivuo 2006 (43)		Finland	cross-sectional	879		53.4	Creatinine and urine volume	1	2	Not stated	Yes	No
Rhodes 2013 (32, 44, 45)		USA	cross-sectional	465		50	Creatinine , urine volume and self report	2	2	Yes	No	Yes
Santos 2017 (46)		Australia	cross-sectional	412	58	55.6	Creatinine and urine volume	1	1	Yes	Yes	No
Satoh 2014 (47)		Japan	cross-sectional	203	67.8	46.3	Creatinine	1	1	Not stated	Yes	Yes

Trijsburg 2015 (48)	DuPLO Study (Measurement errors in dietary assessment)	Netherlands	cross-sectional	197	55.7	53.5	PABA and self report	2	9	Yes	Not stated	Not stated
Yuan 2018 (49, 50)	Women's lifestyle validation study	USA	cross-sectional	624	61	100	Not stated	4	4	Yes	No	Yes
Zhang 2000(51)	Belgium Interuniversity Research on Nutrition	Belgium	cross-sectional	4122		48.5	Not stated	1	1	Not stated	No	No

Meta-analysis

For the 28 studies included in the meta-analysis the 24 hour sodium intakes from 24 hour diet recall and 24 hour urine collection, the pooled weighted mean difference was 607 (95% CI 366, 847) mg/day (Figure 2). This indicates that, on average, the sodium measure from 24 hour urine is 607mg/day higher than that measured in 24 hour diet recall. Overall, there was considerable heterogeneity between the studies (I^2 98.3%, p<0.001).

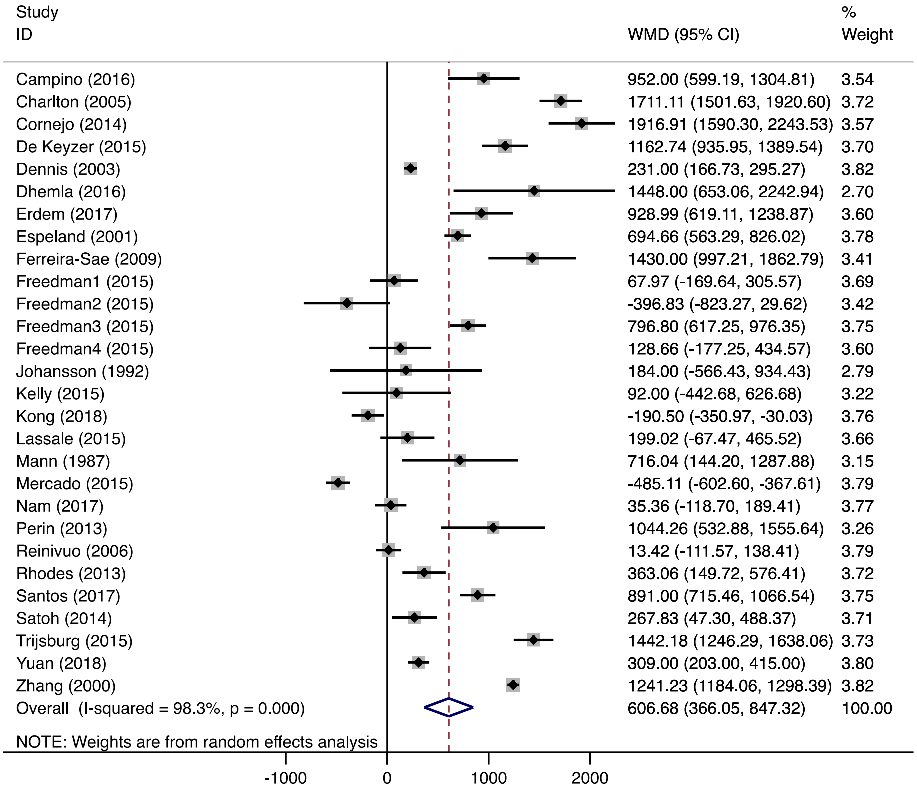


Figure 2: Forest plot of differences in estimated sodium intake from observational studies reporting mean sodium intakes from 24 hour diet recall and 24 hour urine collection in the same subjects.

We found that there was no evidence of a difference in those studies reporting data using geometric means compared to those who did not. Quality of the study showed some evidence of an effect (*p*=0.023). The studies rated as 'excellent quality' showed the smallest mean difference (59 (95% CI -520, 639)mg/day) and the studies rated as 'acceptable quality' had the largest (1249(95% CI 746, 1752)mg/day). Good quality studies had a pooled mean of 602(95% CI 342, 861)mg/day). This means that some of the heterogeneity between the studies can be explained by study quality, although this does not explain the overall sizeable heterogeneity. There was no evidence of an effect of study size on the heterogeneity (Appendix C).

Subgroup analyses indicated a greater difference in the measures in middle income countries compared to high income (*p*=0.008). The pooled mean difference for the middle income countries was 1315 (95% CI 934, 1698)mg/day and for the high income 466 (95% CI 207, 724)mg/day. There was weak evidence of a 'multipass' effect (*p*=0.053). In other words, studies clearly stating that they used multipass showed a smaller difference in the their measures (361 (95% CI 89, 633)mg/day) than others (834 (95% CI 475, 1192)mg/day). An effect is suggested between those studies with or without a clear statement of validation of the urine sample (*p*=0.086). Studies reporting that they validated their urine samples for completeness had a pooled mean difference of 488 (95% CI 250, 726)mg/day, whereas those that did not had 985 (95% CI 470, 1500)mg/day. There was no difference between studies that used a factor (0.86, 0.9, or 0.95) to convert measured 24 hour sodium excretion into an estimate of intake and those that did not.

Discussion

We found that 24 hour diet recall under-estimated population mean sodium intake by an average of 607 mg per day (equivalent to around 1.5 grams salt per day) compared to 24 hour urine collection. The difference between measures from 24 urine and 24 hour diet recall was smaller in high income than other countries, in studies where multipass methods of 24 hour diet recall were reported and where urine was validated for completeness. Higher quality studies also reported smaller differences between measures than lower quality studies.

This study shows that 24 hour urine collection remains the best method of dietary sodium intake for accurate measurement of population sodium intake- a finding consistent with other recently published studies (14, 15). Accurate measurement is especially important where intakes are not substantially above target levels, and under-estimates in assessment in this situation may delay or prevent the development of suitable public health interventions to lower intakes. The degree to which 24 hour diet recall under-estimates population mean sodium intakes is not insubstantial, at around 600mg/day, with differences much higher in some studies (Figure 2). Further, the high degree of heterogeneity in studies suggests that bias over time may not be consistent, thereby unable to detect small decreases or increases in population sodium intake over time, essential for monitoring and evaluation. The difference between high income and non-high income countries may be due to resourcing issues maintaining high quality up to date food composition databases in lower resource countries, although all studies from non-high-income countries used local country-specific food composition databases.

Other differences were observed by study quality, and use of multipass methods in 24-hour diet recall and validation of urine for completeness. Our measure of study quality was specific to nutrient intake validation studies(19), which is how the results of all these studies was assessed in this meta-analysis. However, not all studies included were designed as validation studies, so are not ‘lower quality studies’ per se. Smaller differences among studies that used multipass methods of dietary assessment (where there are multiple passes of assessment with prompts about frequently forgotten foods) , and those that report validating urine for completeness were expected given that these methods are used to enhance the accuracy of both methods of assessment. Although these differences were not statistically significant (p>0.05) the actual differences are relevant in a population monitoring setting.

Interestingly, use of a conversion factor to account for incomplete urinary excretion of sodium was not associated with a greater difference between 24 hour diet recall and 24 hour urine intake measurements. We expected that the difference would be greater in those studies that converted measured 24 hour urinary excretion into estimates of intake based on the assumption that only around 90% of ingested sodium is excreted in the urine. Although not significanlty different, the pooled estimate of the difference for those studies that used a conversion factor was in fact smaller than those that did not (406mg/day vs 740mg/day respectively).

Although there was no difference among studies that report assessment of discretionary salt intake overall, countries where discretionary salt is a large proportion of intake should clearly take account of discretionary salt. For example Perin et al (23) estimated that discretionary salt was around 78% of total salt intake in a Brazilian sample of hypertensive patients. Not measuring discretionary salt in this situation would have led to a substantial under-estimate of total intake.

Many countries already have established nutrition surveys that use 24 hour diet recall to assess intakes of nutrients and foods. While dietary sodium intake is often reported from these studies, 24 hour urinary collection is generally considered the most accurate method of measuring dietary sodium intake. Countries where population 24 hour urine assessment has been undertaken have generally conducted dedicated 24 hour urine collection surveys(9, 52) rather than incorporating 24 hour urine collection into existing surveys. This is largely due to the considerable burden on participants of 24 hour urine collection. This study demonstrates that where countries rely on 24 hour diet recall for estimating population sodium intake, it is important that high quality 24 hour diet recall methods are used. We recommend the use of multiple pass methods and accurate food composition databases, and where discretionary salt is a large proportion of population sodium intake, estimates of discretionary salt intake must be included. We also recommend that counries consider conducting a high quality validation study(19) to indicate the degree to which the 24 hour recall method relates to measured 24 hour urine sodium excretion in the population of interest. This information can be used to plan population sodium intake measurement and monitoring.

Strengths and Limitations

This meta-analysis reports on twenty eight studies, including observational studies, validation studies and intervention studies. We report here only on group means as the mean population intake is the key measure in the WHO voluntary target for reduction of noncommunicable disease(2). We have not compared differences in variability between the two methods. Estimating variability in population sodium intake is important for determining the proportion of the population above recommended levels, but has not been examined here.

We have not been able to fully explain the sizeable heterogeneity between study results. Both measures of sodium intake methods have potential for bias. Twenty four hour diet recall is prone to recall bias which may be systematic or random, and social desirability bias(53, 54). Twenty four hour diet recall relies on accurate data collection, and use of appropriate and up to date food composition databases. Twenty four hour urines have considerable respondent burden, and both under and over collection has been reported(55). Not all studies included in this analysis were validation studies, and so attention to accurate data collection may have been variable. Some authors may have not reported methods such as accounting for discretionary salt, or using methods to assess completeness of 24 hour urine collections that were used in the study- thereby affecting the accuracy of our sensitivity analyses.

Conclusions

Almost all populations have intakes that are substantially above the recommended 2000mg/day population mean for adults. Public Health interventions are urgently required to reduce dietary sodium intake in order to achieve the WHO recommendation to reduce intake by 30% by 2025. Accurate measurement and monitoring of population dietary sodium intake is necessary to assess whether public health interventions to reduce population sodium intake are effective. Monitoring with 24 hour urinary excretion remains the most accurate method of assessment as 24 hour diet recall tends to under-estimate intake. Where 24 hour diet recall is the method used, we recommend using multiple pass methods, ensuring accurate food composition databases, measuring discretionary salt where this is a large proportion of intake. Ideally a high quality validation study comparing 24h diet recall with 24 h urine should be undertaken to assess the degree of bias in the 24h recall method.

References:

1. World Health Organization. Ten threats to global health Geneva: World Health Organization; 2019 [Available from: https://www.who.int/emergencies/ten-threats-to-global-health-in-2019.

2. World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013-2020. Geneva: World Health Organization; 2013.

3. De Keyzer W, Dofková M, Lillegaard ITL, De Maeyer M, Andersen LF, Ruprich J, et al. Reporting accuracy of population dietary sodium intake using duplicate 24 h dietary recalls and a salt questionnaire. British Journal of Nutrition. 2015;113(3):488-97.

4. Bedford JL, Barr SI. Higher urinary sodium, a proxy for intake, is associated with increased calcium excretion and lower hip bone density in healthy young women with lower calcium intakes. Nutrients. 2011;3(11):951-61.

5. Milajerdi A, Djafarian K, Shab-Bidar S. Dose–response association of dietary sodium intake with all-cause and cardiovascular mortality: a systematic review and meta-analysis of prospective studies. Public health nutrition. 2019;22(2):295-306.

6. National Academies of Sciences E, and Medicine,. Dietary Reference Intakes for Sodium and Potassium. Washington, DC: The National Academies Press; 2019.

7. Queiroz A, Damasceno A, Jessen N, Novela C, Moreira P, Lunet N, et al. Urinary Sodium and Potassium Excretion and Dietary Sources of Sodium in Maputo, Mozambique. Nutrients. 2017;9(8).

8. Cogswell ME, Zhang Z, Carriquiry AL, Gunn JP, Kuklina EV, Saydah SH, et al. Sodium and potassium intakes among US adults: NHANES 2003-2008. The American Journal of Clinical Nutrition. 2012;96(3):647-57.

9. Joint Health Surveys Unit. An assessment of dietary sodium levels among adults (aged 19-64) in the general population, based on analyisis of dietary sodium in 24 hour urine samples. London: National Centre for Social Research; 2006.

10. Okuda N, Stamler J, Brown IJ, Ueshima H, Miura K, Okayama A, et al. Individual efforts to reduce salt intake in China, Japan, UK, USA: what did people achieve? The INTERMAP Population Study. Journal of hypertension. 2014;32(12):2385-92.

11. Joint Health Surveys Unit. A survey of 24 hour and spot urinary sodium and potassium excretion in a representative sample of the Scottish population. National Centre for Social Research; 2007.

12. Laatikainen T, Pietinen P, Valsta LM, Sundvall J, Reinivuo H, Tuomilehto J. Sodium in the Finnish diet: 20-year trends in urinary sodium excretion among the adult population. European Journal of Clinical Nutrition. 2006;60:965-70.

13. Cogswell ME, Loria CM, Terry AL, Zhao L, Wang C-Y, Chen T-C, et al. Estimated 24-Hour Urinary Sodium and Potassium Excretion in US AdultsEstimated 24-Hour Urinary Sodium and Potassium Excretion in US AdultsEstimated 24-Hour Urinary Sodium and Potassium Excretion in US Adults. JAMA. 2018;319(12):1209-20.

14. Campbell NR, He FJ, Tan M, Cappuccio FP, Neal B, Woodward M, et al. The International Consortium for Quality Research on Dietary Sodium/Salt (TRUE) position statement on the use of 24-hour, spot, and short duration (< 24 hours) timed urine collections to assess dietary sodium intake. The Journal of Clinical Hypertension. 2019.

15. Lucko AM, Doktorchik C, Woodward M, Cogswell M, Neal B, Rabi D, et al. Percentage of ingested sodium excreted in 24-hour urine collections: a systematic review and meta-analysis. Journal of Clinical Hypertnesion 2018;20(9):1220-9.

16. McLean R, Farmer VL, Nettleton A, Cameron CM, Cook NR, Woodward M, et al. Twenty-Four–Hour Diet recall and Diet records compared with 24-hour urinary excretion to predict an individual's sodium consumption: A Systematic Review. Journal of clinical hypertension. 2018.

17. Higgins JP, Green S. Cochrane handbook for systematic reviews of interventions. 2008.

18. Higgins JP, White IR, Anzures-Cabrera J. Meta-analysis of skewed data: Combining results reported on log-transformed or raw scales. Statistics in medicine. 2008;27(29):6072-92.

19. Serra-Majem L, Andersen LF, Henrique-Sanchez P, Doreste-Alonso J, Sanchez-Villegas A, Ortiz-Andrelluchi A, et al. Evaluating the quality of dietary intake validation studies. British Journal of Nutrition. 2009;102:S3-S9.

20. The World Bank. World Bank Country and Lending Groups: Country Classification undated [Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups%20income%20level%202018-9

21. Erdem Y, Akpolat T, Derici Ü, Şengül Ş, Ertürk Ş, Ulusoy Ş, et al. Dietary Sources of High Sodium Intake in Turkey: SALTURK II. Nutrients. 2017;9(9).

22. Ferreira-Sae M-CS, Gallani M-CB, Nadruz W, Jr, Rodrigues RC, Franchini KG, Cabral PC, et al. Reliability and validity of a semi-quantitative FFQ for sodium intake in low-income and low-literacy Brazilian hypertensive subjects. Public Health Nutrition. 2009;12(11):2168-73.

23. Perin MS, Cornelio ME, Rodrigues RC, Gallani MC. Characterization of salt consumption among hypertensives according to socio-demographic and clinical factors. Revista Latino-Americana de Enfermagem. 2013;21(5):1013-21.

24. Charlton KE, Steyn K, Levitt NS, Zulu JV, Jonathan D, Veldman FJ, et al. Ethnic differences in intake and excretion of sodium, potassium, calcium and magnesium in South Africans. Eur J Cardiovasc Prev Rehabil. 2005;12(4):355-62.

25. Dhemla S, Varma K. Estimation of salt intake of normotensive subjects of Jaipur City. Nutr Food Sci. 2016;46(6):766-77.

26. Johansson G, Callmer E, Gustafsson J-Å. Validity of repeated dietary measurements in a dietary intervention study. European journal of clinical nutrition. 1992;46(10):717-28.

27. Campino C, Hill C, Baudrand R, Martínez-Aguayo A, Aglony M, Carrasco CA, et al. Usefulness and Pitfalls in Sodium Intake Estimation: Comparison of Dietary Assessment and Urinary Excretion in Chilean Children and Adults. American Journal of Hypertension. 2016:hpw056.

28. Cornejo K, Pizarro F, Atalah E, Galgani JE. Assessment of dietary intake and urinary excretion of sodium and potassium in adults. Revista Medica de Chile. 2014;142(6):687-95.

29. Dennis B, Stamler J, Buzzard M, Conway R, Elliott P, Moag-Stahlberg A, et al. INTERMAP: the dietary data—process and quality control. Journal of human hypertension. 2003;17(9):609-22.

30. Anderson CAM, Appel LJ, Okuda N, Brown IJ, Chan Q, Zhao L, et al. Dietary sources of sodium in China, Japan, the United Kingdom, and the United States, women and men aged 40 to 59 Years: The INTERMAP Study. J Am Diet Assoc. 2010;110(5):736-45.

31. Espeland MA, Kumanyika S, Wilson AC, Wilcox S, Chao D, Bahnson J, et al. Lifestyle interventions influence relative errors in self-reported diet intake of sodium and potassium. Ann Epidemiol. 2001;11(2):85-93.

32. 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(7):473-87.

33. Subar AF, Midthune D, Tasevska N, Kipnis V, Freedman LS. Checking for completeness of 24-h urine collection using para-amino benzoic acid not necessary in the Observing Protein and Energy Nutrition study. European Journal of Clinical Nutrition. 2013;67(8):863-7.

34. Arab L, Wesseling-Perry K, Jardack P, Henry J, Winter A. Eight self-administered 24-hour dietary recalls using the Internet are feasible in African Americans and Whites: the energetics study. J Am Diet Assoc. 2010;110(6):857-64.

35. Prentice RL, Mossavar-Rahmani Y, Huang Y, Van Horn L, Beresford SA, Caan B, et al. Evaluation and comparison of food records, recalls, and frequencies for energy and protein assessment by using recovery biomarkers. American journal of epidemiology. 2011:kwr140.

36. Neuhouser ML, Tinker L, Shaw PA, Schoeller D, Bingham SA, Van Horn L, et al. Use of recovery biomarkers to calibrate nutrient consumption self-reports in the Women's Health Initiative. American journal of epidemiology. 2008;167(10):1247-59.

37. Kelly C, Geaney F, Fitzgerald A, Browne G, Perry I. Validation of diet and urinary excretion derived estimates of sodium excretion against 24-hour urine excretion in a worksite sample. Nutr Metab Cardiovasc Dis. 2015;25:771-9.

38. Kong J-S, Lee Y-K, Kim MK, Choi M-K, Heo Y-R, Hyun T, et al. Estimation model for habitual 24-hour urinary-sodium excretion using simple questionnaires from normotensive Koreans. PLoS ONE. 2018;13(2):15.

39. Lassale C, Castetbon K, Laporte F, Camilleri GM, Deschamps V, Vernay M, et al. Validation of a Web-based, self-administered, non-consecutive-day dietary record tool against urinary biomarkers. British Journal of Nutrition. 2015;113(6):953-62.

40. Mann KV, Sullivan PL. Effect of task-centered instructional programs on hypertensives' ability to achieve and maintain reduced dietary sodium intake. Patient Educ Couns. 1987;10(1):53-72.

41. Mercado CI, Cogswell ME, Valderrama AL, Wang C-Y, Loria CM, Moshfegh AJ, et al. Difference between 24-h diet recall and urine excretion for assessing population sodium and potassium intake in adults aged 18-39 y. Am J Clin Nutr. 2015;101(2):376-86.

42. Nam GE, Kim SM, Choi M-K, Heo Y-R, Hyun T-S, Lyu E-S, et al. Association between 24-h urinary sodium excretion and obesity in Korean adults: A multicenter study. Nutrition. 2017;41:113-9.

43. Reinivuo H, Valsta L, Laatikainen T, Tuomilehto J, Pietinen P. Sodium in the Finnish diet: II trends in dietary sodium intake and comparison between intake and 24-h excretion of sodium. European journal of clinical nutrition. 2006;60(10):1160-7.

44. 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.

45. Moshfegh AJ, Rhodes DG, Baer DJ, Murayi T, Clemens JC, Rumpler WV, et al. The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. The American journal of clinical nutrition. 2008;88(2):324-32.

46. Santos JA, Webster J, Land M-A, Flood V, Chalmers J, Woodward M, et al. Dietary salt intake in the Australian population. Public Health Nutrition. 2017;20(11):1887-94.

47. Satoh M, Kato N, Hosaka M, Elnagar N, Tsuchihashi T, Yagi N, et al. Validity of salt intake assessment system based on a 24-h dietary recall method using a touch panel computer. Clin Exp Hypertens. 2014;36(7):471-7.

48. Trijsburg L, de Vries JHM, Boshuizen HC, Hulshof PJM, Hollman PCH, van 't Veer P, et al. Comparison of duplicate portion and 24 h recall as reference methods for validating a FFQ using urinary markers as the estimate of true intake. British Journal of Nutrition. 2015;114(8):1304-12.

49. Yuan C, Spiegelman D, Rimm EB, Rosner BA, Stampfer MJ, Barnett JB, et al. Relative Validity of Nutrient Intakes Assessed by Questionnaire, 24-Hour Recalls, and Diet Records as Compared with Urinary Recovery and Plasma Concentration Biomarkers: Findings for Women. American Journal of Epidemiology. 2018;187(5):1051-63.

50. Yuan C, Spiegelman D, Rimm EB, Rosner BA, Stampfer MJ, Barnett JB, et al. Relative validity of nutrient intakes assessed by questionnaire, 24-hour recalls, and diet records as compared with urinary recovery and plasma concentration biomarkers: findings for women. American journal of epidemiology. 2017;187(5):1051-63.

51. Zhang J, Temme EH, Sasaki S, Kesteloot H. Under-and overreporting of energy intake using urinary cations as biomarkers: relation to body mass index. American journal of epidemiology. 2000;152(5):453-62.

52. McLean R, Edmonds J, Williams S, Mann J, Skeaff SA. Balancing Sodium and Potassium: Estimates of Intake in a New Zealand Adult Population Sample. Nutrients. 2015;7(11):8930-8.

53. Gemming L, Jiang Y, Swinburn B, Utter J, Ni Mhurchu C. Under-reporting remains a key limitation of self-reported dietary intake: an analysis of the 2008/09 New Zealand Adult Nutrition Survey. European Journal of Clinical Nutrition. 2013;68(2):259-64.

54. Bailey R. Evaluating Calorie Intake: Data Science Campus; 2018 [Available from: https://datasciencecampus.ons.gov.uk/2018/02/15/eclipse/

55. John KA, Cogswell ME, Campbell NR, Nowson CA, Legetic B, Hennis AJ, et al. Accuracy and usefulness of select methods for assessing complete collection of 24-hour urine: a systematic review. The Journal of Clinical Hypertension. 2016;18(5):456-67.

Appendices

Appendix A

Medline and Embase

Search Strategy more succinctly: This was for Embase and Ovid

1. Exp Sodium, Dietary OR exp diet OR exp salt consumption.mp OR sodium intake.mp OR diet* sodium OR exp sodium, dietary/or ex sodium chloride, dietary
2. Exp Data Collection OR exp diet records OR Dietary data.mp, OR exp nutrition assessment OR exp Surveys and Questionnaires OR exp Diet Records.
3. Urin*mp OR urin* excretion OR exp Urine specimen collection
4. Combine 1, 2, 3 together and limit to humans. Further limit by adding step 5.
5. 24hr OR 24 hr OR 24 hour OR 24hour

Scopus:

(dietary AND sodium) AND (urin*) AND (24 hour AND recall)

Appendix B

Scoring system from: Serra-Majem L, Andersen LF, Henrique-Sanchez P, Doreste-Alonso J, Sanchez-Villegas A, Ortiz-Andrelluchi A, et al. Evaluating the quality of dietary intake validation studies. British Journal of Nutrition. 2009;102:S3-S9.

Variable	**Specific Variable**	**Points**
Sample and sample size	Non-homogenous sample, n>50	0.5 0.5
Statistics	Compare/test mean or median or difference	1
Correlations *(select one with highest score)*	Correlation Correlations adjusted for energy Intraclass or deattenuated correlations	0.5 1.0 1.5
Agreement	Classification or Bland & Altman Plot	0.5
Data collection	Face to face interview for 24h diet recall	1
Seasonality	Considered	0.5
Supplements	Included and data considered in analysis	1.5

Very Good/excellent, score $\geq$ 5.0
Good 3.5 $\leq$ score < 5
Acceptable/reasonable 2.5 $\leq$ score < 3.5
Poor, score < 2.5

Appendix C: Supplementary Forest Plots

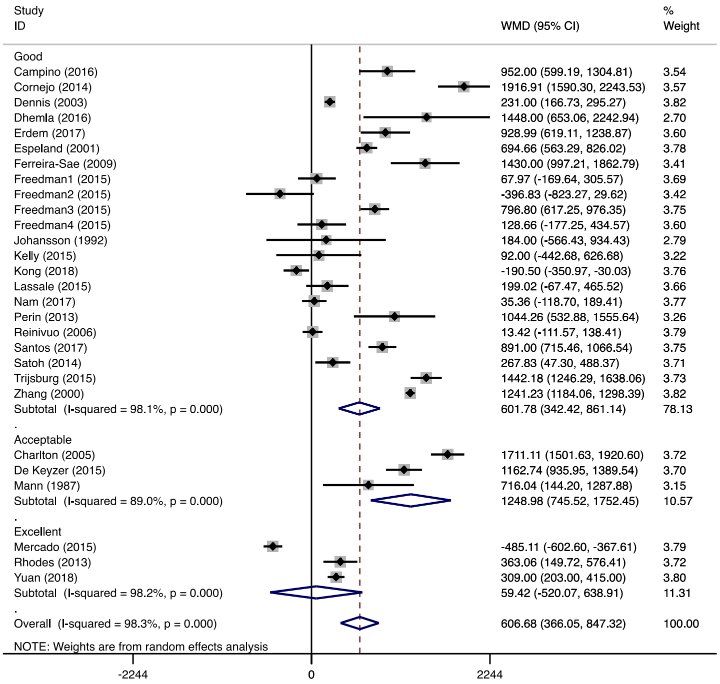
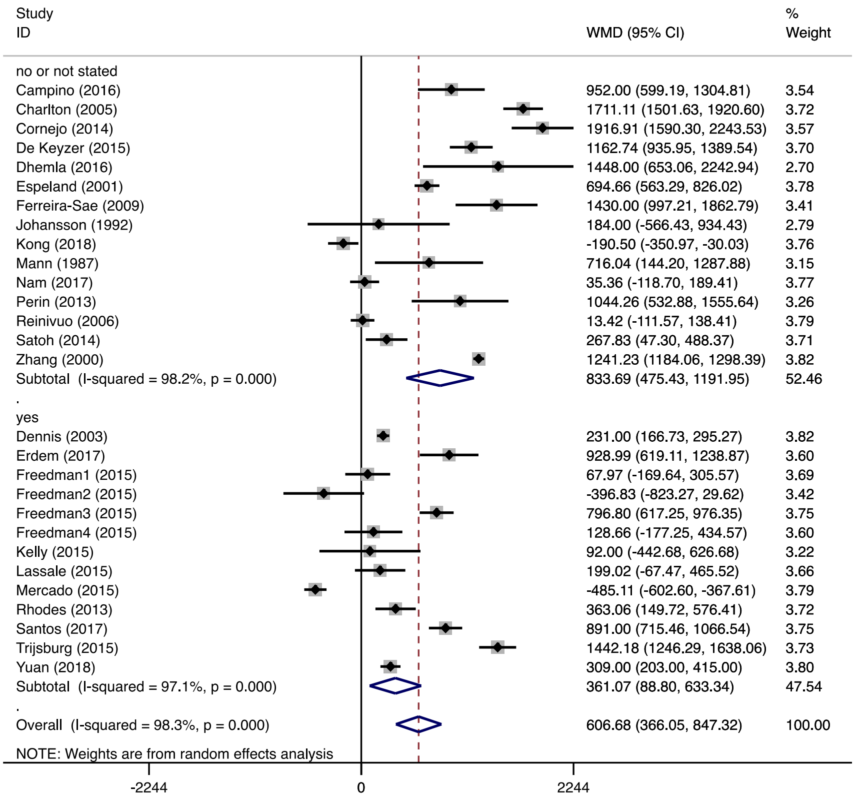


Figure 1: Effect of study quality score based on



Study ID	WMD (95% CI)	% Weight
no or not stated		
Campino (2016)	952.00 (599.19, 1304.81)	3.54
Charlton (2005)	1711.11 (1501.63, 1920.60)	3.72
Cornejo (2014)	1916.91 (1590.30, 2243.53)	3.57
De Keyzer (2015)	1162.74 (935.95, 1389.54)	3.70
Dhemla (2016)	1448.00 (653.06, 2242.94)	2.70
Espeland (2001)	694.66 (563.29, 826.02)	3.78
Ferreira-Sae (2009)	1430.00 (997.21, 1862.79)	3.41
Johansson (1992)	184.00 (-566.43, 934.43)	2.79
Kong (2018)	-190.50 (-350.97, -30.03)	3.76
Mann (1987)	716.04 (144.20, 1287.88)	3.15
Nam (2017)	35.36 (-118.70, 189.41)	3.77
Perin (2013)	1044.26 (532.88, 1555.64)	3.26
Reinivuo (2006)	13.42 (-111.57, 138.41)	3.79
Satoh (2014)	267.83 (47.30, 488.37)	3.71
Zhang (2000)	1241.23 (1184.06, 1298.39)	3.82
Subtotal (I-squared = 98.2%, p = 0.000)	833.69 (475.43, 1191.95)	52.46
.		
yes		
Dennis (2003)	231.00 (166.73, 295.27)	3.82
Erdem (2017)	928.99 (619.11, 1238.87)	3.60
Freedman1 (2015)	67.97 (-169.64, 305.57)	3.69
Freedman2 (2015)	-396.83 (-823.27, 29.62)	3.42
Freedman3 (2015)	796.80 (617.25, 976.35)	3.75
Freedman4 (2015)	128.66 (-177.25, 434.57)	3.60
Kelly (2015)	92.00 (-442.68, 626.68)	3.22
Lassale (2015)	199.02 (-67.47, 465.52)	3.66
Mercado (2015)	-485.11 (-602.60, -367.61)	3.79
Rhodes (2013)	363.06 (149.72, 576.41)	3.72
Santos (2017)	891.00 (715.46, 1066.54)	3.75
Trijsburg (2015)	1442.18 (1246.29, 1638.06)	3.73
Yuan (2018)	309.00 (203.00, 415.00)	3.80
Subtotal (I-squared = 97.1%, p = 0.000)	361.07 (88.80, 633.34)	47.54
.		
Overall (I-squared = 98.3%, p = 0.000)	606.68 (366.05, 847.32)	100.00

NOTE: Weights are from random effects analysis

Figure 2: Effect of using multiple pass methods of 24-hour diet recall assessment

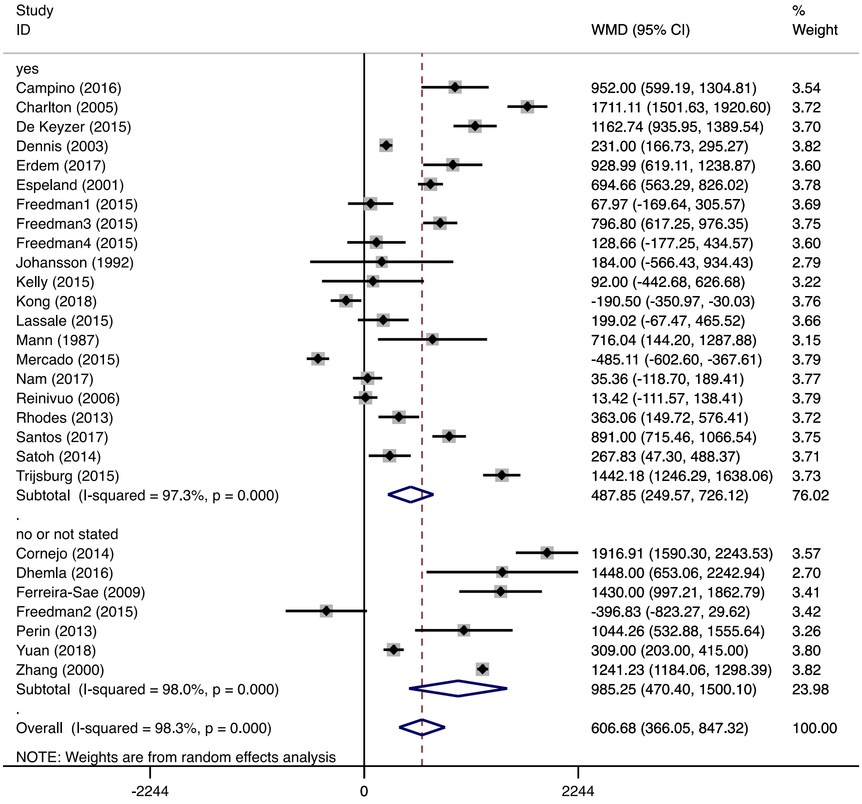


Figure 3: Effect of validating 24-hour urine for completeness

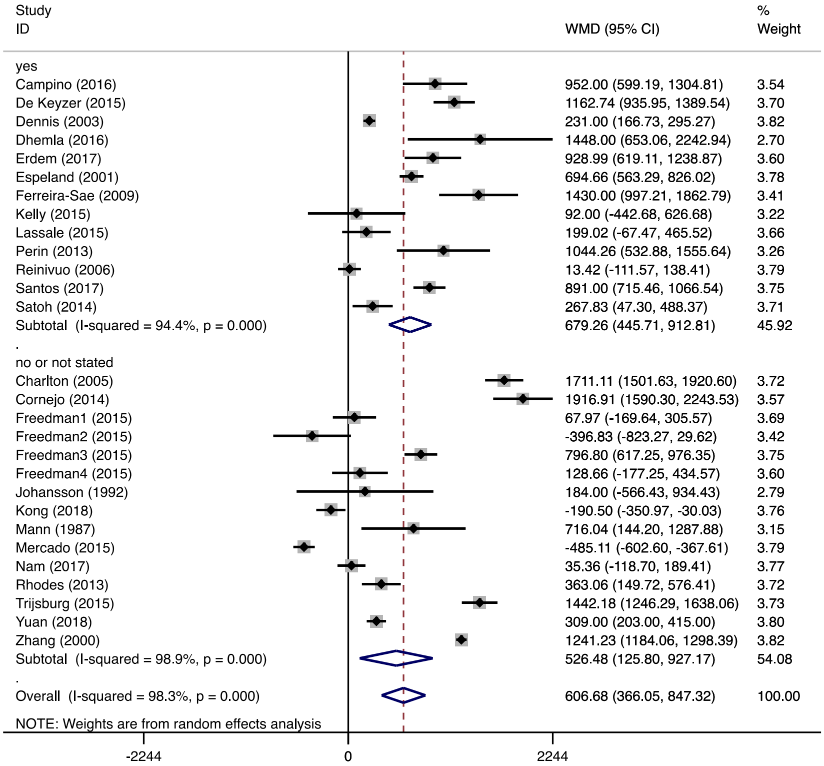


Figure 4: Effect of assessing discretionary salt use as part of 24-hour diet recall

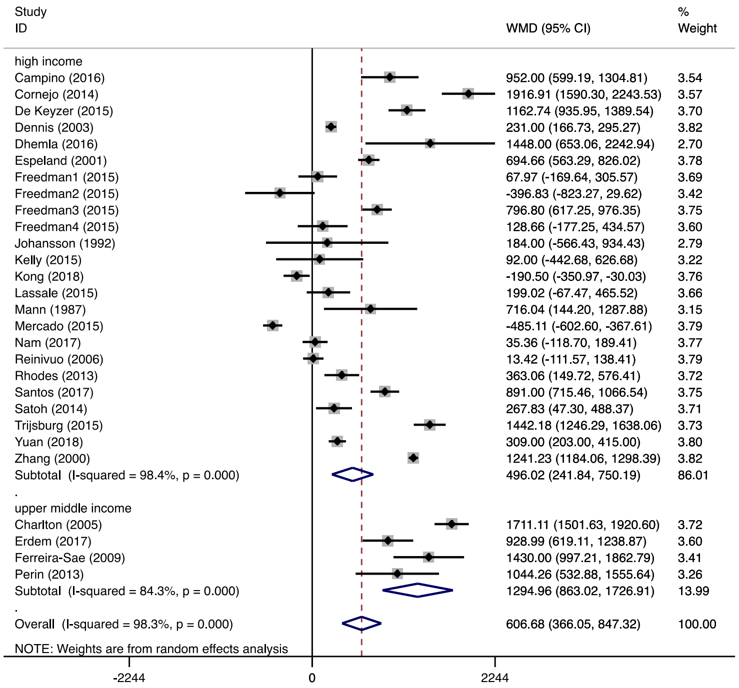


Figure 5: Effect of high income country

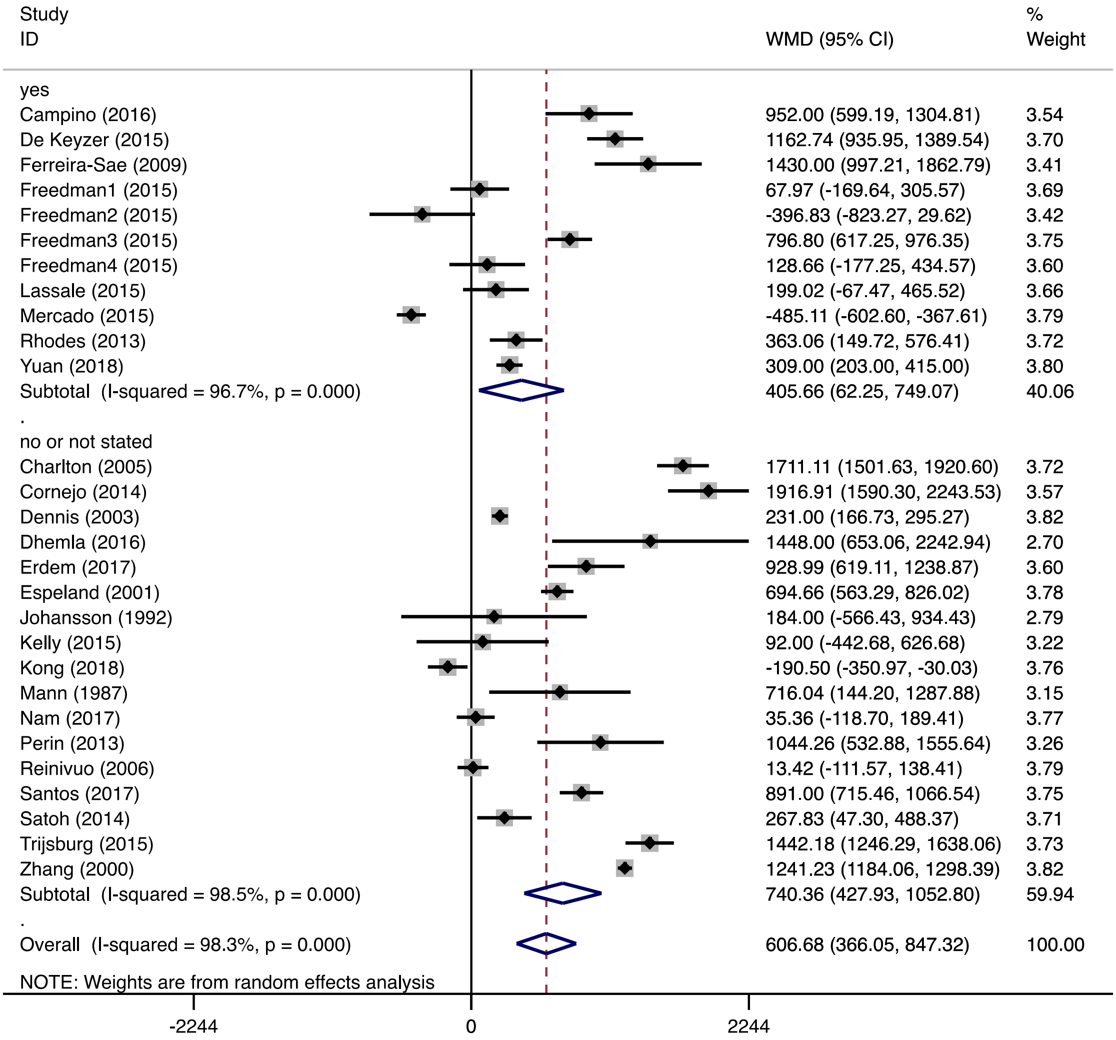


Figure 6: Effect of using conversion factor to account for incomplete urinary excretion of sodium intake