

Twenty Four Hour Diet recall and Diet records compared with 24h urinary excretion to predict an individual's sodium consumption: A Systematic Literature Review

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¹ Details about the TRUE Consortium are mentioned in Appendix B.

Abstract-

This aim of this review is to investigate whether twenty four hour (24h) diet recall and diet records are reliable and valid ways to measure usual dietary sodium intake. Although these dietary assessment methods are often used in epidemiological studies, 24h urine is generally considered to be more accurate measure. Here we describe the results of studies which included dietary assessment of sodium intake (24h diet recall, or diet record,) and 24h urinary collection for assessment of sodium intake in the same participants to predict an individual's sodium intake. Results of 20 studies using 24h diet recall (including 14 validation studies) and 10 studies using food records (including six validation studies) are included in this review. Correlations between estimates from dietary assessment and urinary excretion ranged from 0.16 to 0.72 for 24h diet recall, and 0.11 to 0.49 for food diaries. Bland-Altman analysis in two studies of 24h diet recall showed poor agreement with 24h urinary sodium excretion. Suggestions are made to improve the methods of future validation studies including multiple days of dietary assessment and 24h urine collection, using a variety of statistical tests including Bland-Altman methods, and relevant food composition databases.

Key words: dietary sodium, urine specimen collection, diet surveys

Background

This is the second article of two which describes a systematic review of studies examining the relationship between dietary assessment measures of sodium intake compared with the gold standard biomarker measure: 24 hour (24h) urinary excretion. These reviews have been undertaken because of concerns expressed by many in the scientific community that low quality research, including research which poorly measures usual intake of dietary salt, is contributing to current controversies, and is hampering implementation of public health interventions in many countries. This is despite most international guidelines recommending intakes substantially lower than currently consumed, and the World Health Organization and United Nations recommending a 30% decrease in population salt intake by 2026.¹ In response to these concerns, a consortium of international and national health and scientific organizations was formed to set minimum standards for the conduct of clinical and epidemiological research on dietary salt.²

The first article described the results of studies that compared sodium intake estimates from Food Frequency Questionnaires (FFQs) and 24h urinary excretion.³ This article describes the results for studies that include either 24h diet recall, or diet records (food diaries or weighed food records) and assesses the studies validity for assessing an individual's sodium intake, essential for epidemiological studies of dietary intake and health related outcomes. Twenty four hour diet recalls are often used in large nutrition surveys such as the National Health and Nutrition Examination Survey (NHANES),⁴ and involve researchers contacting participants and asking them to record all foods consumed the previous day. This can be done by interview (in person or by telephone), or online, or some combination of both. Portion size estimates are made using recognised measures such as cups and spoons, or photographs of portion sizes.⁵ Recall bias may be reduced by multiple pass questioning methods, which include specific questions about frequently 'forgotten foods',⁶ however 24h recalls are prone to under-reporting, particularly for overweight participants.^{7 8}

Diet records (or food records) involve documenting all foods consumed over a specified time period (one or more days) prospectively by the participant, and involve estimates of portion size either through weighing (weighed food record) or using other prompts and measures.⁹ Weighed food records are often regarded as the most accurate way of assessing nutrient intakes.⁵ The prospective nature of data recording minimises recall bias, and weighing all food consumed (including weighing any leftovers at the end of a meal) enables accurate assessment of portion size. To assess usual intake several days of recording are undertaken, and are usually specified to include week and weekend days, and may include assessment over several weeks or months. Accurate weighed food records however require detailed training of participants, and a high degree of commitment on participants' behalf. The prospective nature of recording may alter behaviour, for example participants may be less likely to eat out on recording days, or be more likely to consume foods considered desirable or healthy.⁹

Quantification of discretionary salt (added in cooking or at the table) is particularly problematic in diet surveys. For weighed food records, extremely accurate scales are required, as salt added to food is likely to be added as quantities less than a gram which may not register on commonly used dietary scales. Salt added to cooking is likely to be variably absorbed into different foods depending on specific cooking methods, with a substantial proportion lost if cooking liquids are drained or not consumed.¹⁰ For some individuals and populations, difficulty in measuring discretionary salt may not impair estimates, particularly if discretionary salt is not a substantial contributor to overall salt intake. However salt added during cooking is a major source in some populations. In some populations, sauces and condiments are important contributors to discretionary salt intake and must be measured if valid estimates are to be obtained.¹¹

Twenty-four hour urinary sodium is widely regarded as the most accurate method of measurement of dietary sodium intake, provided collection is complete. As a biomarker it reflects around 90% of sodium ingested over the 24h period. However, both under-

collection and over-collection have been reported, and the various methods used to assess completeness of collections such as the use of para-amino benzoic acid(PABA) or urine volume are not robust.¹² Despite this, 24h urine is the most suitable reference method or calibration instrument for comparison in validation studies of dietary assessment methods^{13 14} and is therefore the reference method considered in this review.

This article, commissioned by the TRUE (International Consortium for Quality Research on Dietary Sodium/Salt) consortium, describes a systematic review of studies examining sodium intake assessment from 24h diet recall and diet record compared with the gold standard 24h urine collection, in order to understand whether dietary assessment methods are a reliable and valid way of measuring an individual's usual dietary sodium intake. 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, the Pan American Health Organization/World Health Organization, the World Hypertension League, and the World Stroke Organization.

Methods

Search Strategy:

As described in our previous paper³ the electronic databases Medline, Embase, Cinharl, Lilacs, Google Scholar and the Cochrane Library were searched in 2015, and again in November 2016 using pre-defined terms. (Appendix A, ³ Two authors (R.M. and V.F.) independently reviewed the titles and abstracts of all articles identified, and consensus achieved by subsequent discussion. Titles, abstracts and full-text articles were obtained and translated into English if necessary. Both authors then reviewed the full-text papers independently.

Additional articles not identified in the database search were identified by hand searching reference lists of included studies, and by enquiries with co-authors and academic colleagues.

Eligibility Criteria:

Studies were eligible for inclusion if they were available in full text and assessed adult humans in free-living settings. Studies were included if they included dietary assessment of sodium intake (24h diet recall, or diet record,) and 24h urinary collection for assessment of sodium intake in the same participants. We excluded feeding studies or studies where the amount of sodium in the diet was controlled by investigators. There were no restrictions on language or study sample size. Studies that included populations with an active disease state that might interfere with normal sodium metabolism (e.g. renal failure, congestive heart failure, pregnancy) were excluded. Studies that collected urine samples for less than 24 hours were excluded.

Data extraction:

Two authors independently (R.M. and V.F.) extracted data to a spreadsheet , and accuracy was checked by a third author (A.N.). Extracted data included the study citation, study name, type of study (validation, cohort or cross-sectional), population studied (country, type of sample), participant characteristics (age, ethnicity, sex, disease

status), whether 24h urine collections were validated for completeness and how, 24h urine sodium results, dietary assessment methods and whether discretionary salt (defined as salt added either during cooking or at the table, or both) was accounted for, dietary assessment results, whether dietary assessment and 24h urine collections were concurrent, and what the methods of comparison were (if any) between the two methods.

As this review is exploratory in nature, no formal risk of bias assessment was carried out. All sodium consumption data are expressed in mg sodium/day using the following conversions: 1mmol Na= 1mEq Na = 23mg Na, and 1 g Na = 2.54g NaCl = 2.54g Salt.

Results

The initial search of databases identified 503 articles, and 25 articles were identified from other sources (colleagues and networks, article reference lists and an updated search in November 2016) (see Figure 1: Prisma Flow Diagram). After 70 duplicates were removed, 458 titles and abstracts were screened, and 108 full text articles were assessed for eligibility. One publication¹⁵ included results from five studies. Data were extracted for 20 studies that reported on results of 24h diet recall and 24h urinary sodium in the same participants (Table 1). Data from a further 10 studies that reported on results of food diaries and 24h urinary sodium are summarised in Table 2. Where data from more than one study were included in a single paper¹⁵, data from individual studies were extracted separately where possible. Where data from a single study were reported in two papers^{16 17} this was treated as one study. Supporting papers which described methods of data collection for studies were reviewed for additional data (particularly on methods) where required.

Results 24h diet recall:

There were twenty studies with data on 24h diet recall which are summarized in Table 1 and Appendix C. The three papers listed for De Keyzer describe one study which includes data from three different countries. Freedman (2015) describes a pooled analysis of data from five studies. These are treated as separate studies. Of the 20 studies which described results of dietary assessment by 24h diet recall, 14 were specifically validation studies of 24h diet recall and 6 were population based cross-sectional studies (see Appendix C). Seven studies were conducted in the USA, two in Chile, two in Japan, and one each in Brazil, South Africa, Belgium, Ireland, Netherlands, Finland and Australia. Two studies included participants from more than one country, which included De Keyzer (2015) with participants in Norway, Czech Republic and Belgium, and Dennis (2003) which included participants from China, Japan, USA and UK (Appendix C). Sample sizes of the studies ranged from 50 to 4680 participants, with results for a total of 14,941 subjects across all 20 studies (Table 1). The majority of studies included both men and women, with two studies including women only (Appendix C). Twelve studies included only healthy subjects and excluded those with known medical conditions, while four had subjects with hypertension and two included subjects who were hypertensive and normotensive. Two studies did not state the inclusion and exclusion criteria regarding health status^{18 19} but are included as they are recruited from a population sample.

The number of 24h urine collections carried out by each subject differed between studies (Appendix C). Eleven studies reported one collection, seven studies reported two collections, one study reported three collections and one study had participants complete five urine collections. Sixteen studies described methods used to evaluate the completeness of the 24h urine collections (Appendix C). Four studies used Para-Amino Benzoic Acid PABA alone, three studies used urinary creatinine concentration alone and nine studies used a combination of methods including collection time, self-reported completeness, urine volume, PABA and urinary creatinine concentration. PABA excretion cut-off levels for determination of complete urine were: between 70 and

103% PABA recovery, $\geq 78\%$ PABA recovery, and 85-110% PABA recovery. One study reported that collections with less than 70% PABA recovery were excluded, and those with 70-85% recovery had sodium content adjusted to 93% PABA recovery. Another study stated that collections with less than 50% PABA recovery were excluded, and those with 50-85% recovery had sodium content adjusted to 93% PABA recovery. One study also reported PABA cut-offs of $\leq 75\%$ or $\geq 97\%$ recovery depending on urinary creatinine excretion. Methods of assessment for incomplete samples using creatinine excretion included an assessment of within and between subject variability, exclusion of samples where creatinine (mmol)/body weight (kg) was outside a certain range (different for men and women) and exclusion of samples if creatinine ratio was below a certain value.

There was also variability in the number of 24h diet recalls used to assess dietary sodium intake (Table 1). Six studies conducted a single 24h diet recall, five studies conducted two recalls, five studies conducted three recalls, one study conducted four recalls, one conducted five recalls, one conducted eight and one conducted between one and fifteen 24h diet recalls per participant. Methods used to administer the 24h diet recalls also differed between studies (Table 1). Ten studies were interviewer administered or in person, four were self-administered, one was carried out via telephone, and three used a combination of methods including interview, telephone, web-based and self-administered. Two studies did not specify how the 24h diet recalls were administered. Methods used to estimate portion sizes included photographs, household measures, weight in grams, volume measures, standard portions, rulers and utensils including cups and spoons.

Ten studies specified that discretionary salt was accounted for, three studies did not include discretionary salt and six studies did not provide details about whether discretionary salt was included in their assessment. For nine studies the 24h urine collection and 24h diet recall was concurrent, seven studies were not and four studies

did not state if the 24h diet recall and 24h urine collection covered the same time period (Table 1).

When reporting urinary sodium excretion results seven studies divided the 24h urine results by 0.86, two studies divided by 0.9 and one by 0.95 to account for incomplete excretion of dietary sodium in urine.^{15 20} Estimates from the dietary assessment and the 24hr urine were presented as mean and standard deviation (n=12), mean and standard error (n=1) or geometric mean and 95%CI (n=7).

Many studies reported the results of statistical comparison between methods, including ratios, correlation coefficients, percentage bias and analysis of variance. Ten correlation coefficients of dietary with urinary measures were reported (adjusted and/or unadjusted) which ranged from 0.16 for men in Mercardo et al(2015)²¹ to 0.72 in Satoh et al (2014) ²². Both Mercardo et al and Satoh et al involved analysis of a single 24h urine collection (using creatinine excretion to assess completeness) and a single 24h diet recall which were collected concurrently. Mercardo et al used the United States Department of Agriculture (USDA) Automated Multiple Pass Method (AMPM) and the USDA Food and Nutrient Database , and demonstrated correlations for men of 0.16 and women of 0.25. Satoh et al used a computer based 24h diet recall, and food composition tables of Japan.

Two studies^{23 24} reported results of Bland Altman limits of agreement analyses, which is used to assess differential bias according to the level of estimated sodium intake from both methods²⁵. Cornejo et al presented Bland-Altman plots of the mean difference between dietary and urinary estimates, which show increasing urinary sodium excretion is associated with increasing under-estimation by dietary method, although the limits of agreement are not reported.²³ Kelly et al report a mean difference of 87mg/day with 95% limits of agreement of -3105 and 3289 mg/day.²⁴

Freedman et al ¹⁵ reported on a pooled analysis from five validation studies: the Nutrition Biomarker Study for the Women's Health Initiative (two 24h diet recalls and

one 24h urine assessments)^{26 27}, the Observing Protein and Energy Nutrition (OPEN) Study (two 24h diet recalls and two 24h urines)²⁸, the AMPM Validation Study (three 24h diet recalls and two 24h urines)^{29 30}, the Energetics Study (eight 24hDRs and two 24h urines, although only three of the 24h diet recall results were analysed in the pooled analysis),³¹ and the Nutrition and Physical Activity Assessment Study of the Women's Health Initiative Observational Study (NPAAS) (three 24h diet recalls and one 24h urine).^{26 32} Twenty four hour recalls were all on non-consecutive days and all included multiple pass methods. In the pooled analysis, sodium intake assessed by 24h diet recall was on average 5% to 10% less than that measured in 24h urine collections (ranging from an overestimate of 2% among women in the Energetics Study which collected two 24h urines and eight 24h diet recalls, to an underestimate of 28% among women in the Nutrition Biomarker Study where participants provided a single 24h urine and two 24h diet recalls). Underreporting of intake relating to sodium intake was associated with higher body mass index(BMI). In the pooled analysis correlations of single 24h, two 24h diet recalls and three 24h diet recalls with 24h urine sodium estimates were 0.39, 0.41 and 0.42 for men, and 0.24, 0.28 and 0.39 for women respectively.

The authors also calculated attenuation factors for each study (Table 1), defined as “the multiplicative bias or shrinkage factor in the estimated regression coefficient when a health outcome is regressed on continuous self-reported intake rather than true dietary intake” and are usually between 0 and 1.^{15p477} Pooled average attenuation factors were around 0.20 for a single 24h, 0.25 for two 24h diet recalls and 0.30 for three recalls.¹⁵ Attenuation factors were also reported in Lassale et al (2015) and were 0.23 for women and 0.37 for men for three 24h diet recall and two 24h urine collections.³³

Table 1: Characteristics of included studies with 24 hour diet recall (summary table)

First author, year/ Name of Study	n (final analysis)	24 hour urine collection notes and whether validated for completeness?	Dietary assessment (24hour diet recall)	Discretionary salt accounted for?	24h urine and 24h diet recall concurrent?	Method of comparison
Campino C, (2016) ³⁴	135	Single collection, urinary creatinine concentration used to assess completeness	One 24h diet recall, involving a qualitative and quantitative component. Quantities in household measures. Data analysis was based on Chilean food composition tables.	Yes	Yes	Correlation 0.390 (p < 0.001)
Charlton K, (2005) ³⁵	325	Three collections, urine volume, urinary creatinine concentration and PABA used to assess completeness	Three 24h diet recall. Standard household measures, rulers and photographs were used to quantify food portion sizes. Nutrient intake was calculated using Foodfinder III computer program based on Medical Research Council Food Composition Tables.	No	Yes	Analysis of variance for differences ethnic groups
Cornejo K, (2014) ²³	70	Single collection	Three 24h diet recalls on nonconsecutive days. Chemical Composition Food Chilenos was used or nutritional food labelling to calculate dietary sodium. Intakes were adjusted for energy expenditure.	Yes	No	Bland-Altman plot showed negative slope, mean difference not reported; correlation: 0.46 (p< 0.01)
De Keyzer W, (2015) ³⁶ European Food Consumption Validation (EFCOVAL) study. (Belgium)	123	Two collections, PABA used to assess completeness	Two 24h diet recalls using EPIC-Soft protocols and software. Computer assisted assessment, face to face or by phone. Portion size estimated by household measures, weight, volume drawings and photographs. Country specific food composition tables were used to calculate sodium content in foods.	Yes	Yes	Ratio by country and sex. Geometric mean (95% CI) reporting accuracy: 0.67 (0.62,0.72). By sex, men: 0.80, women: 0.69.
De Keyzer W, (2015) ³⁶ European Food Consumption Validation (EFCOVAL) study. (Czech Republic)	118	Two collections, PABA used to assess completeness	Two 24h diet recalls using EPIC-Soft protocols and software. Computer assisted assessment, face to face or by phone. Portion size estimated by household measures, weight, volume drawings and photographs. Country specific food composition tables were used to calculate sodium content in foods.	Yes	Yes	Ratio by country and sex. Geometric mean (95% CI) reporting accuracy: 0.79 (0.74, 0.85). By sex, men: 0.84, women: 0.87.
De Keyzer W, (2015) ³⁶ European Food Consumption Validation (EFCOVAL) study. (Norway)	124	Two collections, PABA used to assess completeness	Two 24h diet recalls using EPIC-Soft protocols and software. Computer assisted assessment, face to face or by phone. Portion size estimated by household measures, weight, volume drawings and photographs. Country specific food	Yes	Yes	Ratio by country and sex. Geometric mean (95% CI) reporting accuracy: 0.73 (0.68, 0.79). By sex, men: 0.86, women: 0.73.

			composition tables were used to calculate sodium content in foods.			
Dennis B, (2003) ^{11 37 38} INTERMAP (Overall)	4680	Two collections, collection time, urine volume, self-report used to assess completeness	Four 24h diet recalls, two on consecutive days, followed by another two on consecutive days 2-6 weeks later. A multiple pass procedure was used recording all foods and beverages. Country specific aids were used to assist with quantification of portion size. Country specific food and nutrient composition databases were used for analysis of dietary intake.	Yes	Yes	Correlation: overall 0.415 (adjusted for sample and gender). All men 0.417, all women 0.409.
Espeland M, (2001) ³⁹⁻⁴¹ TONE Study	873	Six collections, collection time and urine volume used to assess completeness	Eight 24h diet recalls- standardized open-ended interviews using Minnesota Nutrition Data System software, which automatically prompts participants for descriptions and recipes including salt added during cooking and discretionary use of table salt.	Yes	No	Ratios of average intakes from 24h diet recall/ 24h urine ranged from 0.60 to 0.83
Ferreira-Sae M, (2009) ⁴²	132	Single collection	One 24h diet recall in face-face interview. Portion sizes reported in regionally typical utensil sizes e.g. cup, spoon etc. Nutrient intakes calculated using the Nutwin database software.	Yes	No	Correlation: 24h recall + discretionary salt: 0.18 (p = 0.06). All others not significant.
Freedman L, (2015) ^{15 26 32} Nutrition and Physical Activity Assessment Study of the WHI Observational Study (NPAAS) 2007-2009	450	Single collection. Total excretion divided by 0.86*	Three 24h diet recalls on non-consecutive days using Automated Multi pass method and the nutrient database Nutrition Data System for Research, University of Minnesota was used to analyze the results. Conducted by trained study staff via telephone	N/S	N/S	Bias, Attenuation Factors, Correlation Coefficients adjusted for within-person biomarker variation for pooled data.
Freedman L, (2015) Nutrition Biomarker Study for Women's Health Initiative 2004-2005 ^{15 26 27}	544	Single collection, self-report and PABA used to assess completeness. Total excretion divided by 0.86*	Two 24h diet recalls using Automated Multi pass method and software from University of Minnesota Nutrition Coordinating Center.	N/S	No	Bias, Attenuation Factors, Correlation Coefficients adjusted for within-person biomarker variation for pooled data.
Freedman L, (2015) ^{15 29} Participants in the Automated Multiple-Pass Method (AMPM) Validation Study. Healthy volunteers 2002-2004 Also presented in Rhodes et al 2013 ³⁰	465	Two collections, collection time, urine volume, self-report and urinary creatinine concentration used to assess completeness. Total excretion divided by 0.86*	Three 24h recalls in a 20% subset of participants- USDA Automated Multiple-Pass 5 step Method. Recalls were processed using USDA SURVEYNET software, and the USDA Food and Nutrient Database for Dietary Studies (FNDDS). The first recall was in person, and subsequent via telephone.	Yes	Yes	Bias, Attenuation Factors, Correlation Coefficients adjusted for within-person biomarker variation for pooled data. Reporting accuracy of sodium intake also reported in Rhodes et al (2013) as 0.93 (95%CI 0.89, 0.97) for men and 0.90 (0.87, 0.94) for women. Reporting accuracy was lower for overweight and obese participants compared to normal weight. Correlations were 0.32 (crude)

						and 0.46 (adjusted for within-person variation in biomarker) for men and 0.3 (crude) and 0.42 (adjusted) for women.
Freedman L, (2015) ^{15 31} Validation study data from Energetics Study- 2006-2009.	263	Two collections, PABA used to assess completeness	Eight 24h recalls: - web based self-administered- DietDay, Centrax Corporation Chicago IL which includes multipasses similar to that of USDA multipass method. Nutrient values are based on USDA values. Only the second, third and fourth recalls were analyzed.	N/S	N/S	Bias, Attenuation Factors, Correlation Coefficients adjusted for within-person biomarker variation for pooled data.
Freedman L, (2015) ^{15 28} Validation study data from OPEN Study- data collected 1999-2000	484	Two collections, PABA and self-report used to assess completeness	Two 24h recalls- a standardised five-pass method developed by USDA. Information was collected in person by trained interviewers. Data were analysed using a nutrient database the Food Intake Analysis System, version 3.99 based on the Continuing Survey of Food Intakes by Individuals.	N/S	No	Bias, Attenuation Factors, Correlation Coefficients adjusted for within-person biomarker variation for pooled data.
Kelly 2015) ^{24 43} Food Choice at Work Study	50	Single collection, PABA used to assess completeness	Two face-face 24-h dietary recalls. Method was modified to include specific prompts for discretionary salt consumption (at the table and while cooking). Food and nutrient analysis calculated using NetWISP4.	Yes	Yes	Bland-Altman: Mean difference = 87mg, 95% limits of agreement: -3105, 3180. R ² =0.32.
Lassale C, (2015) ³³ NutriNet-Sante Study	193	Two collections, collection time, urine volume, self-report and urinary creatinine concentration used to assess completeness	Three non-consecutive 24h recall. Self-administered web-based tool. Portion sizes estimated by photographs corresponding to more than 200 different food items. Foods could also be directly entered in grams or volume measure, household measure. Nutrient intakes were calculated using the ad-hoc NutriNet-Sante composition table.	N/S	Yes	Correlation after adjustment for energy intake, age, BMI and level of education. Men: 0.31 (95% CI 0.12,0.48), Women: 0.34 (95% CI 0.14,0.52). Correlation coefficient and attenuation factor by sex. Men: r=0.47 (0.23,0.71), attenuation factor = 0.37 (0.17,0.56). Women: r=0.37 (0.03,0.70), attenuation factor =0.23 (0.01,0.45).
Mercado C, (2015) ²¹	402	Single collection, urine volume, length of collection time, self-report and urinary creatinine concentration used to assess completeness	One Standardised interviewer administered 24h diet recall (from the Automated Multiple-Pass Method). 133 participants completed a second 24h recall. Sodium content of each food was calculated using the USDA's Food and Nutrient Database for Dietary Studies	Yes	Yes	Correlation Men 0.16, p<0.05 Women 0.25, p<0.01. Difference (diet-urine) Men = 936.8mg/d (787.1, 1086.5) Women: 108.3mg/d (11.1, 205.4)
Perin M, (2013) ⁴⁴	108	Single collection	One Interviewer administrated 24 h recall (7 items relating to a meal to quantify sodium naturally present in foods).	Yes	N/S	Means and medians stated only

Reinivuo H, (2006) ⁴⁵	879	Single collection, urinary creatinine concentration and urine volume used to assess completeness	Trained nutritionists conducted one 48 hour recall. Portion sizes were estimated using a picture booklet. The Finnish Food Composition Database was used to calculate nutrient intake. Recall was validated against 3-day food diary collected in 1992.	N/S	No	Correlation 0.30, $p < 0.0001$ (men = 0.25, women = 0.12)
Satoh M, (2014) ²²	203	Single collection, urinary creatinine concentration used to assess completeness	One 24h dietary recall. Beverages and food on the day of their 24h urine collection. Touch panel computer in which participants entered their dietary intake. Dietary intake calculated using the Standard Tables of Food Composition in Japan and Dietary Reference Intakes for Japanese	Yes	Yes	Correlation (adjusted) 0.72, $p < 0.0001$ (unadjusted) 0.66, $p < 0.0001$
Trijsburg L, (2015) ¹⁹ DuPLO study	198	Two collections, PABA used to assess completeness	Between 1-15 24h recalls administered in two ways: web-based, based on five step multiple-pass method. Portion sizes reported using household measures, standard portions, weight in grams. And telephone-based by trained dietitian using five-step multiple pass method. Looked at potassium and sodium.	No	N/S	24h recall (telephone based) under-estimated sodium by 28.7%; 24h recall (web-based) under-estimated sodium by 31.7% compared with 24h urinary sodium excretion.
Zhang J, (2000) ¹⁸	4122	Single collection, urinary creatinine concentration used to assess completeness	One 24h food record. Self-administered questionnaire, verified in interview by trained dietitians. Dietary intake was calculated by food composition table of Paul and Southgate.	No	No	Ratios (dietary/urinary) calculated from the individual values (mean (SD)): Men = 0.80 (0.64), $\beta = -0.024$, $t = -6.11$ Women = 0.71 (0.70), $\beta = -0.017$, $t = -5.04$

*Consumption estimated assuming 86% of ingested sodium excreted in the urine. PABA Para amino Benzoic Acid, SD Standard Deviation, CI Confidence Interval
N/S Not stated

Results- Diet records

Data regarding diet record studies are summarized in Table 2 and Appendix D. Ten studies reported on results of diet records (including food diaries and weighed diet records) including six validation studies and four cross-sectional studies (Appendix D). Of these two were conducted in Australia, two in Japan, two in China and one each in Brazil, Sweden and the UK (Appendix D). Sample sizes of those included in the analysis range from 36 to 2020 participants, with results from a total of 4145 participants across all ten studies (Table 2). Five of the studies included women only, and four studies included both men and women. One study did not specify the proportion of males and females in the study (Appendix D). Six studies reported including healthy participants and excluded participants with listed medical conditions, two studies included participants with hypertension, and two studies did not state whether participants were included or excluded on the basis of any medical conditions (Appendix D).

There was variability in the number of 24h urine collections per participant: seven studies included a single collection, one study included two collections and one included six collections. One study did not specify the number of 24h urine collections. Six studies collected 24h urine samples in the same time period as the food diary or weighed diet record was collected, one collected urine at a different time, and three did not specify whether the dietary assessment and urine collections were concurrent.

Eight studies described a method used to evaluate the completeness of 24h urine collections (Table 2). Of the studies that used a single method of assessing completeness, one study used PABA, one study used an assessment of urine creatinine excretion, one study used urine volume, and one study relied on self-reported completeness. Four studies used a combination of methods including urine volume, self-reported missing urine collections, PABA and creatinine excretion. The criteria used to interpret 24h urinary creatinine and PABA excretion, and therefore which urine

samples were likely to be incomplete, varied between studies. For PABA excretion, one study reported that collections with recovery below 85% were adjusted to 93% for determination of complete urine samples. Methods of assessment of incomplete samples using creatinine excretion included an assessment of within and between subject variability and exclusion of samples where creatinine (mmol/kg body weight) was outside a certain range (different for men and women). For urine volume, cut-off levels for determination of complete urine samples were: >500ml/24h and >1000ml/24h.

Two studies collected a one-day food diary, five studies collected three days and one study four days. In one study participants completed two four-day food records which were four weeks apart and one study did two seven-day food diaries that were 18 months apart (Table 2). For studies that collected dietary data on more than one day, four studies specified that the food diaries were completed on consecutive days. Four studies used weighed food diaries and four studies estimated portion sizes through a combination of photographs, weighing and household measures such as cups, spoons, bowls and utensils. Two studies did not specify the methods used to estimate sodium intake for the food diary (Table 2).

Various methods were used to compare the different measures including ratios, correlation co-efficient and difference between the means. Correlation coefficients of dietary with urinary measures were reported for six studies, and ranged from 0.11 in Liu et al (2014)⁴⁶ to 0.49 in Lassale et al (2009).⁴⁷ Two studies did not provide details for a method of comparison, one study reported ratios by three different diet groups (ratio diet record/ 24h urine: mixed diet ratio 0.93; shellfish diet ratio 0.85; vegetarian diet ratio 0.74)⁴⁸ and one study reported the correlation coefficient between dietary sodium intake and 24h urinary sodium excretion was not significant.⁴² Liu et al reported the mean dietary sodium was on average 800mg (14%) less than that estimated by 24h urinary excretion using a single 24h urine collection and a three day

food record.⁴⁶ None used Bland Altman analysis to compare food records with 24h urinary excretion.

Table 2: Characteristics of included studies Food diaries (summary table)

First author, year , name of study	n	24 hour urine collection	Dietary assessment (Diet record)	Discretionary salt accounted for?	24h urine and 24h diet recall concurrent?	Method of comparison
Charlton K, (2010) ⁴⁹	72	Single collection, urine volume used to assess completeness	Three day food diary , dietary data analysed by FoodWorks 2007 nutrient analysis software and AUSNUT1999 and Aus Brands database off FSANZ database.	Yes	Yes	N/S
Day N, (2001) ⁵⁰ EPIC-Norfolk cohort study	123	Six collections, PABA used to assess completeness	Two 7 day diet records 18 months apart. Photographs were provided to estimate portion size. Other measures e.g. weights and household units were also encouraged.	N/S	Yes	Correlation (0.36)
Ferreira-Sae M, (2009) ⁴²	121	Single collection, urine volume used to assess completeness	Three day self administered food diary. Measures including cups, glasses, spoons, were used to estimate portion size. Nutrient intakes calculated using the Nutwin database software.	Yes	Yes	Spearman correlation (not significant)
Itoh R, (1999) ⁵¹	763	Single collection, self-report and urinary completeness and urinary creatinine concentration used to assess completeness	One day diet record. Records were analysed using a nutrient database compiled from food composition table.	N/S	Yes	Pearson's correlation coefficients between dietary sodium and urinary sodium: Men 20-49y r=0.32, women 20-49y r=0.35. Men 50-79y r=0.34, women 50-79y r=0.27 . All correlations were reported as statistically significant.
Johansson G, (1998) ⁴⁸	74	Single collection, self-report, PABA and urinary creatinine concentration used to assess completeness	Four day weighed diet record using electronic scale for foods consumed in the home, foods consumed away from home had weight often estimated. All food records coded and analysed using the national food database at the National Food administration, Uppsala Sweden.	N/S	N/S	Ratios by three diet groups for diet/urine. Mixed diet ratio: 0.93, shellfish diet ratio:0.85, vegetarian diet ratio:0.74.
Kimira M, (2004) ⁵²	219	Single collection, self-report and urine volume used to assess completeness	One day weighed diet record. Participants were interviewed after the 24h period to check records. Data was analysed using Gotei Japanese food standard component table.	Yes	N/S	Correlation (0.27 p<0.01)
Lassale C, (2009) ⁴⁷	62	Two collections, urinary creatinine concentration used to assess completeness	Two 4 day weighed food records, four weeks apart. Each record was checked for accuracy with the participant. Results were analysed using Australian Foodworks Professional Edition software, based on the Australian nutrient database.	N/S	Yes	Pearson's correlation (0.49 p<0.01)

Lennon-Edwards S, (2014) ⁵³	36	Single collection, self-report used to assess completeness	Three day diet record , estimating portion size. Results were analysed using Nutrition Data System for Research, Minneapolis software.	N/S	Yes	N/S
Li J, (2014) ⁵⁴	2020	Single collection	Three day weighed food record. Researchers visited every household and weighed food in the house, including salt and salty foods. Food was weighed following the 3 day record. Participants recorded food consumed.	Yes	N/S	Correlation (0.13). Difference between means: 2.0g salt (14.3% underestimated), proportion of individuals that under (55.3%) and over (42.4%)-estimated sodium intake compared with urinary sodium.
Liu Z, (2014) ⁴⁶	655	Single collection, urine volume, self-report and urinary creatinine concentration used to assess completeness	Three day food record. Sodium consumption of 15 food groups was calculated. Sodium content of each food was adopted from the Chinese Composition Table and a local food sodium database.	Yes	No	Pearson correlation and partial correlation. Observed correlation coefficient: $r=0.11$, $p<0.01$. Mean dietary sodium was on average 800mg (14%) less than that estimated by 24h urinary excretion.

Discussion

This paper outlines the results of dietary sodium estimates from 24h diet recall (twenty studies) and diet records (food diaries and weighed food records) (ten studies) compared with 24h urinary excretion to predict an individual's sodium consumption. The variety of study methodologies precluded conclusive generalizations about the validity of using food records or dietary recall to predict an individual's dietary sodium. Hence, study findings that rely on an assessment of individual sodium consumption based on dietary assessment and health outcomes must be viewed carefully and sceptically. Only two studies used the recommended Bland-Altman method to validate 24h recall dietary measures against 24h urinary sodium. Cornejo et al compared results of a single 24h urine with average of three 24h diet recalls and reported that the Bland-Altman plot showed a negative slope indicating that the 24h diet recall underestimated intakes at higher levels of urinary excretion.²³ This may reflect general under-reporting of dietary intake at higher intakes, or social desirability bias due to reluctance to report 'unhealthy' (high sodium) foods and further the mean difference in sodium was not reported. Other studies in this review (such the Nutrition Biomarker Study, and AMPM validation study) found under-reporting of dietary intake is associated with higher body mass index and presumably higher usual energy intake,^{15 30} suggesting a systematic error in 24h dietary assessment methods. Kelly et al compared results from two 24h diet recalls with a single 24h urine collection and reported a mean difference of 87mg/day, however the 95% limits of agreement were very wide at -3105, 3180.²⁴ This is much wider than would be considered useful for studies examining relationships between sodium intake and disease outcomes in individuals, although the degree to which this is typical of 24h diet recalls is not known, due to limited use of Bland-Altman methods in this review.

While correlation is most commonly reported in this review, a correlation coefficient is a measure of the degree to which the estimates are linearly related⁵⁵ but is not necessarily a good measure of agreement, and will not give an indication of relative bias at different levels of intake²⁵ Bland Altman analysis is generally preferred as it

measures mean difference between estimates, limits of agreement (95% confidence interval of the mean difference) and relative bias at different levels of intake.²⁵ For 24hDRs there was a wide range correlation coefficients from 0.16²¹ to 0.72.²² Many of the reported correlation coefficients were above 0.4, which is the level previously suggested as being acceptable in validation studies.¹⁵ Furthermore, in the pooled analysis of five validation studies by Freedman et al, it was demonstrated that correlation coefficients were higher with three 24h diet recalls (0.42 for men and 0.39 for women) than only one 24h diet recall (0.39 for men and 0.24 for women).¹⁵ This is consistent with other research which shows that multiple days of recording are required to better estimate usual sodium intake in individuals.⁵⁶ The correlation coefficients reported in six of the ten studies reporting on diet records were generally lower than those of 24h diet recalls, ranging from 0.11⁴⁶ to 0.49,⁴⁷ with only one above the level of 0.4. Attenuation factors were calculated in several studies. Attenuation factors are a way of adjusting relative risk estimates to allow for the estimated measurement error inherent in dietary assessment in cohort studies. Usually this measurement error will result in the estimated effect is 'attenuated' or made closer to 1. The smaller the estimated attenuation factor, the greater the bias towards 1 of the relative risk estimate.^{13 57} In pooled analysis by Freedman et al the attenuation factors were higher than those calculated for FFQs in the same studies, indicating that estimates from 24h diet recalls are more suitable than FFQs for use in cohort studies investigating relationships between sodium intake and disease outcomes, because there is less attenuation of the relationship due to measurement error of sodium intake.¹⁵ Other methods of comparison included reporting a ratio of the means from two methods (dietary estimate/ urinary sodium excretion) to estimate reporting accuracy.^{18 30 36 39 48}

As with our first review evaluating FFQs,³ there was variability between studies as to number of days of dietary assessment, number of 24h urines collected, and interpretation of 24h urine results. Many of the 24h diet recall studies reported using multiple pass methods of assessment, a technique that has been developed to minimise

recall bias which involves an initial overview of foods consumed in the period, followed by more detailed questioning of each eating occasion. The USDA AMPM involves a five-step computerized recall method, which includes a 'forgotten foods' list including savoury snacks and breads which can be important contributors to sodium intake.²⁹ Validation studies of the AMPM show relatively high reporting accuracy compared with 24h urinary excretion (0.93 for men and 0.90 for women. Reporting accuracy was lower for overweight and obese participants compared to normal weight.³⁰ The authors conclude that the AMPM is a valid measure of estimating sodium intake among adults at a population (or group) level, based on these data. Correlations reported in the AMPM study were only moderate however at 0.32 (crude) and 0.46 (adjusted for within-person variation in biomarker) for men and 0.3 (crude) and 0.42 (adjusted) for women.³⁰ This suggests that 24h diet recall is not an accurate measure of intake at an individual level. The overall correlation in the Freedman pooled analysis which included results from the Energetics study, OPEN study, the Nutrition Biomarkers study and the NPAAS was 0.41,¹⁵ which is just over the 0.4 which has been suggested as the cut-off for acceptability in nutrition validation studies.¹⁵

The gold standard for assessing dietary sodium is the quantifying 24h urinary sodium. Although an accepted standard for assessing sodium intake, it is highly dependant on accurate and complete collection of 24 hours of urine.¹² Various methods can be used to assess and exclude incomplete 24h urine samples.⁵⁹ However, when there is a high level of incomplete 24h urines, the different methods of excluding incomplete urine samples can markedly alter estimations of sodium intake.⁵⁹ Using PABA to assess completeness of 24h urine samples has been recommended.¹² In this study, a wide variety of differing methods was found for excluding 24h urine samples based on PABA excretion. Also studies inappropriately corrected sodium intake based on PABA collections that were lower than 85%. PABA urinary excretion is high soon after ingestion and very low after 8 hrs and therefore is not suited to linear corrections. A standard to exclude incomplete urine collections based on PABA excretion is needed. We suggest excluding 24h urine collections with less than 80% PABA recovery or more

than 110% PABA recovery. Studies with less than 80% complete urine samples should not be used in assessing the validation of other methods of assessing sodium intake.

Given the range of study designs included in this review, it is difficult to make definitive conclusions about the validity of 24h diet recall or food diary with respect to measurement of dietary sodium in individuals. These include different numbers of dietary and urinary assessment, differences in specifics of 24h diet recall (eg use of multipass methods, modalities of data collection, inclusion of discretionary salt intake, and different food composition databases) and different statistical analyses. Comparing mean levels using methods such as reporting accuracy, ratio of means may be suitable for studies where a tool is to be used for assessment and monitoring of population level intakes, or for monitoring adherence in intervention studies such as clinical trials of dietary intervention. However where an accurate measure of an individual's usual sodium intake is required such as in epidemiological studies, correlation and Bland Altman methods are required.

Limited use of more appropriate statistical methods of assessing agreement such as Bland-Altman methods limits our ability to assess the suitability of these dietary methods as alternatives to 24h urine. It is perhaps surprising that weighed food records did not perform better as they are often considered the most accurate dietary assessment method.⁹ Prospectively collected food records, however, are subject to bias if the individual changes dietary intake during the observation period. The inclusion of prompts, and forgotten foods lists in the multiple pass 24h diet recall methods may also in some way account for the apparent superiority of 24h diet recall methods. Nine of the studies specifically report the use of multiple pass methods,^{15 19 21 24 37} however due to the range of comparison statistics reported it is difficult to assess whether multiple pass methods are more valid overall. A more standardized method of validation would enable better comparison between specific 24h recall tools. We have made a series of recommendations (Table 3) based on the findings of this review, and our previous review.³ We suggest that at least 2 days assessment using dietary and urinary methods are required for validation studies in this context. These should be concurrent, and

dietary assessment methods should include a measure of discretionary intake of salt and salty condiments and sauces, especially in countries where these make up a substantial proportion of overall sodium intake. Multiple pass methods are likely to improve accuracy of 24h diet recalls, and local regularly updated food composition databases should be used to analyse nutrient data.

Table 3: Recommendations for validation studies of 24h diet recall or diet records measuring individual's usual sodium intake

<p>Twenty-four hour diet recall:</p> <p>Multiple preferably non-consecutive days of dietary assessment per participant should be included⁵⁶</p> <p>Recall methods should include an estimate of discretionary salt used (in cooking or at the table), as well as high salt condiments and sauces where appropriate.</p> <p>Multiple pass methods should be considered</p> <p>Diet records (weighed diet record or food diary)</p> <p>Multiple preferably non-consecutive days of dietary assessment per participant should be included</p> <p>Records should include an estimate of discretionary salt used (in cooking or at the table), as well as high salt condiments and sauces where appropriate.</p> <p>Reference method: 24h urine</p> <p>24h urinary sodium excretion is the recommended reference method</p> <p>Multiple preferably non-consecutive 24h urine collections per participant should be collected</p> <p>Urine collections should be undertaken over the same period of assessment as the dietary assessment</p> <p>Twenty four-hour urine collections should be assessed for completeness using a suitable method (such as PABA excretion)</p> <p>Statistical analysis</p> <p>Multiple methods should be used, depending on the purpose of research⁵⁸</p> <p>Bland Altman methods should be used to assess agreement and relative bias between sodium estimates from 24h diet recall/ diet records and urinary excretion.</p> <p>Additional useful statistical methods include correlation, regression, and Kappa if data is to be presented as categorical or binary.</p> <p>Sample size should be carefully considered- at least 50-100 participants for each population group has been suggested for nutritional validation studies.⁵⁸</p> <p>Reporting:</p> <p>Details of results of validation studies should be reported in utilisation studies (including mean difference and limits of agreement), rather than describing the dietary assessment as a 'validated'.</p>

We also note the validity of any dietary assessment method will depend on access to accurate food composition data, and meticulous data collection. Twenty four hour diet

recall methods are more generic, and transferable across populations, unlike FFQs which require knowledge of which foods are likely to contribute substantially to sodium intake (such as sauces and condiments) , which are population specific. All dietary assessment methods have difficulty estimating discretionary salt intake and this is likely to be a limitation of these methods, especially in individuals and populations where discretionary salt is a major contributor to overall intake.

Recommendations:

- 24h diet recall and food records are not recommended to be used to assess sodium intake in research studies that examine associations between an individual's sodium intake and health related outcomes unless there has been a high quality validation study.
- Validation studies should use a variety of methods, including Bland Altman, calculation of bias at different levels of intake. Attenuation factors that enable interpretation of how systematic measurement error may cause bias may also be used. Studies should not rely on sole correlation coefficients.
- All methods require use of comprehensive, up to date and accurate food composition databases. Validation studies only apply to research in populations where the food composition database is directly applicable.
- 24h urine collection (at least two, and up to seven), should continue to be reference method for validation studies. Twenty four-hour urine collections should be assessed for completeness using a suitable method (such as PABA).
- Multiple days of dietary assessment (at least two, and up to seven) should be used for validation studies.

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contract (2016) to develop a survey and was a paid member of an advisory board for Midmark in 2017. The other authors have no conflicts of interest to disclose

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