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Development and validation of a short questionnaire to assess sodium intake

Karen E Charlton[1,*,†], Krisela Steyn[1], Naomi S Levitt[1,2], Deborah Jonathan[1], Jabulisiwe V Zulu[3] and Johanna H Nel[4]

[1]Chronic Diseases of Lifestyle Unit, Medical Research Council, Tygerberg, South Africa: [2]Division of Diabetes and Endocrinology, University of Cape Town, Observatory, South Africa: [3]School of Public Health, University of the Western Cape, Belville, South Africa: [4]Department of Logistics, University of Stellenbosch, Stellenbosch, South Africa

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Abstract

Objectives: To develop and validate a short food-frequency questionnaire to assess habitual dietary salt intake in South Africans and to allow classification of individuals according to intakes above or below the maximum recommended intake of 6 g salt day^{-1}.

Design Cross-sectional validation study in 324 conveniently sampled men and women.

Methods: Repeated 24-hour urinary Na values and 24-hour dietary recalls were obtained on three occasions. Food items consumed by >5% of the sample and which contributed ≥50 mg Na serving^{-1} were included in the questionnaire in 42 categories. A scoring system was devised, based on Na content of one index food per category and frequency of consumption.

Results: Positive correlations were found between Na content of 35 of the 42 food categories in the questionnaire and total Na intake, calculated from 24-hour recall data. Total Na content of the questionnaire was associated with Na estimations from 24-hour recall data ($r = 0.750$; $P < 0.0001$; $n = 328$) and urinary Na ($r = 0.152$; $P = 0.0105$; $n = 284$). Urinary Na was higher for subjects in tertile 3 than tertile 1 of questionnaire Na content ($P < 0.05$). Questionnaire Na content of <2400 and ≥2400 mg day^{-1} equated to a reference cut-off score of 48 and corresponded to mean (standard deviation) urinary Na values of 145 (68) and 176 (99) mmol day^{-1}, respectively ($P < 0.05$). Sensitivity and specificity against urinary Na ≥100 and <100 mmol day^{-1} was 12.4% and 93.9%, respectively.

Conclusion: A 42-item food-frequency questionnaire has been shown to have content-, construct- and criterion-related validity, as well as internal consistency, with regard to categorising individuals according to their habitual salt intake; however, the devised scoring system needs to show improved sensitivity.

Keywords
Salt
Sodium
Questionnaire
Validity

Epidemiological studies demonstrate that the prevalence of hypertension and its associated cardiovascular consequences are directly related to the level of dietary salt intake in societies throughout the world in whom the daily intake is above 50–100 mmol[1]. A meta-analysis has estimated the contributions of behavioural factors to the prevalence of hypertension in Finland, Italy, The Netherlands, the UK and the USA[2]. After being overweight, high Na intake is the second largest contributor to hypertension, with population-attributable risk of between 9 and 17%.

In order for advice to reduce salt intake to be targeted to those with excessive intakes, reliable estimations of habitual intake are required. Accurate assessments of salt intake are also necessary in epidemiological surveys and clinical trials in which diet–blood pressure associations are being investigated. The INTERSALT study demonstrated that, in order to assess diet–blood pressure relationships, high-quality dietary information is required together with controlling for multiple confounding variables, modern multivariate methods of data analyses, and correction of observed associations for within-person variation in intake[3].

Measurement of dietary Na, either on a population or an individual level, is fraught with methodological difficulties. High intra-subject (45%) and inter-subject (45–56%) variability for reporting of non-discretionary sources (i.e. salt intake which excludes table salt and salt added in cooking) has implications for the reliability of food record estimates[4]. It has been estimated that 81 days of dietary recording would be required to estimate an

†Correspondence address: Smart Foods Centre, Faculty of Health and Behavioural Sciences, University of Wollongong, Wollongong, Australia.

*Corresponding author: Email karenc@uow.edu.au

individual's intake within 10% of the observed mean. For this reason, the gold standard for assessment of salt intake is considered to be repeated 24-hour urinary Na estimations. However, this method is not useful for large community-based studies since it is time-consuming and inconvenient to the individual performing the collections, and under-collections of urine are commonplace. In addition, urinary Na estimations will not identify specific dietary sources of salt. A simple method to estimate population mean levels of 24-hour urinary Na excretion from spot urine specimens collected at any time has been developed by Japanese investigators[5]. This method may be useful for comparing dietary Na intakes between different populations, as well as indicating annual trends of a particular population, but is not appropriate to estimate individual intakes.

There have been various attempts at developing short questionnaires for classifying persons according to their use of salt[6–8]. Other authors have shown that self-reported abstinence from use of table salt is strongly correlated with actual behaviour[9], but this is only useful in identifying practices relating to discretionary salt use. The unique dietary features of a population group limit the applicability of an instrument developed in another ethnic group, in which food availability and food preferences may differ substantially. In developing countries, reliance on processed foods may be relatively less than in more developed countries, a factor which would further affect total salt intake estimations.

This aim of the present study was to develop and validate a short, food frequency-type questionnaire to assess habitual dietary salt intake in South Africans and to enable classification of individuals into desirable and excessive categories of intake.

Methods

Approval for the study was granted by the Research and Ethics Committee of the University of Cape Town, and written informed consent was obtained from all participating subjects. A systematic seven-step approach was undertaken, as described below.

Step 1: Identification of food categories to be included in the salt intake questionnaire

Reported dietary intake of a multi-ethnic (black, mixed ancestry and white) South African sample was used as the basis for identification of food categories to be included in the questionnaire. Volunteers (men and women aged 20–65 years) were recruited from their workplace at the Cape Town City Council offices using stratified convenience sampling. A sample size of $n = 100$ per ethnic group was determined assuming using a mean Na excretion of 126.8 (standard deviation (SD) 55) mmol day^{-1} (reference 10), a desired standard error of 5.47 mmol day^{-1} and 95% precision ($n = sd^2/e^2$, where sd^2 = between-subject variance and e = desired standard error)[11]. We aimed to recruit equal numbers of hypertensive (blood pressure ≥140/90 mmHg and/or on antihypertensive medication) and normotensive (blood pressure <140/90 mmHg) men and women aged 20–65 years (50 from each ethnic group). Three repeated 24-hour dietary recalls, conducted one week apart, were administered on different days of the week, including one weekend day, in each subject's choice of language (English, Xhosa, Afrikaans) by two nurses trained in dietary methodology through role play. Standard household measuring utensils, rulers and validated food photographs of typical South African foods[12] were used to quantify food portion sizes.

All individual food items consumed by >5% of the sample and which contributed at least 50 mg Na per serving of that item (i.e. average portion of consumers) were included in the draft questionnaire. Food items were combined into 42 categories that included both food sources with inherent Na, such as milk, as well as food items with a high added salt content, such as processed meat. The remaining items which fitted the inclusion criteria were combined into an 'other' category.

Step 2: Determination of portion sizes of foods included in food categories

The most representative food item in each of the 42 food categories was selected as a reference food and the average portion size thereof estimated using the repeated 24-hour recall data. To further validate estimated portion sizes, secondary analyses of four dietary surveys undertaken in adult South Africans using the 24-hour recall method[13,14] were used. These surveys included two studies of rural black subjects (Lebowa, 1998; $n = 292$; age 10–25 years[15,16] and Dikgale, 1992; $n = 209$; 19+ years[17,18]), a study of urban black Cape Town residents (BRISK (Black Risk Factor Study), 1990; $n = 1243$; 10–89 years)[19,20] and a study of white subjects in the Western Cape (CORIS (Coronary Risk Factor Study), 1989; $n = 1784$; 15–99 years)[21–23]. Each reference food portion size was compared with the average obtained for that food from the combined secondary dataset, and was adjusted to the nearest standard portion size included in the FoodFinder dietary assessment program, based on the *MRC Food Quantities Manual*[24].

Step 3: Calculation of daily Na intake from questionnaire

Due to the fact that some food items which are relatively low in Na may be consumed frequently (i.e. more than once a day) and thus contribute significantly to overall Na intake, a possible range of six frequency responses was included in the questionnaire: never; 1–3 times per week; 4–6 times per week; once a day; twice a day; and 3+ times a day. In order to assign one of these frequency factors to each of the 42 food categories per subject, the average number of times ('times') per day that each food was consumed was calculated from the three 24 hour-recall periods (times = (times1 + times2 + times3)/3). This average daily frequency was converted to a weekly frequency. For example, if 'times' was >0 and <0.5, it was coded as 1–3 times per week (3.5/7 days = 0.5); if 'times' was ≥0.5 (3.5/7 days) and <0.9286 (6.5/7 days), then it was coded as 4–6 times per week, and so on. The numerator figure in the weekly calculation was taken as the value midway between the upper frequency value of one category and the lower of the next (i.e. 3.5 is midway between 3 and 4).

Absolute amounts of Na per serving size used for a single representative food in each of the 42 categories were calculated from *MRC Food Composition Tables*[25]. This amount (in mg) was multiplied by the frequency factor that each individual reported to arrive at a total daily Na intake for each subject.

Step 4: Reliability of the questionnaire

Alternative-form reliability (i.e. obtained by applying two 'equivalent' forms of the measuring instrument to the same subjects)[26]: subjects collected three 24-hour urinary volumes over a consecutive 3-week period, to correspond with dietary reporting periods. As a marker of completeness of collection, subjects were instructed to take 3 tablets (450 mg day^{-1}) of non-metabolisable *p*-aminobenzoic acid (PABA; Laboratories for Applied Biology) with meals during the collection period[27]. Urine collections were excluded if volume ≤500 ml day^{-1} ($n = 9$), or if either (1) urinary creatinine <0.2 mmol kg^{-1} day^{-1} and PABA ≤97% or (2) urinary creatinine = 0.2–0.3 mmol kg^{-1} day^{-1} and PABA ≤75% ($n = 24$)[28]. Urinary electrolyte concentration was measured using flame photometry and PABA measured calorimetrically. To investigate construct validity with regard to the grouping of food items in the 42 food categories and the portion sizes used for the reference food items in each category, Spearman correlation coefficients were calculated between Na intake of individual food categories ($n = 42$) in the questionnaire, reported Na intake from repeated 24-hour recalls ($n = 43$ food groupings, including the 'other; category), and 24-hour urinary Na.

Internal consistency/internal-comparison reliability (i.e. inter-correlation among the scores of the items on a multiple-item index)[26]: the Cronbach alpha test (coefficient α) was conducted for Na content of the various categories included in the questionnaire.

Step 5: Ensuring criterion validity of the questionnaire

Criterion-related validity can take two forms, based on the time period involved: either concurrent validity (present) or predictive validity (future). To demonstrate concurrent validity (i.e. the extent to which one measure of a variable can be used to estimate an individual's current score on a different measure of the same or a closely related variable)[26], habitual urinary Na excretion was compared across tertiles of dietary Na intake, estimated using the questionnaire. Stanines (i.e. nine categories) of Na intake were also calculated and mean daily urinary Na was compared across various combinations of stanines.

Step 6: Determination of a scoring system

The questionnaire uses actual Na content value for each reference food item (according to its corresponding average serving size) in the 42 food categories, multiplied by the frequency factor. The complexity of this scoring system would probably limit its widespread use by clinicians and academics; therefore a simpler scoring system, based on rounded integers for each food category, was devised.

Step 7: Inter-rater reliability of the questionnaire

A reference cut-off value that equated to greater or less than 6 g salt day^{-1} was assigned to the questionnaire score. Using the cut-off scores for the questionnaire, and comparing these categories with 24-hour urinary Na values of either ≤100 or >100 mmol day^{-1}, the κ statistic was calculated. Sensitivity and specificity of the questionnaire was determined, as well as positive and negative predictive values.

Results

Determination of food items/food groupings to be included in the questionnaire

All recruited volunteers ($n = 180$ hypertensives; $n = 145$ normotensives) completed the dietary recalls. Compliance with the study protocol was improved by having two fieldworkers working within the in-house clinic facility of the office building where all data collection took place. The sample included 110 black, 112 mixed ancestry and 103 white subjects; 159 men and 166 women with a mean age of 39.7 (SD 10.5) years. The various food items included in each of the 42 categories and the reference food item for each category, together with the accompanying serving size and Na content, are shown in Table 1. Throughout the results, Na content of questionnaire = sum of absolute Na intake per day for reported frequency of intake of food items from each of the 42 food categories. To simplify the Na scoring system, absolute amounts of Na per serving for each food category were divided by 50 and rounded to the nearest integer (all foods included in questionnaire contained at least 50 mg Na serving^{-1} – dividing the score by 50 provides a score in number of 50 mg units).

Reliability of the questionnaire

Alternative-form reliability

Table 2 shows Spearman correlation coefficients between Na intake of food categories in the questionnaire (using

Table 1 Food categories, index food items, serving size and Na content of each category included in the questionnarie

Food category	Index food	Serving size	Serving (g)	Na content/100 g	Na content/serving	Na score
Bread and grain products						
1. White bread or rolls/croissants/pita bread/bread crumbs	White bread	3 slices	75	490	367.5	7
2. Brown and wholewheat bread or rolls/health bread	Brown bread	3 slices	90	451	405.9	8
3. Breakfast cereal (processed): cornflakes/rice crispies/all bran/hi-bulk fibre bran/Pro Nutro/frosties/puffed corn/Special K	Cornflakes	1 large bowl	40	1211	484.4	10
4. Breakfast cereal (minimally processed): weetbix, muesli, puffed wheat	Weetbix	2 weetbix	50	165	82.5	2
5. ProVita/crackers/rye bread and crispbread/matzos	ProVita	5×6 g crackers	30	710	213	4
6. Cookies, biscuits, rusks	Commercial plain	3×10 g biscuits	30	410	123	2
7. Cake/scone/muffin/puddings (baked and instant)/pancake/tarts/ sweet breads and buns/semolina/*koeksister*	Muffin, plain	1 unit	70	130	91	2
8. Roti/samosa/spring roll/doughnut/savoury tart/dumplings	Doughnut, plain	long, 130 mm	90	230	207	4
9. Pizza	Pizza	1/2 unit	170	570	969	19
10. Pasta/noodle dishes with cheese sauce (lasagne/macaroni cheese/noodle salad/spaghetti bolognaise)	Macaroni and cheese, white sauce type	2 ladles	150	168	252	5
11. Popcorn	Popcorn, plain, salted	2 cups	40	1940	776	16
12. Potato crisps/Niknaks/Chipkins	Potato crisps	Small packet	30	1000	300	6
Meat and meat products						
13. Beef sausage – *boerewors*	*Boerewors*	Average thick piece	100	805	805	16
14. Processed, smoked, cooked and canned meat (polony/salami/ham/canned corned meat/vienna/bacon/frankfurter/ luncheon meat)	Polony	Homecut slice	60	1019	611.4	12
15. Meat or chicken pies, sausage rolls	Steak and kidney pie	Commercial pie	140	460	644	13
16. Chicken burger/chicken patties/fried battered chicken (KFC, etc.)	Kentucky fried chicken	Thigh	100	292	292	6
17. Meat and meat dishes (minced beef, cottage pie, meatballs, stew, chicken stew)	Meatballs	Ladle	105	97	101.9	2
18. Gravy, made with stock or gravy powder	Brown gravy powder, reconstituted	Level ladle	35	4893	1712.6	34
19. *Biltong* (beef, game, fish), dry beef sausage	*Biltong*	Short piece	60	2213	1327.8	27
Dairy products/eggs						
20. Milk (all types, dairy fruit juice, malted milk, milk shakes, drinking chocolate, evaporated and condensed milk)	Full-cream milk	1/2 cup	120	48	57.6	1
21. *Maas*/sour milk/buttermilk	*Maas*	Small carton	500	71	355	7
22. Cheese, including processed cheese, feta, cottage	Cheddar cheese	1/2 cup	40	487	194.8	4
23. Yoghurt	Low-fat sweetened	Small carton	175	74	129.5	3
24. Eggs (any preparation – boiled, fried, scrambled, omelette)	Egg fried in sunflower oil	1 egg	50	120	60	1
Fish						
25. Tinned fish (pilchards, tuna, salmon, mackerel)	Tuna canned in water	1/2 cup	100	338	338	7
26. Other fish and seafood (shrimp, abalone, calamari, oyster, mussel, crab, fish cake, battered fish, fish fingers, fish paste)	Fish, medium fat, fried in sunflower oil	Medium piece	120	94	112.8	2
Vegetables/pulses						
27. French fries and potato salad	French fries	1.5 household serving	120	198	237.6	5
28. Baked beans, canned vegetables, tomato paste, olives (canned)	Beaked beans in tomato sauce	Heaped ladle	100	397	397	8
29. Soup (all types)	Average soup	Large mug	250	431	1077.5	22
Vegetable oils						
30. Salad dressing/mayonnaise	Mayonnaise	Level dessert-spoon	15	755	113.3	2
31. Ice cream (sorbet or dairy)	Soft Serve^{TM} (13% fat)	Large serving	150	61	91.5	2
32. Margarines, all types, butter, Butro	Brick margarine	Heaped teaspoon	10	805	80.5	2

Table 1 Food categories, index food items, serving size and Na content of each category included in the questionnarie

Food category	Index food	Serving size	Serving (g)	Na content/100 g	Na content/serving	Na score
Condiments, spreads and other						
33. Chutney/*atchar*/*chakalaka*/Worcester sauce	Fruit chutney	Heaped tablespoon	30	811	243.3	5
34. Savoury sauces (mushroom, pepper, cheese, white)	Mushroom sauce	2 level tablespoons	40	575	230	5
35. Tomato sauce	Tomato sauce	Level tablespoon	20	582	116.4	2
36. Salt	Iodised salt	Pinch	1	38 850	388.5	8
37. Aromat/seasoning/mustard	Aromat	1 serving	1	24 030	240.3	5
38. Peanuts (salted, unsalted, raw)	Salted peanuts	Handful	30	433	129.9	3
39. Peanut butter	Peanut butter	Heaped teaspoon	12	478	57.4	1
40. Marmite/Bovril/Fray Bentos spread	Marmite	5 ml teaspoon	5	4500	225	5
41. Chocolate sweets/chocolate sauce	Chocolate bars	Average bar	40	165	66	1
42. Beer/cider	Commercial beer	2 cans	680	10	68	1

the determined serving size of the single reference food item per category as shown in Table 1) and reported Na intake per category from repeated 24-hour recalls, as well as mean daily urinary Na excretion. The very high correlation coefficients indicate a similar behaviour between the questionnaire and actual 24-hour recalls. Only eight food categories were significantly associated with urinary Na (cookies; popcorn; processed meats; meat and meat dishes; fish (not tinned fish); canned vegetables; Aromat; and peanuts). Similar associations were found between Na intake of food categories from 24-hour recall data and urinary Na, with the exception of no association with meat/meat dishes group (data not shown).

Also shown in Table 2 are correlations between Na content of each of the questionnaire food categories (using actual reported serving sizes of food items within each of the categories) and total Na intake of the 24-hour recall data (including all foods consumed, including 'other' category). Positive and significant correlations were found for all food groups except the following: minimally processed breakfast cereal; crackers; roti/samosa/spring roll/doughnut; pizza; fried battered chicken/chicken patties; gravy; *maas*;* yoghurt; tinned fish; canned vegetables/baked beans; chutney; savoury sauces; and Marmite/Bovril.

Internal consistency/internal comparison reliability

Spearman correlation coefficient between Na content of the total questionnaire ($n = 42$ categories) and the repeated 24-hour Na data was $r = 0.683$ ($P < 0.0001$) ($n = 328$). For urinary Na, the association with total questionnaire Na was $r = 0.173$ ($P = 0.0034$) ($n = 284$). The 24-hour recall data, which included the remaining reported food items in a very large 'other' food group, did not perform better against the urinary Na data ($r = 0.141$; $P = 0.0174$; $n = 284$). Spearman correlation coefficient between questionnaire score and repeated 24-hour recall Na data was $r = 0.684$ ($P < 0.0001$) and vs. urinary Na was $r = 0.171$ ($P = 0.0039$).

The overall standardised Cronbach's α between total questionnaire Na content and that calculated from the mean of three repeated 24-hour recalls was less than acceptable (i.e. <0.6) at 0.443. Cronbach's α for each of the individual food categories are shown in Table 3. Nine food categories had undesirable values of Cronbach's α that exceeded the overall coefficient of 0.443. Four of these nine categories were also not significantly correlated with total Na content of 3×24-hour recalls (Table 2): fried battered chicken/chicken patties; gravy; *maas*; and Marmite/Bovril.

No difference was found between questionnaire Na content and that reported using 24-hour recall data using non-parametric measures (sign test: $P = 0.2040$; sign-rank test: $P = 0.7425$).

* Fermented milk product, commonly consumed with maize meal porridge.

Table 2 Spearman correlation coefficients between Na intake of individual food categories in questionnaire, reported Na intake from repeated 24-hour recalls and 24-hour urinary Na excretion

Individual food category	Questionnaire vs. 24-hour recalls (per food category)	Questionnaire† vs. 24-hour recalls (total Na)	Questionnaire vs. urinary Na
1. White bread/rolls	0.915***	0.341***	0.011
2. Brown bread/rolls	0.966***	0.142*	0.020
3. Breakfast cereal (processed)	0.983***	0.295***	0.069
4. Breakfast cereal (minimally processed)	0.989***	−0.038	0.036
5. Crackers (ProVita, etc.)	0.997***	0.082	0.037
6. Cookies, biscuits, rusks	0.988***	0.160**	0.132*
7. Cake/scone/muffin/puddings/pancake/fruit pie/ *koeksister*	0.977***	0.151*	0.014
8. Roti/samosa/spring roll/doughnut	0.992***	0.057	−0.071
9. Pizza	0.999***	0.092	0.080
10. Pasta/noodle dishes with cheese sauces (macaroni cheese, lasagne, noodle salad, etc.)	0.999***	0.113*	0.110
11. Popcorn	0.999***	0.119*	0.128*
12. Crisps (Simba, Niknaks, etc.)	0.992***	0.179**	−0.079
13. Beef sausage (*boerewors*)	0.995***	0.253***	−0.005
14. Polony/salami/bacon/salami/pork sausages (processed meat, cooked, smoked and canned)	0.955***	0.411***	0.122*
15. Meat or chicken pies/sausage rolls	0.995***	0.242***	−0.010
16. Chicken – battered (KFC, etc.) and chicken burger only	0.999***	0.074	0.036
17. Meat and meat dishes (steaks, minced meat, cottage pie, mince, meatballs, stew, etc.)	0.760***	0.123*	0.121*
18. Gravy, made with stock or gravy powder	0.999***	0.023	0.088
19. *Biltong* (beef, game, fish), dry beef sausage	0.999***	0.130*	0.112
20. Milk (all types, also dairy fruit juice, malted milk, milk shakes)	0.781***	0.226***	−0.011
21. *Maas*	0.999***	−0.030	0.022
22. Cheese	0.953***	0.255***	0.077
23. Yoghurt	0.997***	0.035	0.043
24. Eggs	0.981***	0.203**	0.003
25. Tinned fish (pilchards, tuna, etc.)	0.994***	0.101	0.071
26. Other fish and seafood	0.983***	0.169**	0.118*
27. Potato chips/French fries and potato salad	0.977***	0.123*	−0.036
28. Canned vegetables, incl. baked beans, tomato paste, sweet corn, etc.	0.993***	0.063	0.120*
29. Soup (all types)	0.996***	0.130*	−0.040
30. Salad dressing/mayonnaise	0.986***	0.233***	0.056
31. Ice cream (all types)	0.998***	0.184**	0.083
32. Margarines, all types, also butter and Butro	0.897***	0.468***	−0.019
33. Chutney/*atchar*/*chakalaka*/Worcester sauce	0.999***	0.086	0.020
34. Savoury sauces (mushroom, monkey gland, white, cheese)	0.998***	0.059	0.035
35. Tomato sauce	0.999***	0.106*	0.045
36. Salt (not included in 24-hour data)	–	–	–
37. Aromat/Fondor/mustard	0.999***	0.180**	−0.124*
38. Peanuts	0.999***	0.174**	0.128*
39. Peanut butter	0.995***	0.152**	0.008
40. Marmite/Bovril	0.999***	0.081	0.067
41. Chocolate sweets and sauce	0.994***	0.199**	0.030
42. Beer and cider	0.999***	0.109*	0.095
43. All other foods (not included in final questionnaire)	–	0.272***	–

* $P<0.05$; ** $P<0.005$; *** $P<0.0001$.

† Average Na content per individual food category of questionnaire (using actual reported serving sizes of food items within the groupings, not the single assigned serving size of one reference food per category, as in final questionnaire) vs. average total Na content of 3 × 24-hour recalls ($n = 43$ categories; all items consumed).

Na intake, estimated from both the questionnaire (1221 (SD 641), 1853 (SD 589) and 1873 (SD 663) mg day^{-1}) and the repeated 24-hour recalls (1459 (SD 890), 1761 (SD 884) and 1922 (SD 911) mg day^{-1}) differed significantly ($P<0.0001$) between black, mixed ancestry and white ethnic groups, respectively. Questionnaire Na score also differed between black, mixed ancestry and white subjects (24.2 (SD 12.8), 36.6 (SD 11.6), and 37.2 (13.3), respectively; $P<0.0001$).

Criterion validity of the questionnaire

Both Na intake from 24-hour recall data and urinary Na were assessed according to tertiles of the Na content of the questionnaire (Table 4). Urinary Na was significantly higher for subjects in tertile 3, compared with those in tertile 1 (Bonferroni test: $P = 0.0312$; Kruskal–Wallis test: $P = 0.0635$). However, dietary Na intake (24-hour recall data) differed significantly across all three tertiles (Bonferroni test: $P<0.05$; Kruskal–Wallis test: $P<0.0001$).

Table 3 Internal consistency of questionnaire: Cronbach's α coefficient (standardised α) between Na content of questinnaire food categories and repeated 24-hour dietary recall values

Individual food category	Cronbach's α between questionnaire food categories and 24-hour recalls†
1. White bread/rolls	0.439
2. Brown bread/rolls	0.452*
3. Breakfast cereal (processed)	0.448*
4. Breakfast cereal (minimally processed)	0.432
5. Crackers (ProVita, etc.)	0.441
6. Cookies, biscuits, rusks	0.444*
7. Cake/scone/muffin/puddings/pancake/fruit pie/*koeksister*	0.433
8. Roti/samosa/spring roll/doughnut	0.424
9. Pizza	0.440
10. Pasta/noodle dishes with cheese sauces (macaroni cheese, lasagne, noodle salad, etc.)	0.421
11. Popcorn	0.435
12. Crisps (Simba, Niknaks, etc.)	0.440
13. Beef sausage (*boerewors*)	0.441
14. Polony/salami/bacon/salami/pork sausages (processed meat, cooked, smoked and canned)	0.434
15. Meat or chicken pies/sausage rolls	0.445*
16. Chicken – battered (KFC, etc.) and chicken burger only	0.449*
17. Meat and meat dishes (steaks, minced meat, cottage pie, mince, meatballs, stew, etc.)	0.437
18. Gravy, made with stock or gravy powder	0.445*
19. *Biltong* (beef, game, fish), dry beef sausage	0.439
20. Milk (all types)	0.424
21. *Maas*	0.474*
22. Cheese	0.427
23. Yoghurt	0.440
24. Eggs	0.440
25. Tinned fish (pilchards, tuna, etc.)	0.442
26. Other fish and seafood	0.418
27. Potato chips/French fries and potato salad	0.431
28. Canned vegetables	0.442
29. Soup (all types)	0.458*
30. Salad dressing/mayonnaise	0.437
31. Ice cream (all types)	0.437
32. Margarines, all types, also butter and Butro	0.419
33. Chutney/*atchar*/*chakalaka*/Worcester sauce	0.443
34. Savoury sauces (mushroom, white, cheese)	0.431
35. Tomato sauce	0.425
36. Salt (not included in 24-hour data)	–
37. Aromat/Fondor/mustard	0.429
38. Peanuts	0.439
39. Peanut butter	0.442
40. Marmite/Bovril	0.446*
41. Chocolate sweets and sauce	0.432
42. Beer and cider	0.443
43. Other foods (not included in final questionnaire)	0.404

* Cronbach's α with deleted variable larger than Cronbach's α of all variables (i.e. >0.443), using standardised variables (i.e. undesirable coefficients).
† Excluding Na content of that food category.

Mean daily urinary Na was compared across a combination of stanines of questionnaire Na content: 1, 2 and 3 together (Group 1); 4, 5 and 6 together (Group 2); and 7, 8 and 9 together (Group 3). Urinary Na differed significantly between Groups 1 and 3 (mean difference = 35.6 mmol day^{-1}; 95% confidence interval (CI) = 4.4 to 66.7 mmol day^{-1}), using General Linear Modelling (Bonferroni test: $P = 0.0203$; Wilcoxon test: $P = 0.1003$).

Since the first group differed significantly from the third group, but no difference was found between either the first and second groups or the second and third groups, the questionnaire Na intake value corresponding to cut-off point of stanine 6 (upper limit) was identified to be 2133 mg. Since added salt intake (discretionary) was not quantified in the 24-hour recall data (from which the questionnaire food categories were developed), it was decided to account for this by increasing the cut-off value of the questionnaire from 2133 mg to 2400 mg. This value also equates to the current international dietary guideline for the maximum recommended salt intake (i.e. 6 g NaCl day^{-1})[29]. This categorisation of <2400 mg day^{-1} ($n = 252$) and ≥ 2400 mg day^{-1} ($n = 32$) yielded a significant difference in urinary Na between groups, equivalent to a mean of 145 (SD 68) and 177 (SD 103)

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Table 4 Mean reported daily Na intake and 24-hour urinary Na excretion according to tertiles of Na content of questionnaire

	Tertile of Na content of questionnaire		
	Tertile 1 (<1255 mg day^{-1})	Tertile 2 (1259–1931 mg day^{-1})	Tertile 3 (>1935 mg day^{-1})
n	108	108	112
Na score			
Mean (SD)	17.3 (6.1)	32.0 (4.2)	47.6 (7.6)
Range (minimum–maximum)	0–25.7	25.0–39.3	38.0–76.7
Dietary Na intake (24-hour dietary recall) (mg day^{-1})			
Mean (SD)	1015 (548)	1693 (739)	2382 (836)*
Range (minimum–maximum)	54–4007	782–5409	1084–6114
Urinary Na excretion (mg day^{-1})			
Mean (SD)	3049 (1182)	3514 (1659)	3670 (2039)**
Range (minimum–maximum)	1004–6745	297–9090	1097–4173
Mean urinary Na in salt (NaCl) equivalent (g day^{-1})	7.62	8.78	9.17**

SD – standard deviation.
* $P<0.05$: Difference between tertiles 1, 2 and 3, using general linear models (Bonferroni test).
** $P<0.05$: Difference between tertiles 1 and 3, using general linear models (Bonferroni test; Kruskal–Wallis: $P=0.0635$).

Table 5 Daily Na intake and excretion accoring to two categories of Na intake estimated by questionnaire, using cut-off scores†

	Group 1 (score <48‡)	Group 2 (score ≥48)
n (questionnaire)	288	40
n (urinary Na)	253	31
Questionnaire score		
Mean (SD)	28.7 (11.1)	55.4 (6.3)***
Questionnaire dietary Na intake (mg day^{-1})		
Mean (SD)	1453 (556)	2788 (317)***
24-hour recall dietary Na intake (mg day^{-1})		
Mean (SD)	1553 (808)	2798 (862)***
Urinary Na excretion (mmol day^{-1})		
Mean (SD)	144.9 (67.9)	178.4 (104.5)*
95% CI (SD)	136.5 (62.5)–153.3 (74.4)	140.1 (83.5)–216.7 (139.6)
Salt (NaCl) equivalent (g day^{-1})	8.33	10.26

SD – standard deviation; CI – confidence interval.
* $P<0.05$, ** $P<0.0001$; Wilcoxon *t*-test for differences between score groups.
† Score = sum of absolute Na intake per day for each food category divided by 50, and rounded to nearest integer.
‡ Score <48 equates to Na intake of <2400 mg day^{-1}.

mmol day^{-1}, respectively (one-sided Wilcoxon approximation for *t*-test: $P=0.0225$). Mean difference in urinary Na between these two groups was −32.7 (SD 72.7) mmol day^{-1} (95% CI = −59.5 to −5.8 mmol day^{-1}).

In keeping with the simplified scoring system, the reference value of 2400 mg Na day^{-1} was divided by 50, yielding a value of 48 to indicate a cut-off score for desirable versus excessive Na intake. Both reported Na intake and urinary Na excretion differed significantly according to this classification (Table 5).

Inter-rater variability

A κ statistic of 0.0318 was found between the questionnaire cut-off scores (<48 and ≥48) and 24-hour urinary Na concentration categories (<100 and ≥100 mmol day^{-1}) ($n=284$).

Sensitivity and specificity of questionnaire

The questionnaire, using the cut-off score of ≥48 to indicate an excessive Na intake, has a sensitivity of 12.4% (27/218) against 24-hour urinary Na values of ≥100 mmol day^{-1}. Using the cut-off score of <48, the questionnaire has a specificity of 93.9% (62/66) against 24-hour urinary Na values of <100 mmol day^{-1}. Positive predictive value is 87.1% (27/31), while negative predictive value is 24.5% (62/253).

Discussion

Accurate measurement of Na intake is difficult due to extensive Na distribution in foods and the widespread use of Na compounds in food processing[30–32], the extensive use of NaCl as table salt[33] and the presence of Na compounds in drinking water[34]. In Europe and the USA, it has been shown that about three-quarters of Na intake comes from food processing, 10–11% is naturally occurring (inherent) in foods, about 15% is discretionary (half of which is contributed by table salt and half by added salt in cooking) and less than 1% is provided by water[5,27–29,35].

We have developed a simplified food frequency-type questionnaire (see Appendix) to assess habitual salt intake using representative dietary data from three ethnic

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groups of the South African population and from secondary analyses of dietary datasets from other large surveys in the country. As well as being able to quantify Na intake, as would be required for the purpose of epidemiological surveys and clinical trials, a rapid scoring system was developed to enable its use in public health-related activities. The majority of South African hypertensive patients receive dietary advice from nurses at primary care clinics but there is a lack of health promotion tools to assist clinic staff in empowering patients to consume a diet that is low in Na and high in potassium[36]. Despite hypertensive patients having a good knowledge of the role of salt intake in the development of hypertension[32], few are consuming diets with daily salt content <6 g[37]. The availability of an instrument that does not require detailed dietary records may be used as a motivational tool to quantify salt intake and to set targets for lifestyle changes within a clinic setting.

A significant, but poor, positive correlation was found between reported Na intake, estimated from either the questionnaire or the repeated 24-hour dietary recall data, and urinary Na excretion. The discrepancy between the questionnaire estimations of Na and the urinary excretion values highlights the difficulty in quantifying discretionary (i.e. added) salt intake in dietary surveys. In this study, the average of three repeated 24-hour recall dietary assessments was used as the basis for identifying food items and food categories which were significant contributors to overall salt intake in South Africans. The obvious under-reporting of discretionary salt intake using this method is problematic.

Low correlations between dietary reports and urinary estimations of Na excretion have been reported by other authors. In a cross-over study, participants were provided with a diet containing either 2000 or 3500 mg Na for 7 days and Na intake was estimated from seven 24-hour urinary Na collections per diet period[6]. Urinary Na analyses were significantly associated with duplicate chemical food analysis ($r = 0.61$), but not with Na intake estimated from food composition tables ($r = 0.05$). Thus, even under strictly controlled conditions, whereby food not provided by the research centre was obtained in duplicate and accounted for, where monitoring of intake and wastage took place daily, and where added salt intake was carefully measured, dietary analyses did not correlate with urinary Na excretion. These findings suggest that dietary assessment methods that rely on food composition tables are unable to accurately calculate the Na content of foods, probably due to the large variation in the Na content of processed foods.

In terms of reliability of the questionnaire, only eight of the individual 42 food categories were significantly associated with urinary Na. The questionnaire has been designed and validated as a composite measure and should be used in its entirety. In assessing Na intake, both the Na density of various foods as well as the frequency of consumption of those foods in the population of interest needs to be ascertained. We included all individual food items that were consumed by more than 5% of the sample and which contributed at least 50 mg Na per serving of that item in the questionnaire. Thus, some foods, such as popcorn and salted peanuts, which are consumed by few individuals but which are very high in salt, may have skewed the relationship.

Criterion validity of the questionnaire (assessed against urinary Na) has been demonstrated; however internal consistency is low. A possible reason why Cronbach's α of the questionnaire is low could be related to the way in which the food choices of individuals in the sample are grouped together. For example, factor analysis identified that white bread consumption was associated with margarine, beef sausage (*boerewors*), eggs and soup intake, whereas consumers of brown bread were more likely to have peanut butter or Marmite/Bovril, together with milk (data reported elsewhere[38]). Similarly, the lack of an association between some of the questionnaire food categories, such as minimally processed breakfast cereal, *maas* and yoghurt, with total Na intake (24-hour recall data) may be because individuals who consume large quantities of these food items consume less of the foods that are higher in Na (such as bread, cookies, pies, etc.). Alternatively, few subjects may be consuming these items, contributing to a weak correlation.

The two-category scoring system that categorises individuals into either a desirable or excessive salt intake is able to detect a significant difference in urinary Na excretion, thus demonstrating a degree of construct validity. However, corresponding urinary values far exceed the reference cut-off value of either greater or less than 6 g salt day^{-1}. Published data report that the estimated added salt intake of South Africans is 4.08 g day^{-1} or 45.5% of total Na intake[33]. If this value is used as a proxy, urinary Na values related to non-discretionary salt intake only would be 4.34 and 5.92 gday^{-1} for questionnaire score categories of <48 and ≥48, respectively. These values are much closer to the mean estimated Na content of the questionnaire that corresponds to these cut-off scores, namely 3.65 and 6.95 g day^{-1}.

Using the proposed scoring, the questionnaire has a high specificity (94%) but a poor sensitivity (12%). The positive predictive value indicates that, given a score ≥48, there is 87.1% chance that an individual will have a urinary Na concentration above 100 mmol day^{-1}. The negative predictive value, however, is low – given a questionnaire score of <48, there is 24.5% chance that the urinary Na concentration of that individual will be less than 100 mmol day^{-1}. The instrument, using the current reference cut-off scores, is thus much more useful to determine high salt intakes rather than identifying people with habitually low/desirable salt intakes. The low κ statistic between urinary Na reference values and questionnaire score categories further indicates that the scoring system needs additional refinement.

We attempted to account for discretionary salt intake by extrapolating responses obtained from a set of qualitative questions included in the same sample (data not shown). Subjects were asked about the use of salt and flavour enhancers (e.g. Aromat^{TM}) in food preparation; whether they usually add salt to their food before tasting it; and about their preference for a saltiness taste in foods. If either salt or Aromat were used in food preparation, an additional 389 mg Na (score = 8) or 240 mg Na (score = 5), respectively, was added to the composite Na content of the questionnaire. If subjects also reported that they add salt before tasting food, then the salt and/or Aromat estimation was further multiplied by a factor of 2. If subjects liked their food to taste either 'very salty' or 'a little salty', these amounts were multiplied by a factor of 2 and 1.5, respectively. For example, Na content of 778 mg (score = 16) was assigned to subjects if they used salt in cooking and if they had a preference for a 'very salty' taste. However, the addition of these data to the questionnaire score did not improve the sensitivity of the questionnaire nor improve the κ statistic.

Limitations of the study need to be considered. The main benefits of the salt questionnaire are that it is simple, requires little participant time and effort, and is easy to score. The questionnaire reflects Na intake over the past 7-day period which includes weekend days when Na consumption patterns may differ. However, only a single nutrient is being measured. The current version of the questionnaire does not allow provision for the testing of hypotheses about other nutrients, such as potassium, calcium or magnesium, either singly or interactively with Na, in the blood pressure–diet relationship. Another potential limitation is that the instrument did not account for total energy intake nor did it consider Na intake as a function of estimated energy requirements, as other methods have attempted to do[6]. The more food a person consumes, the more likely they are to have a higher intake of Na, unless the diet is traditional, with no access to processed foods. As with all food-frequency questionnaires, the checklist of included food items may not necessarily be inclusive of all the important sources of Na in another sample. The instrument may require modification for subpopulations whose food habits differ substantially from the group of urban, economically active adults that were included in our study.

Consideration needs to be given to the validity of using three 24-hour urinary collections as the gold standard measure against which Na intake using the questionnaire is assessed. Two decades ago, Luft *et al.* cautioned against the use of single or occasional 24-hour urine collections to identify biological correlations due to the presence of considerable intra-individual variability[39]. Intra-individual variability was high for both measures against which the questionnaire was being tested, namely urinary Na (coefficient of variation (CV) = 33.7%) and 24-hour dietary recall Na estimates (CV = 44.4%)[14]. The use of only three repeated measurements each of dietary recalls and urinary collections may not have been sufficient to accurately characterise individuals' usual Na intake.

Conclusion

A short food-frequency questionnaire to assess habitual Na intake has been developed using repeated 24-hour dietary from a multi-ethnic, economically active South African sample. The questionnaire demonstrates acceptable internal consistency and criterion validity against the gold standard indicator of repeated 24-hour urinary Na concentrations. It performs as well as three repeated 24-hour recalls against urinary Na excretion and an acceptable correlation was demonstrated between the questionnaire and the repeated 24-hour recalls. However, the questionnaire considerably underestimates the dietary intake of Na in the studied population, presumably due to the large proportion of salt intake that is provided from salt added by individuals. The devised categorical scoring system needs to show improved sensitivity. Further validation studies of the instrument should be undertaken in different geographical areas (i.e. urban and rural) where local communities are known to have different eating patters with regard to processed foods and salt use. The questionnaire may be used to monitor dietary compliance in research studies but in its current format cannot be used to estimate habitual dietary salt intake.

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Appendix – Salt intake questionnaire

NUTRITIONAL AND LIFESTYLE HABITS
The following questions are about your dietary and lifestyle habits. All your answers will be strictly confidential

Office use

Study number: 3

During the **PAST 7 days (1 week)** did you eat any of the following? IF YES, ASK HOW OFTEN
(*if no, circle never*) [DO NOT PROMPT THE ANSWER OPTIONS BELOW]

Food item	***NEVER***	NOT EVERY DAY		EVERY DAY			Office use
		1–3 times per **week**	4–6 times per **week**	1 time a **day**	2 times a **day**	3+ times a **day**	
White bread/white bread rolls	0	1	2	3	4	5	4
Brown/wholewheat bread/ rolls	0	1	2	3	4	5	
Breakfast cereal (processed)	0	1	2	3	4	5	
Breakfast cereal (minimally processed – weetbix, muesli, etc.)	0	1	2	3	4	5	
Crackers (ProVita, etc.)	0	1	2	3	4	5	
Cookies, biscuits, rusks	0	1	2	3	4	5	
Cake/scone/muffin/puddings/pancake/fruit pie/koeksister	0	1	2	3	4	5	
Roti/samosa/spring roll/doughnut	0	1	2	3	4	5	
Pizza	0	1	2	3	4	5	
Pasta/noodle dishes with cheese sauces (macaroni cheese, lasagne, noodle salad, etc.)	0	1	2	3	4	5	
Popcorn	0	1	2	3	4	5	
Crisps (Simba, Niknaks, etc.)	0	1	2	3	4	5	
Beef sausage (boerewors)	0	1	2	3	4	5	
Polony/salami/bacon/salami/pork sausages (processed meat, cooked, smoked and canned)	0	1	2	3	4	5	
Meat or chicken pies/sausage rolls	0	1	2	3	4	5	
Chicken – battered (KFC, etc.) and chicken burger only	0	1	2	3	4	5	
Meat and meat dishes (steaks, minced meat, cottage pie, mince, meatballs, stew, bobotie, etc.)	0	1	2	3	4	5	20
Gravy, made with stock or gravy powder	0	1	2	3	4	5	
Biltong/dry *wors*/fish biltong	0	1	2	3	4	5	
Milk (all types, also dairy fruit juice, malted milk, milk shakes)	0	1	2	3	4	5	
Maas (fermented milk)	0	1	2	3	4	5	
Cheese	0	1	2	3	4	5	
Yoghurt	0	1	2	3	4	5	
Eggs	0	1	2	3	4	5	
Tinned fish (pilchards, tuna, etc.)	0	1	2	3	4	5	
Other fish and seafood	0	1	2	3	4	5	
Potato chips/French fries and potato salad	0	1	2	3	4	5	
Canned vegetables, incl. baked beans, tomato paste, sweet corn, etc.	0	1	2	3	4	5	
Soup (all types)	0	1	2	3	4	5	
Salad dressing/mayonnaise	0	1	2	3	4	5	
Ice cream (all types)	0	1	2	3	4	5	
Margarines, all types, also butter	0	1	2	3	4	5	
Chutney/atchar/chakalaka/Worcester sauce	0	1	2	3	4	5	
Savoury sauces (mushroom, monkey gland, white, cheese)	0	1	2	3	4	5	
Tomato sauce	0	1	2	3	4	5	
Salt	0	1	2	3	4	5	
Aromat/Fondor/mustard	0	1	2	3	4	5	
Peanuts	0	1	2	3	4	5	
Peanut butter	0	1	2	3	4	5	
Marmite/Bovril	0	1	2	3	4	5	
Chocolate sweets and sauce	0	1	2	3	4	5	
Beer and cider	0	1	2	3	4	5	

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