Public Health England

Protecting and improving the nation's health

# National Diet and Nutrition Survey: assessment of dietary sodium

## Adults (19 to 64 years) in England, 2014

NatCen Social Research that works for society

MRC Human Nutrition Research

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# Notes to text and tables

1 The data used in the report has been weighted. The weighting is described in appendices A and C of this report. Unweighted sample sizes (as well as weighted sample sizes – where appropriate) are shown at the foot of each table.

2 This survey requires weights to adjust for differences in sample selection and response. The weights adjust for:
- differential selection probabilities of addresses, households and individuals
- non-response to the nurse visit
- non-response to providing a 24-hour urine sample

3 The data in chapters 4 and 5 and appendix C were analysed with the complex survey package R (version 3.0.2).

4 The following conventions have been used in tables:

| | |
|---|---|
| - | no observations (zero value) |
| 0 | non-zero values of less than 0.5% and thus rounded to zero |
| [ ] | unless stated otherwise data and bases for a variable with a cell size between 30-49 are presented in square brackets. For cell sizes below 30, bases have been presented in square brackets, but data has not been presented |

5 Because of rounding, row or column percentages may not add exactly to 100%.

6 A percentage may be quoted in the text for a single category that aggregates two or more of the percentages shown in a table. The percentage for the single category may, because of rounding, differ by one percentage point from the sum of the percentages in the table.

7 Values for means, medians, percentiles and standard deviations and standard errors are shown to an appropriate number of decimal places. For reasons of space, standard error may sometimes be abbreviated to SE and standard deviation to SD.

8 ‘Missing values’ occur for several reasons, including refusal or inability to answer a particular question and cases where the question is not applicable to the participant. In general, missing values have been omitted from all tables and analyses.

9 The age/sex group each table refers to is stated at the upper left corner of the table.

10 The term ‘significant’ refers to statistical significance (at the 95% level) and is not intended to imply substantive importance.

# Contents

# Executive summary

There is an established relationship between salt intake and risk of high blood pressure (BP).[1] High blood pressure (hypertension) is a risk factor for cardiovascular disease (CVD) and scientific evidence shows that a high salt intake can contribute to the development of elevated blood pressure.

The Scientific Advisory Committee on Nutrition (SACN)[2] recommend a target reduction in the average salt intake of the population to no more than 6g per day.[3] This figure has been adopted by the UK government as the recommended maximum salt intake for adults and children aged 11 years and over. Following publication of the SACN report in 2003,[2] the government began a programme of reformulation work with the food industry aimed at reducing the salt content of processed food products. Voluntary salt reduction targets were first set in 2006, and subsequently in 2009, 2011 and 2014, for a range of food categories that contribute the most to the population's salt intakes. Population representative urinary sodium data were collected in England in 2005-06, 2008 (UK), 2011 and 2014.

In the latest survey assessment, estimated salt intake of adults aged 19 to 64 years in England was assessed from 24-hour urinary sodium excretion of 689 adults, selected to be representative of this section of the population. Estimated salt intake was calculated using the equation 17.1mmol of sodium = 1g of salt and assumes all sodium was derived from salt. The data were validated as representing daily intake by checking completeness of the urine collections by the para-aminobenzoic acid (PABA) method. Urine samples were collected over five months (May to September) in 2014, concurrently with a similar survey in Scotland.

This report presents the results for the latest survey assessment (2014) and a new analysis of the trend in estimated salt intake over time. The trend analysis is based on data for urinary sodium excretion from this survey and previous sodium surveys (including data from the National Diet and Nutrition Survey Rolling Programme (NDNS RP) Years 1 to 5) carried out in England over the last ten years, between 2005-06 and 2014. This data has been adjusted to take account of biases resulting from differences between surveys in laboratory analytical methods used for sodium. The analysis provides a revised assessment of the trend in estimated salt intake over time. The trend analysis in this report supersedes the trend analysis published in the report of the 2011 England urinary sodium survey.

## Key findings

1. In 2014, mean[4] estimated salt intake for adults aged 19 to 64 years was 8.0g/day (33% higher than the SACN recommended maximum); 9.1g/day for men and

6.8g/day for women. Median estimated salt intake was 7.6g/day (27% above the SACN recommended maximum); 8.6g/day for men, 6.2g/day for women

2. As in the past, the distribution of sodium excretion/estimated salt intake among the adult population aged 19 to 64 years was wide, ranging from 0.8g/day to 24.2g/day. The estimated salt intake of adult men aged 19 to 64 years was on average higher than women of the same age

3. The revised trend analysis, which investigated both gradual trends and step-changes between 2005-06 and 2014, used log-transformed data and geometric means due to the skewed nature of the data. The results showed a downward linear trend in the geometric mean salt intake from 2005-06 (8.1g/day) to 2014 (7.2g/day). This 0.9g difference equates to a relative reduction in mean estimated salt intake of approximately 11%

4. This is a smaller difference than found in the earlier trend analysis published with the 2011 survey, due to (a) adjustments of data from previous analytical surveys to take account of changes in laboratory analytical methods for sodium over time (b) a focus on England only urinary sodium data (rather than UK data as used in the previously published trend analysis) and (c) exclusion of data from the 2000-01 NDNS of adults aged 19 to 64 years from this analysis (this was included in the previous trend analysis)

5. There was a statistically significant downward step-change in salt intake between 2005-06 and 2008-09. The change in mean estimated salt intake between 2005-06 and 2008-09 was 0.5g/day. This difference equates to a relative reduction in mean estimated salt intake of approximately 6%. While the data suggests further gradual decline in subsequent years, there was no statistically significant downward linear trend or further significant step-change between the remaining neighbouring years from 2008-09 to 2014[5]

# Chapter 1 Introduction

This survey provides data to establish progress towards meeting the government recommendation to reduce the average population salt intake in England to 6g per day (g/day).[2] It builds on the series of previous urinary sodium excretion surveys reporting estimated salt intake in the general adult population (19 to 64 years) in the UK countries.[6,7,8,9,10,11]

Dietary salt intake can be assessed by measuring sodium excretion in urine. Salt is the predominant source of sodium in the UK diet and estimation of intake from excretion is more reliable than through dietary assessment because it is difficult to quantify discretionary salt used in cooking and at the table. A 24-hour urine collection method, validated by the para-aminobenzoic acid (PABA) method (see chapter 2, section 2.6), was used for this survey, and is consistent with previous sodium studies. This method is accepted as being the most reliable and practical method for assessing estimated salt intake in the population. The level of sodium in urine fluctuates according to what was eaten at the last meal and how much fluid an individual had drunk, making assessments based on a 24-hour collection more accurate than a single spot sample.

A sample size of 600 complete 24-hour urine collections, representative of the population aged 19 to 64 years living in England, was required to detect a difference of 0.5g of salt intake compared with the previous survey in England in 2011 (calculated from the standard error in that survey).[10]

This report presents a new trend analysis of estimated salt intake over time for England and supersedes that provided in the report of the England 2011 sodium survey. Based on adjusted data for urinary sodium excretion the analysis has taken into account changes in laboratory methods over time and has included new data for the National Diet and Nutrition Survey Rolling Programme (NDNS RP) Years 1 to 5 and the current survey. The trend analysis considered both gradual and step-changes in trend through the survey periods 2005-06 to 2014.

## 1.1 Background

There is an established relationship between salt intake and risk of high blood pressure (BP).[1] High blood pressure (hypertension) is a risk factor for cardiovascular disease (CVD) and scientific evidence shows that a high salt intake can contribute to the development of elevated blood pressure.[2] CVD is a major cause of morbidity and mortality in the UK and worldwide. The British Heart Foundation (BHF) in 2015 estimated that CVD causes 155,000 deaths in the UK and costs the UK economy £19bn

annually.[12] Dietary modification is a major component in the preventative strategy to reduce the risk of CVD.

Since the early 1990s the UK government has recommended a reduction in salt intake in the interest of public health. In 1994, the Committee on Medical Aspects of Food and Nutrition Policy's (COMA) cardiovascular review group recommended that population average salt intake should be gradually reduced from 9g/day to 6g/day or less for adults.[13] In 2003, the Scientific Advisory Committee on Nutrition (SACN) published its Report on Salt and Health which endorsed COMA's recommendation for a maximum of 6g/day.[3] The SACN report noted that a reduction in the salt content of processed foods would be necessary to achieve the recommendation.[2]

Considerable effort has been made over recent years to raise public awareness of salt intake and health to enable individuals to make informed choices through information (including front-of pack labelling) and education. Action has also focused on reformulation of manufactured foods, because around 75% of the salt consumed is added during food manufacturing. Following the publication of the SACN report, the government began a programme of reformulation work with the food industry aimed at reducing the salt content of processed food products. Voluntary salt reduction targets were first set in 2006 for a range of food categories that contribute the most to the population's salt intakes. The targets provided guidance to the food industry and have resulted in gradual, stepwise reductions in salt levels across categories.[14] These targets were revised in 2009 and 2011 to take account of industry achievements in salt reduction. In 2014 the Department of Health set new voluntary targets to be met by 2017, maintaining the focus on the food categories that contribute the most to the population's salt intakes. Major retailers, manufacturers and eating out businesses are now working towards these targets.[15] To increase consumer awareness of the salt content of foods, many businesses are using front of pack labelling alongside mandatory food labelling.

Targeted public awareness campaigns by the Food Standards Agency (FSA) have aimed to inform the population about health risks associated with high salt consumption.[16] More recently the national Change 4 Life[17] campaign has focused on healthy lifestyles, including salt reduction. These campaigns have advised individuals to decrease their salt intake to no more than 6g/day (less for children).

Prior to this report, there have been three main urinary sodium surveys of representative samples of adults aged 19 to 64 years in England, all using 24-hour collections. The first survey carried out in 2005-06 in England included 445[18] complete urine collections,[6] the second carried out in 2008 (UK) included 571 complete collections from participants in England[8] and the third carried out in 2011 in England included 547 complete collections.[10]

Twenty-four hour urine samples were also collected between 2008 and 2013 as part of the NDNS RP. A total of 668 complete collections from adults aged 19 to 64 years in England were obtained through the NDNS RP.[19]

There were a number of methodological differences from survey to survey: ie, in the laboratory analytical methods used for measuring sodium, in the methods of defining "complete" urine collections for inclusion in the data analysis and in the sample design such as stratification and clustering. In this report previous data have been adjusted to take account of differences in laboratory methods.

## 1.2 Aims of the survey

The aims of the survey were to:

- assess urinary sodium excretion in adults aged 19 to 64 years living in England, by collecting and analysing 24-hour urine samples for a representative sample of the population
- estimate dietary salt intakes (g/day) from urinary sodium excretion
- conduct an analysis of trends in estimated salt intake (g/day) based on data collected from the urinary sodium surveys carried out between 2005-06 and this survey (2014) and data from the NDNS RP collected between 2008 and 2013

Ethical approval for the survey was granted by the Cambridge South NRES Committee (Ref. No. 13/EE/0016).

The survey was carried out by NatCen Social Research (NatCen) and MRC Human Nutrition Research (HNR) and was funded by Public Health England (PHE). A parallel survey using the same methodology was carried out concurrently in Scotland.[20]

# Chapter 2 Methodology

## 2.1 Sample design

The aim was to obtain, over a five-month period (May to September 2014), 600 complete 24-hour urine collections representative of the population of England aged 19 to 64 years. The survey was designed to be:

- representative of the population aged 19 to 64 years living in England, and
- able to detect a difference of 0.5g of salt intake compared with the previous survey in England in 2011 (calculated from the standard error in that survey)[10]

The Postcode Address File[21] was used to sample postcodes that were representative of the population. Forty-five postcode sectors were selected and within these, a random sample of landline telephone numbers was drawn using Random Digit Dialling (RDD).[22]

The participants were recruited by NatCen's Telephone Unit (TU) interviewers. Within each household a maximum of two people aged 19 to 64 years were eligible to take part in the survey. Where there were more than two eligible adults in a household, two were randomly selected. Those living in institutions and females who were pregnant or breastfeeding were not eligible to take part in the survey.

## 2.2 Participant recruitment

NatCen's TU interviewers attempted to make contact with the households of the generated telephone numbers and when successful, followed a Computer Assisted Telephone Interviewing (CATI) script to introduce the survey, check the eligibility of household members and attempt to recruit up to two participants per household. The TU interviewer then sought agreement for a nurse to contact the selected participant(s) in order to arrange a home visit for collection of the 24-hour urine sample(s).

The nurse made initial contact with the participant(s) via telephone, after which they sent a letter confirming details of the appointment date and time to the participant(s). The nurse then visited participating households twice: the first visit to explain the collection protocol and provide the participant(s) with the collection equipment and the second visit to take a subsample of the urine collection.

## 2.3 Urine collection protocol

After obtaining written consent (see appendix D), the nurse instructed participants in the 24-hour urine protocol. They were asked to collect all urine during a 24-hour period starting from the second morning urine pass of the 24-hour collection day, and ending

after the first urine passed the following morning. The nurse used the Computer Assisted Personal Interview (CAPI) programme to randomly allocate a day of collection for the participant. If the allocated date was unsuitable for the participant, CAPI would allocate an alternative start day. Nurses would discuss the allocation of the collection day with participant and emphasising the importance of the representativeness of the survey across the whole week. However, in order to maximise response, participants were allowed to collect their sample on the day of their choice. Women were instructed to collect their urine on non-period days.

Participants were provided with the necessary equipment to do the 24-hour collection and were asked to take three PABA tablets at evenly spaced intervals throughout the day of the collection. Participants were still eligible to take part if they were willing to carry out the 24-hour urine collection but did not want to (or could not) take PABA.

During the collection period, participants were required to record the time they took the PABA tablets, the start and finish times of their urine collection, any missed urine passes, and any medication or supplements taken during the collection period (see appendices A and D for more details).

The nurse revisited participants on the day or the day after the 24-hour urine collection was completed. This ensured that the urine did not deteriorate before reaching HNR for analysis. At this second visit the nurse weighed the urine collection using Salter Breknell ElectroSamson digital handheld scales and collected two samples from the total 24-hour urine sample and disposed of the remaining urine and equipment (see appendix A, section A.7 for more details).

The nurse then packaged and posted the samples and paperwork to the laboratory at HNR.

## 2.4 The household questionnaire

During the second visit the nurse also asked a variety of household questions and recorded the responses in CAPI. Participants were asked about household income (including earnings and pension benefits), occupational status and housing tenure.

Finally, each participant providing a urine sample was given a £15 gift card as a token of appreciation for their participation in the survey.

## 2.5 Urinary sodium measurement and analytical laboratory procedures

Measurement of urinary sodium was carried out at HNR using an ion selective electrode (ISE) on the Siemens Dimension® Xpand clinical chemistry system with the QuikLYTE® module. The 24-hour sodium excretion was determined by multiplying

urinary concentration by 24-hour volume (determined by weighing the collection, see appendix A, section A.7 for more details). This was then multiplied by a method-specific factor, derived from method comparison studies, to enhance accuracy and enable comparison with previous urinary sodium survey data obtained with different methods. Urinary potassium and creatinine were measured alongside sodium and results for these analytes will be included in the dataset deposited at the UK Data Archive. Details of the analytical procedures are given in appendix B.

Laboratory methods for assessment of urinary sodium concentration have evolved over time and consequently different surveys have used different methods. Historically the most common method was flame photometry. This method has since been superseded by ISE methods; the NDNS RP from 2008-09 and urinary sodium surveys from 2011 have used ISE technology on the Siemens Dimension Xpand for urinary sodium measurement. The sodium assays for all surveys except 2005-06 were performed by HNR.

HNR has carried out comparison studies between these methods to derive factors which can be applied to urinary sodium concentrations measured by each method so that the results over time are all directly comparable, irrespective of the instrument and analytical method used. This facilitates a more accurate description of estimated salt intake trends (see appendix B, section B.2.1).

Urinary sodium measurement in the 2005-06 survey was conducted by The Doctors' Laboratory, London (TDL), using the Roche P module (ISE technology). No direct comparison study has been performed between this instrument and those used at HNR; however the external quality assessment data provided by TDL covering the relevant time period suggest that a factor of 1.0 was appropriate for this survey.

## 2.6 Assessment of completeness of collection

Completeness of 24-hour urine collections was assessed using the PABA method23 with modifications as described below and in appendix B (section B.2.2). Where participants reported taking the three 80mg PABA tablets at appropriate intervals, 24-hour urine collections were considered to be complete if they contained between 70% and 104% of the PABA, ie, 168 to 250mg[24] (further details are provided in appendix B).

Urine collections with a PABA recovery under 70% were considered incomplete, while those with a PABA recovery greater than 104% were considered unfeasibly high and therefore unreliable. Complete collections (those with a PABA recovery of between 70% and 104% of the PABA) were included in the results, while collections deemed incomplete or unreliable were excluded.

Individuals who elected not to take PABA but recorded they had completed a 24-hour urine collection were included. Such individuals who recorded start and finish times within one hour of a 24-hour collection period (ie, recorded urine collected between 23 to 25 hours) were deemed to have a complete 24-hour collection. In addition, participants who elected to take PABA but reported that they did not take all three PABA tablets yet still completed a 24-hour urine collection were also included.

PABA was used as a marker of complete excretion for all studies from 2005-06 onwards. However, the criteria by which 24-hour urine collections were selected for inclusion in the dataset have evolved over time. For example, completeness of 24-hour urine collections from participants who declined to take PABA was assessed on the basis of each participant's claim in some of the surveys (see tables A and B in chapter 5 for full details).

The analytical method for PABA was originally colorimetry with high performance liquid chromatography (HPLC) reanalysis of urines containing unfeasibly high excretion, and "correction" of results from urines in which PABA excretion indicated marginal incompleteness. From late 2010 onwards HNR moved to measure PABA by HPLC only as this is a more robust method and is not subject to interference by azo compounds, which includes some medications. The PABA excretion consistent with a complete 24-hour urine collection was re-validated based on HPLC and on colorimetric analysis. All urine collections classified as incomplete by PABA excretion were excluded from the dataset; no correction factors were used.

Further detail of the analytical methodology used in this survey can be found in appendix B.

## 2.7 Considerations for data interpretation

The following should be borne in mind when interpreting the data:

- analyses were based on each participant's sodium excretion during a single 24-hour period and assumed that the 24-hour collections defined as "useable" contained all urine passed during the collection period
- the estimated salt intake distributions show a very wide scatter (approximately five-fold difference between the lower and upper 2.5 percentiles)
- a single 24-hour urine collection does not represent a typical sodium excretion for an individual participant. Salt excretion varies day to day depending not only on intake but also on hormonal and other physiological influences. Each urine collection contributing to a survey provides a data point describing the population distribution
- the effect of changing methodologies over time in the analysis of urinary sodium was accounted for retrospectively as far as possible in the trend analysis in order to allow combination of data from the different surveys and hence improve the

reliability of the conclusion. This process was relatively straightforward and the analytical factors adopted were experimentally verified. However, there were also differences over time in survey design and in the identification of 24-hour collections as “complete” which are more complex and difficult to harmonise. Therefore, it is likely that some inherent variation may remain between data collected in the different surveys that cannot be accounted for

- as in the previous surveys, the number of people in the youngest age group (19 to 34 years) providing 24-hour urine collections in 2014 was low, highlighting the challenges in involving younger adults in 24-hour urine studies. This may also have been influenced by the household/participant selection method which included only households with landline telephones

# Chapter 3 Response and Weighting

Information about response, the useability of the 24-hour urines collected (and urine collection days) is presented below.

## 3.1 RDD and nurse response

Of 12,296 telephone numbers attempted by NatCen's TU interviewers, 85% (10,430) were useable. Of these, 19% (1,985) were households that had at least one eligible adult aged 19 to 64 years who agreed to the telephone interview (37% were ineligible, 30% refused the telephone interview and 14% were unproductive for another reason).

In total, 1,086 households containing 1,132 individuals were issued to the nurses.

***(Table 1)***

Of the 1,132 individuals issued to nurses, 92% (1039) were visited by a nurse and 86% (993) provided a 24-hour urine collection.

***(Table 2)***

## 3.2 Number of useable urine collections

In total, 993 24-hour urines were collected. However, 14 were lost in transit and not received by the HNR laboratory and one urine collection was provided by a participant outside the 19 to 64 years age group.

Therefore, 978 urines, from 404 men and 574 women, were processed by the HNR laboratory. Of these, 70% (689/978) were classified as 'complete' and 30% (289/978) were classified as 'incomplete or unreliable'. Of the urine collections included in the final analysis, 43% (298/689) were from men and 57% (391/689) were from women.

***(Table 3)***

The sex profile of participants included in the analysis was significantly different ($p<0.05$) from the participants excluded from the analysis. From all of the urine collections provided by men 74% (298/404) were classified as complete and 26% (106/404) were classified as 'incomplete or unreliable'. From all of the urine collections provided by women 68% (391/574) were classified as complete and 32% (183/574) were classified as 'incomplete or unreliable'. The age of participants was not significantly different between the included and excluded sample. The mean age for men in the included sample was 49.3 years and 46.3 years in the excluded sample. For women the mean age of those in the included sample was 50.1 years and 49.4 years in the excluded sample. These data are similar to previous urinary sodium surveys.

***(Tables 3 and 5)***

## 3.3 Urine collection days

Start days for 24-hour urine collections were randomly allocated by CAPI in order to spread sampling throughout the week and avoid over-representation of weekend days when diet may be different from weekdays. Nurses encouraged participants to follow this allocation but in order to maximise response they were allowed to choose a different start day.

Overall, 56% (387/689) of urines were collected from Monday to Friday, and 44% (302/689) were collected at the weekend, so samples collected at the weekend were over-represented in the dataset, as in previous surveys.

***(Table 4)***

## 3.4 Weighting

The data were weighted to minimise any bias in the observed results which may be due to differences in the probability of households and individuals being selected to take part; and to attempt to reduce non-response bias[25] (see appendix A for detail of the weighting strategy).

# Chapter 4 Results

## 4.1 Estimated salt intake

The aim of the 24-hour urine collection analysis was to estimate the mean and population distribution of estimated salt intake (g/day) in England among adults aged 19 to 64 years. In line with the previous urinary sodium surveys[6,7,8,9,10,11] estimated salt intake was calculated using the equation:

17.1 mmol of sodium = 1 g of salt

This assumes that dietary intake of sodium is equal to the 24-hour sodium output in urine, and that all sodium in the diet comes from salt.[10] The urinary sodium excretion data were adjusted using a method-specific equation in order to improve accuracy and to enable comparison across the different datasets which have used different laboratory analytical methods (for information on derivation of the adjustment factor see appendix B, section B.2.1). For the purpose of the trend analysis (chapter 5), appropriate method-specific factors were applied to results from earlier studies and are described in this section.

Table 6 provides mean urinary sodium excretion by sex/age group expressed as mmol/24hr and table 7 shows the cumulative percentage distribution of urinary sodium excretion. Table 8 provides mean estimated salt intake by sex/age group expressed as g/day and table 9 shows the cumulative percentage distribution of estimated salt intake.

Mean urinary sodium excretion for adults was 136mmol/24hr; 156mmol/24hr for men and 116mmol/24hr for women.

***(Table 6)***

The mean[4] estimated salt intake for adults aged 19 to 64 years in this survey (2014) was 8.0g/day, which is 33% greater than the SACN recommendation of a population average of no more than 6g/day.[2,3] Men had a mean daily intake of 9.1g/day and women had a mean daily intake of 6.8g/day. As in the past, there was a wide distribution in estimated salt intake and some urine collections contained a large amount of salt. This may make the median a more robust estimate of the overall population status than the mean. The median estimated salt intake for the adult population was 7.6g/day (27% above the SACN recommended maximum); 8.6g/day for men, 6.2g/day for women.

***(Table 8)***

There was a wide distribution of estimated salt intakes. Overall, 67% of the estimates were higher than the population target maximum of 6g/day.

***(Table 9)***

# Chapter 5 Estimated salt intake trend analysis (2005-06 – 2014)

## 5.1 Introduction

The objective of the estimated salt intake trend analysis was to estimate the change in salt intake in England, between 2005-06, the first assessment after salt reduction work began, and the most recent assessment in 2014 and to consider whether there had been any step-changes between survey years and/or gradual change over time. Additional information is provided in appendix C of this report.

Care should be taken in interpreting population statistics collected over time. Improvements in data collection and analytical methods may mean that previous interpretations are no longer valid, and must be reappraised. Key considerations for performing a trend analysis are the comparability of data available at each time point and the comparability of different methods used in the various surveys. Factors considered in the present analysis include:

- accuracy/comparability of laboratory methods used over time for the measurement of urinary sodium concentration
- identification of complete/incomplete 24-hour urine collections
- complex sample design (sample weights, clustering and stratification)
- comparability of data for England at different time points

The trend analysis is based on data for England only and takes into account all the individual data points instead of survey means. It also includes new data from the NDNS RP Years 1 to 5 and the current 2014 survey.

Urinary sodium concentrations from current and previous surveys using different analytical methods have been adjusted using factors to take account of method-specific analytical biases so that the results are more directly comparable between surveys (see chapter 2, section 2.5).

The new trend analysis presented in this report gives a different assessment of the change in estimated salt intake from the previous analysis published in the 2011 England urinary sodium survey report. The new analysis shows a smaller change in estimated salt intake than was indicated by the earlier assessment. This report supersedes and is not comparable to the earlier report.[10]

## 5.2 Data preparation and methodological considerations

This section describes the sources of urinary sodium excretion data and summarises the methodological considerations undertaken to ensure a valid combination and interpretation of data.

Table A provides a description of the number of complete collections and sample design for each survey included in the trend analysis (2005-06-2014). The 2000-01 NDNS of adults aged 19 to 64 years[26] is included for reference, but was not included in the trend analysis (see bullet points at the end of this section for more information).

For reporting purposes, arithmetic means have been provided. Due to the skewed nature of the data, geometric means have also been calculated (by transforming the data on a natural logarithmic scale) and used for statistical analyses to evaluate relative changes in the data (eg, between years or groups) and minimize bias from the skewed data.

## Table A. Sources of England urinary sodium excretion data by year

| Survey[a] | Sample size included (complete/ corrected collections)[a] | PABA method (Criteria for inclusion/exclusion of 24h urine collections)[b] | Sample design | Group that this survey data was placed in for trend analysis |
|---|---|---|---|---|
| NDNS 19-64y 2000-01 | 1153[c] | Not used[d] | Stratified and clustered | (N/A) These data were not included in the trend analysis. |
| England Sodium Survey 2005-06 | 445[18] | PABA method performed by MRC Dunn Nutrition Unit (colorimetry). Samples with:85-110% PABA recovery considered complete.<br>70-84% recovery included after applying a correction equation.<br>Over 110% recovery considered high but included in analysis as exclusion did not change direction of results.<br>Under 70% recovery considered incomplete and excluded. | Stratified and clustered | 1 |
| UK Sodium Survey 2008 | 571 | PABA method performed by MRC Dunn Nutrition Unit (colorimetry). Samples with:<br>85-110% PABA recovery considered complete.<br>70-84% recovery included after applying a correction equation.<br>Under 70% considered incomplete and excluded.<br>Over 110% recovery reanalysed by HPLC – HPLC below 75% and results above 110% excluded. | Stratified and clustered | 2 |
| NDNS RP Y1 2008-09 | 117 | 85-119% PABA (colorimetry) complete.<br>Under 85% (colorimetry) incomplete and excluded.<br>No correction factors applied.<br>Over 119% by colorimetry were re-assayed by HPLC and 70%-104% PABA (HPLC) complete.<br>Samples with no PABA but collection time of 23-25 hours with no missed collections included. | Stratified and clustered | 2 |
| NDNS RP Y2 2009-10 | 109 | | | 3 |

## Table A (continued). Sources of England urinary sodium excretion data by year

| Survey[a] | Sample size included (complete/ corrected collections)[a] | PABA method (Criteria for inclusion/exclusion of 24h urine collections)[b] | Sample design | Group that this survey data was placed in for trend analysis |
|---|---|---|---|---|
| NDNS RP Y3 2010-11 | 109 | 70%-104% PABA (HPLC) complete. Below 70% (HPLC) incomplete and excluded. No correction factors applied. Samples with no PABA but collection time of 23-25 hours with no missed collections included. | Stratified and clustered | 4 |
| NDNS RP Y4 2011-12 | 178 | | | 5 |
| NDNS RP Y5 2012-13[e] | 155 | | | 6 |
| England Sodium Survey 2011 | 547 | 70%-104% PABA (HPLC) complete. Below 70% (HPLC) incomplete and excluded. No correction factors applied. Samples with no PABA but collection time of 23-25 hours with no missed collections included. | Stratified and clustered | 5 |
| England Sodium Survey 2014 | 689 | 70%-104% PABA (HPLC) complete. Below 70% (HPLC) incomplete and excluded. No correction factors applied. Samples with no PABA but collection time of 23-25 hours with no missed collections included. | Stratified and clustered | 7 |

[a] Where source survey was UK, only England data have been provided and included in the analysis.
[b] Where not stated, analysis was performed by MRC HNR.
[c] While there were 1153 complete urine collections, there were only 1147 sodium results included in the report.
[d] Use of PABA was discontinued partway through wave 1 due to a suspected allergic response in one participant, however this was subsequently found to be unrelated to PABA.
[e] 24-hour urine was only measured as part of the main NDNS RP in Years 1-5.

Laboratory methods for the measurement of sodium have evolved over time and different surveys have consequently used different methods (see table B). Sodium excretion data used to estimate salt intakes were multiplied by the appropriate method-specific factor for each survey in order to adjust for analytical biases and enable comparison of data obtained with different laboratory methods at different times (see table B). Application of these factors has resulted in slightly lower estimates of sodium concentration in urine collections assayed by flame photometry for the earlier surveys and slightly higher estimates of sodium concentration in urine collections measured by Siemens ISE technology for the more recent surveys. Further details are provided in chapter 2, section 2.5 and in appendix B, section B.2.1. Refer to appendix E for tables of adjusted data for the England 2005-06,[6] UK 2008[8] and England 2011[10] sodium surveys.

**Table B. Laboratory analytical methods used; selection of useable urine collections**

| Survey[a] | Method of sodium analysis | Method-specific factor | Identification of complete collections | Group that this survey data was placed in for trend analysis |
|---|---|---|---|---|
| NDNS 19-64y 2000-01 | Flame photometer (IL 943) at HNR | 0.952 | Participant claim substantiated by urine:plasma creatinine ratio assessment[b] | (N/A) These data were not included in the trend analysis. |
| England Sodium Survey 2005-06 | ISE (Roche/Hitachi) at The Doctors Laboratory in London (TDL) | 1.0[c] | PABA (colorimetry / HPLC) | 1 |
| UK Sodium Survey 2008 | Flame photometer (IL 943) at HNR | 0.952 | PABA (colorimetry / HPLC) | 2 |
| NDNS RP Y1 2008-09 | ISE (Siemens Dimension Xpand) at HNR | 1.052 | PABA (colorimetry / HPLC) or participant claim | 2 |
| NDNS RP Y2 2009-10 | | | | 3 |
| NDNS RP Y3 2010-11 | ISE (Siemens Dimension Xpand) at HNR | 1.052 | PABA (HPLC) or participant claim | 4 |
| NDNS RP Y4 2011-12 | | | | 5 |
| NDNS RP Y5 2012-13 | | | | 6 |
| England Sodium Survey 2011 | ISE (Siemens Dimension Xpand) at HNR | 1.052 | PABA (HPLC) or participant claim | 5 |
| England Sodium Survey 2014 | ISE (Siemens Dimension Xpand) at HNR | 1.052 | PABA (HPLC) or participant claim | 7 |

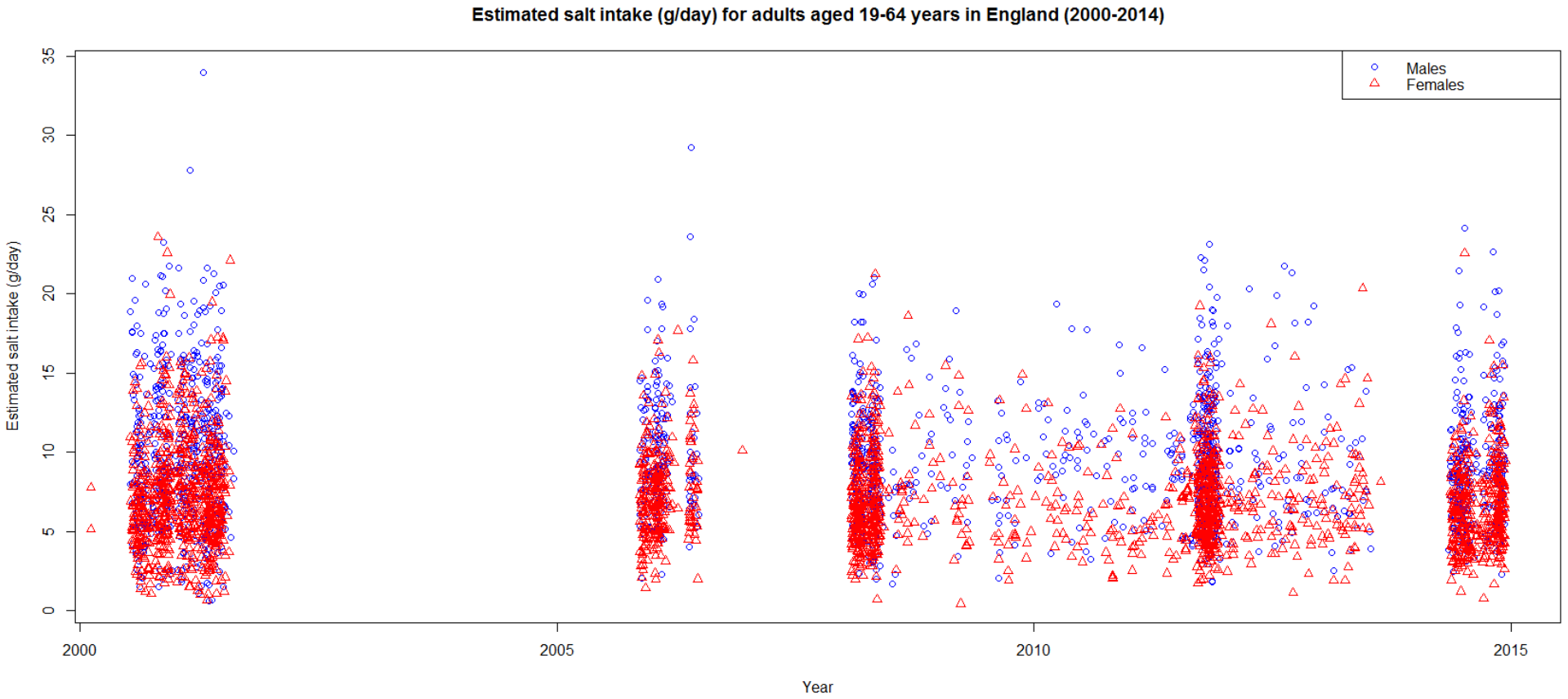
[a] Where the source survey was UK, only England data have been included in the analysis.
[b] Use of PABA was discontinued partway through wave 1 due to a suspected allergic response in one participant, however this was subsequently found to be unrelated to PABA.
[c] Factor determined from contemporaneous external quality assessment, not from comparison study.

Only 24-hour urine collections regarded as complete were included in the trend analysis. The definition of “complete” used in each survey was specific to that survey; no attempt has been made here to standardise the definition. The number and characteristics of individuals with incomplete urine collections were explored to check that no substantial loss of information resulted from their exclusion and that there were no patterns in the characteristics of excluded individuals which needed to be considered in the analysis. Additionally, for the UK 2008 survey,[8] the representativeness of the England-only data included in the trend analysis was checked. Where the source survey was UK, only England data have been included in the analysis.

The scatterplot of the available survey data in figure 5.1 demonstrates overlapping time points between surveys (date of collection). For information, data collected in 2000-01 as part of the NDNS of adults aged 19 to 64 years[26] (from England only) are displayed in figure 5.1, but these data were not included in the trend analysis in this report for the following reasons:

- no substantial changes were expected between 2000-01 and 2005-06 because 2005-06 was when the work with food manufacturers to encourage product reformulation started, although awareness-raising publicity campaigns to the public had started earlier
- 24-hour collections were not verified using PABA recovery in 2000-01. As indicated in the 2000-01 report (see section 4.2.1 of that report)[26] this probably caused an underestimate in the 24-hour urine results of that survey. This is not quantifiable and reduces confidence in the 2000-01 data
- the time interval between 2000-01 and 2005-06 is large in comparison with the remaining time intervals and therefore this time point, compromised by the insecurity detailed in the preceding point, would exert a disproportionately large influence in the trend analysis

## Figure 5.1. Scatterplot of individual estimated salt intake (g/day) in England, by sex (2000-01-2014)[a,b]




[a] Data collected in 2000/01 are displayed in the figure for completeness of data presentation, but these data have not been included in the trend analysis because they do not provide an appropriate baseline for the target trend analysis (2005/06-2014).
[b] Where a UK survey has been used, data presented are for England only.

Following inspection of the plot shown in figure 5.1, the following combinations of individual England data points by year were used in the trend analysis:

- Group 1: England 2005-06
- Group 2: UK 2008 and NDNS Y1 (2008-09)
- Group 3: NDNS Y2 (2009-10)
- Group 4: NDNS Y3 (2010-11)
- Group 5: NDNS Y4 (2011-12) and England 201127
- Group 6: NDNS Y5 (2012-13)
- Group 7: England 2014 (this survey)

## 5.3 Sample design

For the purposes of the trend analysis, all available England urinary sodium data from surveys conducted between 2005-06 and 2014 were considered. Each of the surveys had a complex sample design, detailed in table A, and for which their stratification and clustering were taken into account in the analysis. Certain surveys were combined according to survey periods if the collection time points overlapped. To combine the surveys and account for the complex sample design, the sampling weights for each survey were combined using the 'combining sample weights' approach detailed in O'Muircheartaigh et al. (2002).[28] Additional information regarding the trend analysis methodology is provided in appendix C.

## 5.4 Trend analysis

The availability of sodium excretion data by survey is summarised in table A. Tables A and B provide details on the laboratory and complex sample design methods used in each survey. The objective for the trend analysis was to assess the change in estimated salt intake in the England population between 2005-06 and 2014.

Prior to carrying out statistical analysis to assess trend, distributions and outliers of estimated salt intake were investigated through boxplots and histograms for males and females aged 19 to 64 years (see appendix C). The initial exploratory data analysis showed the distribution of estimated salt intake to be positively skewed; hence a natural logarithmic transformation was applied. Such scaling or transformation of data reduces skewness resulting in a more symmetric distribution of the data. The mean of the log-transformed data converted back to raw units equates to the geometric mean,[29] providing a relative measure that is comparable, easily interpretable, and a more accurate estimate of a percent change. As an illustration, suppose between hypothetical time points 1 and 2, there is an observed difference of 0.032. The exact percent difference is given by $100(e^{diff}-1)\% = 100(e^{0.032}-1)\% = 3.25\%$, and hence the (mean) percent change between time points 1 and 2 is 3.25%.

Procedures for the trend analysis involved regression and hypothesis testing (involving two sample t-tests) methods where the explanatory variable was time and the directionality of the trend was of interest. Methods to determine and understand both gradual (eg, linear) and sudden (step) trends (change over time) with and without the effects of confounding variables (eg, sex) were employed. The regression and hypothesis testing methods took account of the complex survey design, incorporating the sampling weights, clustering and stratification.

### 5.4.1 Results of trend analysis

The purpose of the trend analysis was to detect both gradual trends and step-changes over time (from 2005-06-2014), replacing the previously published trend analysis with a more up to date and robust assessment, taking account of changes in laboratory analytical methods for sodium over time. Regression (to assess gradual change) and hypothesis testing (step-changes) methods were performed. Figure 5.2 presents a scatterplot of the data used for the trend analysis, and the estimated trend of estimated salt intake.[30]

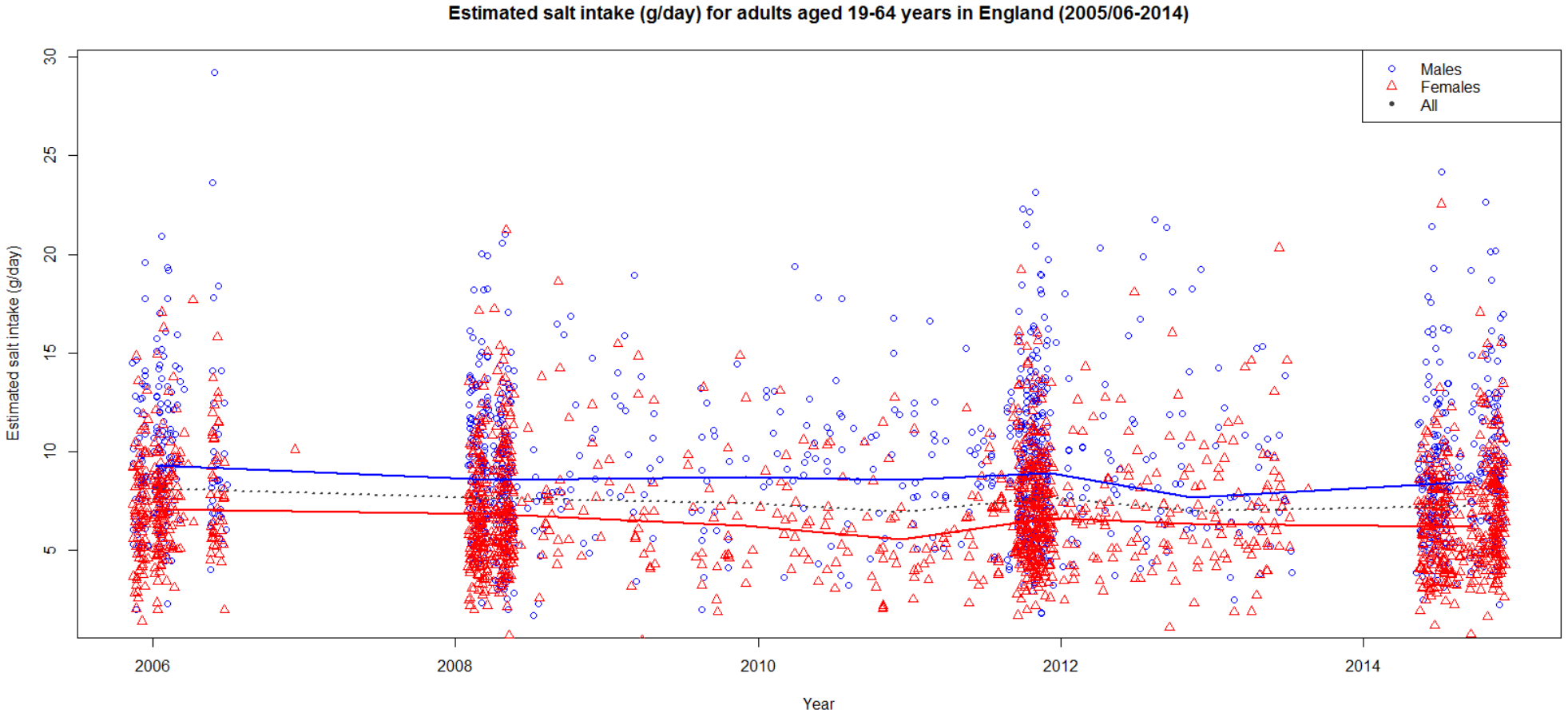
Using log-transformed estimates of salt intake, a linear regression model showed a downward linear trend from 2005-06 (geometric mean 8.1g/day) to 2014 (geometric mean 7.2g/day). This 0.9g difference equates to a relative reduction in mean estimated salt intake of approximately 11%. This is a smaller difference than found in the previously published trend analyses due to (a) adjustments of data from previous analytical surveys to take account of changes in laboratory analytical methods for sodium and (b) a focus on England only urinary sodium data (rather than UK data as used in the previously published trend analysis).

Further investigation into step changes showed there was a statistically significant downward step-change between 2005-06 and 2008-09. The change in mean estimated salt intake between 2005-06 and 2008-09 was 0.5g/day. This difference equates to a relative reduction in mean estimated salt intake of approximately 6%. While the data suggest further gradual decline in subsequent years, there was no statistically significant downward linear trend or further significant step-change between the remaining neighbouring years from 2008-09 to 2014.

A linear regression model with sex as a covariate was employed to ascertain whether there was a difference in the linear pattern and characteristics of men and women with respect to change over time, ie, investigating an interaction between sex and time (year on year). There was no statistically significant difference in the linear trend between men and women. However, sex is statistically significant as a factor in the linear model to ascertain a downward linear trend.

A step-change analysis was conducted to determine if there were differences in the pattern and characteristics in the step-change periods. The step-change analysis indicated there was a difference in the step-change pattern between men and women. The main difference is that the initial change is observed only in men between 2005-06 (9.3g/day) and 2008-09 (8.6g/day). There was no statistically significant downward step-change in data from women between these years, or between later years. These differences in observed step-changes (between men and women) are demonstrated in the boxplots (presented in appendix C) and table C of the geometric means. Figure 5.2 presents the scatterplot of the data (as in figure 5.1) with three lines for men (blue line), women (red line), all (sex-combined adults (black dotted line)) demonstrating the relative trends. The lines pass through the respective geometric mean.

## Figure 5.2. Estimated trend of estimated salt intake (g/day) in England, by sex (2005-06[18]-2014)[a]




[a] Where a UK survey has been used, data presented are for England only.

**Table C. Number of participants, geometric means and SE of estimated salt intake (g/day) between 2005-06[18] and 2014**

| Survey year | Combined | | | Men | | | Women | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | Mean (g/day) | SE | N | Mean (g/day) | SE | N | Mean (g/day) | SE |
| **2005-06**[18] | 445 | 8.1 | 0.16 | 187 | 9.3 | 0.26 | 258 | 7.1 | 0.16 |
| **2008-09** | 688 | 7.6 | 0.16 | 301 | 8.6 | 0.25 | 387 | 6.8 | 0.22 |
| **2009-10** | 109 | 7.4 | 0.39 | 50 | 8.7 | 0.74 | 59 | 6.2 | 0.49 |
| **2010-11** | 109 | 6.9 | 0.33 | 56 | 8.6 | 0.45 | 53 | 5.6 | 0.37 |
| **2011-12** | 725 | 7.7 | 0.19 | 325 | 8.9 | 0.30 | 400 | 6.7 | 0.18 |
| **2012-13** | 155 | 7.0 | 0.35 | 60 | 7.7 | 0.67 | 95 | 6.4 | 0.31 |
| **2014** | 689 | 7.2 | 0.20 | 298 | 8.5 | 0.29 | 391 | 6.2 | 0.20 |

Note: The means in this table are geometric means as used for the trend analysis. The geometric mean is different from the arithmetic mean (see chapter 4).

At the same time as the England 2014 sodium survey a parallel survey was conducted in Scotland.[20] A comparison of the results from the two countries is provided in the report for the Scotland 2014 sodium survey.

# Appendix A Methodology: 2014 England urinary sodium survey (adults aged 19 to 64 years)

## A.1 Sample design

The aim was to obtain, over a five-month period (May to September), 600 complete 24-hour urine collections representing the population of England aged 19 to 64 years.

The Postcode Address File was used to sample postcodes that were representative of the population. The sample was stratified by initially sorting the file by Government Office Region, then within each region the file was stratified into five equal bands based on the Index of Multiple Deprivation. Within each band the file was then sorted by population density. From this, 45 postcodes were selected.

Within the 45 postcode sectors a random sample of telephone numbers was drawn using Random Digit Dialling (RDD). RDD is a method where a representative sample of landline telephone numbers is generated at random from a frame of all possible telephone numbers.[31] The RDD sample covered all eligible telephone area codes located in the 45 selected postcode sectors. The database lists the first seven digits of all telephone numbers, including ex-directory numbers, which have been allocated to telephone companies for land lines (e.g. 01234 56XXXX). For each selected area code, the last four digits were randomly generated.

As well as including ex-directory numbers, RDD samples include disconnected numbers. As many non-working numbers as possible were removed before the sample was drawn.

## A.2 Participant selection

The participants were recruited by NatCen's Telephone Unit (TU) interviewers. Within each household a maximum of two people aged 19 to 64 years were eligible to take part in the survey. Where there were more than two eligible adults in a household, two were randomly selected. Females who were pregnant or breastfeeding were not eligible to take part.

The sample from the previous 2011 England Sodium Survey[10] was skewed towards women; 46% of urine collections were from men (N=250) and 54% of urine collections

were from women (N=297). To increase the number of male participants in this current survey, men were given a higher chance of being selected (see section 3.4 for further detail) and the results were weighted in order to make them representative of the adult population of England.

## A.3 Participant recruitment

Participants were recruited by NatCen's TU interviewers. Prior to starting work on the survey, TU interviewers attended a half-day training session which covered the background and purpose of the survey and their role in recruiting participants. Interviewers were also given detailed written project instructions covering the aims of the survey, methodology and fieldwork procedures.

The survey was referred to in the field as the "Diet and Health Study 2014" to minimise risk of participants changing their diets. Telephone interviewers (and nurses) were briefed not to mention salt but instead to say that we were interested in measuring nutrients such as sodium and potassium in the diet.

Telephone numbers were issued to the TU in seven batches. The TU interviewers attempted to make contact with the households of the generated telephone numbers and when successful, followed a Computer Assisted Telephone Interviewing (CATI) script to introduce the survey and check the eligibility of household members. Within each household, up to two adults, aged between 19 and 64 years, were eligible to take part in the survey. If there were three or more eligible adults, two were selected at random within the CATI programme. The TU interviewer then sought agreement for a nurse to contact the selected participant(s) in order to arrange a home visit for collection of the 24-hour urine sample(s).[32]

Each household that agreed to take part received a letter thanking them for their agreement to take part in the survey and informing them that the nurse would be in touch shortly to arrange a visit. They were also sent a leaflet outlining the survey in more detail. The details of those agreeing to be visited were passed on to the assigned nurse, who then provided further explanation about the survey and arranged a home visit appointment at a time convenient to the participant(s).

## A.4 Nurse training

A combination of nurses who had previous experience of the 24-hour urine protocol and nurses who were new to the procedure were involved in the survey. Nurses who were not experienced in administering the 24-hour urine protocol attended a half-day face-to-face briefing. The briefings covered all elements of the survey including aims, background and methodology, fieldwork procedures and documentation, the CAPI

(Computer Assisted Personal Interview) questionnaire and a practical demonstration of the equipment used to collect urine and the despatch procedures.

To ensure that all nurses followed the standard protocol, all fieldworkers, including those who did not attend a full briefing as they had previously worked on studies that included a 24-hour urine collection, such as the 2011 sodium study, were trained in the weighing and sub-sampling of the urine collection. All nurses were also given detailed written project instructions covering the aims and objectives of the survey, fieldwork procedures and methodology of the survey and their performance in the use of the spring balance to measure accurately the mass of the filled urine container was assessed.

## A.5 Nurse contact and first visit

The nurse made initial contact with the participant(s) via telephone, after which they sent a letter confirming details of the appointment date and time to the participant(s). The nurse then visited participating households at least twice. The purpose of the first nurse visit was to:

- encourage the participant(s) to take part and answer any questions they may have had
- check eligibility
- provide the participant(s) with detailed leaflets about PABA and the urine collection instructions (see appendix D)
- obtain written consent and deliver the equipment
- randomly allocate a date, via the CAPI programme, for when the participant(s) would carry out the 24-hour urine collection
- provide labelled Urine Collection Sheet
- book an appointment for the second visit (usually the day, or the day after, the 24-hour urine collection finished). The nurse completed an appointment card for the participant(s) to serve as a reminder of when the nurse would return to pick up the urine sample(s)

## A.6 Urine collection protocol

After obtaining written consent (see appendix D), the nurse instructed participants in the 24-hour urine protocol. They were asked to collect all urine during a 24-hour period starting from the second morning urine pass of the 24-hour collection day, and ending with the first urine passed the following morning. The nurse used the CAPI programme to randomly allocate a day of collection for the participant(s). If the allocated date was unsuitable for the participant, CAPI would allocate an alternative start day. Participants often preferred to do their collection on a weekend day but in order to give an even representation across the week nurses would ask participants to collect on a Monday to

Friday if a weekday was the day allocated by CAPI, explaining that diet often differs between weekdays and weekends. Women were instructed to collect their urine on non-period days.

To make the 24-hour collection, participants were provided with the following equipment:

- five litre capacity screw cap (or jerry can) container to serve as the collection container for urine
- two litre capacity screw cap container for collections made away from the home This was also used as an overflow container should the participant fill the five litre jerry can
- one litre plastic jug, kept inside a re-sealable plastic bag when not used
- funnel kept inside a re-sealable plastic bag when not used
- plastic carrier bags for transporting the equipment away from home
- an aide-memoire safety pin for the participant to pin the under- and outer- garments together during the period of the collection to remind that the specimen of urine about to be passed should be collected
- three PABA tablets to be taken to verify completeness of the 24-hour collection
- coloured stickers to distinguish equipment between two participants in the same household

Participants were instructed to pass urine into the one litre plastic jug, and then pour the sample into the five litre collection container using the funnel provided. Plastic bags were provided for participants to carry the equipment (including a smaller two litre collection container) if they were not at home for some of the collection period.

Participants were asked to take one PABA tablet on three occasions at evenly spaced intervals throughout the day of the collection. Participants were still eligible to take part if they were willing to carry out the 24-hour urine collection but did not want to (or could not) take PABA.

Before leaving the household the nurse recorded the participant details, the agreed start date of the 24-hour collection and whether the participant had consented to take PABA tablets on a Urine Collection Sheet (see appendix D). This sheet was then completed by the participant during the collection period. They were required to record the time they took the PABA tablets, the start and finish times of their urine collection, any missed urine passes, and any medication or supplements taken during the collection period.

## A.7 Second nurse visit

Visit 2 took place on the day or the day after the 24-hour urine collection was completed. The nurse collected two sub-samples from the 24-hour urine sample and

disposed of the remaining urine and equipment. To do this the nurse was supplied with the following equipment:

- Salter Brecknell ElectroSamson digital hand held scales for weighing the urine collection container (set to kg)
- two x 10ml Sarstedt Urine syringe and two extension tubes for urine monovettes for aliquoting urine
- disposable gloves, apron, disposable work mat for handling the urine
- jiffy bag and packaging material for despatching the samples
- participant-specific pre-printed labels for the filled monovettes

The container with the 24-hour collection was weighed twice by the nurse and the weight recorded on the despatch sheet and in the CAPI programme. The nurse then thoroughly mixed the urine by repeated inversion of the container before carrying out the sub-sampling procedure. Then the nurse discarded the remainder of the 24-hour collection and labelled the samples. The nurse also checked that the Urine Collection Sheet was complete (asking the participant for any missing information), paying particular notice to the start and end time, report of any missed collections or missed PABA tablets and any medications/supplements taken during the collection period. This information was entered into CAPI.

The nurse then packaged and posted the samples, Urine Collection Sheet, PABA blister pack and despatch paperwork to the laboratory at HNR.

## A.8 Weighting

There were two stages to the weighting. The first step was to generate a set of weights to correct for unequal selection probabilities of individuals within households. The second stage was to make an adjustment for different levels of non-response.

### A.8.1 Selection weights

A set of selection weights were generated to adjust the sample for selection of individuals within eligible households. Selection probabilities varied depending on the household type. Up to two adults aged 19 to 64 years were selected from each household, with male household members having a higher chance of being selected. Men in households with three or more eligible individuals were weighted by a factor of 1.56, while women within the households were given a weight of 1.00. A factor of 1.56 was chosen as it was estimated that this would increase young males in the responding sample by around 30% (as previous studies had shown that men had lower response rates). Two household members were then selected at random with probability proportional to this weight.

Selection weights are equal to the inverse of the selection probabilities:

- the selection weights for sample members in households with up to two eligible household members are equal to 1.00, since all eligible individuals were selected
- the selection probabilities for sample members in households with more than two eligible household members are equal to: 2 x (weighting factor / total
- weighting factor), where the weighting factor is 1.56 if the individual was male and 1.00 if the individual was female, and the total weighting factor is the sum of the weighting factors of all eligible household members. The selection weights are then equal to the inverse of this selection probability

### A.8.2 Calibration of the selection weights

The selection weights were then adjusted to create a final set of weights for analysis. All individuals who provided a useable sample were given an analysis weight. The analysis weights were generated using calibration methods. The aim was to reduce bias resulting from sampling error and differential non-response by sex, age and Government Office Region (GOR). An iterative procedure was used to adjust the selection weight until the distribution of the (weighted) sample matched that of the English population by age, sex and GOR. The adjustment keeps the values of the final weights as close as possible to those of the initial weights to ensure the properties of the initial weights are retained in the final calibrated weights. Population information about individuals aged 19 to 64 years and living in England was taken from the 2014 mid-year population estimates.[33] The distributions of the population and weighted and unweighted samples are shown in table 11.

***(Table 11)***

# Appendix B Urine analytical methods and quality control procedures: 2014 England urinary sodium survey (adults aged 19 to 64 years)

## B.1 Introduction

This appendix describes the methods used to measure urinary analytes and provides details of the quality control (QC) procedures for these assays for the England urinary sodium survey 2014. The quality of the laboratory analyses is assured by rigorous instrument maintenance, staff training, adherence to standard operating procedures, membership of external quality assurance schemes and good laboratory practice. The QC and assessment practices used at HNR are all standard procedures for the type of assay used and HNR is ISO certified (BS EN ISO 9001:2008).

## B.2 Analysis of urine samples

### B.2.1 Sodium and potassium

Urinary sodium and potassium were measured using ion-specific electrodes (ISEs). The sodium and potassium methods on the Siemens Dimension® Xpand clinical chemistry system with the QuikLYTE® module are *in vitro* diagnostic tests intended for the quantitative measurement of sodium and potassium in urine, which use indirect sample sensing with the QuikLYTE® Integrated Multi-sensor Technology (IMT) to develop an electrical potential proportional to the activity of each specific ion in the sample. Each urine sample is diluted automatically and then transferred automatically to the sensor, where $Na^+$ and $K^+$ ions establish equilibrium with the electrode surface. A potential is generated proportional to the logarithm of the analyte activity in the sample. The electrical potential generated by a sample is compared with the electrical potential generated by a standard solution, and the concentration of the desired ions is calculated.

Sampling, dilution, reagent delivery, mixing, processing, calculation and printing of results are automatically performed by the Dimension® system. Samples are identified with bar codes; the instrument automatically uploads barcode and concentration information to a results spreadsheet, thus eliminating transcription errors. The assay range is for sodium is 5-300mmol/L and for potassium 1-300mmol/L.

The Dimension method for sodium measurement shows good consistency but gives results which are lower than those given by other analytical methods in the external quality assessment scheme (NEQAS). Crossover studies have been performed in the HNR laboratories, comparing sodium concentrations in NDNS RP urines as measured using the Siemens Dimension with those obtained using the Roche Cobas C111 which gives results consistent with the consensus All Laboratory Trimmed Mean (ALTM) established by the UK National External Quality Assessment Scheme (UK NEQAS).[34] The ALTM is the target concentration, the best indication available of the accurate concentration. These showed that urinary sodium measured using the Siemens Dimension at the time of this survey was approximately 5.2% lower than when measured on the Roche Cobas C111. Therefore, a method-specific factor of 1.052 was applicable to the Dimension results for urinary sodium. Application of this factor resolves the negative bias shown in unchanged Siemens Dimension urine results relative to the ALTM for external quality assessment samples, (table B.2).

In this report, all urinary sodium concentrations determined using the Dimension™ were multiplied by 1.052 to calculate the concentration of sodium in urine consistent with the ALTM. Other factors were applied to data from previous surveys as required to align them to the consensus ALTM (as detailed in chapter 5, table B).

#### B.2.1.1 Quality controls (QC) for sodium and potassium

##### B.2.1.1.1 Internal QC

Internal commercially-prepared QC samples (Biorad Liquichek, Level 1 and Level 2) were run on the analyser to check for correct calibration and function before the samples were analysed, and included in every batch to determine between-assay precision. Once a bottle was opened, the remaining volume was aliquoted into smaller tubes and frozen at -20°C and then brought to room temperature and mixed thoroughly before use. The batch was accepted provided that the QC result obtained was within the manufacturer's specified range and also within the more stringent range determined within the laboratory.

**Table B.1 Internal QC for sodium and potassium**

| | Internal QCs for sodium | | Internal QCs for potassium | |
|---|---|---|---|---|
| | Level 1 | Level 2 | Level 1 | Level 2 |
| mean (mmol/L) | 77.8 | 164 | 30.3 | 69.4 |
| SD | 0.90 | 0.95 | 0.51 | 0.77 |
| % coefficient of variation | 1.16 | 0.58 | 1.67 | 1.11 |
| n | 6 | 6 | 6 | 6 |

#### B.2.1.1.2 External quality assessment (QA)

HNR is a member of UK NEQAS for urinary sodium and potassium. This scheme sends samples to all hospital and many other analytical laboratories in the UK for analysis and compares results, to improve harmonisation of results between laboratories. NEQAS samples are urine or artificial matrices spiked to simulate the range of concentrations found in human urine.

Table B.2 summarises the results obtained over seven NEQAS cycles analysed alongside samples from the survey using the HNR Siemens Dimension assay relative to those obtained by other laboratories using the same method ("method mean"), and relative to the ALTM derived from the results of all participating laboratories by combining results obtained by all methods. The ALTM is the target concentration, the best indication available of the accurate concentration.

The first column of table B.2 shows that urinary sodium in the survey as measured on the DimensionTM analyser was lower than the ALTM. The second column demonstrates that when each individual sodium result is multiplied by the method-specific factor (1.052) as defined from the cross-calibration experiments carried out in our laboratories, the bias is resolved and the overall accuracy is improved. This factor has been applied to all urinary sodium concentrations measured for the 2014 assessment of dietary sodium survey and all previous urinary sodium concentrations measured using the Dimension at HNR and included in the trend analysis.

**Table B.2 NEQAS results for urinary sodium and potassium July 2014 to Jan 2015**

| | sodium | sodium*1.052 | potassium |
|---|---|---|---|
| % bias from ALTM | -5.57 | -1.10 | -3.16 |
| SD of bias from ALTM | 3.08 | 3.16 | 1.44 |
| % bias from method mean | -2.29 | 2.87 | 3.04 |
| SD of bias from method mean | 4.08 | 4.09 | 2.03 |
| n | 21 | 21 | 21 |

### B.2.2 Measurement of urinary para-aminobenzoic acid (PABA) by high performance liquid chromatography (HPLC)

PABA metabolites in urine are hydrolysed under alkaline conditions, the solution is then neutralised and the resultant PABA concentration determined by HPLC. The HPLC method is a reverse-phase method using an internal standard to compensate for volume losses during hydrolysis. The PABA HPLC method used at HNR is based upon that previously used at the MRC Dunn Nutrition Unit which in turn was based upon the

method described by Jakobsen *et al*. (1997);[24] it was then modified at HNR to replace the acetonitrile in the mobile phase with methanol because of the unavailability of acetonitrile.

A recent methodological study (unpublished data) conducted at HNR showed that for the current analytical HPLC method, the appropriate cut-off for completeness in healthy adults is 70% (mean - 2SD) which incorporates both biological and methodological variation. The reference range for PABA excretion indicating a complete 24-hour urine collection, as assessed by this HPLC assay, was therefore established at HNR as 70 to 104% of the 240mg dose, using 50 adult volunteers (mean ±2 SD range). PABA excretion above this range could indicate either inadequate mixing of the urine before sampling or inaccurate recording of the volume, and therefore an incorrect 24-hour sodium excretion result, or ingestion of PABA in supplements which precludes assessment of completeness of urine collections by this method. Such urines were excluded from the dataset.

24-hour PABA excretion is calculated by multiplying concentration by 24-hour volume; this is then expressed as the percentage of the 240mg PABA dose recovered in the 24-hour collection ("PABA recovery") for comparison with the reference range above.

### B.2.2.1 QC for PABA HPLC assay

#### B.2.2.1.1 Internal quality control (QC)

A sample of urine containing PABA is analysed with each batch of samples in order to determine inter-assay variation. Assay results for each run are accepted if the QC results fall within limits defined within the laboratory, otherwise the batch is re-assayed.

Completeness of hydrolysis is monitored by including a sample containing PAHA (*para*-aminohippuric acid) with each batch. This is hydrolysed to PABA which is then quantitated by HPLC. 2mM PAHA theoretically yields 2mM PABA (i.e. 275mg/L). Quantitative hydrolysis of the PAHA indicates quantitative hydrolysis of urines prepared at the same time.

**Table B.3 Quality control (QC) for PABA assay during the 2014 assessment of dietary sodium survey**

| | QC1 | QC2 | PAHA |
|---|---|---|---|
| Mean (mg/L) | 76.0 | 34.2 | 273 |
| SD (mg/L) | 4.7 | 2.3 | 6.9 |
| % coefficient of variation | 6.2 | 6.6 | 2.5 |
| n | 113 | 107 | 115 |

#### B.2.2.1.2 External QA

There is no external QA scheme for PABA.

### B.2.3 Creatinine

The creatinine method, performed on the Siemens Dimension® Xpand, employs a modification of the kinetic Jaffe reaction (Larsen). In the presence of a strong base such as sodium hydroxide, picrate reacts with creatinine to form a red chromophore. The rate at which absorbance at 510nm increases due to the formation of the chromophore is directly proportional to the creatinine concentration in the sample and is measured using a bichromatic (510, 600nm) rate technique. The reagents are formulated to avoid interference from any bilirubin present in the urine.

$$\text{Creatinine + picrate} \xrightarrow{\text{NaOH}} \text{red chromophore (absorbs at 510nm)}$$

Creatinine in boric acid treated urine is stable for two to three days at room temperature and therefore posting of the urine aliquots to the laboratory was acceptable.

The assay range is 0 – 1768µmol/L. The limit of detection of the creatinine method is 4µmol/L; this represents the lowest concentration of creatinine that can be distinguished from zero (Siemens data).

Creatinine excretion is affected by muscle mass and recent meat consumption and therefore varies considerably from person to person.

#### B.2.3.1 QC for Creatinine

##### B.2.3.1.1 Internal QC

The creatinine assay on the Siemens Dimension® Xpand is controlled with Lyphochek QC 1 and 2 produced by Bio-Rad Laboratories, included in every batch to determine between-batch precision. Once a bottle is opened, the remaining volume is aliquoted into smaller tubes and frozen at -20°C. QC material is brought to room temperature and mixed thoroughly before use. The batch is accepted if the QC results fall within limits defined by the manufacturer and also within the more stringent range defined by the HNR laboratory.

**Table B.4 Internal QC for creatinine during the 2014 assessment of dietary sodium survey**

| | Internal QCs for urinary creatinine | |
|---|---|---|
| | Level 1 | Level 2 |
| mean (mmol/L) | 5.29 | 10.99 |
| SD | 0.04 | 0.22 |
| % coefficient of variation | 0.81 | 2 |
| n | 6 | 6 |

#### B.2.3.1.2 External QA

HNR subscribes to NEQAS for urinary creatinine; this scheme sends samples to all hospital and many other analytical laboratories in the UK for analysis and compares results, to improve harmonization of results between laboratories. NEQAS samples are urine or artificial matrices spiked to simulate the range of concentrations found in human urine.

Table B.5 summarises the results obtained using the HNR Siemens Dimension assay relative to those obtained by other laboratories using the Siemens Dimension kinetic Jaffe method, and relative to the ALTM derived from the results of all participating laboratories, over the period July 2014 to January 2015. The results are close to (i.e. within 1 standard deviation of) the ALTM target.

**Table B.5 NEQAS results for urinary creatinine July 2014 – January 2015**

| | creatinine |
|---|---|
| % bias from ALTM | -3.48 |
| SD of bias | 4.76 |
| n | 21 |

# Appendix C Methodology of trend analysis

## C.1 Weightings used in the trend analysis

All available urinary sodium survey data (as detailed in chapter 5, table A) was included in the trend analysis. All surveys involved a complex survey design. Some surveys had overlapping collection periods and hence were combined. To combine the surveys and account for the complex survey design sample, sampling weights from each survey were appropriately combined and rescaled using the 'combining weights' approach as set out by O'Muircheartaigh et al (2002).[28]

## C.2 Distribution of estimated salt intake

The distribution of estimated salt intake data included in the trend analysis is presented as boxplots by survey year and histograms (both original and logarithmic (natural log) scales) for men, women and sex-combined data. These plots incorporate the sampling weights used to reflect the distribution of the target population of the surveys.[35,36]

The abbreviations in figures C.1 and C.2 are as follows:

- ESS 2005/06: England 2005/06 sodium survey
- UK SS 2008 & NDNS Y1: UK 2008 sodium survey and NDNS Year 1 (2008/09)
- NDNS Y2: NDNS Year 2 (2009/10)
- NDNS Y3: NDNS Year 3 (2010/11)
- NDNS Y4 & ESS 2011: England 2011 sodium survey and NDNS Year 4 (2011/12)
- NDNS Y5: NDNS Year 5 (2012/13)
- ESS 2014: England 2014 sodium survey

**Figure C.1A: Boxplots of estimated salt intake of adults aged 19 to 64 years in England by survey (2005/06[18]- 2014) - showing median, first and third quartiles, and very high or very low observations[35]**

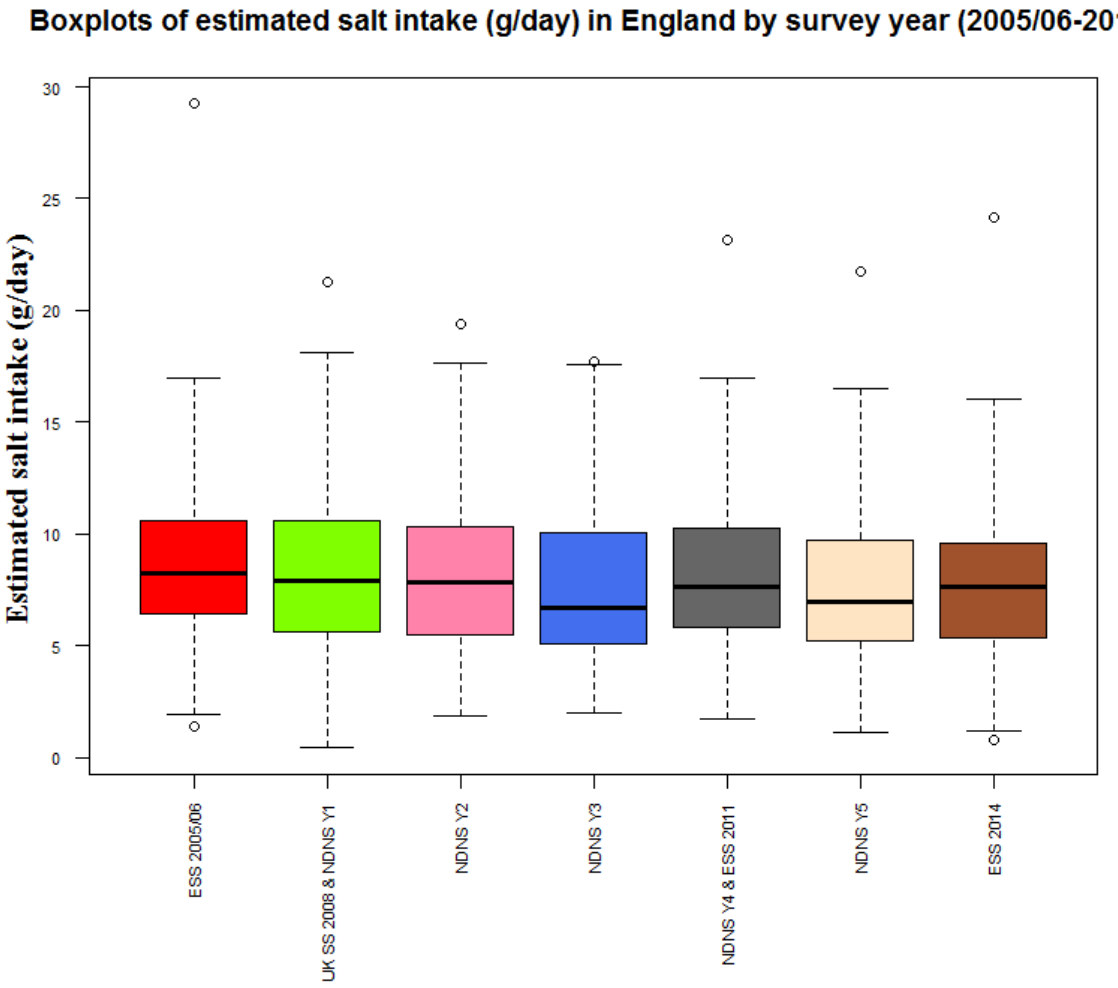


**Figure C.1B: Boxplots of estimated salt intake (in natural log scale) of adults aged 19 to 64 years in England by survey (2005/06[18]-2014) - showing median, first and third quartiles, and very high or very low observations[35]**

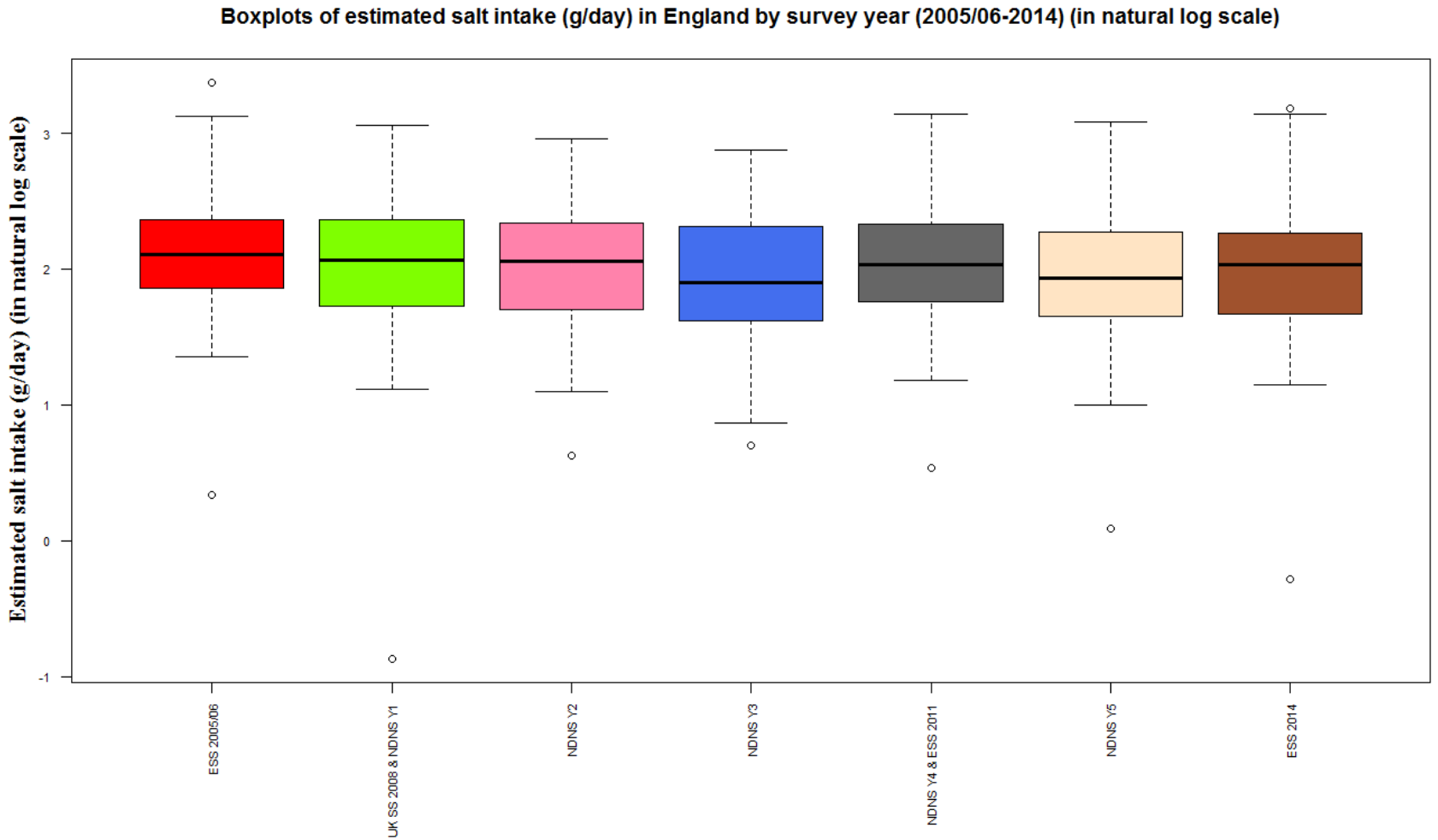


**Figure C.2A: Boxplots of estimated salt intake of adults aged 19 to 64 years in England by sex and survey year (2005/06[18]-2014) - showing median, first and third quartiles, and very high or very low observations[35]**

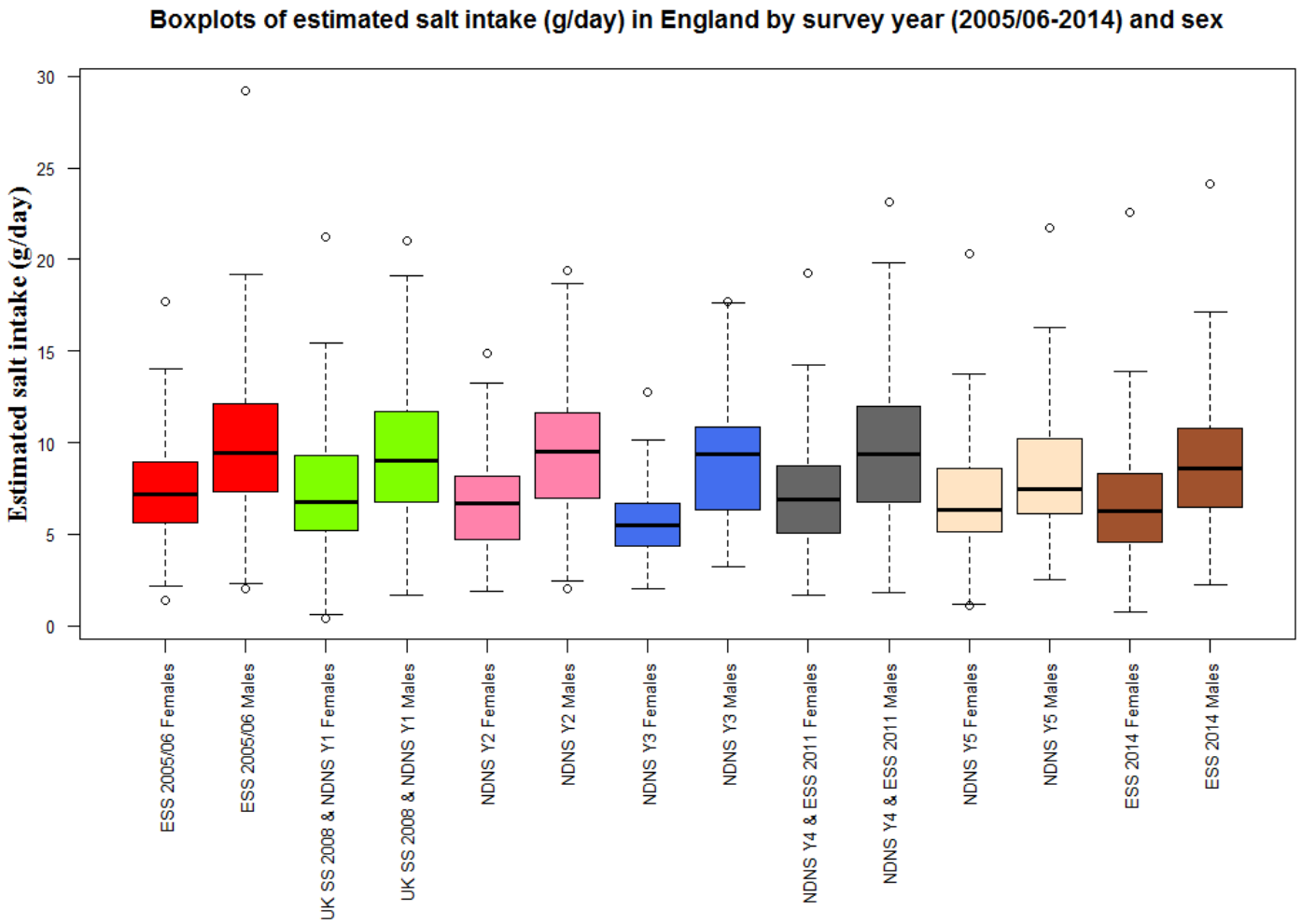
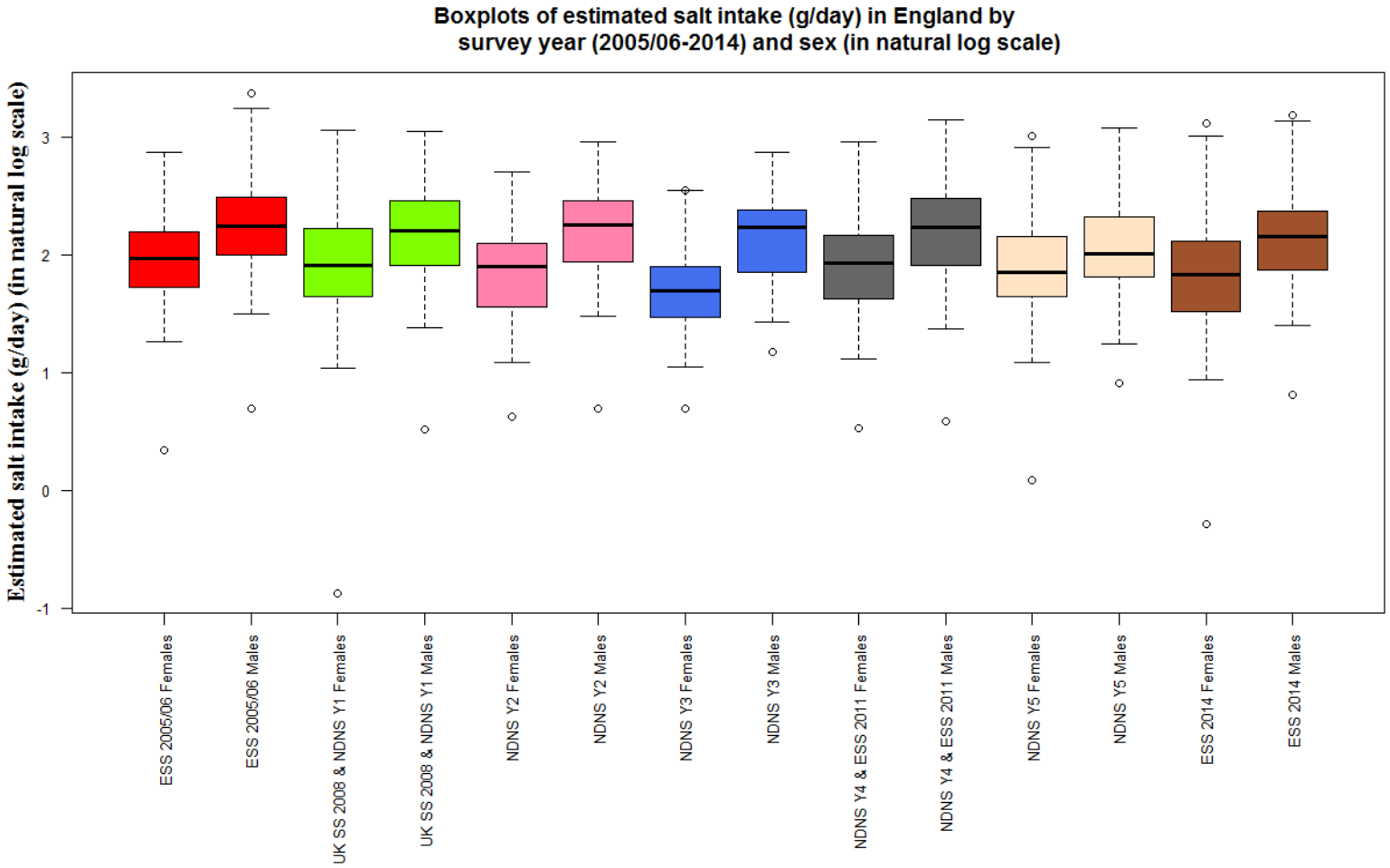
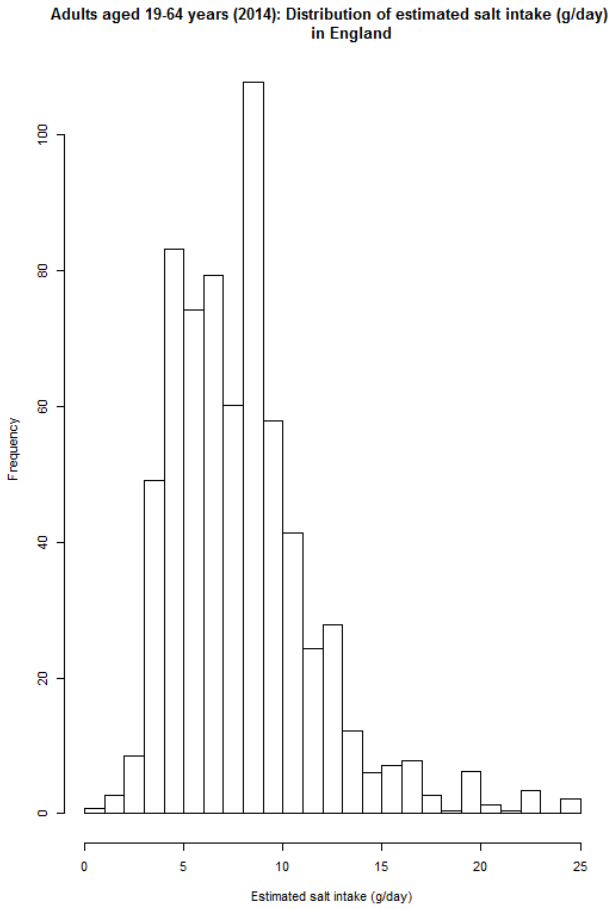


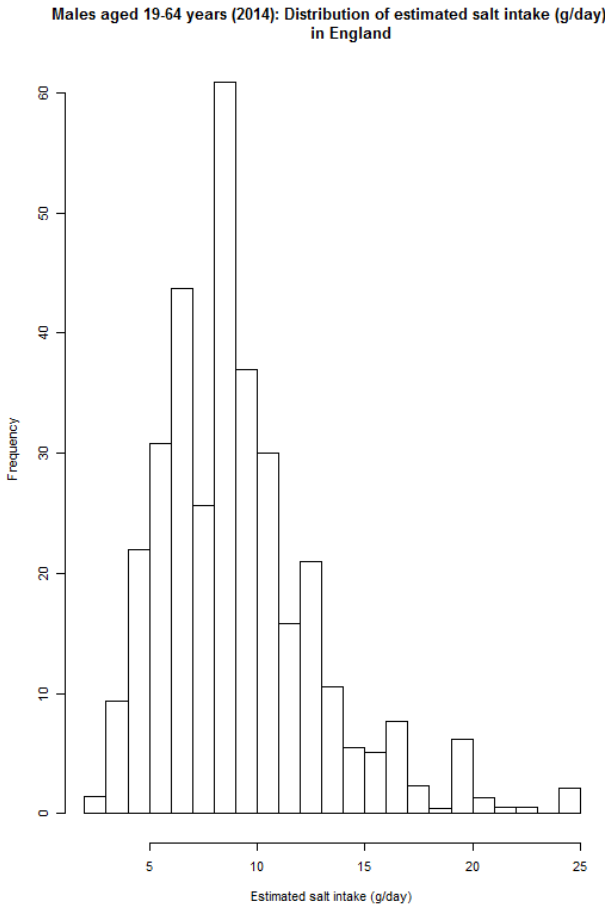
**Figure C.2B: Boxplots of estimated salt intake (in natural log scale) of adults aged 19 to 64 years in England by sex and survey year (2005/06[18]-2014) - showing median, first and third quartiles, and very high or very low observations[35]**



The asymmetrical histograms above demonstrate that the data are not normally distributed. They are plotted below as log-transformed data which produce a more symmetrical normal distribution.

**Figure C.3: Histograms of estimated salt intake of adults aged 19 to 64 years in England by sex (2014)[36]**



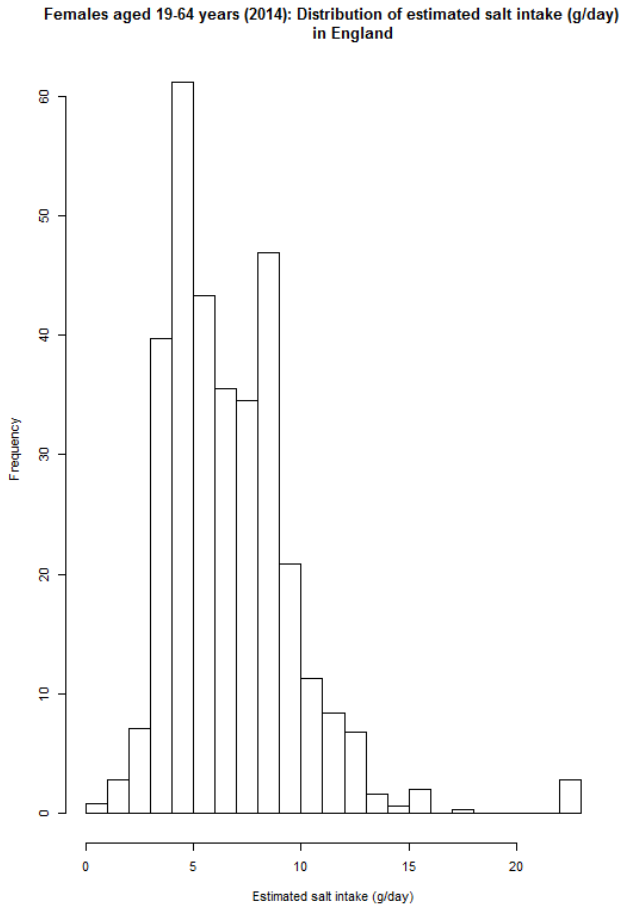
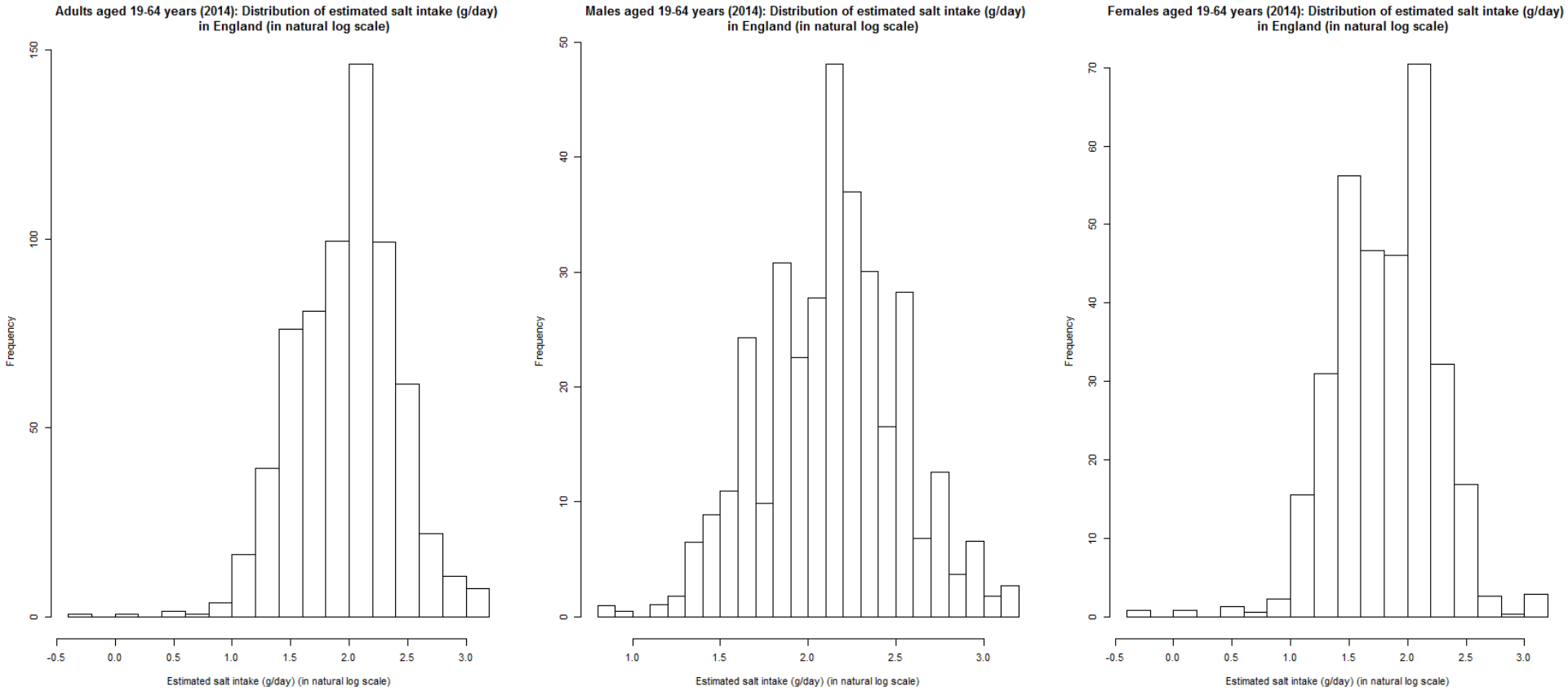



**Figure C.4: Histograms of estimated salt intake (in natural log scale) of adults aged 19 to 64 years in England by sex (2014)[36]**



# Appendix D Field documents

See separate document

# Appendix E Updated estimated salt intake data for the England 2005/06, UK 2008 and England 2011 sodium studies

Descriptive statistics and cumulative frequencies for adjusted sodium excretion and estimated salt intake data for the England 2005/06,[6] UK 2008[8] and England 2011[10] sodium surveys are presented in tables E.1-E.12. These tables differ to those presented in the published reports for those surveys as follows:

- the sodium excretion data have been multiplied by a method-specific factor (see table B of chapter 5 for more details)
- an error has been corrected in the equation used in the England 2005/06[6] and UK 2008[8] sodium surveys to adjust sodium excretion data for collections deemed marginally incomplete (see appendix F of the England 2011 sodium survey report[10] for more details)

*England 2005/06 survey (tables E.1-E.4)*

- revision to correct an error in the equation used to adjust sodium excretion data for collections deemed marginally incomplete. This correction has resulted in slightly lower estimated salt intakes than in the original published report – a difference of around 0.1-0.2g/day for mean estimated salt intake
- the adjustment factor for the analytical method for sodium used in this survey was 1.0 so this adjustment had no effect on the values

*UK 2008 survey (tables E.5-E.8)*

- revision to correct an error in the equation used to adjust sodium excretion data for collections deemed marginally incomplete in the 2008 survey
- the adjustment factor for the analytical method for sodium used in this survey was 0.952 – all 24-hour sodium excretion values have been multiplied by this factor
- these corrections have resulted in slightly lower estimated salt intakes than in the original published report – a difference of around 0.4-0.5g/day for mean estimated salt intake

*England 2011 survey (tables E.9-E.12)*

- the adjustment factor for the analytical method for sodium used in this survey was 1.052 – all 24-hour sodium excretion values have been multiplied by this factor. This correction has resulted in slightly higher estimated salt intakes than in the original published report – a difference of around 0.4-0.5g/day for mean estimated salt intake

[1] Bibbins-Domingo, K., Chertow, G. M. , Coxson, P.G., Moran, A. , Lightwood, J.M., Pletcher, M. J., and Goldman, L. (2010) *Projected Effect of Dietary Salt Reductions on Future Cardiovascular Disease*. The New England Journal of Medicine. 362:590-599.

[2] Scientific Advisory Committee on Nutrition (2003). Salt and Health. The Stationery Office. http://www.sacn.gov.uk/pdfs/sacn_salt_final.pdf (accessed 22/01/16).

[3] The recommendation is no more than 5g/day of salt intake for females and no more than 7g/day of salt intake for males.

[4] For reporting purposes, arithmetic means have been provided here. Due to the skewed nature of the data, geometric means have been calculated (by transforming the data on a natural logarithmic scale) and used for statistical analyses to evaluate relative changes in the data (e.g. between years or groups) and minimize bias from the skewed data.

[5] Between remaining neighbouring years i.e:

- 2008/09 'v' 2009/10,
- 2009/10 'v' 2010/11,
- 2010/11 'v' 2011/12,
- 2012/13 'v' 2014.

[6] An assessment of dietary sodium levels among adults (aged 19-64) in the general population, based on analysis of sodium in 24 hour urine samples. England 2005/06 (published October 2006) http://webarchive.nationalarchives.gov.uk/20101211052406/http://www.food.gov.uk/multimedia/pdfs/englandsodiumreport.pdf (accessed 22/02/16).

[7] An assessment of dietary sodium levels among adults (aged 19-64) in the general population in Wales based on analysis of dietary sodium in 24 hour urine samples. 2006 (published Feb 2007). http://webarchive.nationalarchives.gov.uk/20101211052406/http://www.food.gov.uk/multimedia/pdfs/walessodiumreport.pdf (accessed 22/02/16).

[8] An assessment of dietary sodium levels among adults (aged 19-64) in the UK general population in 2008, based on analysis of dietary sodium in 24 hour urine samples, (published June 2008); http://tna.europarchive.org/20110116113217/http://www.food.gov.uk/multimedia/pdfs/08sodiumreport.pdf (accessed 22/02/16).

[9] Assessment of dietary sodium levels in the general population. http://www.foodstandards.gov.scot/assessment-dietary-sodium-levels-general-population-scotland. Scotland 2006 Originally published March 2007, revised May 2011, (accessed 22/02/16).

[10] National Diet and Nutrition Survey - Assessment of dietary sodium in adults (aged 19 to 64 years) in England, 2011 (published June 2012) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/127916/Sodium-Survey-England-2011_Text_to-DH_FINAL1.pdf.pdf (accessed 22/02/16).

[11] A survey of 24 hour urinary sodium excretion in a representative sample of the Scottish population as a measure of salt intake. http://w ww.foodstandards.gov.scot/survey-24-hour-urinary-sodium-excretion-representative-sample-scottish-population-measure-salt. 2009 (Published April 2011). (accessed 22/02/16).

[12] British Heart Foundation (2015) BHF Headline Statistics. British Heart Foundation. http://www.bhf.org.uk/research/statistics.aspx (accessed 22/02/16).

[13] Department of Health (1994). Nutritional Aspects of Cardiovascular Disease. Report on Health and Social Subjects 46. London: The Stationery Office.

[14] Wyness, Laura and Buttriss, Judy and Stanner, Sara (2012) *Reducing the population's sodium intake: the Food Standard Agency's salt reduction programme.* Public Health Nutrition, 15 (2): 254-261.

[15] https://responsibilitydeal.dh.gov.uk/salt-reduction-onwards-and-downwards (accessed 22/02/16).

[16] http://tna.europarchive.org/20090810121540/http://salt.gov.uk/index.html (accessed 22/02/16).

[17] http://www.nhs.uk/Change4Life/Pages/change-for-life.aspx (accessed 22/02/16).

[18] It should be noted that while the 2006 England sodium survey included 448 complete 24-hour samples, three samples were excluded from the trend analyses in this report as the participants were outside the 19 to 64 years age range.

[19] https://www.gov.uk/government/statistics/national-diet-and-nutrition-survey-results-from-years-1-to-4-combined-of-the-rolling-programme-for-2008-and-2009-to-2011-and-2012 (accessed 22/02/16).

[20] A survey was also carried out in Northern Ireland in 2015; results will be published later in 2016.

[21] The sample was drawn from the 'small users' sub-file of the Postcode Address File (PAF), a computer list, prepared by the Post Office, of all the addresses (delivery points) which receive fewer than 25 articles of mail a day.

[22] Households without a landline were excluded.

[23] Bingham S and Cummings J H. The use of 4-aminobenzoic acid as a marker to validate the completeness of 24h urine collections in man. Clin Sci (Lond) 1983; 64(6):629-35.

[24] Jakobsen J, Ovesen L, Fagt S, et al. Para-aminobenzoic acid used as a marker for completeness of 24-hour urine: Assessment of control limits for a specific HPLC method. Eur J Clin Nutr 1997; 5: 514.

[25] Non-response bias occurs if those who respond to the survey (or elements of the survey) differ from those who do not respond. Data were weighted to reduce such bias.

[26] Henderson L, Irving K, Gregory J, Bates CJ, Prentice A, Perks J, Swan G, Farron M. National Diet and Nutrition Survey: adults aged 19 to 64 years. Volume 3: Vitamin and mineral intake and urinary analytes. London: TSO, 2003. http://webarchive.nationalarchives.gov.uk/20101211052406/http://www.food.gov.uk/science/dietarysurveys/ndnsdocuments/ndnspreviousurveyreports (accessed 22/02/16).

[27] Some cases from NDNS Y4 (2011/12) formed part of the England 2011 dataset, but the method used to combine the estimates takes this into account.

[28] O'Muircheartaigh, Colm and Pedlow, Steven (2002). Combining samples vs. cumulating cases: a comparison of two weighting strategies in NLSY97. ASA Proceedings of the Joint Statistical Meetings, pp. 2557-2562. American Statistical Association (Alexandria, VA).

[29] The geometric mean is calculated using log-transformed data whereas the arithmetic mean is calculated from non-transformed data. If there are no zero vales, then the geometric mean equals the exponential of the mean of the logarithmic values. Due to the skewed nature of the data, use of log-transformed data and geometric means for statistical analyses allows for the evaluation and interpretation of relative changes between groups and reducing bias that would arise from comparing arithmetic means of skewed data. The relative change can be calculated as the difference between two geometric means, divided by the larger mean and multiplied by 100%. For example, a 0.8g difference between 8.8g/day and 8.0g/day equates to a 9% change.

[30] As noted earlier data from 2000/2001 (figure 5.1) were not included in the analysis because these data would not set a suitable baseline for the target trend following the salt reduction policy introduced in 2003. There is also

the risk that these data would unduly influence the overall trend because there is no data available between 2001 and 2006.

[31] As the sampling frame excluded households without landlines, there was an element of non-coverage bias (as those without a landline had zero chance of being included).

[32] At this point the participant was only agreeing to be contacted by a nurse. Formal consent to take part in the study was obtained by the nurse.

[33] http://www.ons.gov.uk/ons/rel/pop-estimate/population-estimates-for-uk--england-and-wales--scotland-and-northern-ireland/mid-2014/index.html (accessed 22/02/16).

[34] The consensus is the All Laboratory Trimmed Mean (ALTM).

[35] Each box in the boxplots of figures C.1A-C.2B represent the first quartile (bottom of the box; 25th percentile), the median (middle of the box; 50th percentile) and the third quartile (top of the box; 75th percentile). The whiskers (bottom and top) help the identification of very high or very low observations. These are demarcated by the maximum and minimum observations or by 1.5 interquartile ranges beyond the end of the box, whichever are closer to the box. The maximum and minimum are plotted as outliers if they are beyond the ends of the whiskers, but other outlying points are not plotted.

[36] The histograms in figures C.3-C.4 illustrate the skewed distribution of salt intake in its original (or raw) form, and subsequent less skewed distributional form after a natural log-transformation of the data.