



Salt content in cheese – a major contributor to salt intake in the UK

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2014-005051
Article Type:	Research
Date Submitted by the Author:	13-Feb-2014
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Primary Subject Heading:	Public health
Secondary Subject Heading:	Public health, Health policy
Keywords:	Public health , NUTRITION & DIETETICS, PUBLIC HEALTH

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4 **Title: Salt content in cheese – a major contributor to salt intake in the UK**
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ABSTRACT

Objectives: To investigate the salt content of cheese sold in the UK supermarkets.

Study design: We carried out a cross-sectional survey in 2012, including 612 cheeses available in UK supermarkets.

Methods: The salt content (g/100g) was collected from product packaging and nutrient information panels of cheeses available in the top seven retailers.

Results: Salt content in cheese was high with a mean (\pm SD) of 1.7 ± 0.58 g/100g. There was a large variation in salt content between different types of cheeses and within the same type of cheese. On average, Halloumi (2.71 ± 0.34 g/100g) and imported blue cheese (2.71 ± 0.83 g/100g) contained the highest amounts of salt and Cottage cheese (0.55 ± 0.14 g/100g) contained the lowest amount of salt. Overall, among the 394 cheeses that had salt reduction targets, 84.5% already met their respective Department of Health 2012 salt targets.

Cheddar and Cheddar style cheese is the most popular/biggest selling type of cheese in the UK and has the highest number of products in the analysis (N=250). On average, salt level was higher in branded compared with supermarket own brand Cheddar and Cheddar style products (1.78 ± 0.13 vs 1.72 ± 0.14 g/100g, $P<0.002$). 90% of supermarket own brand products met the 2012 target for Cheddar and Cheddar style cheese compared to 73% of branded products ($P=0.001$).

Conclusions: Salt content of cheese in the UK is high. There is a wide variation in the salt content of cheeses and even within the same type of cheeses. Despite this, 84.5% of cheeses already met their respective 2012 targets. These findings demonstrate that much larger reductions in the amount of salt added to cheese could be made and more challenging targets need to be set, so that the UK can continue to lead the world in salt reduction.

Key words: cheese, reformulation, public health, food industry, salt

ARTICLE SUMMARY

Article focus:

- Populations around the world are consuming too much salt, largely as a result of the high salt content of processed foods.
- The UK is leading the world with salt reduction, having already achieved a reduction in average population salt intake of 15% from 9.5g to 8.1g from 2001 to 2011
- The UK food industry is working towards a set of voluntary salt reduction targets across more than 80 categories of food as part of the Government's Responsibility Deal
- Cheese is an important contributor of salt intake to the UK diet – this research was carried out to assess the salt content of cheeses sold in the UK supermarkets and compared them with the salt reduction targets

Key messages:

- The salt content of cheese is high and there is a wide variation in salt content between different types of cheeses and within the same type of cheese.
- Among the 394 cheeses that had salt reduction targets, 84.5% already met their respective Department of Health 2012 salt targets.
- These findings demonstrate that much larger reductions in the amount of salt added to cheese could be made and much more challenging targets need to be set, so that the UK can continue to lead the world in salt reduction and save the maximum number of lives.

Strengths and limitations of this study:

- This paper for the first time investigates the salt content of cheese products available in the UK supermarkets.
- This study was based on salt content data provided on cheese packaging labels in store; hence we relied on the accuracy of the data provided on the label. Therefore, it is assumed that the manufacturers provide accurate and up to date information in line with EU Regulations.

INTRODUCTION

There is strong evidence that a high salt intake increases blood pressure and thereby increases the risk of cardiovascular disease (i.e. strokes, heart attacks and heart failure) and kidney disease.^{1 2} A high salt intake also has other harmful effects on health, e.g. increasing the risk of stomach cancer³ osteoporosis⁴ and is indirectly linked to obesity⁵. Furthermore, it has been demonstrated that a reduction in population salt intake is one of the most cost-effective measures to improve public health.⁶ Populations around the world are consuming salt in quantities that far exceed physiological requirements.⁷ As such, the World Health Organisation (WHO) has recommended salt reduction as one of the top three priority actions to tackle the non-communicable disease crisis.⁸ At the recent World Health Assembly, it was unanimously agreed that all countries should reduce their salt intake by 30% towards a target of 5g per day, by 2025.⁹

The UK has successfully developed a voluntary salt reduction programme which is considered one of “the most successful nutrition policies in the UK since the second world war”.¹⁰ First developed by Consensus Action on Salt & Health (CASH), the strategy involves lowering salt intakes by a) reducing the salt levels of processed foods by a gradual reduction in the amount of salt added to the processed foods by 40% and b) reducing salt in cooking or at the table by 40%. In order to reduce average salt intake from the 9.5 g/d to the projected target of 6.0 g/d in adults, the Food Standards Agency (FSA) then set a series of progressively lower salt targets for over 80 categories of food,^{11 12} which have now been incorporated as part of the Government’s Public Health Responsibility Salt Reduction Pledge as the ‘2012 targets’.¹³ Other countries around the world, including Australia, United States and Canada, are adopting a similar target based approach to salt reduction⁷. To date, significant progress has been made by many food manufacturers and retailers in the UK, with salt content being reduced across the board, including by up to 50% in breakfast cereals, 45% in biscuits, 40% in pastry products, 25% in cakes and pasta sauces¹⁴ and 20% in bread.¹⁵ Furthermore, it has been reported that less salt is being added at the table by consumers.¹⁶ The average salt intake in the UK population is steadily decreasing in parallel, with intakes at 8.1g/d,¹⁷ the lowest known accurate figure of any developed country (i.e. measured by 24h urinary sodium excretion),⁷ but continues to exceed the maximum recommended limit of 6 g/d. However, this represents a 15% reduction from 2001 (9.5g).¹⁸ This reduction is estimated to be saving ≈9000 lives every year and resulting in major cost-savings to the UK economy of more than £1.5 billion per year.¹⁹

Approximately 75% of the salt consumed in the UK and other developed countries comes from processed foods, and is added by food manufacturers prior to consumer purchase.²⁰ A wide range of food products contain salt, including everyday foods such as bread, breakfast cereals, cheese and processed meat. Cheese is widely consumed. In the UK, cheese production for the 12 months ending

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3 April 2013 was 376,350 tonnes,²¹ with an average person consuming 9 kg of cheese per year.²²
4 Cheese is an important contributor of salt intake. In the UK, milk and milk products are estimated to
5 contribute about 9% of salt intake, with cheeses accounting for 44% of the salt consumption in this
6 category and the percentage has not decreased over the last 10 years.^{18 22} Furthermore, in an analysis
7 of 44,000 foods purchased by 21,000 households it was shown that more than one third of the salt
8 purchased (37%) was accounted for by 5 food categories, one of which is cheese.²³ Also, cheese also
9 contributes to salt intake in many other countries such as United States (3.8 - 11%),^{24 25} Australia (4 -
10 7%)^{26 27}, New Zealand (2.8%)²⁸ and Canada (3.2 - 5.4%).^{29 30}

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16 Cheese is heavily marketed for its high calcium content, particularly to children.³¹ But as cheese is
17 high in salt and salt intake is the main factor increasing calcium excretion in the urine, this claimed
18 benefit requires more evidence to show the effect of cheese on the net calcium balance.³² Cheese is
19 also a major contributor to fat and saturated fat intake in the UK diet, 6% and 10% respectively.²²

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23 Very little work has been conducted looking at the salt content of cheese in the UK. This research was
24 carried out to evaluate the salt content listed on the labels of cheese products sold in the UK, report
25 the variability in salt level and assess the salt levels in relation to the salt reduction targets.

26 27 28 29 30 **METHODS**

31 **Data Collection**

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33 The data was collected from product packaging and nutrient information panels. The survey was
34 designed as a comprehensive survey of all cheeses available in a snapshot in time, using one large
35 outlet per each of the 7 main retailers in the UK.

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39 For each cheese, the data collected included the company name, product name, pack weight, serving
40 size, sodium/salt per 100 grams and sodium/salt per portion. When there were missing figures, they
41 were calculated where possible, e.g. the missing sodium or salt values were converted by multiplying
42 by 2.5 (sodium to salt) or dividing by 2.5 (salt to sodium). All data was double checked after entry,
43 and a further 5% of entries were checked against the original source in a random selection of
44 products.

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50 *Inclusion/exclusion criteria:* Data were collected from each of the major UK supermarkets (Asda,
51 Sainsbury's, Tesco, Waitrose, Morrisons, The Co-operative and Marks and Spencer) to represent salt
52 levels of cheese in the UK. Data were collected for supermarket own brand and branded cheese
53 products available. However, due to resource restrictions only the data for cheddar and cheddar style
54 cheese products were collected from Morrisons. Packaged cheese products with salt or sodium
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3 information labeled were included. Cheese products with other food components such as
4 biscuits/crackers or ham were excluded, with the exception of Cottage cheese, cream cheese and
5 Wensleydale traditionally produced with fruits or vegetables. Also, cheese products that contained
6 two different types of cheese were excluded such as a product of grated mozzarella and Cheddar
7 cheese and a Torta con Gorgonzola which is blend of Mascarpone and layered Gorgonzola cheese.
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9 When two sizes were available, the standard weight was used. Cheese types with a sample size less
10 than 8 products with nutrient information on the packaging, found across the different supermarkets,
11 were excluded; Jarlsberg (4 products), Mascarpone (5), Lancashire (2), Leerdammer (4), Maasdam
12 (2), sheep, Appenzeller (1), Bavarian Smoked (1) and Ricotta (2).
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18 *Product categories:* Products were categorised into the following types of cheese: Brie, Camembert,
19 Cheddar and Cheddar style, Cheshire, Cottage cheese (plain and with pineapple, chilli, pepper, onion
20 and chives), Cream cheese (plain and with garlic, herbs, chilli, onion and chives), Double Gloucester,
21 Edam, Emmental, Feta, Goat's cheese, Blue cheese (produced in the UK), other blue cheese (not
22 produced in the UK), Gouda, Gruyere, Halloumi, Mozzarella, Parmesan (Grana Padano, Parmigiano
23 Reggiano and Perorino Romano), Red Leicester, Wensleydale (plain and with fruits), Spread and
24 other processed cheese (included singles and string cheeses). This was partially based on the criteria
25 set by the UK Department of Health for the cheese salt reduction targets. The data was also
26 categorised separately into supermarket own brand and branded and hard pressed with and without
27 salt reduction targets and blue cheese with and without salt targets. The hard pressed cheese category
28 included the following cheese types; Emmental, Wensleydale, Cheshire, hard Mozzarella
29 Gruyere, Red Leicester, Double Gloucester, Cheddar /Cheddar style, Parmesan, Gouda, Edam and
30 Halloumi. The blue cheese category included blue cheese produced in the UK and imported into the
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41 **Statistical analysis**

42 *Comparison among products:*

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44 Independent Samples T Test was used to compare the levels of salt between supermarket own brand
45 and branded products, and hard pressed with and without salt reduction targets and blue cheese with
46 and without salt targets and cheddar cheese with and without salt targets.
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52 Data are reported as mean, SD, range as indicated. Significance in all tests carried out was deemed
53 significant as being $p < 0.05$. All data were analysed using SPSS .
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3 *Salt targets:* For each cheese type, we calculated the total number and percentage of products that met
4 the Department of Health's 2012 salt target for cheese. We used Chi-square test to compare the
5 proportion of supermarket own brand and branded products for Cheddar and Cheddar style cheese
6 that met the Department of Health's 2012 salt targets.
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10 **RESULTS**

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13 A total of 612 cheese products met the inclusion criteria.
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16 **Within each type of cheese analysis**

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19 Figure 1 shows the salt level in different types of cheeses per 100g. Salt content in cheese was high
20 and there was a large variation in salt content between different types of cheeses and within the same
21 type of cheese. On average, eight out of 23 types of cheese contain more than 2g of salt per 100g;
22 Halloumi ($2.71 \pm 0.34\text{g}/100\text{g}$) and imported blue cheese ($2.71 \pm 0.83\text{g}/100\text{g}$) contained the highest
23 amounts of salt. Whereas, only three types of cheeses contained less than 1g of salt per 100g; Cottage
24 cheese (0.55g) contained the lowest amount of salt.
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31 Table 1 compares the salt levels for each type of cheese between supermarket and branded products.
32 10 out of the 23 types of cheeses had a large enough sample size to analyse further, of these, seven
33 showed a higher salt level in branded than supermarket own brand products and three showed that
34 supermarket own products had a higher salt level.
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39 Cheddar and Cheddar style cheese is the major type of cheese in the UK and has the highest number
40 of products in our analysis. The salt level in branded Cheddar and Cheddar style was 3.5% higher than
41 supermarket own brand ($p < 0.001$) (figure 2).
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44 **Comparing with the 2012 targets**

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46 We compared the salt levels in our survey with the 2012 cheese targets, as part of the Department of
47 Health's Responsibility Deal. Among 23 types of cheese, 10 types had salt targets and 13 did not have
48 targets. Overall, cheeses with targets had significantly lower levels of salt compared to those without
49 targets (Table 2). Hard pressed cheese and blue cheeses with targets also had significantly lower
50 levels of salt compared to those without targets (Table 2).
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55 Table 3 shows the cheese products meeting the Department of Health 2012 salt targets. Within each
56 cheese category, the average salt level was lower in products that met the targets compared to
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3 products that did not meet the target. Overall, among the 394 cheeses that had salt reduction targets,
4 84.5% already met their respective 2012 targets. There are three cheese types where all of the
5 products surveyed have met the 2012 targets (Table 3) and a larger proportion of cheese types are
6 close to meeting the 2012 targets. However, only Double Gloucester (60%) and other processed
7 cheeses, includes singles and strings (54.5%) had the lowest proportion of products meeting the
8 targets.
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13 Table 4 compares the supermarket and branded products that met the 2012 targets. A greater number
14 of supermarket own brand products (90%) compared to branded products (73%) met the target for
15 Cheddar and Cheddar style cheese (Figure 2).
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19 **DISCUSSION**

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21 Salt content in cheeses was found to be high and there was a large variation in salt content between
22 different types of cheeses and within the same type of cheese. In most types of cheese, branded cheese
23 had a higher salt level compared with supermarket own. Overall, among the 394 cheeses that had salt
24 reduction targets, 84.5% already met their respective 2012 targets. Furthermore, 90% of supermarket
25 own brand products met the target for Cheddar and Cheddar style cheese compared to 73% of branded
26 products.
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32 Our finding of a high salt content in cheeses sold in the UK is similar to those observed in the USA,³³
33 ³⁴ Australia,³⁵ France,³⁶ Belgium,³⁷ Canada,³⁸ New Zealand,³⁹ South Africa⁴⁰ and Brazil⁴¹ showing
34 that high levels of salt in cheese is a global challenge in countries of all levels of development. Clearly
35 the high level of salt in cheese is a global challenge in countries of all levels of development.
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40 Salt has been claimed to be important in the flavour, texture, structure, acceptability, shelf-life and
41 safety of cheese.⁴²⁻⁴⁴ But the development of cheese with lower salt content has been thriving.⁴⁵⁻⁵¹
42 Studies describing the reduction of salt in Cheddar cheese are limited, despite the dominance
43 importance of this cheese in the British diet. Those studies that exist involve reducing salt in cheddar
44 cheese⁵² or the addition of other compounds that can function in ways similar to salt (sodium
45 chloride), such as potassium chloride,^{45 53-57} magnesium chloride and calcium chloride.^{58 59}
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47 Supermarket own brand cheese have been produced with lower levels of salt, which demonstrates that
48 – despite claims to the contrary - delivering salt reduction appears not to be a technical issue related to
49 cheese manufacture. Corporate decisions about food composition are often based upon factors such as
50 common practice, taste and price, rather than health. However, evidence suggests that where salt
51 reductions are made gradually in products, no reduction in consumer preference is reported.^{60 61}
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Our paper, using the example of one of the top 10 contributors of salt to the UK diet – cheese, demonstrates that a national target based approach to reformulation can be a successful method for reducing the salt content in food. Our findings show that the cheese types with salt targets contained less salt than cheese types without salt targets, suggest that the targets have helped focus and drive the manufacturer to reduce their salt levels. There were three cheese types where all of the products surveyed have met the 2012 targets (Table 3) and a larger proportion of cheese types are close to meeting the 2012 targets. This clearly shows that the targets need to be reset to much lower levels as they are currently not sufficiently challenging. However, not all cheese types sold in the UK (Appendix 1) have a salt target, unlike in other countries such as the New York City salt reduction targets, where they have included a target for parmesan type of cheese.⁶² Also, some of UK cheese salt targets are less ambitious when compared to New York City salt reduction targets, particularly the main target in this food category, which is for hard pressed cheeses such as Cheddar cheese. In the UK the target is 1.8g/100g but in New York it is 1.58g/100g for 2012 and 1.5g/100g for 2014. Furthermore, the sales weighted mean (1.67g) is lower than the average found in our study and lower than the UK 2012 salt target. There is a bigger variation in the cheese types without targets (18-500%); setting an average target (suggest 30% reduction on the highest available products) would narrow this variability.

LIMITATIONS

Our study was based on salt content data provided on cheese packaging labels in store; hence we relied on the accuracy of the data provided on the label. Therefore, it is assumed that the manufacturers provide accurate and up to date information in line with EU Regulations. However, further study should include salt content determined through laboratory analysis to achieve a better understanding of the true salt content. When collecting data we did not capture ingredients list, this means we are unable to ascertain if salt has been replaced with any other ingredients/additives in the cheese that came out lowest. Such data should be collected in future surveys. Nevertheless, the results of this study are relevant and serve to document the salt content of cheese products sold in UK supermarkets, providing a foundation for future studies and providing information for programs and the dairy industry to potentially move toward the reformulation of these products.

CONCLUSION

This research demonstrates that salt content of cheese in the UK is high and there is a wide variation in the salt content of cheeses and even within the same type of cheeses. Despite this, 84.5% of cheeses already met their respective 2012 targets. These findings demonstrate that much larger reductions in the amount of salt added to cheese could be made and much more challenging targets need to be set.

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4 Other countries around the world now need to follow suit and set up a target based approach to
5 reducing salt content of processed foods. While the food category emphasis may differ between
6 countries, the concept of using salt targets to achieve a 'level playing field' amongst the industry is
7 universal. A product like cheese is widely consumed internationally and this research demonstrates
8 the variability in salt levels within each type and how targets can help to lower the levels of salt.
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15 **Legend for figure 1: salt levels (g/100g) in each type of cheese**

16 **Legend for figure 2: salt levels in supermarket and branded Cheddar and Cheddar-style cheese**
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Table 1 Salt levels for each type of cheese between supermarket and branded products.

Cheese type	Supermarket		Branded	
	N	Mean±SD	N	Mean±SD
Camembert	12	1.63±0.16	4	1.49±0.01
Cheddar /Cheddar style	187	1.72±0.14	63	1.78±0.13
Other processed	14	2.48±0.38	8	2.01±0.44
Cheese Spread	7	1.89±0.28	12	1.88±0.31
Cream cheese	14	0.68±0.24	5	0.86±0.13
Edam	12	2.38±0.28	4	2.01±0.28
Emmental	5	0.60±0.14	4	1.66±0.28
Feta	18	2.51±0.58	4	2.52±0.71
Goat's cheese	16	1.23±0.40	4	1.24±0.58
Mozzarella	18	0.65±0.33	4	1.16±0.35

Table 2 Salt levels in cheese with and without salt targets (g salt/100g)

Cheese type	With target		Without target		p value
	N	Mean±SD	N	Mean±SD	
All	394	1.66±0.42	218	1.78±0.79	0.04
Hard pressed	303	1.70±0.20	99	1.96±0.72	0.00
Blue cheese*	15	2.02±0.09	13	2.71±0.83	0.01

* The blue cheese category here included blue cheese produced in the UK and imported into the UK.

Table 3 cheese products meeting the Department of Health 2012 salt targets (g salt/100g)

Cheese type	2012 salt target (g/100g)	Number of products	Meeting target		
			N	percent	Mean±SD
Cheddar /Cheddar style	1.8	250	214	85.6	1.71±0.12
Other processed	2	22	12	54.5	1.93±0.17
Cheese Spread	2.25	19	19	100	1.88±0.29
Cheshire	1.8	8	8	100	1.43 n/a
Cottage cheese	0.63	16	14	87.5	0.51±0.03
Cream cheese	0.75	19	14	73.7	0.61±0.07
Double Gloucester	1.8	10	6	60.0	1.58±0.14
Red Leicester	1.80	21	18	85.7	1.69±0.11
Blue cheese	2.10	15	14	93.3	2.00±0.02
Wensleydale	1.80	14	14	100	1.13 n/a
Overall	n/a	394	333	84.5%	1.61±0.38

Table 4 Salt levels in supermarket and branded products that meet the 2012 targets

Cheese type	2012 salt target		Meeting target		
	(g/100g)	N	Supermarket (%)	N	Branded (%)
Cheddar /Cheddar style	1.8	168	90	46	73
Other processed	2.0	5	36	7	88
Cheese Spread	2.25	7	100	12	100
Cheshire	1.8	8	100	0	n/a
Cottage cheese	0.63	14	93	0	n/a
Cream cheese	0.75	12	86	2	40
Double Gloucester	1.8	6	100	0	n/a
Red Leicester	1.8	17	85	1	100
Blue cheese	2.1	12	92	2	100
Wensleydale	1.8	13	100	1	100

AUTHOR CONTRIBUTIONS

GM and KJ conceived the idea and designed research; KH conducted research; KH and FH analysed data; KH wrote the first draft of the manuscript and all authors contributed to the interpretation of the results and revision of the manuscript, and approved the final manuscript. GM had primary responsibility for final content.

Funding: None

FUNDING STATEMENT

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors

COMPETING INTERESTS

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years. KH and KJ are employees of Consensus Action on Salt & Health (CASH), a nonprofit charitable organisation. FH is a member of CASH and its international branch World Action on Salt & Health (WASH) and does not receive any financial support from CASH or WASH. MacGregor GA is Chairman of Blood Pressure UK (BPUK), Chairman of CASH and Chairman of WASH. BPUK, CASH and WASH are nonprofit charitable organisations. GM does not receive any financial support from any of these organisations.

DATA SHARING STATEMENT

Extra data is available by emailing Kawther Hashem on k.hashem@qmul.ac.uk.

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APPENDIX 1

Cheese type	Salt/100g
Cheddar and other similar "hard pressed" cheeses e.g. Cheshire, Lancashire, Wensleydale, Caerphilly, Double Gloucester, Leicester, Derby etc, including mild, medium or mature and those products where levels of fat have been reduced	1.8 (average r)
"Fresh" cheeses Excludes fromage frais as no salt is added to this product. Also excludes Brie, Camembert and other similar soft rinded cheeses. 4.2.1 Soft white cheese e.g. Philadelphia - Includes all soft white cheese, flavoured or unflavoured, including reduced fat products.	0.55 (average r) 0.75 (maximum)
Cottage cheese, plain Includes all unflavoured cottage cheese. Excludes flavoured products Cottage cheese, flavoured Includes all flavoured cottage cheese (onion and chive, pineapple)	0.55 (average r) 0.63 (maximum)
Mozzarella (used in food products) Includes mozzarella products for food industry use only. Excludes fresh mozzarella sold in retail outlets.	1.5 (average p)
Blue cheese UK produced blue cheeses only	2.1 (average p)
Processed Cheese	1.63 (average r)
Cheese spreads	2.25 (maximum)
Other processed cheese (e.g. slices, strings, etc.)	2.0 (average r)

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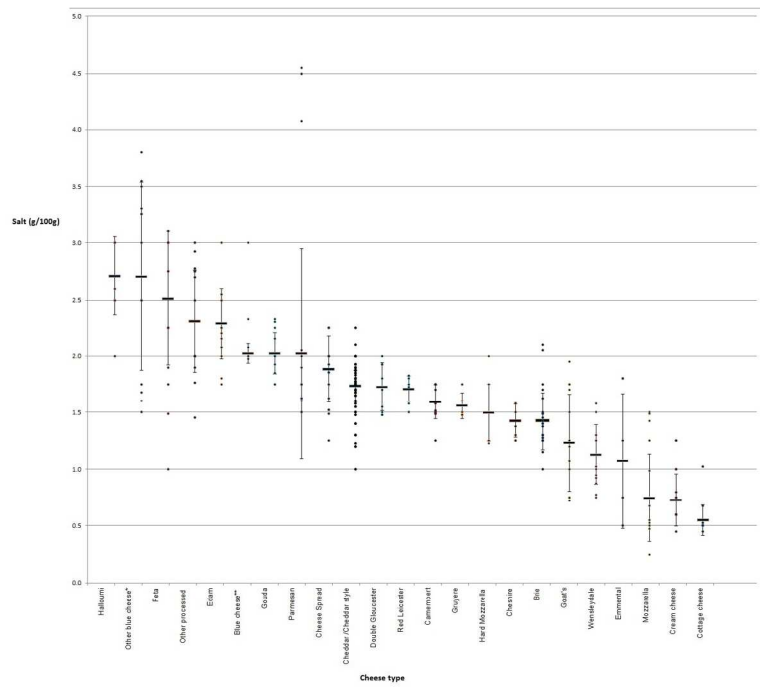


Figure 1 salt levels in each type of cheese
486x335mm (96 x 96 DPI)

view only

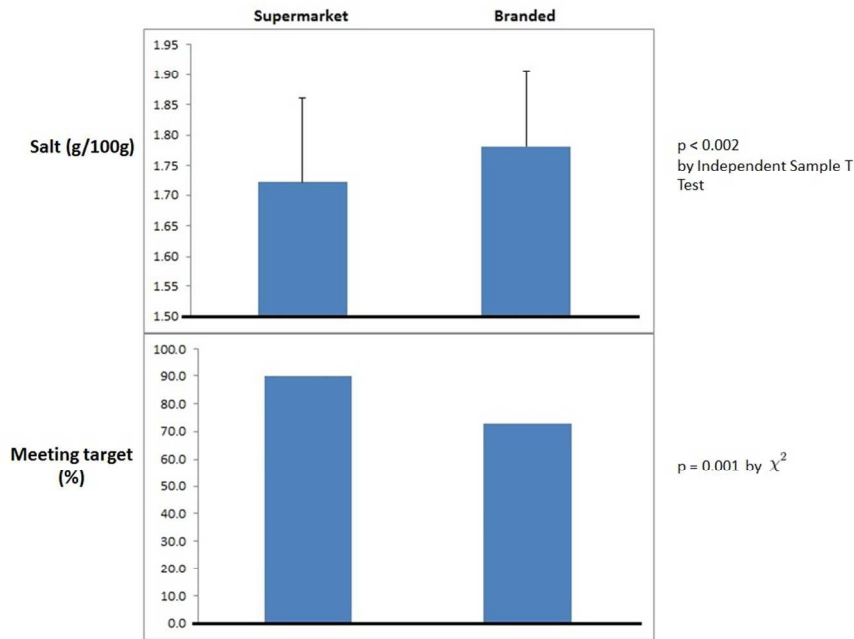


Figure 2 salt levels in supermarket and branded Cheddar and Cheddar-style cheese
318x222mm (96 x 96 DPI)

view only

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page Number Reported
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	Not applicable
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-6
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	Not applicable
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	6-7
		(b) Describe any methods used to examine subgroups and interactions	6
		(c) Explain how missing data were addressed	6
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking	Not applicable

		account of sampling strategy	
		(e) Describe any sensitivity analyses	6-7
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Not applicable
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-8
		(b) Indicate number of participants with missing data for each variable of interest	7-8
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	Not applicable
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	7-8
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Not applicable
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-8
		(b) Report category boundaries when continuous variables were categorized	Fig 1
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7-8 & Tab 1-5
Discussion			
Key results	18	Summarise key results with reference to study objectives	8-9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	9
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-9
Generalisability	21	Discuss the generalisability (external validity) of the study results	8-9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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2 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and
3 published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely
4 available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at
5 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is
6 available at www.strobe-statement.org.
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BMJ Open

Cross-sectional survey of salt content in cheese – a major contributor to salt intake in the UK

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2014-005051.R1
Article Type:	Research
Date Submitted by the Author:	29-May-2014
Complete List of Authors:	Hashem, Kawther; Queen Mary University of London, Wolfson Institute of Preventive Medicine He, Feng; Queen Mary University of London, Wolfson Institute of Preventive Medicine Jenner, Katharine; Queen Mary University of London, Wolfson Institute of Preventive Medicine MacGregor, Graham; Barts and the London School of Medicine and Dentistry, Wolfson Institute of Preventive Medicine
Primary Subject Heading:	Public health
Secondary Subject Heading:	Public health, Health policy
Keywords:	Public health , NUTRITION & DIETETICS, PUBLIC HEALTH

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4 **Title: Cross-sectional survey of salt content in cheese – a major contributor to salt intake in the**
5 **UK**
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9 Kawther M Hashem, Feng J He, Katharine Jenner, Graham A MacGregor
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ABSTRACT

Objectives: To investigate the salt (sodium chloride) content of cheese sold in the UK supermarkets.

Study design: We carried out a cross-sectional survey in 2012, including 612 cheeses available in UK supermarkets.

Methods: The salt content (g/100g) was collected from product packaging and nutrient information panels of cheeses available in the top seven retailers.

Results: Salt content in cheese was high with a mean (\pm SD) of 1.7 ± 0.58 g/100g. There was a large variation in salt content between different types of cheeses and within the same type of cheese. On average, Halloumi (2.71 ± 0.34 g/100g) and imported blue cheese (2.71 ± 0.83 g/100g) contained the highest amounts of salt and Cottage cheese (0.55 ± 0.14 g/100g) contained the lowest amount of salt. Overall, among the 394 cheeses that had salt reduction targets, 84.5% already met their respective Department of Health 2012 salt targets.

Cheddar and Cheddar style cheese is the most popular/biggest selling type of cheese in the UK and has the highest number of products in the analysis (N=250). On average, salt level was higher in branded compared with supermarket own brand Cheddar and Cheddar style products (1.78 ± 0.13 vs 1.72 ± 0.14 g/100g, $P<0.002$). 90% of supermarket own brand products met the 2012 target for Cheddar and Cheddar style cheese compared to 73% of branded products ($P=0.001$).

Conclusions: Salt content of cheese in the UK is high. There is a wide variation in the salt content of cheeses and even within the same type of cheeses. Despite this, 84.5% of cheeses already met their respective 2012 targets. These findings demonstrate that much larger reductions in the amount of salt added to cheese could be made and more challenging targets need to be pushed, so that the UK can continue to lead the world in salt reduction.

Key words: cheese, reformulation, public health, food industry, salt

ARTICLE SUMMARY

Article focus:

- Populations around the world are consuming too much salt and in most developed countries approximately 80% of salt in the diet is from processed foods.
- The UK is leading the world with salt reduction, having already achieved a reduction in average population salt intake of 15% from 9.5g to 8.1g from 2001 to 2011, with an accompanying fall in population blood pressure and cardiovascular mortality.
- The UK food industry is working towards a set of voluntary salt reduction targets across more than 80 categories of food as part of the Government's Responsibility Deal
- Cheese is an important contributor of salt intake to the UK diet – this research was carried out to assess the salt content of cheeses sold in the UK supermarkets and compared them with the salt reduction targets

Key messages:

- The salt content of cheese is high and there is a wide variation in salt content between different types of cheeses and within the same type of cheese.
- Among the 394 cheeses that had salt reduction targets, 84.5% already met their respective Department of Health 2012 salt targets.
- These findings demonstrate that much larger reductions in the amount of salt added to cheese could be made and much more challenging targets need to be pushed, so that the UK can continue to lead the world in salt reduction and save the maximum number of lives.

Strengths and limitations of this study:

- This paper for the first time investigates the salt content of cheese products available in the UK supermarkets.
- This study was based on salt content data provided on cheese packaging labels in store; hence we relied on the accuracy of the data provided on the label. Therefore, it is assumed that the manufacturers provide accurate and up to date information in line with EU Regulations.

INTRODUCTION

There is strong evidence that a high salt intake increases blood pressure and thereby increases the risk of cardiovascular disease (i.e. strokes, heart attacks and heart failure) and kidney disease.^{1 2} A high salt intake also has other harmful effects on health, e.g. increasing the risk of stomach cancer³ osteoporosis⁴ and is indirectly linked to obesity⁵. Furthermore, it has been demonstrated that a reduction in population salt intake is one of the most cost-effective measures to improve public health.⁶ Populations around the world are consuming salt in quantities that far exceed physiological requirements.⁷ As such, the World Health Organisation (WHO) has recommended salt reduction as one of the top three priority actions to tackle the non-communicable disease crisis.⁸ At the recent World Health Assembly, it was unanimously agreed that all countries should reduce their salt intake by 30% towards a target of 5g per day, by 2025.⁹

The UK has successfully developed a voluntary salt reduction programme which is considered one of “the most successful nutrition policies in the UK since the second world war”.¹⁰ First developed by Consensus Action on Salt & Health (CASH), the strategy involves lowering salt intakes by a) reducing the amount of salt added to processed foods by 40% and b) reducing salt in cooking or at the table by 40%. In order to reduce average salt intake from the 9.5 g/d to the projected target of 6.0 g/d in adults, the Food Standards Agency (FSA) then set a series of progressively lower salt targets for over 80 categories of food,^{11 12} which have now been incorporated as part of the Government’s Public Health Responsibility Salt Reduction Pledge as the ‘2012 targets’.¹³ Other countries around the world, including Australia, United States and Canada, are adopting a similar target based approach to salt reduction⁷. To date, significant progress has been made by many food manufacturers and retailers in the UK, with salt content being reduced across the board, including by up to 50% in breakfast cereals, 45% in biscuits, 40% in pastry products, 25% in cakes and pasta sauces and 20% in bread.^{14 15} Furthermore, it has been reported that less salt is being added at the table by consumers.⁶ The average salt intake in the UK population is steadily decreasing in parallel, with intakes at 8.1g/d,¹⁶ the lowest known accurate figure of any developed country (i.e. measured by 24h urinary sodium excretion),⁷ but continues to exceed the maximum recommended limit of 6 g/d. However, this represents a 15% reduction from 2001 (9.5g).¹⁷ This reduction in salt intake is accompanied by a fall in the average population blood pressure and a reduction in mortality for stroke and ischaemic heart disease¹⁸. This is estimated to be saving ≈9000 lives every year and resulting in major cost-savings to the UK economy of more than £1.5 billion per year.¹⁹

Approximately 75% of the salt consumed in the UK and other developed countries comes from processed foods, and is added by food manufacturers prior to consumer purchase.²⁰ Based on the

1
2
3 National Diet and Nutrition Survey, the top 10 contributors of salt intake in the UK are bread; bacon
4 and ham; pasta, rice, pizza and other cereals; vegetables (not raw) and vegetable dishes; chicken and
5 turkey dishes; savoury sauces, pickles, gravies and condiments; cheese; sausages; beef and veal
6 dishes; biscuits, buns, cakes, fruit pies and pastries.²¹ Cheese is one of the top 10 contributors and is
7 widely consumed. In the UK, cheese production for the 12 months ending April 2013 was 376,350
8 tonnes,²² with an average person consuming 9 kg of cheese per year.²¹ Cheese is an important
9 contributor of salt intake. In the UK, milk and milk products are estimated to contribute about 9% of
10 salt intake, with cheeses accounting for 44% of the salt consumption in this category and the
11 percentage has not decreased over the last 10 years.^{17 21} Cheese also contributes to salt intake in many
12 other countries such as United States (3.8 - 11%),^{23 24} Australia (4 - 7%)^{25 26}, New Zealand (2.8%)²⁷
13 and Canada (3.2 - 5.4%).^{28 29}

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Cheese is heavily marketed for its high calcium content, particularly to children.³⁰ But as cheese is
high in salt and salt intake is the main factor increasing calcium excretion in the urine³¹, this claimed
benefit requires more evidence to show the effect of cheese on the net calcium balance. Cheese is
also a major contributor to fat and saturated fat intake in the UK diet, 6% and 10% respectively.²¹

Very little work has been conducted looking at the salt content of cheese in the UK. This research was
carried out to evaluate the salt content listed on the labels of cheese products sold in the UK, report
the variability in salt level and assess the salt levels in relation to the Department of Health 2012 salt
reduction targets.

METHODS

Data Collection

The data was collected from product packaging and nutrient information panels. The survey was
designed as a comprehensive survey of all cheeses available in a snapshot in time, using one large
outlet per each of the 7 main retailers in the UK.

For each cheese, the data collected included the company name, product name, pack weight, serving
size, sodium/salt per 100 grams and sodium/salt per portion. When there were missing figures, they
were calculated where possible, e.g. the missing sodium or salt values were converted by multiplying
by 2.5 (sodium to salt) or dividing by 2.5 (salt to sodium). All data was double checked after entry,
and a further 5% of entries were checked against the original source in a random selection of
products.

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3 *Inclusion/exclusion criteria:* Data were collected from each of the major UK supermarkets (Asda,
4 Sainsbury's, Tesco, Waitrose, Morrisons, The Co-operative and Marks and Spencer) to represent salt
5 levels of cheese in the UK. Data were collected for supermarket own brand and branded cheese
6 products available. However, due to resource restrictions only the data for cheddar and cheddar style
7 cheese products were collected from Morrisons. Packaged cheese products with salt or sodium
8 information labeled were included. Cheese products with other food components such as
9 biscuits/crackers or ham were excluded, with the exception of Cottage cheese, cream cheese and
10 Wensleydale traditionally produced with fruits or vegetables. Also, cheese products that contained
11 two different types of cheese were excluded such as a product of grated mozzarella and Cheddar
12 cheese and a Torta con Gorgonzola which is blend of Mascarpone and layered Gorgonzola cheese.
13 When two sizes were available, the standard weight was used. Cheese types with a sample size less
14 than 8 products with nutrient information on the packaging, found across the different supermarkets,
15 were excluded; Jarlsberg (4 products), Mascarpone (5), Lancashire (2), Leerdammer (4), Maasdam
16 (2), sheep, Appenzeller (1), Bavarian Smoked (1) and Ricotta (2).
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26 *Product categories:* Products were categorised into the following types of cheese: Brie, Camembert,
27 Cheddar and Cheddar style, Cheshire, Cottage cheese (plain and with pineapple, chilli, pepper, onion
28 and chives), Cream cheese (plain and with garlic, herbs, chilli, onion and chives), Double Gloucester,
29 Edam, Emmental, Feta, Goat's cheese, Blue cheese (produced in the UK), other blue cheese (not
30 produced in the UK), Gouda, Gruyere, Halloumi, Mozzarella, Parmesan (Grana Padano, Parmigiano
31 Reggiano and Perorino Romano), Red Leicester, Wensleydale (plain and with fruits), Spread and
32 other processed cheese (included singles and string cheeses). This was partially based on the criteria
33 set by the UK Department of Health for the cheese salt reduction targets. The data was also
34 categorised separately into supermarket own brand and branded and hard pressed with and without
35 salt reduction targets and blue cheese with and without salt targets. The hard pressed cheese category
36 included the following cheese types; Emmental, Wensleydale, Cheshire, hard Mozzarella
37 Gruyere, Red Leicester, Double Gloucester, Cheddar /Cheddar style, Parmesan, Gouda, Edam and
38 Halloumi. The blue cheese category included blue cheese produced in the UK and imported into the
39 UK.
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49 **Statistical analysis**

50 *Comparison among products:*

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53 Independent Samples T Test was used to compare the levels of salt between supermarket own brand
54 and branded products, and hard pressed with and without salt reduction targets and blue cheese with
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3 and without salt targets and cheddar cheese with and without salt targets.
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6 Data are reported as mean, SD, range as indicated. Significance in all tests carried out was deemed
7 significant as being $p < 0.05$. All data were analysed using SPSS .
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11 *Salt targets:* For each cheese type, we calculated the total number and percentage of products that met
12 the Department of Health's 2012 salt target for cheese. We used Chi-square test to compare the
13 proportion of supermarket own brand and branded products for Cheddar and Cheddar style cheese
14 that met the Department of Health's 2012 salt targets.
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17 18 **RESULTS**

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20 A total of 612 cheese products met the inclusion criteria and were included in our analysis.
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23 24 **Within each type of cheese analysis**

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27 Figure 1 shows the salt level in different types of cheeses per 100g. Salt content in cheese was high
28 and there was a large variation in salt content between different types of cheeses and within the same
29 type of cheese. On average, eight out of 23 types of cheese contain more than 2g of salt per 100g;
30 Halloumi ($2.71 \pm 0.34\text{g}/100\text{g}$) and imported blue cheese ($2.71 \pm 0.83\text{g}/100\text{g}$) contained the highest
31 amounts of salt. Whereas, only three types of cheeses contained less than 1g of salt per 100g; Cottage
32 cheese (0.55g) contained the lowest amount of salt.
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38 Table 1 compares the salt levels for each type of cheese between supermarket and branded products.
39 10 out of the 23 types of cheeses had a large enough sample size to analyse further, of these, seven
40 showed a higher salt level in branded than supermarket own brand products and three showed that
41 supermarket own products had a higher salt level.
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46 Cheddar and Cheddar style cheese is the major type of cheese in the UK and has the highest number
47 of products in our analysis. The salt level in branded Cheddar and Cheddar style was 3.5% higher than
48 supermarket own brand ($p < 0.001$) (figure 2).
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51 52 **Comparing with the 2012 targets**

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54 Among 23 types of cheese, 10 types had salt targets and 13 did not have targets. Overall, cheeses with
55 targets had significantly lower levels of salt compared to those without targets (Table 2). Hard pressed
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3 cheese and blue cheeses with targets also had significantly lower levels of salt compared to those
4 without targets (Table 2).
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8 Table 3 shows the cheese products meeting the Department of Health 2012 salt targets. Within each
9 cheese category, the average salt level was lower in products that met the targets compared to
10 products that did not meet the target. Overall, among the 394 cheeses that had salt reduction targets,
11 84.5% already met their respective 2012 targets. There are three cheese types where all of the
12 products surveyed have met the 2012 targets (Table 3) and a larger proportion of cheese types are
13 close to meeting the 2012 targets. However, only Double Gloucester (60%) and other processed
14 cheeses, includes singles and strings (54.5%) had the lowest proportion of products meeting the
15 targets.
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21 Table 4 compares the supermarket and branded products that met the 2012 targets. A greater number
22 of supermarket own brand products (90%) compared to branded products (73%) met the target for
23 Cheddar and Cheddar style cheese (Figure 2).
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27 DISCUSSION

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29 Salt content in cheeses was found to be high and there was a large variation in salt content between
30 different types of cheeses and within the same type of cheese. In most types of cheese, branded cheese
31 had a higher salt level compared with supermarket own. Overall, among the 394 cheeses that had salt
32 reduction targets, 84.5% already met their respective 2012 targets. Furthermore, 90% of supermarket
33 own brand products met the target for Cheddar and Cheddar style cheese compared to 73% of branded
34 products.
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40 Our finding of a high salt content in cheeses sold in the UK is similar to those observed in the USA,³²
41 ³³ Australia,³⁴ France,³⁵ Belgium,³⁶ Canada,³⁷ New Zealand,³⁸ South Africa³⁹ and Brazil⁴⁰ showing
42 that high levels of salt in cheese is a global challenge.
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46 Salt has been claimed to be important in the flavour, texture, structure, acceptability, shelf-life and
47 safety of cheese.⁴¹⁻⁴³ But the development of cheese with lower salt content has been thriving.⁴⁴⁻⁵⁰
48 Studies describing the reduction of salt in Cheddar cheese are limited, despite the importance of this
49 cheese in the British diet. Those studies that exist involve reducing salt in cheddar cheese⁵¹ or the
50 addition of other compounds that can function in ways similar to salt (sodium chloride), such as
51 potassium chloride,^{44 52-56} magnesium chloride and calcium chloride.^{57 58}
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3 Supermarket own brand cheese have been produced with lower levels of salt, which demonstrates that
4 – despite claims to the contrary - delivering salt reduction appears not to be a technical issue related to
5 cheese manufacture. Corporate decisions about food composition are often based upon factors such as
6 common practice, taste and price, rather than health. However, evidence suggests that where salt
7 reductions are made gradually in products, no change in consumer preference is reported.^{59 60}
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12 Our paper, using the example of one of the top 10 contributors of salt to the UK diet – cheese,
13 demonstrates that a national target based approach to reformulation can be a successful method for
14 reducing the salt content in food. Our findings show that the cheese types with salt targets contained
15 less salt than cheese types without salt targets, suggest that the targets have helped focus and drive the
16 manufacturer to reduce their salt levels. There were three cheese types where all of the products
17 surveyed have met the 2012 targets (Table 3) and a large proportion of cheese types are close to
18 meeting the 2012 targets. Therefore the Department of Health has recently reset the targets to lower
19 levels. However, not all cheese types sold in the UK (Appendix 1) have a salt target, unlike in other
20 countries such as the New York City salt reduction targets, where they have included a target for
21 parmesan type of cheese.⁶¹ Also, some of UK cheese salt targets are less ambitious when compared
22 to New York City salt reduction targets, particularly the main target in this food category, which is for
23 hard pressed cheeses such as Cheddar cheese. In the UK the target is 1.8g/100g but in New York it is
24 1.58g/100g for 2012 and 1.5g/100g for 2014. Furthermore, the sales weighted mean (1.67g) is lower
25 than the average found in our study and lower than the UK 2012 salt target. There is a bigger variation
26 in the cheese types without targets (18-500%); setting an average target (suggest 30% reduction on the
27 highest available products) would narrow this variability.
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38 **LIMITATIONS**

39 Our study was based on salt content data provided on cheese packaging labels in store; hence we
40 relied on the accuracy of the data provided on the label. Therefore, it is assumed that the
41 manufacturers provide accurate and up to date information in line with EU Regulations. However,
42 further study should include salt content determined through laboratory analysis to achieve a better
43 understanding of the true salt content. When collecting data we did not capture ingredients list, this
44 means we are unable to ascertain if salt has been replaced with any other ingredients/additives in the
45 cheese that came out lowest. Such data should be collected in future surveys. Additionally the salt
46 content of cheese is likely to differ across countries; our data is primarily relevant to the UK.
47
48 Nevertheless, the results of this study are relevant and serve to document the salt content of cheese
49 products sold in UK supermarkets, providing a foundation for future studies and providing
50 information for programs and the dairy industry to potentially move toward the reformulation of these
51 products.
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CONCLUSION

This research demonstrates that salt content of cheese in the UK is high and there is a wide variation in the salt content of cheeses and even within the same type of cheeses. Despite this, 84.5% of cheeses already met their respective 2012 targets. These findings demonstrate that much larger reductions in the amount of salt added to cheese could be made and much more challenging targets need to be set.

Other countries around the world now need to follow suit and develop a target based approach to reducing salt content of processed foods. While the food category emphasis may differ between countries, the concept of using salt targets to achieve a 'level playing field' amongst the industry is universal. A product like cheese is widely consumed internationally and this research demonstrates the variability in salt levels within each type and how targets can help to lower the levels of salt.

AUTHOR CONTRIBUTIONS

GM and KJ conceived the idea and designed research; KH conducted research; KH and FH analysed data; KH wrote the first draft of the manuscript and all authors contributed to the interpretation of the results and revision of the manuscript, and approved the final manuscript. GM had primary responsibility for final content.

Funding: None

FUNDING STATEMENT

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors

COMPETING INTERESTS

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years. KH and KJ are employees of Consensus Action on Salt & Health (CASH), a nonprofit charitable organisation. FH is a member of CASH and its international branch World Action on Salt & Health (WASH) and does not receive any financial support from CASH or WASH. MacGregor GA is Chairman of Blood Pressure UK (BPUK), Chairman of CASH and Chairman of WASH. BPUK, CASH and WASH are nonprofit charitable organisations. GM does not receive any financial support from any of these organisations.

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4 **DATA SHARING STATEMENT**
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7 Extra data is available by emailing Kawther Hashem on k.hashem@qmul.ac.uk.
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11 **Legend for figure 1: salt levels (g/100g) in each type of cheese**

12 **Legend for figure 2: salt levels (mean \pm SD) and percentage meeting salt targets in supermarket**
13 **and branded Cheddar and Cheddar-style cheese**
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Table 1 Salt levels (g/100g) for each type of cheese between supermarket and branded products.

Cheese type	Supermarket		Branded	
	N	Mean±SD	N	Mean±SD
Camembert	12	1.63±0.16	4	1.49±0.01
Cheddar /Cheddar style	187	1.72±0.14	63	1.78±0.13
Other processed	14	2.48±0.38	8	2.01±0.44
Cheese Spread	7	1.89±0.28	12	1.88±0.31
Cream cheese	14	0.68±0.24	5	0.86±0.13
Edam	12	2.38±0.28	4	2.01±0.28
Emmental	5	0.60±0.14	4	1.66±0.28
Feta	18	2.51±0.58	4	2.52±0.71
Goat's cheese	16	1.23±0.40	4	1.24±0.58
Mozzarella	18	0.65±0.33	4	1.16±0.35

Table 2 Salt levels in cheese with and without salt targets (g/100g)

Cheese type	With target		Without target		p value
	N	Mean±SD	N	Mean±SD	
All	394	1.66±0.42	218	1.78±0.79	0.04
Hard pressed	303	1.70±0.20	99	1.96±0.72	0.00
Blue cheese*	15	2.02±0.09	13	2.71±0.83	0.01

* The blue cheese category here included blue cheese produced in the UK and imported into the UK.

Table 3 cheese products meeting the Department of Health 2012 salt targets

Cheese type	2012 salt target (g/100g)	Number of products	Meeting target		
			N	percent	Mean±SD (g/100g)
Cheddar /Cheddar style	1.8	250	214	85.6	1.71±0.12
Other processed	2	22	12	54.5	1.93±0.17
Cheese Spread	2.25	19	19	100	1.88±0.29
Cheshire	1.8	8	8	100	1.43 n/a
Cottage cheese	0.63	16	14	87.5	0.51±0.03
Cream cheese	0.75	19	14	73.7	0.61±0.07
Double Gloucester	1.8	10	6	60.0	1.58±0.14
Red Leicester	1.80	21	18	85.7	1.69±0.11
Blue cheese	2.10	15	14	93.3	2.00±0.02
Wensleydale	1.80	14	14	100	1.13 n/a
Overall	n/a	394	333	84.5%	1.61±0.38

Table 4 Percentage of supermarket and branded products that meet the 2012 targets

Cheese type	2012 salt target (g/100g)	Meeting target			
		N	Supermarket (%)	N	Branded (%)
Cheddar /Cheddar style	1.8	168	90	46	73
Other processed	2.0	5	36	7	88
Cheese Spread	2.25	7	100	12	100
Cheshire	1.8	8	100	0	n/a
Cottage cheese	0.63	14	93	0	n/a
Cream cheese	0.75	12	86	2	40
Double Gloucester	1.8	6	100	0	n/a
Red Leicester	1.8	17	85	1	100
Blue cheese	2.1	12	92	2	100
Wensleydale	1.8	13	100	1	100

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4 **Title: Cross-sectional survey of salt content in cheese – a major contributor to salt intake in the**
5 **UK**
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ABSTRACT

Objectives: To investigate the salt (sodium chloride) content of cheese sold in the UK supermarkets.

Study design: We carried out a cross-sectional survey in 2012, including 612 cheeses available in UK supermarkets.

Methods: The salt content (g/100g) was collected from product packaging and nutrient information panels of cheeses available in the top seven retailers.

Results: Salt content in cheese was high with a mean (\pm SD) of 1.7 ± 0.58 g/100g. There was a large variation in salt content between different types of cheeses and within the same type of cheese. On average, Halloumi (2.71 ± 0.34 g/100g) and imported blue cheese (2.71 ± 0.83 g/100g) contained the highest amounts of salt and Cottage cheese (0.55 ± 0.14 g/100g) contained the lowest amount of salt. Overall, among the 394 cheeses that had salt reduction targets, 84.5% already met their respective Department of Health 2012 salt targets.

Cheddar and Cheddar style cheese is the most popular/biggest selling type of cheese in the UK and has the highest number of products in the analysis (N=250). On average, salt level was higher in branded compared with supermarket own brand Cheddar and Cheddar style products (1.78 ± 0.13 vs 1.72 ± 0.14 g/100g, $P<0.002$). 90% of supermarket own brand products met the 2012 target for Cheddar and Cheddar style cheese compared to 73% of branded products ($P=0.001$).

Conclusions: Salt content of cheese in the UK is high. There is a wide variation in the salt content of cheeses and even within the same type of cheeses. Despite this, 84.5% of cheeses already met their respective 2012 targets. These findings demonstrate that much larger reductions in the amount of salt added to cheese could be made and more challenging targets need to be pushed, so that the UK can continue to lead the world in salt reduction.

Key words: cheese, reformulation, public health, food industry, salt

ARTICLE SUMMARY

Article focus:

- Populations around the world are consuming too much salt and in most developed countries approximately 80% of salt in the diet is from processed foods.
- The UK is leading the world with salt reduction, having already achieved a reduction in average population salt intake of 15% from 9.5g to 8.1g from 2001 to 2011, with an accompanying fall in population blood pressure and cardiovascular mortality.
- The UK food industry is working towards a set of voluntary salt reduction targets across more than 80 categories of food as part of the Government's Responsibility Deal
- Cheese is an important contributor of salt intake to the UK diet – this research was carried out to assess the salt content of cheeses sold in the UK supermarkets and compared them with the salt reduction targets

Key messages:

- The salt content of cheese is high and there is a wide variation in salt content between different types of cheeses and within the same type of cheese.
- Among the 394 cheeses that had salt reduction targets, 84.5% already met their respective Department of Health 2012 salt targets.
- These findings demonstrate that much larger reductions in the amount of salt added to cheese could be made and much more challenging targets need to be pushed, so that the UK can continue to lead the world in salt reduction and save the maximum number of lives.

Strengths and limitations of this study:

- This paper for the first time investigates the salt content of cheese products available in the UK supermarkets.
- This study was based on salt content data provided on cheese packaging labels in store; hence we relied on the accuracy of the data provided on the label. Therefore, it is assumed that the manufacturers provide accurate and up to date information in line with EU Regulations.

INTRODUCTION

There is strong evidence that a high salt intake increases blood pressure and thereby increases the risk of cardiovascular disease (i.e. strokes, heart attacks and heart failure) and kidney disease.^{1 2} A high salt intake also has other harmful effects on health, e.g. increasing the risk of stomach cancer³ osteoporosis⁴ and is indirectly linked to obesity⁵. Furthermore, it has been demonstrated that a reduction in population salt intake is one of the most cost-effective measures to improve public health.⁶ Populations around the world are consuming salt in quantities that far exceed physiological requirements.⁷ As such, the World Health Organisation (WHO) has recommended salt reduction as one of the top three priority actions to tackle the non-communicable disease crisis.⁸ At the recent World Health Assembly, it was unanimously agreed that all countries should reduce their salt intake by 30% towards a target of 5g per day, by 2025.⁹

The UK has successfully developed a voluntary salt reduction programme which is considered one of “the most successful nutrition policies in the UK since the second world war”.¹⁰ First developed by Consensus Action on Salt & Health (CASH), the strategy involves lowering salt intakes by a) reducing the amount of salt added to processed foods by 40% and b) reducing salt in cooking or at the table by 40%. In order to reduce average salt intake from the 9.5 g/d to the projected target of 6.0 g/d in adults, the Food Standards Agency (FSA) then set a series of progressively lower salt targets for over 80 categories of food,^{11 12} which have now been incorporated as part of the Government’s Public Health Responsibility Salt Reduction Pledge as the ‘2012 targets’.¹³ Other countries around the world, including Australia, United States and Canada, are adopting a similar target based approach to salt reduction⁷. To date, significant progress has been made by many food manufacturers and retailers in the UK, with salt content being reduced across the board, including by up to 50% in breakfast cereals, 45% in biscuits, 40% in pastry products, 25% in cakes and pasta sauces and 20% in bread.^{14 15} Furthermore, it has been reported that less salt is being added at the table by consumers.⁶ The average salt intake in the UK population is steadily decreasing in parallel, with intakes at 8.1g/d,¹⁶ the lowest known accurate figure of any developed country (i.e. measured by 24h urinary sodium excretion),⁷ but continues to exceed the maximum recommended limit of 6 g/d. However, this represents a 15% reduction from 2001 (9.5g).¹⁷ This reduction in salt intake is accompanied by a fall in the average population blood pressure and a reduction in mortality for stroke and ischaemic heart disease¹⁸. This is estimated to be saving ≈9000 lives every year and resulting in major cost-savings to the UK economy of more than £1.5 billion per year.¹⁹

Approximately 75% of the salt consumed in the UK and other developed countries comes from processed foods, and is added by food manufacturers prior to consumer purchase.²⁰ **Based on the**

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3 National Diet and Nutrition Survey, the top 10 contributors of salt intake in the UK are bread; bacon
4 and ham; pasta, rice, pizza and other cereals; vegetables (not raw) and vegetable dishes; chicken and
5 turkey dishes; savoury sauces, pickles, gravies and condiments; cheese; sausages; beef and veal
6 dishes; biscuits, buns, cakes, fruit pies and pastries²¹. Cheese is one of the top 10 contributors and is
7 widely consumed. In the UK, cheese production for the 12 months ending April 2013 was 376,350
8 tonnes,²² with an average person consuming 9 kg of cheese per year.²¹ Cheese is an important
9 contributor of salt intake. In the UK, milk and milk products are estimated to contribute about 9% of
10 salt intake, with cheeses accounting for 44% of the salt consumption in this category and the
11 percentage has not decreased over the last 10 years.^{17 21} Cheese also contributes to salt intake in many
12 other countries such as United States (3.8 - 11%),^{23 24} Australia (4 - 7%)^{25 26}, New Zealand (2.8%)²⁷
13 and Canada (3.2 - 5.4%).^{28 29}

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Cheese is heavily marketed for its high calcium content, particularly to children.³⁰ But as cheese is
high in salt and salt intake is the main factor increasing calcium excretion in the urine³¹, this claimed
benefit requires more evidence to show the effect of cheese on the net calcium balance. Cheese is
also a major contributor to fat and saturated fat intake in the UK diet, 6% and 10% respectively.²¹

Very little work has been conducted looking at the salt content of cheese in the UK. This research was
carried out to evaluate the salt content listed on the labels of cheese products sold in the UK, report
the variability in salt level and assess the salt levels in relation to the Department of Health 2012 salt
reduction targets.

METHODS

Data Collection

The data was collected from product packaging and nutrient information panels. The survey was
designed as a comprehensive survey of all cheeses available in a snapshot in time, using one large
outlet per each of the 7 main retailers in the UK.

For each cheese, the data collected included the company name, product name, pack weight, serving
size, sodium/salt per 100 grams and sodium/salt per portion. When there were missing figures, they
were calculated where possible, e.g. the missing sodium or salt values were converted by multiplying
by 2.5 (sodium to salt) or dividing by 2.5 (salt to sodium). All data was double checked after entry,
and a further 5% of entries were checked against the original source in a random selection of
products.

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3 *Inclusion/exclusion criteria:* Data were collected from each of the major UK supermarkets (Asda,
4 Sainsbury's, Tesco, Waitrose, Morrisons, The Co-operative and Marks and Spencer) to represent salt
5 levels of cheese in the UK. Data were collected for supermarket own brand and branded cheese
6 products available. However, due to resource restrictions only the data for cheddar and cheddar style
7 cheese products were collected from Morrisons. Packaged cheese products with salt or sodium
8 information labeled were included. Cheese products with other food components such as
9 biscuits/crackers or ham were excluded, with the exception of Cottage cheese, cream cheese and
10 Wensleydale traditionally produced with fruits or vegetables. Also, cheese products that contained
11 two different types of cheese were excluded such as a product of grated mozzarella and Cheddar
12 cheese and a Torta con Gorgonzola which is blend of Mascarpone and layered Gorgonzola cheese.
13 When two sizes were available, the standard weight was used. Cheese types with a sample size less
14 than 8 products with nutrient information on the packaging, found across the different supermarkets,
15 were excluded; Jarlsberg (4 products), Mascarpone (5), Lancashire (2), Leerdammer (4), Maasdam
16 (2), sheep, Appenzeller (1), Bavarian Smoked (1) and Ricotta (2).
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26 *Product categories:* Products were categorised into the following types of cheese: Brie, Camembert,
27 Cheddar and Cheddar style, Cheshire, Cottage cheese (plain and with pineapple, chilli, pepper, onion
28 and chives), Cream cheese (plain and with garlic, herbs, chilli, onion and chives), Double Gloucester,
29 Edam, Emmental, Feta, Goat's cheese, Blue cheese (produced in the UK), other blue cheese (not
30 produced in the UK), Gouda, Gruyere, Halloumi, Mozzarella, Parmesan (Grana Padano, Parmigiano
31 Reggiano and Perorino Romano), Red Leicester, Wensleydale (plain and with fruits), Spread and
32 other processed cheese (included singles and string cheeses). This was partially based on the criteria
33 set by the UK Department of Health for the cheese salt reduction targets. The data was also
34 categorised separately into supermarket own brand and branded and hard pressed with and without
35 salt reduction targets and blue cheese with and without salt targets. The hard pressed cheese category
36 included the following cheese types; Emmental, Wensleydale, Cheshire, hard Mozzarella
37 Gruyere, Red Leicester, Double Gloucester, Cheddar /Cheddar style, Parmesan, Gouda, Edam and
38 Halloumi. The blue cheese category included blue cheese produced in the UK and imported into the
39 UK.
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49 **Statistical analysis**

50 *Comparison among products:*

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53 Independent Samples T Test was used to compare the levels of salt between supermarket own brand
54 and branded products, and hard pressed with and without salt reduction targets and blue cheese with
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3 and without salt targets and cheddar cheese with and without salt targets.
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6 Data are reported as mean, SD, range as indicated. Significance in all tests carried out was deemed
7 significant as being $p < 0.05$. All data were analysed using SPSS .
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11 *Salt targets:* For each cheese type, we calculated the total number and percentage of products that met
12 the Department of Health's 2012 salt target for cheese. We used Chi-square test to compare the
13 proportion of supermarket own brand and branded products for Cheddar and Cheddar style cheese
14 that met the Department of Health's 2012 salt targets.
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17 18 **RESULTS**

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21 A total of 612 cheese products met the inclusion criteria and were included in our analysis.
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24 **Within each type of cheese analysis**

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27 Figure 1 shows the salt level in different types of cheeses per 100g. Salt content in cheese was high
28 and there was a large variation in salt content between different types of cheeses and within the same
29 type of cheese. On average, eight out of 23 types of cheese contain more than 2g of salt per 100g;
30 Halloumi (2.71 ± 0.34 g/100g) and imported blue cheese (2.71 ± 0.83 g/100g) contained the highest
31 amounts of salt. Whereas, only three types of cheeses contained less than 1g of salt per 100g; Cottage
32 cheese (0.55g) contained the lowest amount of salt.
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38 Table 1 compares the salt levels for each type of cheese between supermarket and branded products.
39 10 out of the 23 types of cheeses had a large enough sample size to analyse further, of these, seven
40 showed a higher salt level in branded than supermarket own brand products and three showed that
41 supermarket own products had a higher salt level.
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45 Cheddar and Cheddar style cheese is the major type of cheese in the UK and has the highest number
46 of products in our analysis. The salt level in branded Cheddar and Cheddar style was 3.5% higher than
47 supermarket own brand ($p < 0.001$) (figure 2).
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51 **Comparing with the 2012 targets**

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53 Among 23 types of cheese, 10 types had salt targets and 13 did not have targets. Overall, cheeses with
54 targets had significantly lower levels of salt compared to those without targets (Table 2). Hard pressed
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3 cheese and blue cheeses with targets also had significantly lower levels of salt compared to those
4 without targets (Table 2).
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8 Table 3 shows the cheese products meeting the Department of Health 2012 salt targets. Within each
9 cheese category, the average salt level was lower in products that met the targets compared to
10 products that did not meet the target. Overall, among the 394 cheeses that had salt reduction targets,
11 84.5% already met their respective 2012 targets. There are three cheese types where all of the
12 products surveyed have met the 2012 targets (Table 3) and a larger proportion of cheese types are
13 close to meeting the 2012 targets. However, only Double Gloucester (60%) and other processed
14 cheeses, includes singles and strings (54.5%) had the lowest proportion of products meeting the
15 targets.
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21 Table 4 compares the supermarket and branded products that met the 2012 targets. A greater number
22 of supermarket own brand products (90%) compared to branded products (73%) met the target for
23 Cheddar and Cheddar style cheese (Figure 2).
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27 DISCUSSION

28 Salt content in cheeses was found to be high and there was a large variation in salt content between
29 different types of cheeses and within the same type of cheese. In most types of cheese, branded cheese
30 had a higher salt level compared with supermarket own. Overall, among the 394 cheeses that had salt
31 reduction targets, 84.5% already met their respective 2012 targets. Furthermore, 90% of supermarket
32 own brand products met the target for Cheddar and Cheddar style cheese compared to 73% of branded
33 products.
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39 Our finding of a high salt content in cheeses sold in the UK is similar to those observed in the USA,³²
40 ³³ Australia,³⁴ France,³⁵ Belgium,³⁶ Canada,³⁷ New Zealand,³⁸ South Africa³⁹ and Brazil⁴⁰ showing
41 that high levels of salt in cheese is a global challenge.
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45 Salt has been claimed to be important in the flavour, texture, structure, acceptability, shelf-life and
46 safety of cheese.⁴¹⁻⁴³ But the development of cheese with lower salt content has been thriving.⁴⁴⁻⁵⁰
47 Studies describing the reduction of salt in Cheddar cheese are limited, despite the importance of this
48 cheese in the British diet. Those studies that exist involve reducing salt in cheddar cheese⁵¹ or the
49 addition of other compounds that can function in ways similar to salt (sodium chloride), such as
50 potassium chloride,^{44 52-56} magnesium chloride and calcium chloride.^{57 58}
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3 Supermarket own brand cheese have been produced with lower levels of salt, which demonstrates that
4 – despite claims to the contrary - delivering salt reduction appears not to be a technical issue related to
5 cheese manufacture. Corporate decisions about food composition are often based upon factors such as
6 common practice, taste and price, rather than health. However, evidence suggests that where salt
7 reductions are made gradually in products, no change in consumer preference is reported.^{59 60}
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12 Our paper, using the example of one of the top 10 contributors of salt to the UK diet – cheese,
13 demonstrates that a national target based approach to reformulation can be a successful method for
14 reducing the salt content in food. Our findings show that the cheese types with salt targets contained
15 less salt than cheese types without salt targets, suggest that the targets have helped focus and drive the
16 manufacturer to reduce their salt levels. There were three cheese types where all of the products
17 surveyed have met the 2012 targets (Table 3) and a large proportion of cheese types are close to
18 meeting the 2012 targets. Therefore the Department of Health has recently reset the targets to lower
19 levels. However, not all cheese types sold in the UK (Appendix 1) have a salt target, unlike in other
20 countries such as the New York City salt reduction targets, where they have included a target for
21 parmesan type of cheese.⁶¹ Also, some of UK cheese salt targets are less ambitious when compared
22 to New York City salt reduction targets, particularly the main target in this food category, which is for
23 hard pressed cheeses such as Cheddar cheese. In the UK the target is 1.8g/100g but in New York it is
24 1.58g/100g for 2012 and 1.5g/100g for 2014. Furthermore, the sales weighted mean (1.67g) is lower
25 than the average found in our study and lower than the UK 2012 salt target. There is a bigger variation
26 in the cheese types without targets (18-500%); setting an average target (suggest 30% reduction on the
27 highest available products) would narrow this variability.
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38 **LIMITATIONS**

39 Our study was based on salt content data provided on cheese packaging labels in store; hence we
40 relied on the accuracy of the data provided on the label. Therefore, it is assumed that the
41 manufacturers provide accurate and up to date information in line with EU Regulations. However,
42 further study should include salt content determined through laboratory analysis to achieve a better
43 understanding of the true salt content. When collecting data we did not capture ingredients list, this
44 means we are unable to ascertain if salt has been replaced with any other ingredients/additives in the
45 cheese that came out lowest. Such data should be collected in future surveys. **Additionally the salt
46 content of cheese is likely to differ across countries; our data is primarily relevant to the UK.**
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52 Nevertheless, the results of this study are relevant and serve to document the salt content of cheese
53 products sold in UK supermarkets, providing a foundation for future studies and providing
54 information for programs and the dairy industry to potentially move toward the reformulation of these
55 products.
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CONCLUSION

This research demonstrates that salt content of cheese in the UK is high and there is a wide variation in the salt content of cheeses and even within the same type of cheeses. Despite this, 84.5% of cheeses already met their respective 2012 targets. These findings demonstrate that much larger reductions in the amount of salt added to cheese could be made and much more challenging targets need to be set.

Other countries around the world now need to follow suit and develop a target based approach to reducing salt content of processed foods. While the food category emphasis may differ between countries, the concept of using salt targets to achieve a 'level playing field' amongst the industry is universal. A product like cheese is widely consumed internationally and this research demonstrates the variability in salt levels within each type and how targets can help to lower the levels of salt.

AUTHOR CONTRIBUTIONS

GM and KJ conceived the idea and designed research; KH conducted research; KH and FH analysed data; KH wrote the first draft of the manuscript and all authors contributed to the interpretation of the results and revision of the manuscript, and approved the final manuscript. GM had primary responsibility for final content.

Funding: None

FUNDING STATEMENT

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors

COMPETING INTERESTS

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years. KH and KJ are employees of Consensus Action on Salt & Health (CASH), a nonprofit charitable organisation. FH is a member of CASH and its international branch World Action on Salt & Health (WASH) and does not receive any financial support from CASH or WASH. MacGregor GA is Chairman of Blood Pressure UK (BPUK), Chairman of CASH and Chairman of WASH. BPUK, CASH and WASH are nonprofit charitable organisations. GM does not receive any financial support from any of these organisations.

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4 **DATA SHARING STATEMENT**
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7 Extra data is available by emailing Kawther Hashem on k.hashem@qmul.ac.uk.
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11 **Legend for figure 1: salt levels (g/100g) in each type of cheese**

12 **Legend for figure 2: salt levels (mean \pm SD) and percentage meeting salt targets in supermarket**
13 **and branded Cheddar and Cheddar-style cheese**
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Table 1 Salt levels (g/100g) for each type of cheese between supermarket and branded products.

Cheese type	Supermarket		Branded	
	N	Mean±SD	N	Mean±SD
Camembert	12	1.63±0.16	4	1.49±0.01
Cheddar /Cheddar style	187	1.72±0.14	63	1.78±0.13
Other processed	14	2.48±0.38	8	2.01±0.44
Cheese Spread	7	1.89±0.28	12	1.88±0.31
Cream cheese	14	0.68±0.24	5	0.86±0.13
Edam	12	2.38±0.28	4	2.01±0.28
Emmental	5	0.60±0.14	4	1.66±0.28
Feta	18	2.51±0.58	4	2.52±0.71
Goat's cheese	16	1.23±0.40	4	1.24±0.58
Mozzarella	18	0.65±0.33	4	1.16±0.35

Table 2 Salt levels in cheese with and without salt targets (g/100g)

Cheese type	With target		Without target		p value
	N	Mean±SD	N	Mean±SD	
All	394	1.66±0.42	218	1.78±0.79	0.04
Hard pressed	303	1.70±0.20	99	1.96±0.72	0.00
Blue cheese*	15	2.02±0.09	13	2.71±0.83	0.01

* The blue cheese category here included blue cheese produced in the UK and imported into the UK.

Table 3 cheese products meeting the Department of Health 2012 salt targets

Cheese type	2012 salt target (g/100g)	Number of products	Meeting target		
			N	percent	Mean±SD (g/100g)
Cheddar /Cheddar style	1.8	250	214	85.6	1.71±0.12
Other processed	2	22	12	54.5	1.93±0.17
Cheese Spread	2.25	19	19	100	1.88±0.29
Cheshire	1.8	8	8	100	1.43 n/a
Cottage cheese	0.63	16	14	87.5	0.51±0.03
Cream cheese	0.75	19	14	73.7	0.61±0.07
Double Gloucester	1.8	10	6	60.0	1.58±0.14
Red Leicester	1.80	21	18	85.7	1.69±0.11
Blue cheese	2.10	15	14	93.3	2.00±0.02
Wensleydale	1.80	14	14	100	1.13 n/a
Overall	n/a	394	333	84.5%	1.61±0.38

Table 4 Percentage of supermarket and branded products that meet the 2012 targets

Cheese type	2012 salt target (g/100g)	Meeting target			
		N	Supermarket (%)	N	Branded (%)
Cheddar /Cheddar style	1.8	168	90	46	73
Other processed	2.0	5	36	7	88
Cheese Spread	2.25	7	100	12	100
Cheshire	1.8	8	100	0	n/a
Cottage cheese	0.63	14	93	0	n/a
Cream cheese	0.75	12	86	2	40
Double Gloucester	1.8	6	100	0	n/a
Red Leicester	1.8	17	85	1	100
Blue cheese	2.1	12	92	2	100
Wensleydale	1.8	13	100	1	100

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APPENDIX 1. 2012 salt reduction targets for cheeses

Cheese type	Salt/100g
Cheddar and other similar "hard pressed" cheeses e.g. Cheshire, Lancashire, Wensleydale, Caerphilly, Double Gloucester, Leicester, Derby etc, including mild, medium or mature and those products where levels of fat have been reduced	1.8 (average r)
"Fresh" cheeses Excludes fromage frais as no salt is added to this product. Also excludes Brie, Camembert and other similar soft rinded cheeses. 4.2.1 Soft white cheese e.g. Philadelphia - Includes all soft white cheese, flavoured or unflavoured, including reduced fat products.	0.55 (average r) 0.75 (maximum)
Cottage cheese, plain Includes all unflavoured cottage cheese. Excludes flavoured products Cottage cheese, flavoured Includes all flavoured cottage cheese (onion and chive, pineapple)	0.55 (average r) 0.63 (maximum)
Mozzarella (used in food products) Includes mozzarella products for food industry use only. Excludes fresh mozzarella sold in retail outlets.	1.5 (average p)
Blue cheese UK produced blue cheeses only	2.1 (average p)
Processed Cheese Cheese spreads	1.63 (average r) 2.25 (maximum)
Other processed cheese (e.g. slices, strings, etc.)	2.0 (average r)

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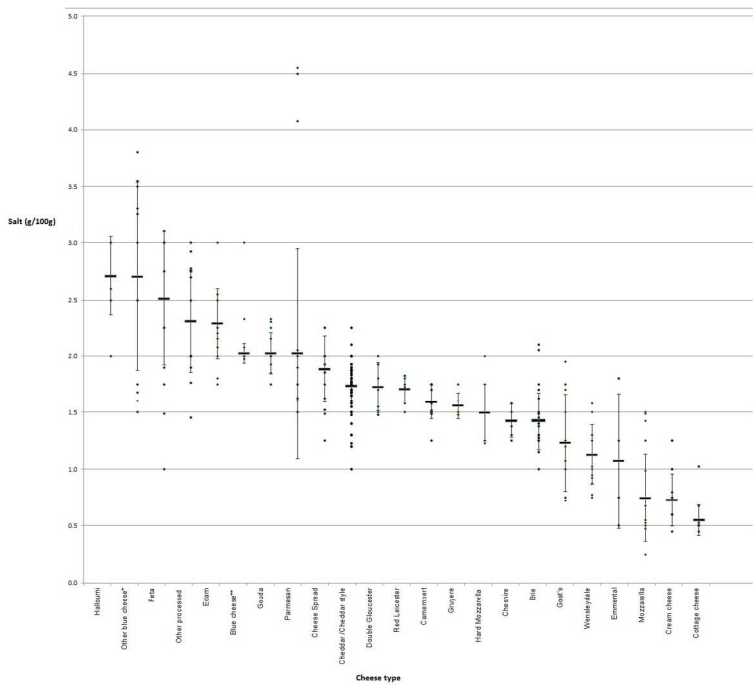
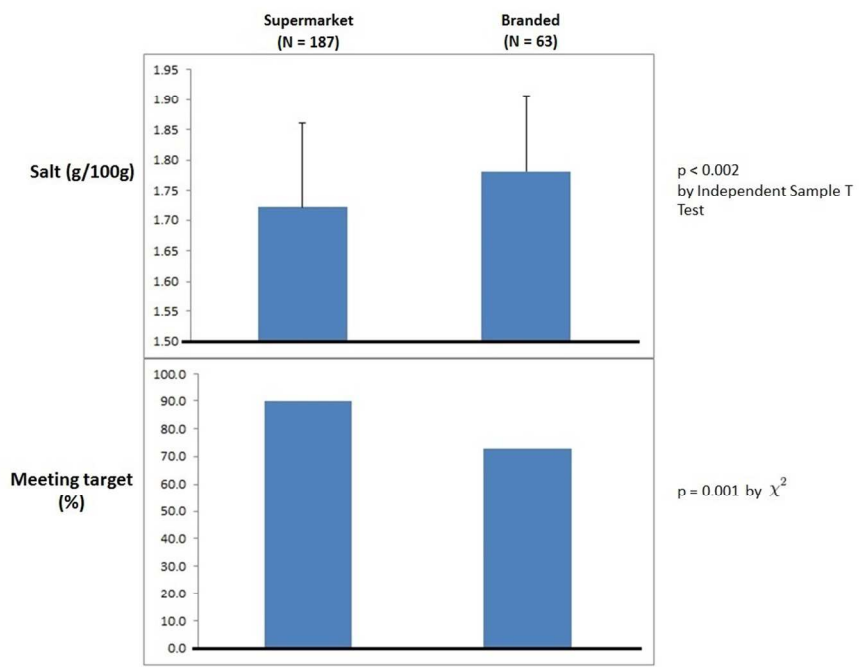


Figure 1 salt levels in each type of cheese
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APPENDIX 1. 2012 salt reduction targets for cheeses

Cheese type	Salt/100g
Cheddar and other similar "hard pressed" cheeses e.g. Cheshire, Lancashire, Wensleydale, Caerphilly, Double Gloucester, Leicester, Derby etc, including mild, medium or mature and those products where levels of fat have been reduced	1.8 (average r)
"Fresh" cheeses Excludes fromage frais as no salt is added to this product. Also excludes Brie, Camembert and other similar soft rinded cheeses. 4.2.1 Soft white cheese e.g. Philadelphia - Includes all soft white cheese, flavoured or unflavoured, including reduced fat products.	0.55 (average r) 0.75 (maximum)
Cottage cheese, plain Includes all unflavoured cottage cheese. Excludes flavoured products Cottage cheese, flavoured Includes all flavoured cottage cheese (onion and chive, pineapple)	0.55 (average r) 0.63 (maximum)
Mozzarella (used in food products) Includes mozzarella products for food industry use only. Excludes fresh mozzarella sold in retail outlets.	1.5 (average p)
Blue cheese UK produced blue cheeses only	2.1 (average p)
Processed Cheese	1.63 (average r)
Cheese spreads	2.25 (maximum)
Other processed cheese (e.g. slices, strings, etc.)	2.0 (average r)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page Number Reported
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	2
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	Not applicable
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5-6
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	Not applicable
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5-7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	6-7
		(b) Describe any methods used to examine subgroups and interactions	6
		(c) Explain how missing data were addressed	6
		(d) <i>Cohort study</i> —If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> —If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> —If applicable, describe analytical methods taking	Not applicable

		account of sampling strategy	
		(e) Describe any sensitivity analyses	6-7
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Not applicable
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7-8
		(b) Indicate number of participants with missing data for each variable of interest	7-8
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	Not applicable
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	7-8
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Not applicable
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7-8
		(b) Report category boundaries when continuous variables were categorized	Fig 1
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Not applicable
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7-8 & Tab 1-5
Discussion			
Key results	18	Summarise key results with reference to study objectives	8-9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	9
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-9
Generalisability	21	Discuss the generalisability (external validity) of the study results	8-9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

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Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at www.strobe-statement.org.

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