

Exposure to High Ultra-processed Food and Sodium Intake and its effect on Hypertension using the cross sectional study UK National Dietary and Nutritional Survey (NDNS) in England 2008-2019

Table of Contents

Exposure to High Ultra-processed Food and Sodium Intake and its effect on Hypertension using the cross sectional study UK National Dietary and Nutritional Survey (NDNS) in England 2008-2019

David O'Hagan

200299857

Dissertation submitted in partial fulfilment of the requirements for the degree of Master of Public Health, The University of Liverpool

August 2023

Dedication

To Julie Andrew and Sophie
for your loving patience and support

Acknowledgments

Thanks to Zoe and Martin

Thanks to Paul for the project which didn't quite come together

Abstract

Context

This study looked at the outcome of hypertension compared with exposure to high intake of UPF and high Sodium Intake. This examined the assumption that it is the salt content of UPF which contributes to its 'unhealthiness' and to query the idea that 'reformulation' will generate 'healthy UPF'.

Method

Secondary data analysis of the National Dietary and Nutrition Survey (NDNS) used multivariable logistic regression analysis of high sodium intake and high UPF intake against hypertension.

Results

increased odds hypertension with higher sodium intake 5.43 (1.44, 20.4) $p=0.012$

lower odds hypertension with high upf intake. 0.57(0.35, 0.95) $p=0.032$

no correlation between UPF intake and sodium intake! $\beta = 0$

This study shows that high Na intake is associated with hypertension. Reduction of sodium intake may be effective at reducing the overall risk. UPF intake is also associated with hypertension.

Conclusion

confirms sodium and hyp

upf and bp ? due to age separation, high upf in young, high bp in old

high upf not necessarily linked to high na!

Policy should aim to reduce intake of Na. The accompanying discussion examines aspects of policy and their effectiveness.

Keywords

UPF, Sodium, hypertension, NOVA, Nutrition

abstract 200 words

Dissertation 12054

Table of Abbreviations used

tion	Term
	National Dietary and Nutrition Survey
	Blood Pressure
	Sodium intake in mg
	Ultra Processed Foods
	Non communicable Disease
	Cardiovascular Disease
	Cheshire and Merseyside public health collaborative
	NOVA is a classification system, it is not an acronym
	non- alcohol fatty liver disease
	Body Mass Index
	Akaike Information Criterion

Introduction

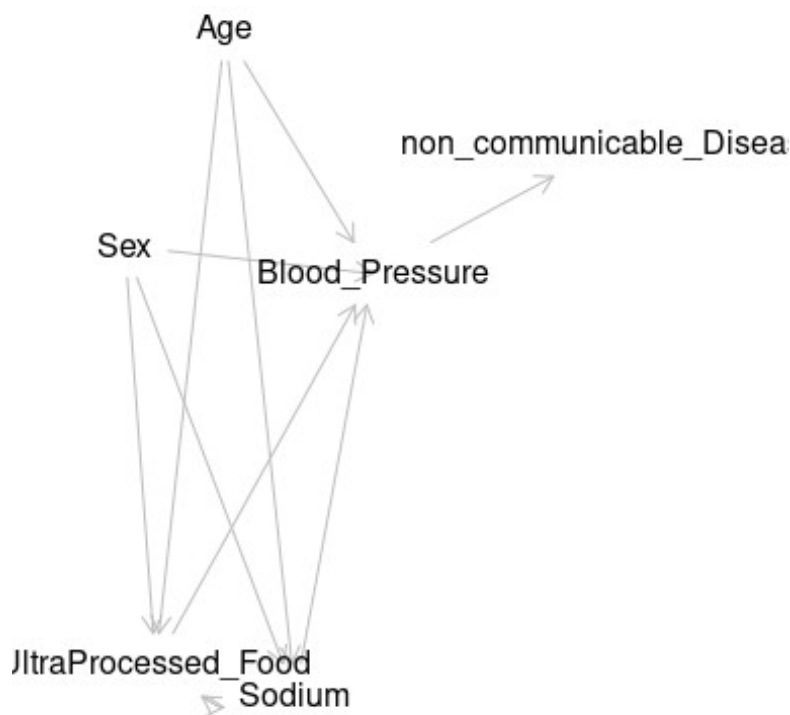
417482 people, 15.4% of the population, have hypertension in Cheshire and Merseyside (1). Cheshire and Merseyside public health collaborative (CHAMPs) have a plan to reduce BP by 2029 (2). The strategy aims to increase 'awareness'. This is intended to increase individual compliance with testing and treatment of raised BP. This study intends to offer additional opportunities for improving outcomes.

UPF makes up up to 60% diet in UK especially in the North West of England. There is evidence of an association between hypertension and intake of Ultra-processed Foods (UPF) (3) and hypertension and Salt intake (4) from studies of different types in multiple countries. Monteiro et al (5) model a scenario where "halving intake of (NOVA) group 3 foods could result in approximately 22,055 fewer deaths" across the UK in 2030. Local food policies around UPF might be a way of reducing hypertension at a population level. There is potential for significant public health impact.

Marmot (6) identifies the external influences in Cheshire and Merseyside which need to be improved to permit individual action to be effective. Using a better understanding of the role of UPF, and the interaction with sodium, might give a mechanism of action of some of Marmot's categories of influence.

This study assessed prevalence of exposure to sodium and UPF, and hypertension in the data set of the National Dietary and Nutrition Survey (NDNS) (7). The study gives data from the UK from 2008 to 2019. It is stratified to be representative of the population of the UK by sex, age, region and index of multiple deprivation (IMD). Exposure to high UPF and high Sodium intake, and outcome BP were recorded. Age and sex remain important background factors. This leads to the research question below.

I have used STROBE guidance (8) in producing this report. This study explored this complex web pulling out strands within it, [diagram 1](#) shows a possible arrangement of this.



The relationships explored in the analysis

Research Question

Using PICO (9) approach,

In adults and children across the four home nations of the UK between 2008 and 2019, did exposure to high sodium dietary intake, and or high UPF dietary intake, compared to lower exposure, increase the odds of having a mean systolic blood pressure of over 140mmHg?

This primary question can be split into parts,

For a representative population across the UK What was dietary intake of UPF between 2008 and 2019? What was dietary intake of salt between 2008 and 2019? What was BP between 2008 and 2019? What was the correlation between these?

In addition it may be possible to consider, How did each of these change over that time? Is there evidence of interaction between these? Was UPF or Na most important in these changes?

Objectives

1 Literature Review of UPF and BP, with Na

2 Descriptive analysis of participants from NDNS with amalgamation of data across the rolling programme.

3 Analysis of exposure to UPF and Na, and prevalence of BP >140mmHg using regression models.

4 Discussion of implications of results in relation to limitations of cross-sectional studies, and available data, as well as suggestions for further research

Epistemology

The epistemological approach of this study is positivist. I use a quantitative approach in a mechanistic and deterministic model. However, I am aware that this model is incomplete. Positivism encourages experimental isolation. The study is isolated from the world through control of the experimental environment.

Real world dietary change requires understanding interaction with social and economic factors, not isolation. Critical realist and social constructionist studies are needed to complement the information from this study. The commercial and social determinants of health are models which have a great deal of impact on exposure to UPF and Na and on dietary effects on BP.

Positionality

In a positivist paradigm the observer is external to the experiment. Acknowledging the constructivist aspects to this study allows that the observer is closer to the model making my positionality of interest. Jafar (10) argues that understanding the position of the investigator be of interest to understanding this quantitative study.

I bring an attachment to positivist ideals from my biomedical background. As an older physician I am aware of social factors impacting health of participants as Evans and Trotter (11) discuss. I also understand that my perception of the world is from a position of significant privilege. To proceed, I need to be aware of the limitations of the positivist approach. I need to make pragmatic selections to bring some degree of validity to the resulting dataset.

These constructed ideas, social expectations, income, or geography affect food and health 'choices'. They also impact on 'hard' clinical measurements such as BP, through physical position and room temperature as well as by the relationship between the observer and the participant.

This work is primarily to complete requirements for an MPH degree which means that it is influenced by factors around health equity and classic epidemiology as taught on the course. It is produced in collaboration with a research group with a long established reputation in food research in public health, which may steer the results in a conservative direction.

University Research Governance and Ethical Review

The ethics process for the University of Liverpool was followed and confirmation of compliance is attached at [Appendix 2 Ethics Certificate](#)

The storage of the data is in keeping with the research governance agreements of the University and the Data set owners.

Literature Review

Rationale

- 1 develop search
- 2 review search and confirm inclusion
- 3 describe literature
- 4 synthesise literature
- 5 critique literature
- 6 explain role of study within context

This literature review was intended as a systematic search, to identify papers with information about UPF, sodium and blood pressure informed by PRISMA (12).

The rationale for this review is to contribute background and to answering the research question;

What is the evidence that in adults and children across the four home nations of the UK between 2008 and 2019, would exposure to high sodium dietary intake, and or high UPF dietary intake, compared to lower exposure, increase the odds of having a mean systolic blood pressure of over 140mmHg?

Method

Eligible studies were primary research, cohort and cross-sectional studies, and systematic reviews considering the relationship between the exposure, and outcome in comparable general populations. Papers were excluded where the population was specifically of one type, or had a specified health condition. Another exclusion criterion was where specific foods were considered. The search was restricted to human populations.

An additional area of policy and policy implementation was also considered.

Scopus (13) and Medline(ovid) (14) were searched.

The search strategy is included in [table 2.1](#) below. The search identified a wide variety of articles, which outlined and augmented the review. Others were identified by reading abstracts and cross referencing with other papers. Colleagues identified further relevant literature. Additional papers were identified from the bibliographies of relevant papers. Reviews and meta-analyses presented search strategies and identified highly relevant studies. It has a core systematic approach with additional items from a range of sources.

My search terms

Description of Search

Search 1	Search 2
10/6/23	11/6/23
Scopus	Medline(Ovid)
((TITLE-ABS-KEY(salt Or sodium OR Na)) AND (TITLE-ABS-KEY("BP" OR "Blood pressure" OR "hypertension" OR "high blood pressure" OR "systolic"))) AND (TITLE-ABS-KEY("ultra-processed food" OR "ultra-processed foods" OR "ultraprocessed food" OR "ultraprocessed foods" OR "ultra-processed product" OR "ultra-processed products" OR "ultra-processing" OR "food processing" OR "processed food" OR "processed foods" OR "NOVA" OR "NOVA system" OR "NOVA food classification" OR "NOVA classification system")AND (EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "PHAR") OR EXCLUDE (SUBJAREA, "AGRI") OR EXCLUDE (SUBJAREA, "EART") OR EXCLUDE (SUBJAREA, "VETE") OR EXCLUDE (SUBJAREA, "MATE") OR EXCLUDE (SUBJAREA, "PHYS") OR EXCLUDE (SUBJAREA, "CHEM") OR EXCLUDE (SUBJAREA, "ENER") OR EXCLUDE (SUBJAREA, "ENVI")))	1 (salt or sodium c 2 ("BP" or "Blood p blood pressure" or "sy 3 ("ultra-processed "ultraprocessed food" processed product" or processing" or "food p "processed foods" or classification" or "NOV 4 1 and 2 and 3 book title, abstract, or subject heading word, heading word, organis protocol supplementa supplementary concep population supplement supplementary concep
ultraprocessed and dietary and prevention or lifestyle	same
food technology and processing only, experimental reports using rats, cows rabbits and parrots, those investigating specific foods or food groups, or specific disease groups	same
385	211

Selection strategy

Inclusions and exclusions are identified in the table. No time limits, language limits or availability limits were included in the initial search.

Data collection process the papers were reviewed by the author only.

The key data items sought were odds ratios for the effect of UPF or sodium on blood pressure.

There is risk of bias due to the single reviewer approach.

Data was collated and compared to identify useful odds ratios

There is no agreed approach to reporting exposure or outcome. This made for a wide variety of difficult to compare items.

Search results

Search 1 produced 385 results. 204 articles, 77 reviews, 25 editorials, 24 notes, 20 letters, 17 book chapters, 11 conference papers, 6 'short surveys' and 1 book. These came from 159 institutions, St George's, University of London provided the most with 14. 112 funding bodies were involved, National Heart, Lung, and Blood Institute providing funds for 14. He, F.J., with 11 papers, was the most represented first author out of 157.

Search 2 gave 211 papers. The lists of details from each search were downloaded. Then the two lists were added together using Refmanager (15). The contents of the resulting file were examined for duplicates. Once these were eliminated the total unique papers was 430. These were then reviewed by comparing the titles against the inclusion and exclusion criteria. The remaining literature was still large 380. Cohort studies 7 and cross-sectional studies 14 were identified within this group. Several additional relevant studies have also been identified by my supervisors.

discussion of results

The literature has developed over time. UPF is a recent concept developed within the NOVA framework, described in 2009, but Dahl's paper (16) from 1968, identifies the 'artificial' nature of food for infants. However, articles around UPF and its relation to BP and NCD are more recent. Importantly they analyse the way that UPF is correlated with BP.

Cohort studies

There were 7 articles identified in the search. These articles reported on 5 cohorts, (3) (17) USA (18), a south african cohort (19) (20), one from Mexico (21), and another from Spain (22). Only the spanish study looked at hypertension as an outcome. The others assessed sodium intake and excretion levels and assumed that this would affect blood pressure. Du's 2021 study in the USA used CVD as an outcome.

The results identified

Cohort country	First Author	results
China	Du	Sodium intake decreased from 6.3 g/d in 1991 to 4.1 g/d in 2015
	Du	Sodium intake is decreasing
South Africa	Ware	overall salt intake dropped by 1.15 g/day (P = 0.028)
	Charlton	Median salt intake (6.8 g/day) was higher in younger than older adults (8.6 g vs 6.1 g/day; p < 0.001), and in urban compared to rural

Cohort country	First Author	results
		populations (7.0 g vs 6.0 g/day; p = 0.033).
USA	Du	Participants in the highest compared with lowest quartile of ultra-processed food intake had a 19% higher risk of coronary artery disease (HR: 1.19; 95% CI: 1.05, 1.35)
Mexico	Colin-Ramirez	Mean daily sodium intake estimated by three-day food records and 24-h urinary sodium excretion was 2647.2 +/- 976.9 mg/day and 3497.2 +/- 1393.0,
Spain	de Deus Mendonca	adjusted HR, 1.21; 95% CI, 1.06, 1.37; P for trend = 0.00
	middle aged uni grads	

cross-sectional studies

14 studies were identified as cross-sectional studies on general populations looking at hypertension, sodium, and ultraprocessed food.

Cross-sectional studies

UPF, Na and BP	Salt	Awareness	Other conditions
barbosa (23)	reyhani (24)	ponzo (25)	hajmir (26) ,
harrington (27)	korff (28)	westrick (29)	cunha (30)
	johner (31)		
asma (32)	quader (33)		
d'avila (34)	jovic (35)		

The studies looked at awareness, and intake of sodium, UPF, and only a few assessed BP. Again a clearly stated assumption was that changing salt intake would change BP. Even when BP or hypertension was explicitly included it was often 'self reported'. There were 2-3 which were used for this study.

Table of relevant cross sectional studies

C
o de
h sc
o ri
r pti
t on results

odds ratio (OR)=1.48; 95% confidence interval (CI) 1.14-1.91 and OR=2.17; 95% CI 1.68-2.79, respectively), the consumption of ≥ 2 /day salty snacks (OR=1.86; 95% CI 1.32-2.63 and OR=2.38; 95% CI 1.69-3.37, respectively)

Additional relevant studies likely no mention of salt !!

other relevant studies

Col1	Col2	Col3
shim (36)	wang (37)	rezendez-alves (38)
scranni (39)		

Literature review Conclusion

The literature review identified and analysed a range of literature across the field. Key points being that CVD is a significant NCD, and has links with Na and UPF. These links are often described from different epistemological viewpoints within the study of food. This study aims to look at how Na and UPF interact and looking to understand from a positivist approach what are the effects UPF. Whilst knowing and accepting that effects of UPF in this paradigm are a subset of their total effect, which also includes cultural and economic aspects. Also understanding that Na in its nutritional paradigm similarly projects into the cultural and economic. Only by understanding biologic, cultural and economic aspects of food can we manage change to reduce the burden of disease.

Method

Study Setting and Design

This is a secondary data analysis of data from the National Dietary and Nutritional Survey (NDNS (7)). This analysis is designed to analyse the correlation between sodium intake, UPF intake and BP.

The NDNS was commissioned in collaboration between government departments responsible for health and for food production. Academic partners delivered reports on diet and nutrition across the United Kingdom. The study is designed to be representative across the four home nations, and across age with balanced representation for children. NDNS data are available via the UK national Data service for research purposes.

NDNS is a rolling cross-sectional study, in each year a new cross section of participants is enrolled from the wider population. Questionnaires, food diaries, and nurse assessments are used to gather data. It has been running since 2008. The most recent data is available from 2019.

Participants, Inclusion and Exclusion

Participants were identified by random selection across postal units. The sample is stratified to ensure a representative sample across the four nations (England, Wales, Scotland, and Northern Ireland) and across regions in England (North West, North East, Yorkshire and Humberside, East Midlands, West Midlands, London, The South East, The South West). The sample is also stratified for age and sex and IMD.

For NDNS the intended sample is 1000 per year with 50% adults. Each year the sample is slightly different due to differential uptake. Oversampling is used to control this.

The relationship between salt and systolic blood pressure may be different in individuals with pathologically high BP. Those taking BP controlling medications may have a different relationship to sodium and UPF and were excluded for analysis.

Exposure Variables

The participants recorded their food intake prospectively over 4 days recording food and portion size as well as where food was eaten. Adults recorded this for the child participants.

Based on the food and drink intake reported and with a composition data table, the NDNS team have estimated the overall intake of a large range of nutrients.

Salt estimation

The sodium milligram (mg) value (Na) was calculated from intake. Food diaries were analysed against standard food nutrient values. Hence, this value reflects the expected Na content of standard foods. It assumes the content remains consistent.

Serum sodium values are available for the early dataset, but not the later one. 24 urinary sodium is a better indicator of dietary sodium but values are not available across the whole time period.

UPF

The NOVA classification was used to estimate the intake of UPF developed by Monteiro et al. (40). There is no record of NOVA classification in NDNS. The dataset provided by Dr Colombet (personal communication) was used to identify food by NOVA group. This was developed by comparing every food level entry in NDNS against NOVA. A standard methodology describing the approach used has been published by Martinez-Steele et al. (41).

Next the energy content of the day's food was calculated by Nova group. This was added to the intake for the other 3 days and the total intake by Nova group established. The percentage of the total intake of energy was then calculated for each of the 4 Nova categories. Nova group 4 or UPF intake (UPF) is used for this study.

Outcome Variable

BP is a quality assured mean systolic BP which is reliable across the dataset. It was measured in mmHg using a calibrated automatic sphygmomanometer by a study nurse under specified conditions. These conditions controlled for the effects of exercise, temperature and ill health. The data on all these is in the dataset. Raw BP values are also present in the dataset to allow quality review.

Other Variables

Additional explanatory variables are ones which can also influence BP. They include Age, Sex, and BMI. Age at completion of education (educfinh), and Index of multiple deprivation (IMD) are also used. Participants on BP medication (bpd) is used to exclude those taking medication which may lower their BP.

Data Sources

The data from the NDNS study contains information about each individual, and their household. This was collected through questionnaires. Then weight, height, and blood pressure were measured by a nurse. Finally, dietary information was collected through a 4-day food diary.

The food was analysed for nutritional content using a bespoke database. These reference tables are available in the available dataset.

Data was not available for some categories and years. This was identified in tables as missing data.

Bias

Selection bias was approached by using random selection of participants using a carefully constructed stratification model. Addresses were selected by postal units to ensure geographic spread of participants.

Take up and Drop out bias was approached by ensuring that sample sizing included scope for this to enable comparable sample sizes across annual waves.

Social desirability bias acknowledges that participants remember and record intake framed by their beliefs about the needs of the study, and their beliefs about what is perceived as being healthy. To examine this, in the first wave a double labelled water study was incorporated. This compared reported energy intake with measured values (42) .

Finally bias at the analysis stage used weighting to standardise the sample for several variables. Those selected were Age, Sex, region and IMD. Weights are available for different levels of analysis as participants who did not complete the initial interview were not selected for subsequent blood analysis.

Quantitative variables

A categorical variable (hiNa), has been produced with a cut off values at 3000mg, 5000mg and 6000mg. These values are the WHO recommended amount and match values used in Du et al (3).

A variable (UPF3) was developed from the mean UPF intake. The central category is the mean with one standard deviation above and below. This effectively identifies 67% in the centre of the distribution. Categories used in other papers eg (43) are low for the UK.

I have created a variable (hyp) which identifies participants with BP over 140 mmHg to enable logistic regression. This value is identified by Du et al ((3)) and others.

Study Size

A sample size calculation for this secondary analysis is available in appendix 1 the initial proposal from OpenEpi (44) . This calculated the sample size of 3526, with a ratio of 0.75 unexposed to exposed. An intended power of 80%, at a level of statistical significance of 95% was used. An odds ratio of 1.2 was used based on a meta-analysis by Wang et al (45) .

Statistical Methods

Four data batches of data (2008-2012, 2013-2014, 2015-2016, 2017-2019) were combined. The data was read using 'r-studio' with the processing being carried out using packages (see appendix 3) available from CRAN (46). In particular the package 'survey' (47) was used to manage weighted data. Generated weighting values account for

differences uptake and drop out across the annual cohorts. 'Survey' also accounts for sample stratification.

Data was analysed for correlation by regression. Categorical data was analysed using chi-squared. In all analysis P.values and confidence intervals were calculated and a value of $p < 0.05$ was taken as the threshold of statistical significance. Multivariable regression models were constructed to manage variables which might have confounding effects on the outcome of the analysis. Sample stratification was also used to reduce potential confounding. Tables of results were produced to best demonstrate the data. For the main results a set of multivariable logistic regression models was developed. Each exposure variable was modelled separately, the final model included both of the exposure variables. AIC was used to understand the relative importance of variables.

Results

Participants

NDNS identified a 9990 addresses 2008-2011 for the first 3 years of the programme. Either one adult and one child, or one child only were included. The response rate was 55% in year one for completion of a food diary. By 2019, 3466 completed food diaries of four days. Subsequent years had different response rates, but within a similar scale allowing weighting to be used to balance the samples.

Considering participants who opted in and completed questionnaires, the whole NDNS population was 15,655. The median age was 40. Categorising age shows that 22% of the population was between 19 and 35. There were 49% male participants.

After excluding those on medication, the population was 14217 participants.

This table [table 4.1.1](#) shows the participants.

Continuous variables are represented by the median and interquartile range in brackets. Categorical variables give the number of participants and the percentage of the sample in brackets.

Characteristics of the sample population from National Dietary and Nutrition Study (2008-2019)

Whole Population	Population with those on BP medication excluded	UPF >63%	Na >50
N = 15,655¹	N = 14,217¹	N = 4,793¹	N =
7,699 (49%)	6,992 (49%)	2,568 (54%)	58 (8
7,956 (51%)	7,225 (51%)	2,225 (46%)	15 (2
40 (22, 58)	37 (20, 54)	23 (12, 42)	31 (22
2,930 (19%)	2,927 (21%)	1,755 (37%)	2 (2.0
526 (3.4%)	524 (3.7%)	307 (6.4%)	2 (2.8
3,372 (22%)	3,357 (24%)	1,183 (25%)	44 (6

Whole Population	Population with those on BP medication excluded	UPF >63%	Na >50%
N = 15,655¹	N = 14,217¹	N = 4,793¹	N = 1,793¹
3,355 (21%)	3,241 (23%)	799 (17%)	21 (2.4%)
2,912 (19%)	2,475 (17%)	418 (8.7%)	1 (1.8%)
2,561 (16%)	1,692 (12%)	330 (6.9%)	3 (4.0%)
1,773 (14%)	1,426 (12%)	472 (13%)	5 (8.3%)
3,483 (27%)	3,160 (27%)	1,180 (33%)	24 (3.0%)
1,074 (8.3%)	974 (8.3%)	332 (9.2%)	2 (2.5%)
1,588 (12%)	1,484 (13%)	482 (13%)	7 (11.2%)
4,172 (32%)	3,922 (33%)	878 (24%)	25 (3.0%)
2,645	2,502	1,174	8 (1.8%)
2,977 (19%)	2,748 (19%)	1,139 (24%)	28 (3.0%)
3,128 (20%)	2,870 (20%)	1,086 (23%)	21 (2.4%)
2,905 (19%)	2,609 (18%)	850 (18%)	15 (2.4%)
3,269 (21%)	2,953 (21%)	914 (19%)	5 (7.2%)
3,372 (22%)	3,031 (21%)	804 (17%)	4 (5.2%)

	Whole Population	Population with those on BP medication excluded	UPF >63%	Na >50%
	N = 15,655¹	N = 14,217¹	N = 4,793¹	N = 4,793¹
	5	5	0	0
	641 (4.1%)	562 (4.0%)	228 (4.8%)	5 (6.5%)
	1,735 (11%)	1,564 (11%)	554 (12%)	17 (2.9%)
Humber	1,308 (8.4%)	1,187 (8.3%)	449 (9.4%)	12 (1.5%)
	1,128 (7.2%)	1,023 (7.2%)	365 (7.6%)	8 (11%)
	1,384 (8.8%)	1,243 (8.7%)	469 (9.8%)	6 (8.6%)
	1,460 (9.3%)	1,338 (9.4%)	444 (9.3%)	7 (9.8%)
	2,029 (13%)	1,863 (13%)	428 (8.9%)	4 (5.8%)
	2,148 (14%)	1,962 (14%)	642 (13%)	2 (2.9%)
	1,321 (8.4%)	1,201 (8.4%)	346 (7.2%)	0 (0.0%)
	753 (4.8%)	682 (4.8%)	247 (5.2%)	1 (1.5%)
	1,302 (8.3%)	1,181 (8.3%)	439 (9.2%)	8 (12%)
	447 (2.9%)	413 (2.9%)	181 (3.8%)	2 (2.7%)
	1,459 (9.3%)	1,323 (9.3%)	481 (10%)	12 (15%)
	1,429 (9.1%)	1,284 (9.0%)	496 (10%)	7 (10%)
	1,372 (8.8%)	1,246 (8.8%)	472 (9.9%)	13 (17%)
	1,432 (9.1%)	1,291 (9.1%)	495 (10%)	6 (8.4%)

Whole Population	Population with those on BP medication excluded	UPF >63%	Na >50
N = 15,655¹	N = 14,217¹	N = 4,793¹	N =
1,485 (9.5%)	1,361 (9.6%)	461 (9.6%)	6 (8.5%)
1,362 (8.7%)	1,234 (8.7%)	473 (9.9%)	1 (1.7%)
1,442 (9.2%)	1,312 (9.2%)	421 (8.8%)	10 (1.7%)
1,405 (9.0%)	1,276 (9.0%)	378 (7.9%)	5 (6.0%)
1,444 (9.2%)	1,305 (9.2%)	362 (7.6%)	5 (6.8%)
1,481 (9.5%)	1,360 (9.6%)	375 (7.8%)	1 (1.0%)
1,345 (8.6%)	1,226 (8.6%)	379 (7.9%)	6 (8.3%)

Descriptive Data

The study population the median age was 38. The largest age group was 19-35. 49% of the participants were male.

Internal consistency was examined by comparing background data across survey years. General linear regression modelling was used, with wave 1 as a comparator for analysis of the other waves. Age was a variable which the whole sample was weighted to be maintained across the waves. BMI was lower in most years but this was statistically significant only in wave 7 and 8.

Table 4.2.2 shows results for continuous variables.

p.values for correlation of Continuous variables and survey year from National Dietary and Nutrition Study (2008-2019)

Group	Characteristic	Beta	95% CI ¹	p-value
Age	SurveyYear			0.3
	1	—	—	
	2	0.70	-1.5, 2.9	

Group	Characteristic	Beta	95% CI ¹	p-value
	3	-0.21	-2.2, 1.8	
	4	1.8	-0.29, 4.0	
	5	2.0	-0.16, 4.1	
	6	0.14	-1.9, 2.2	
	7	1.6	-0.71, 4.0	
	8	0.94	-1.1, 3.0	
	9	1.5	-0.68, 3.7	
	10	1.5	-0.68, 3.7	
	11	2.0	-0.27, 4.2	
	BMI			
	SurveyYear			
	1	—	—	
	2	0.06	-0.56, 0.69	
	3	-0.32	-0.93, 0.29	
	4	0.43	-0.18, 1.0	
	5	-0.35	-0.94, 0.24	
	6	-0.41	-1.0, 0.23	
	7	-2.1	-3.0, -1.3	
	8	-2.1	-3.0, -1.2	
	9	-0.32	-0.93, 0.30	
	10	-0.18	-0.79, 0.43	

Group	Characteristic	Beta	95% CI ¹	p-value
	11	-0.35	-0.94, 0.25	

¹CI = Confidence Interval

The categorical data also had p.values >0.05 for the controlled variables (age, sex, IMD) against annual wave. UK region is part of the weighting, but this sample showed variation with p.value <0.05.

Vegetarian had a p.value of <0.05. BMI had a p.value of 0.77.

Table 4.2.3 follows.

p.values for correlation of categorical variables and survey year from National Dietary and Nutrition Study (2008-2019)

Variable	ChiSq ¹	p.value
Sex	0.90	0.53
IMD	0.86	0.71
Age	0.94	0.58
BMI	0.78	0.77
Region	1.37	0.02
Vegetarian	1.97	0.02

¹Chi Squared for categorical data

The table 4.1.1 shows the population exposed to UPF >63% of their calories is made up of 4793 from a total of 14217 participants. This compares with 9424 participants with lower exposure. That is an exposure prevalence of 34%.

High UPF is more common in younger males than in the overall population or those not on medication. 37% are 0-16 years old. There is a gradient in deprivation with more exposure in the most deprived group. England's South East has 13% of those with high UPF intake. With 11% in the North West.

The population exposed to Na >5000mg has only 73 out of 14217 participants. An exposure frequency of 0.5%.

Younger men are more commonly affected, 61% are 19-35. The least deprived makes up 5.2% of the participants compared with 39% of the most deprived. The north west has 23% of those with high Na intake, much the highest.

The exposure variables were compared across annual waves in [Table 4.3.1](#) . Most people have Na exposure less than 3000mg. In year one this was 81%, with only 0.9% exposed to more than 5000mg. By year eleven 92% are reporting less than 3000mg, and 0.5% over 500mg.

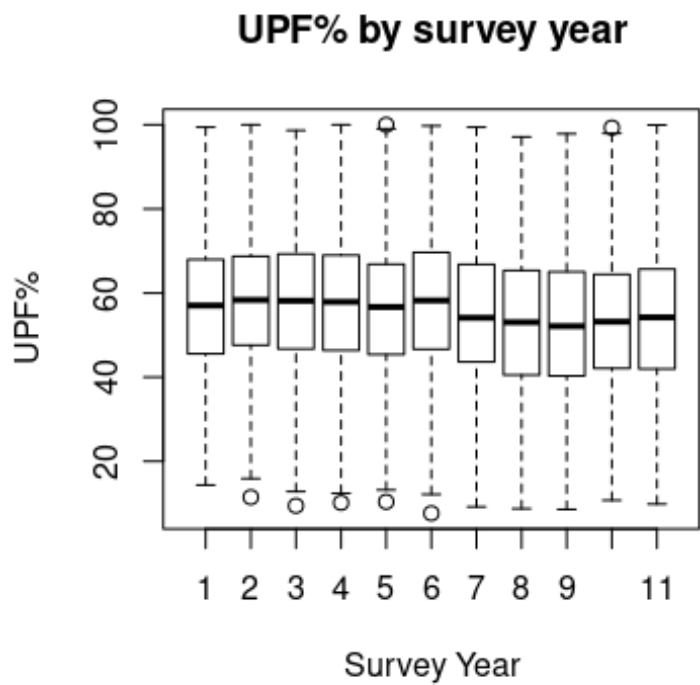
UPF exposure was steady with 37%-40% of the participants exposed to 45%-63% throughout the survey. Up to 38.2% of the participants were exposed to levels of more than 63%, the peak being in year 6.

Exposure by survey year from National Dietary and Nutrition Study (2008-2019)

	3, N = 1,246¹	4, N = 1,291¹	5, N = 1,361¹	6, N = 1,234¹	7, N = 1,312¹	8, N = 1,276¹	9, N = 1,276¹
	240 (19%)	301 (23%)	362 (27%)	330 (27%)	366 (28%)	396 (31%)	410 (32%)
	799 (64%)	837 (65%)	861 (63%)	779 (63%)	821 (63%)	752 (59%)	775 (61%)
	193 (16%)	147 (11%)	131 (9.6%)	123 (10%)	114 (8.7%)	123 (9.6%)	114 (9.1%)
	13 (1.0%)	4 (0.3%)	4 (0.3%)	1 (0.1%)	7 (0.6%)	3 (0.2%)	4 (0.3%)
	0 (0%)	2 (0.2%)	2 (0.1%)	0 (0%)	3 (0.2%)	2 (0.1%)	1 (<0.1%)
	81 (6.5%)	86 (6.7%)	123 (9.1%)	92 (7.4%)	111 (8.5%)	164 (13%)	159 (12.5%)
	183 (15%)	207 (16%)	207 (15%)	193 (16%)	258 (20%)	266 (21%)	294 (23.1%)
	509 (41%)	504 (39%)	569 (42%)	475 (39%)	522 (40%)	467 (37%)	490 (38.4%)
	353 (28%)	403 (31%)	385 (28%)	378 (31%)	331 (25%)	319 (25%)	298 (23.3%)
	119 (9.6%)	92 (7.1%)	77 (5.6%)	95 (7.7%)	90 (6.8%)	58 (4.6%)	64 (5.0%)
	0	0	0	0	1	0	0

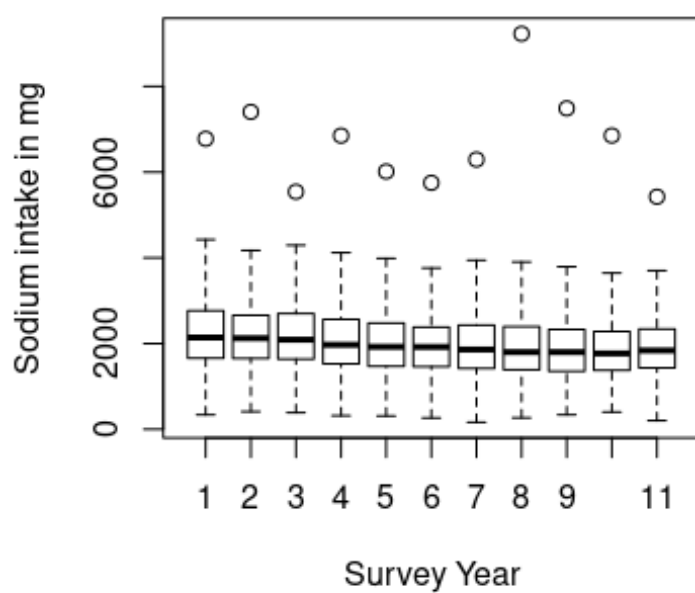
rection

Results were illustrated by plots against survey year. [figure 4](#) showed overlap between the waves for UPF intake. [figure 5](#) showed Na exposure overlap between waves.



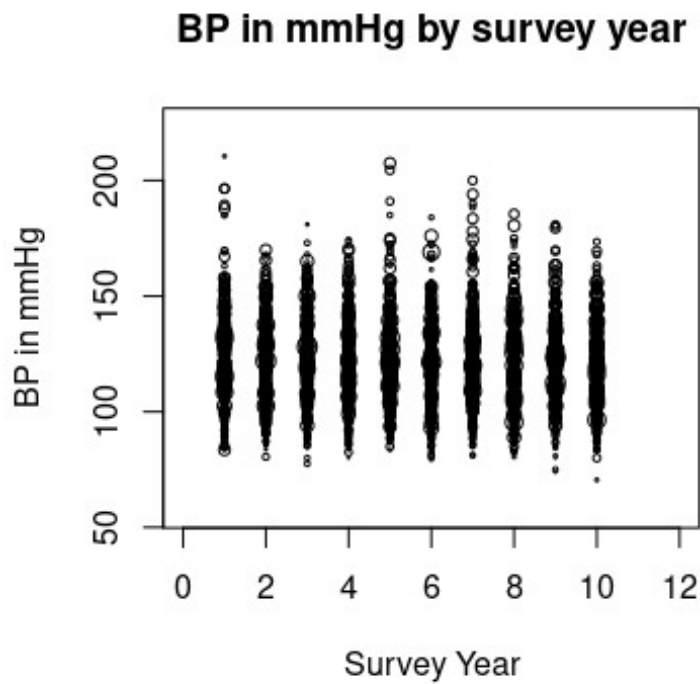
Energy from UPF% in each annual cohorts NDNS (2008-2019)

Sodium Intake in mg by survey year



Na in mg in each annual cohort NDNS(2008-2019)

Outcome variable



Plot of the BP in mmHg by year from NDNS (2008-2018)

figure 6 identified the lack of data for year 11.

The table 4.1.1 shows the population with BP > 140 mmHg is 876 participants. This gives a prevalence of 6%.

Men are once again overrepresented. These participants are older than the population median, 44% of theses participants are over 65. This group are statistically significantly different from the populations with high Na, or high UPF! There is a reverse gradient with IMD in this population. The most deprived are least represented in this population. The largest proportion are in the least deprived category. The north west is second highest in raised BP after the south east. The BP was highest in year one with 125 mmHg, and the lowest 120 mmHg in year 6. BP rose through life to a mean of 134 mm Hg in the over 65 age category.

BP by survey year from National Dietary and Nutrition Study (2008-2019)

3 , N = 1,246 ¹	4 , N = 1,291 ¹	5 , N = 1,361 ¹	6 , N = 1,234 ¹	7 , N = 1,312 ¹	8 , N = 1,276 ¹	9 , N = 1,3
573 (86%)	569 (86%)	760 (90%)	600 (89%)	650 (89%)	671 (90%)	670 (89%

3, N = 1,246¹	4, N = 1,291¹	5, N = 1,361¹	6, N = 1,234¹	7, N = 1,312¹	8, N = 1,276¹	9, N = 1,3
90 (14%)	93 (14%)	81 (9.6%)	72 (11%)	83 (11%)	75 (10%)	80 (11%)
583	629	520	561	579	530	555

correction

Main Results

The main results are the correlation between the exposure and the outcome variables. These are presented using 2*2 tables with no additional control for confounding. Univariable regression demonstrated the interaction with other explanatory variables. This is complicated by the effect of stratification.

Chi squared table The odds ratio for hypertension in participants exposed to UPF >63% is 0.5. The odds ratio for hypertension in participants exposed to Na >5000mg is 1.45

```
## X-squared
## 0.5477235

##          hiNa2 (0,5e+03] (5e+03,1e+04]
## hyp
## (0,140]          12907.71          64.53
## (140,300]        1676.69          12.08

##      X-squared
## 1.955483e-08

##          zPF2 (0,63] (63,100]
## hyp
## (0,140]          8479.86  4492.38
## (140,300]        1339.49   349.27
```

The regression model for Sodium against BP shows that there is no linear relationship between Sodium and BP in this table [Table 4.4.1](#). UPF compared to Na also shows a zero beta value indicating no linear relationship.

UPF does show a negative relationship with age, which is statistically significant. There is also a negative relationship with Age, again statistically significant.

Age has a relationship with BP with a statistically significant positive gradient. There is also a positive relationship with Na, which is also statistically significant to the 95% level.

Table of Regressions of BP, Na and UPF against Age, bmi, educfinh full population NDNS data 2008-2019

Group	Characteristic	Beta	95% CI¹	p-value
BP/Na	Na	0.00	0.00, 0.00	<0.001
UPF/Na	Na	0.00	0.00, 0.00	<0.001
UPF/bp	zPF	-0.19	-0.22, -0.15	<0.001
UPF/Age	zPF	-0.43	-0.46, -0.40	<0.001
Age/BP	Age	0.43	0.41, 0.45	<0.001
Age/Na	Age	1.5	0.77, 2.3	<0.001
BP/bmi	bmi _{val}	1.0	0.92, 1.1	<0.001
BP/Agg1	agegad3			
	(0,16]	—	—	
	(16,19]	9.7	7.9, 11	<0.001
	(19,35]	12	11, 13	<0.001
	(35,50]	15	14, 17	<0.001
	(50,65]	23	21, 24	<0.001
	(65,108]	28	26, 30	<0.001
BP/ed	educfinh			
	Not yet finished	—	—	
	Never went to school	7.6	3.6, 12	<0.001
	14 or under	19	14, 24	<0.001
	15	15	12, 18	<0.001

Group	Characteristic	Beta	95% CI¹	p-value
	16	7.2	4.8, 9.6	<0.001
	17	8.2	5.4, 11	<0.001
	18	6.4	3.8, 9.0	<0.001
	19 or over	5.5	3.3, 7.7	<0.001
UPF/bmi	bmival	-0.29	-0.35, -0.23	<0.001
UPF/age	agegad3			
	(0,16]	—	—	
	(16,19]	-1.1	-3.0, 0.76	0.2
	(19,35]	-9.5	-11, -8.4	<0.001
	(35,50]	-13	-14, -12	<0.001
	(50,65]	-17	-18, -16	<0.001
	(65,108]	-14	-16, -13	<0.001
UPF/ed	educfinh			
	Not yet finished	—	—	
	Never went to school	-20	-34, -5.3	0.007
	14 or under	-7.5	-11, -4.4	<0.001
	15	-5.7	-8.3, -3.0	<0.001
	16	-4.0	-6.4, -1.5	0.002
	17	-5.9	-8.5, -3.2	<0.001
	18	-7.0	-9.6, -4.4	<0.001

Group	Characteristic	Beta	95% CI¹	p-value
	19 or over	-11	-14, -8.7	<0.001
Na/bmi	bmival	17	14, 19	<0.001
Na/Agg	agegad3			
	(0,16]	—	—	
	(16,19]	477	384, 569	<0.001
	(19,35]	586	529, 643	<0.001
	(35,50]	454	408, 499	<0.001
	(50,65]	295	250, 341	<0.001
	(65,108]	137	91, 183	<0.001
Na/ed	educfinh			
	Not yet finished	—	—	
	Never went to school	-759	-1,354, -164	0.012
	14 or under	-362	-517, -206	<0.001
	15	-223	-361, -85	0.002
	16	-121	-255, 14	0.078
	17	-174	-321, -26	0.021
	18	-126	-268, 17	0.083
	19 or over	-136	-270, -0.85	0.049

¹CI = Confidence Interval

Multivariable regression models were constructed based on the outcomes of the univariable regression identifying relevant additional variables.

The selected models regressed against (hyp) a variable identifying hypertension as 140mmHg in patients who are not on BP reducing medication.

The model, “Sodium Only”, adds sodium as the exposure variable. The odds ratio for the group taking between 5000mg and 6000mg per day is statistically significantly different from those taking less than 3000mg per day. There is an odds ratio of 5.07 for this group.

“UPF only” shows a significant difference in odds ratio 0.61 for the group 63-80% with a p.value of 0.049.

The last model, “Sodium and UPF”, shows that when combined the effect remains. The odds ratio for 5000-6000mg of Na remains statistically significant. The odds ratio for UPF also remains.

Table 4.5.1 follows below.

Exposures	Na only			UPF only			Na and UPF	
	OR ¹	95% CI ¹	p-value	OR ¹	95% CI ¹	p-value	OR ¹	95% CI ¹
Sodium Intake in mg								
<3000]	—	—					—	—
[3000, 5000]	0.99	0.68, 1.43	>0.9				1.04	0.72, 1.51
(5000, 6000]	1.24	0.74, 2.07	0.4				1.37	0.81, 2.29
(6000, 8000]	5.07	1.37, 18.8	0.015				5.43	1.44, 20.4
(8000, 10000]	0.00	0.00, 0.00	<0.001				0.00	0.00, 0.00
Ultra-processed Food								
<10%				—	—		—	—
(10, 20%]				0.86	0.54, 1.36	0.5	0.83	0.52, 1.33
(20, 30%]				0.73	0.48, 1.12	0.2	0.71	0.46, 1.09
(30, 40%]				0.61	0.37, 1.00	0.049	0.57	0.35, 0.95
(40, 50%]				0.74	0.26, 2.06	0.6	0.69	0.24, 1.95

	Na only			UPF only			Na and UPF	
Statistic	OR ¹	95% CI ¹	p-value	OR ¹	95% CI ¹	p-value	OR ¹	95% CI ¹

s Ratio, CI = Confidence Interval

include additional variables Sex, Age, BMI, Education, IMD and Survey Year

Using the AIC statistic for each model gives another way of understanding the comparative effects. The subsequent [Table 4.5.2](#) shows the size of the effect relating to sodium. The lowest scored model is the optimal model. The ‘best’ of these models is that with only sodium included “Na only”. The UPF models both being further away from the lowest value.

Of the difference between the lowest scoring model and the highest 80/20 is due to UPF

There is a significant sensitivity of the data set to improved modelling. Though the set of models around the same values includes the four regressed against BP, and two of those against UPF which include BP.

```
## [1] 100
```

```
## [1] 195.2547
```

Table of AIC NDNS data 2008-2019

Model	AIC
character	numeric
No Na or UPF	3,586.3
Na only	3,580.8
UPF only	3,584.4
Na and UPF	3,577.5

Discussion

Key Results

The chi squared test shows a statistically significant correlation between UPF and hypertension. This simple model does not allow for confounding or additional variables to be taken into account.

The multivariable logistic regression controls a number of additional variables. Sex and age probably contribute the largest affects. These models show a statistically significant correlation between high Na intake and hypertension , and between high UPF and hypertension. This is present with each variable independently and with both in the model.

Limitations

The study

This is a cross-sectional study, and so has the limitations of this design. In particular the study measures exposure and outcome at the same time. This makes interpretation of the direction of causation difficult. This is particularly an issue here where participants aware of their BP might have chosen to reduce their UPF intake.

This study was organised by the government departments connected with food and farming alongside the Department of Health. This means it was intended to monitor outcomes relevant to these departments. The funding and commissioning processes might affect the structure of the study and might also affect participant engagement and expectation. In particular this might affect social desirability bias. Social desirability and other participant reporting bias may well be significant within dietary diaries. Double labelled water studies on the first wave showed some significant differences between measured energy intake, and reported energy intake with differences between different age groups.

The data

The result depends on participants recording foods in the same way as time goes on. Exposure of the whole population to a stimulus to change their diet or the recording of their diet may result in systematic changes in results.

A uniform change in the nutrient content of the food or changing the nutritional definitions would affect results. Years 9-11 used a slightly different methodology for identifying foods for analysis as researchers have started to become aware of the need to understand 'processing'. This may account for the apparent lower exposure in the last three years.

These changes would affect the outcome variable less. However BP measurement technology has changed over ten years. BP machines derive their results from the changes in pressure detected in the arm of the participant, the algorithm used by the sphygmomanometer may have changed.

Weighting maintains age, sex, IMD, and government region across the waves. BMI is no different, and educational attainment is also unaffected. There are more vegetarians as time goes on.

The populations do change over time as some of the added variables do show statistical significant changes. In particular the number of vegetarians increases, which perhaps is one indicator of social desirability affecting the study.

In populations with exclusions the careful sample selection and weighting are overcome by the biasing effect of different selections. When this is on BP there is a change between cohort sex balance. This is possibly as a result of changing/ increasing acceptance of BP results of all people whereas in earlier cohorts there were less women with raised BP levels.

This effect is perhaps greater when medication exclusions are made. Treatment of women and younger men has increased over the 10 years of the study.

The analysis

Interpretation

Participants with high Na >5000mg are more likely to have hypertension. Causation from other studies is likely to be that this high Na intake is contributing to high BP. However from this study causation cannot be identified. Other possibilities are that raised BP stimulates ingestion of Na, that Na ingestion increases hypertension, or that people with hypertension share another characteristic that increases their Na intake.

The results around high UPF intake also do no more than imply correlation. Causation might be the high BP reduces intake of UPF, or that participants with high BP are more aware of dietary UPF content. This can affect the detected directionality of the correlation.

Ideas for further research

I will divide these suggestions into quantitative and qualitative.

Quantitative

There is scope for more research based on this data set. Within this same biomedical paradigm there are whole range of variables which can be compared against the clinical and biochemical outcomes. These include measured variables such as BMI, biochemical indicators such as HbA1c and medical diagnostic categories such as Diabetes.

Modelling research has allowed projections to be made using the data from studies such as this as a base for projected models. This can evaluate policy effects.

Mixed and Qualitative

The richness of the quantitative data in this survey calls for its use within an approach allowing more detailed description and in depth assessment with participants. In the study

data there are data allowing research around cooking activities, hobbies, and eating activities.

It could also be used as a template for studies smaller in geographical scope, but more in depth as cross over studies collecting both quantitative and qualitative data.

Ideas for policy

Policy is an 'upstream' approach. It can be used to reduce exposure indirectly or directly. Ideas include legislation to reduce UPF use, this might be by pricing, or other approaches. Health promotion policy needs to match policy activity. People who know that UPF is bad, are more likely to accept policy limiting availability.

Reformulation is a policy suggestion, where UPF is further processed to remove the salt. This is frequently discussed. By demonstrating that UPF is not just high in salt this study supports the argument of avoiding further formulation as a policy for reducing BP.

Dietary approaches to improving public health are able to deliver proportionate and universal interventions to populations to reduce the incidence of NCD. When delivered upstream at the policy level they are effective and efficient and minimise cost. These approaches offer significant benefits over actions targeted at individuals.

Dietary and 'awareness' approaches can be used by individuals. These approaches risk the development of a culture of blame of individuals and of sub-groups in society. The commercial and social determinants of health play out a significant role in research, and delivery of public health improvements around food.

This study aims to inform local policy to reduce BP and so Non-Communicable Disease. If UPF and sodium intake increase the risk of hypertension then policy to reduce exposure might deliver change at a population level.

Generalisability

This study used national data. This was stratified across the four home nations. It was stratified for IMD, and sex and to cover adults and children. The study can therefore be generalised to the UK population. The results are comparable with those in Korea, Brazil and USA. These include countries with lower UPF intake, but also similar levels.

Conclusion

In summary the research question was In adults and children across the four home nations of the UK between 2008 and 2019, did exposure to high sodium dietary intake, and or high UPF dietary intake, compared to lower exposure, increase the odds of having a mean systolic blood pressure of over 140mmHg?

In answer, the odds ratio for hypertension is increased and statistically significant for high Na compared to lower exposure to Na. The odds ratio for hypertension is statistically significant for high UPF, being lower compared to lower exposure to UPF.

The first finding matches the findings of other researchers in other countries and in past studies in the UK. The second finding seems to be contrary to other studies. Further research will be needed to understand this result.

Other objectives were also met with a literature review examining the research around Na and UPF and BP, and discussion of the interpretation and generalisability of the study. I will present the findings to support policy development.

Bibliography

::: {#refs} :::

Appendix

Appendix 1 Approved Proposal

The approved proposal

Appendix 2 Ethics Certificate

The ethics cert.

Appendix 3 Software used

The software used

1. Cardiovascular disease - data - OHID [Internet]. Available from: <https://fingertips.phe.org.uk/profile/cardiovascular/data#page/1/gid/1938133106/pat/223/par/E40000010/ati/221/are/nE54000008/iid/219/age/1/sex/4/cat/-1/ctp/-1/yr/1/cid/4/tbm/1/page-options/car-do-0>
2. High Blood Pressure & Cardiovascular Disease Prevention | Champs Public Health Collaborative [Internet]. 2020. Available from: <https://champspublichealth.com/blood-pressure/>
3. Du S, Neiman A, Batis C, Wang H, Zhang B, Zhang J, et al. Understanding the patterns and trends of sodium intake, potassium intake, and sodium to potassium ratio and their effect on hypertension in China 1,2,3. The American Journal of Clinical Nutrition [Internet]. 2014 Feb 1;99(2):334–43. Available from: <https://www.sciencedirect.com/science/article/pii/S0002916523049511>
4. Cappuccio FP, Capewell S. Facts, Issues, and Controversies in Salt Reduction for the Prevention of Cardiovascular Disease. 2015;7(1):21.
5. Moreira PVL, Baraldi LG, Moubarac JC, Monteiro CA, Newton A, Capewell S, et al. Comparing Different Policy Scenarios to Reduce the Consumption of Ultra-Processed Foods in UK: Impact on Cardiovascular Disease Mortality Using a Modelling Approach. Hernandez AV, editor. PLOS ONE [Internet]. 2015 Feb 13;10(2):e0118353. Available from: <https://dx.plos.org/10.1371/journal.pone.0118353>

6. Marmot M, Allen J, Boyce T, Goldblatt P, Callaghan O. All together fairer: Health equity and the social determinants of health in cheshire and merseyside. London; 2022.
7. University Of Cambridge MEU, NatCen Social Research. NDNS RPNational diet and nutrition SurveysNational diet and nutrition survey years 1-11, 2008-2019. 2022; Available from: <https://beta.ukdataservice.ac.uk/datacatalogue/doi/?id=6533#19>
8. Elm E von, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. BMJ [Internet]. 2007 Oct 18;335(7624):806–8. Available from: <https://www.bmj.com/content/335/7624/806>
9. Bruce N, Pope D, Stanistreet D. Quantitative methods for health research: A practical interactive guide to epidemiology and statistics. Second edition. Hoboken, NJ: Wiley; 2018.
10. Jafar AJN. What is positionality and should it be expressed in quantitative studies? Emergency Medicine Journal [Internet]. 2018 Jan 11; Available from: <https://emj.bmj.com/lookup/doi/10.1136/emered-2017-207158>
11. Evans L, Trotter DRM. Epistemology and Uncertainty in Primary Care: An Exploratory Study. Family Medicine. 41(5):8.
12. Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ [Internet]. 2021 Mar 29;n160. Available from: <https://www.bmj.com/lookup/doi/10.1136/bmj.n160>
13. Scopus | the largest database of peer-reviewed literature | elsevier [Internet]. Available from: <https://www.elsevier.com/en-gb/solutions/scopus>
14. Ovid: Search form [Internet]. Available from: <https://ovidsp.dc1.ovid.com/ovid-b/ovidweb.cgi?QS2=434f4e1a73d37e8cf66185f15d893d09240dc867c99b537069b551c0426841bbc6d4c4bcf1cb76dab1f9942ed8716272304cfa1dda7c2540178089af00d2be2da024db246851a260e30a99a35a0b305fdd220d8528bc6964ca701aa2828288873ef69169deed62b35b9a90a5e36c7f2d4813a4f135eda2c83f0a385349cbbb758e4c16cb3ac1291c704a94203038dc0ff849a67807328e8000b370b5f2b1191a500a6c4b22c0f909a786216f3817a25c83da34acd720eb96a1f34f944d57a5030f554c4861ef4c235ecd46bd3b4e5737f17c5e58cdb685c139982761767a57a10b3da88adce86aa245ae3f89ecfe6e23cdeadd102ef459f246894b69d120a6ba37c70f9f2c7d19ae>
15. McLean MW. Straightforward bibliography management in r using the RefManager package [Internet]. 2014. Available from: <https://arxiv.org/abs/1403.2036>
16. Dahl LK. Salt in processed baby foods. The American journal of clinical nutrition. 1968;21(8):787–92.

17. Du S, Wang H, Zhang B, Popkin BM. [Dietary potassium intake remains low and sodium intake remains high, and most sodium is derived from home food preparation for chinese adults, 1991-2015 trends](#). The Journal of nutrition. 2020;150(5):1230–9.
18. Du S, Kim H, Rebholz CM. Higher ultra-processed food consumption is associated with increased risk of incident coronary artery disease in the atherosclerosis risk in communities study. Journal of Nutrition [Internet]. 2021;151(12):3746–54. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85121460182&doi=10.1093%2fjn%2fmxab285&partnerID=40&md5=04099f56ae4452a95dfb9e2198e98747>
19. Ware LJ, Charlton K, Schutte AE, Cockeran M, Naidoo N, Kowal P. [Associations between dietary salt, potassium and blood pressure in south african adults: WHO SAGE wave 2 salt & tobacco](#). Nutrition, metabolism, and cardiovascular diseases : NMCD. 2017;27(9):784–91.
20. Charlton KE, Corso B, Ware L, Schutte AE, Wepener L, Minicuci N, et al. Effect of south africa’s interim mandatory salt reduction programme on urinary sodium excretion and blood pressure. Preventive Medicine Reports [Internet]. 2021;23. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85111196456&doi=10.1016%2fj.pmedr.2021.101469&partnerID=40&md5=8767a7a129aeb93240f33cfe57cc15e8>
21. Colin-Ramirez E, Espinosa-Cuevas A, Miranda-Alatrliste PV, Tovar-Villegas VI, Arcand J, Correa-Rotter R. [Food sources of sodium intake in an adult mexican population: A sub-analysis of the SALMEX study](#). Nutrients. 2017;9(8).
22. De Deus Mendonça R, Souza Lopes AC, Pimenta AM, Gea A, Martinez-Gonzalez MA, Bes-Rastrollo M. Ultra-processed food consumption and the incidence of hypertension in a mediterranean cohort: The seguimiento universidad de navarra project. American journal of hypertension. 2017;30(4):358–66.
23. Barbosa LB, Vasconcelos NBR, Dos Santos EA, Dos Santos TR, Ataíde-Silva T, Ferreira H da S. [Ultra-processed food consumption and metabolic syndrome: A cross-sectional study in quilombola communities of alagoas, brazil](#). International journal for equity in health. 2023;22(1):14.
24. Reyhani P, Azabdaftari F, Ebrahimi-Mamagani M, Asghari-Jafarabadi M, Shokrvash B. The predictors of high dietary salt intake among hypertensive patients in iran. International Journal of Hypertension [Internet]. 2020;2020. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85084057696&doi=10.1155%2f2020%2f6748696&partnerID=40&md5=ae7096cb2c2a9a87129217578e378ae8>
25. Ponzio V, Ganzit GP, Soldati L, De Carli L, Fanzola I, Maiandi M, et al. [Blood pressure and sodium intake from snacks in adolescents](#). European journal of clinical nutrition. 2015;69(6):681–6.

26. Hajmir MM, Shiraseb F, Ebrahimi S, Noori S, Ghaffarian-Ensaf R, Mirzaei K. Interaction between ultra-processed food intake and genetic risk score on mental health and sleep quality. *Eating and Weight Disorders* [Internet]. 2022;27(8):3609–25. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85144645474&doi=10.1007%2fs40519-022-01501-8&partnerID=40&md5=269f554bbeba252a8a1a2391fd82fbad>
27. Harrington JM, Fitzgerald AP, Kearney PM, McCarthy VJ, Madden J, Browne G, et al. DASH diet score and distribution of blood pressure in middle-aged men and women. *American journal of hypertension* [Internet]. 2013;26(11):1311–20. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84933499946&doi=10.1093%2fajh%2fhpt106&partnerID=40&md5=61fc359ae16fbc1c228f0c5591b3ebf7>
28. Korff M, Wicks M, Zyl T van, Westhuizen B van der. The south african sodium regulation (R214): Does it make provision for processed foods frequently consumed by young children? *SAJCH South African Journal of Child Health* [Internet]. 2020;14(1):45–9. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85083850020&doi=10.7196%2fSAJCH.2020.v14i1.1671&partnerID=40&md5=5dfd1cbf977ba7ae82eed6acc9255a7b>
29. Westrick SC, Garza KB, Stevenson TL, Oliver WD. *Association of blood pressure with sodium-related knowledge and behaviors in adults with hypertension*. *Journal of the American Pharmacists Association : JAPhA*. 2014;54(2):154–8.
30. Cunha N de M, Frehner C, Zanini AC, Zaina FE, Matos CH de, Bertacco RTA, et al. *Contribution of ultra-processed foods consumption in sodium ingestion of atherosclerotic disease patients, residents in the southern region of brazil*. *Clinical nutrition ESPEN*. 2019;32(101654592):140–4.
31. Johnner SA, Thamm M, Schmitz R, Remer T. *Current daily salt intake in germany: Biomarker-based analysis of the representative DEGS study*. *European journal of nutrition*. 2015;54(7):1109–15.
32. Asma A, Lokman NAH, Hayati MY, Zainuddin AA. Ultra-processed food classification, their contribution to sodium and added sugar availability, and its relationship with nutritional status among adults in terengganu, malaysia. *IIUM Medical Journal Malaysia* [Internet]. 2019;18(3):49–58. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85096873804&doi=10.31436%2fimjm.v18i3.193&partnerID=40&md5=a9643393d9f12cca0b443b39a285e939>
33. Quader ZS, Zhao L, Harnack LJ, Gardner CD, Shikany JM, Steffen LM, et al. Self-reported measures of discretionary salt use accurately estimated sodium intake overall but not in certain subgroups of us adults from 3 geographic regions in the salt sources study. *Journal of Nutrition* [Internet]. 2019;149(9):1623–32. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0->

85072056500&doi=10.1093%2fjn
%2fnxz110&partnerID=40&md5=e553db6a95ac94ed82356fae0d55b9b6

34. D'Avila HF, Kirsten VR. [ENERGY INTAKE FROM ULTRA-PROCESSED FOODS AMONG ADOLESCENTS](#). CONSUMO ENERGETICO PROVENIENTE DE ALIMENTOS ULTRAPROCESSADOS POR ADOLESCENTES. 2017;35(1):54–60.

35. Jovičić-Bata J, Grujičić M, Raen S, Novaković B. Sodium intake and dietary sources of sodium in a sample of undergraduate students from novi sad, serbia [unos natrijuma i nutritivni izvori natrijuma u uzorku studenata iz novog sada, srbija]. Vojnosanitetski Pregled [Internet]. 2016;73(7):651–6. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84977591900&doi=10.2298%2fVSP141010063J&partnerID=40&md5=52519e9d2b8be3f358fb9bb4bf75fb81>

36. Shim SY, Kim HC, Shim JS. Consumption of ultra-processed food and blood pressure in korean adults. Korean circulation journal. 2022;52(1):60–70.

37. Wang L, Du M, Wang K, Khandpur N, Rossato SL, Drouin-Chartier JP, et al. Association of ultra-processed food consumption with colorectal cancer risk among men and women: Results from three prospective US cohort studies. BMJ [Internet]. 2022 Aug 31 [cited 2022 Dec 1];378:e068921. Available from: <https://www.bmj.com/content/378/bmj-2021-068921>

38. Rezende-Alves K, Hermsdorff HHM, Miranda AE da S, Lopes ACS, Bressan J, Pimenta AM. Food processing and risk of hypertension: Cohort of Universities of Minas Gerais, Brazil (CUME Project). Public Health Nutrition [Internet]. 2021 Sep;24(13):4071–9. Available from: <http://www.cambridge.org/core/journals/public-health-nutrition/article/food-processing-and-risk-of-hypertension-cohort-of-universities-of-minas-gerais-brazil-cume-project/100DCOD407DBEAAA99C701A707061329>

39. Scaranni P de O da S, Cardoso L de O, Chor D, Melo ECP, Matos SMA, Giatti L, et al. Ultra-processed foods, changes in blood pressure and incidence of hypertension: The Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). Public health nutrition. 2021;24(11):3352–60.

40. Monteiro CA, Levy RB, Claro RM, Castro IRR de, Cannon G. A new classification of foods based on the extent and purpose of their processing. Cadernos de Saúde Pública [Internet]. 2010 Nov;26:2039–49. Available from: <http://www.scielo.br/j/csp/a/fQWy8tBbJkMFhGq6gPzsGkb/?lang=en>

41. Martinez-Steele E, Khandpur N, Batis C, Bes-Rastrollo M, Bonaccio M, Cediel G, et al. Best practices for applying the nova food classification system | nature food. Nature Food [Internet]. 2023 Jan 6; Available from: <https://www.nature.com/articles/s43016-023-00779-w>

42. Lennox A, Bluck L, Page P, Pell D, Cole D, Steer T, et al. Misreporting in the National Diet and Nutrition Survey Rolling Programme (NDNS RP): summary of results and their interpretation.
43. Wang M, Du X, Huang W, Xu Y. Ultra-processed foods consumption increases the risk of hypertension in adults: A systematic review and meta-analysis. *American journal of hypertension*. 2022;35(10):892–901.
44. OpenEpi. OpenEpi - sample size for unmatched case-control studies [Internet]. 2021. Available from: <https://www.openepi.com/SampleSize/SSCC.htm>
45. Wang M, Du X, Huang W, Xu Y. Ultra-Processed Foods Consumption Increases the Risk of Hypertension in Adults: A Systematic Review and Meta-Analysis. *American Journal of Hypertension* [Internet]. 2022 Oct 1 [cited 2022 Nov 12];35(10):892–901. Available from: <https://doi.org/10.1093/ajh/hpac069>
46. R Core Team. R: A language and environment for statistical computing [Internet]. Vienna, Austria: R Foundation for Statistical Computing; 2022. Available from: <https://www.R-project.org/>
47. Lumley T. Analysis of complex survey samples. *Journal of Statistical Software*. 2004;9(1):1–19.