Food insecurity, macronutrient intake and patterns of eating in a sample of UK adults

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Abstract

How do the dietary intake patterns of people exposed to food insecurity differ from those of people who are food secure? A recent study of a US sample found that food insecurity was associated with greater reliance on carbohydrate, a lower diversity of food, and more variable time gaps between eating. We examined whether these features were also present in a sample of UK adults. From a low-income population, we recruited matched groups of participants who were classified as food insecure ($n = 196$) or food secure ($n = 198$) according to a standard questionnaire measure. We collected up to five twenty-four-hour dietary recalls from each participant. Results were strikingly like those from the US study. Food insecure respondents consumed relatively more carbohydrate and less protein; had fewer distinct foods per meal; and had more variable time gaps between meals. Food insecure participants did not have significantly higher body mass indices in this study. Food insecurity as measured by questionnaire appears to relate to a repeatable set of changes to dietary intake across populations.

Introduction

How do the diets of people experiencing food insecurity differ from people who are food secure? In this paper, we address this question using four days of 24-hour food recall data from a sample of British adults designed to contain equal numbers of food secure and food insecure individuals. Food insecurity (FI) is defined as the ‘the inability to acquire or consume an adequate quality or sufficient quantity of food in socially acceptable ways, or the uncertainty that one will be able to do so’ (Dowler & O’Connor, 2012, p. 1). FI is associated with poorer health, higher mortality, and, in the case of women, a greater risk of overweight or obesity, even after adjusting for socioeconomic position (Kowaleski-Jones et al., 2018; Laraia, 2012; Larson & Story, 2011; Nettle et al., 2017; Pan et al., 2012; Townsend et al., 2001; Vozoris & Tarasuk, 2003). Some of these health consequences may be due to different patterns of dietary intake in people experiencing FI, compared with people who are not (Kendall et al., 1996; Nettle & Bateson, 2019; Zizza et al., 2008). But how exactly do patterns of dietary intake differ with FI? The questionnaires used to assess FI do not answer this question in detail, since they consist of general statements such as “we couldn’t afford to eat balanced meals”. The response to this question carries no information about exactly how the meals were unbalanced. The question can therefore only be addressed with datasets where the same individuals complete FI questionnaires, and also provide detailed dietary recall information separately.

In a recent study, Nettle & Bateson, (2019) used two days of nutritional intake data from the US National Health and Nutrition Examination Survey (NHANES, 2013-4) to quantify the differences in dietary intake patterns between women classified as food insecure and food secure. They found several clear differences, which we review below, some of which have also been observed in other studies. However, the same analyses have not yet been replicated in other samples, so the generality of the observed patterns is unknown. Here, we seek to replicate the analyses of Nettle & Bateson (2019) in an independent sample from a different country, the UK. Our goal is to answer the questions: are the ways that food-insecure people eat differently, as documented in Nettle and Bateson (2019), specific to the US population they studied, or can they be independently observed in a sample from the UK population, 6-7 years later?

Nettle & Bateson (2019) found no difference in total energy intake between food secure and food insecure women but significant associations between FI status and macronutrient intake; the number of consumption events (CEs); and the temporal patterning of CEs. Food insecure

women ate more carbohydrate but less protein and fibre. They had fewer CEs each day with fewer distinct foods and less variability of foods at each CE. Their first CE was also later in the day and they had greater variability in time gaps between CEs. Food insecure women also had a higher BMI. Similarly, prior research has found no difference in total energy intake between food secure and food insecure adults (Basiotis & Lino, 2002; Bocquier et al., 2015; Dixon et al., 2001; Leung et al., 2014; Zizza et al., 2008), but that FI was associated with eating fewer but larger meals (Zizza et al., 2008) and a higher BMI in women (Basiotis & Lino, 2002; Kowaleski-Jones et al., 2018; Larson & Story, 2011; Nettle et al., 2017; Pan et al., 2012; Townsend et al., 2001). Nettle & Bateson (2019) further found that variability in eating patterns, the gap between CEs, the lack of variety of foods consumed at each CE, and low intake of fibre accounted statistically for 14.5% of the association between FI and BMI.

Several studies have found that macronutrient and energy intake are important factors in regulating weight (Labayen et al., 2014; Martinez, 2000; Nelson & Tucker, 1996; Sarebanhassanabadi et al., 2020). Temporal variability in eating patterns, including for example, skipping breakfast and eating late at night are also associated with a greater risk of obesity/overweight (Howarth et al., 2007; Murtaugh et al., 2007; Nettle & Bateson, 2019; Saneai et al., 2016; St-Onge et al., 2017). Moreover, randomised trials showing that making the timing of food intake more variable changes the thermic effect of food, in ways that, if sustained over the long term, would lead to weight gain (Alhussain et al., 2016; Farshchi et al., 2004). Research in animal models shows that experimentally introducing variable time gaps between CEs can lead to mass gain, even without any simultaneous increase in total energy intake (Bateson et al., 2021; Bednekoff & Krebs, 1995; Cuthill et al., 2000).

Establishing whether macronutrient and energy intake and variability in time gaps between CEs differ by food insecurity status could help us to understand why food insecure women are at greater risk of obesity.

Here, we seek to replicate and extend the analysis of the NHANES 2013-14 dataset undertaken by Nettle & Bateson (2019), but using a UK sample, with four days of nutritional intake data. Our sample, which was generated as a part of an ongoing project, differs from the NHANES in a number of regards. Whereas NHANES is large and nationally representative, ours was smaller (final $n=394$), and recruited by purposive sampling. We targeted a population (UK adults on relatively low incomes) likely to contain substantial exposure to food insecurity. From a large number of responses to an initial screening survey, we recruited

a food insecure group, and a food secure group of equal size matched for age and gender. Thus, where the analysis of NHANES relied on controlling statistically for a large number of covariates, our study used a matched group design to make the food secure and food insecure groups roughly comparable in other regards.

In their main paper Nettle & Bateson, (2019) just presented data from women, though they also showed in an appendix that the patterns in men were very similar. As the present UK sample consisted of all genders, we here re-analyse the NHANES 2013-4 data to present all genders combined, for direct comparability.

Materials and Methods

Data for this study were collected in two phases, as depicted in Figure 1. Phase 1 of the study was a screening exercise used to identify potential participants for phase 2.

Figure 1. A chart depicting the recruitment and sampling (phase 1) and data collection (phase 2) stages of the study.

Phase 1

Participant recruitment

Participants were recruited to phase 1 of this study via Prolific. Prolific is an internet based crowd sourcing platform that provides access to a high quality pool of potential research participants (for a review of Prolific, see Peer et al., (2017)). A pre-screening filter was applied to ensure that participants were resident in the UK, were not in full-time education and had a total household income of less than £30,800 per annum (the median household income in the UK (Office for National Statistics, 2020)). The household income filter was applied in order to identify individuals likely to experience FI, as well as food secure participants of similar socio-economic status. A total of 1500 participants were recruited to phase 1 of the study (male, 598, female, 898, other, 4, see Table S1 of supplementary materials). This sample size was designed to ensure a final food insecure sample of 200 based on the proportion of the UK population estimated to be food insecure at the time of data collection (Loopstra, 2020).

Demographic data

Demographic data were collected via a Qualtrics questionnaire distributed via Prolific (see Table S1). Measures included: age, gender, self-reported weight and height (from which we calculated body mass index (BMI)), number of people living in the household, whether participants did/paid for most of the food shopping for the household, employment status, and household income.

Food insecurity

Household FI status was assessed using the Household Food Security Survey Six-Item Short Form module (HFSSM) developed by the US National Centre for Health Statistics (NCHS) (USDA Economic Research Services, 2020). The six-item short form module identifies households which are food insecure and/or have very low food security. It has relatively high specificity compared to the longer, 18 item measure developed by the NCHS (USDA Economic Research Services, 2020).

Data for this study were collected during spring/summer 2020, during which pandemic lockdowns had caused turmoil and disruption to normal routines. The type of food insecurity experience we were interested in was that directly comparable to earlier studies such as Nettle and Bateson (2019), not shorter-term anxieties that might have been provoked by the onset of

the pandemic. We thus amended the HFSSM questions from their usual ‘in the last 12 months’ timeframe to ‘in the 12-month period prior to the pandemic’.

Responses to questions in the HFSSM were coded in accordance with guidance issued by the USA National Centre for Health Research (USDA Economic Research Services, 2020). In accordance with USDA HFSSM guidance, we dichotomised participants’ scores into two groups, food secure/marginal food security (score of 0-1) (n =1268) and low/very low food security (score of 2-6) (n = 232).

Phase 2

Participant recruitment

Data collected in Phase 1 were used to identify participants for phase 2 of the study (see Figure 1). At the end of phase 1, participants were asked to indicate if they could be contacted about participating in phase 2 of the study. A total of 93 participants (77 high or marginal food security status, 16 low or very low food security status) indicated that they did not want to take part in phase 2, resulting in a potential phase 2 participant pool of 1407. We invited 216 participants who had low/very low food security status to participate in phase 2 of the study. Sixteen participants declined to take part. The remaining 200 low/very low food security status participants were then matched by age and gender with 200 participants who had high/marginal food security status in phase 1. Four food secure participants declined to take part. In addition, in accordance with guidance from the developers of Intake 24, the dietary intake collection tool (see below), dietary intake data on two low/very low food secure participants were excluded from the analysis due to incorrect food diary completion. This resulted in a final sample for analysis of 198 low/very low food secure participants and 196 high/marginal food secure participants. For brevity, we henceforth refer to these groups as ‘food insecure’ and ‘food secure’ respectively.

Dietary intake

Dietary intake data were collected using Intake24. Intake24 is an open source, on-line, self-completion dietary recall system which was designed to capture food intake in population wide studies. In trials, Intake24 compared favourably with face to face nutritional intake data collection (Bradley et al., 2016; Simpson et al., 2017). Participants were asked to complete four consecutive days of dietary recall. On day 1, participants were sent a link and were asked to record all food and drink and timing of consumption in the previous 24 hours. The following day, a link was sent for day 2 of data collection. This process was repeated until up

to four days of dietary intake data were recorded. Two participants accidentally completed five days; 370 participants completed four days; 11 participants completed three days; 6 completed two days; and 5 participants, one day.

Mood and sleep

Data on participants' mood for the previous 24 hours, and how well they slept the night before, were also collected before completing each day's dietary recall. These data are not analysed here but will form the focus of a future study.

Food consumption variables

In line with the approach adopted by Nettle & Bateson (Nettle & Bateson, 2019), we extracted 16 variables of interest from the recall data, organised by CE, with each CE representing a time when participants consumed an item of food or drink (including water). Details of the variables extracted are presented in Table 1. The variables were of three types: those concerning consumption amounts; those concerning the intra-day patterning of CEs; and those concerning inter-day variation in eating patterns. The consumption amount variables were expressed as daily averages. The relative consumption of different macronutrients was adjusted for total food consumption (i.e., the residual of a regression on amount of macronutrient consumption on total food consumption). In Nettle and Bateson (2019), the inter-day variables were (unsigned) difference scores between the two days, since there were two days of food recall data for each participant in NHANES. For the present UK sample, since there were up to 5 days of recall per participant, the inter-day variables were standard deviations across days rather than difference scores.

Data analysis strategy

All data analyses were performed in R (R Core Development Team, 2020).

UK data

Our data analysis closely followed that of Nettle and Bateson (2019). We first used multivariate analyses of variance (MANOVAs) to investigate differences between food secure and food insecure adults for each of the three sets of consumption variables, using FI status as the predictor. The three sets of consumption variables were: consumption amounts (total energy intake and relative carbohydrate, protein, fat, and fibre intake); intraday patterns of eating (time of the first CE, number of CEs, mean number of foods per CE, variability in time gaps between CEs and variability in the amount of energy consumed at each CE), and interday patterns of eating (energy intake, time of the first CE, number of foods, number of CEs and

mean time gaps between CEs). We then followed up these MANOVAs with separate general linear models for each of the sixteen variables individually. We also tested whether FI status predicted BMI.

For analysis of our data, we only included gender as a covariate. This was because our food secure and food insecure groups were already matched by age, the recruitment strategy restricted the range of incomes to those below the median; and because, with a much smaller sample size than Nettle and Bateson (2019), statistical power for additional control variables was more limited.

NHANES data

To compare the patterns found in the UK data with those from NHANES 2013-4, we repeated the analyses reported by Nettle and Bateson (2019), but with all genders pooled. As per the approach adopted by Nettle & Bateson (2019), we controlled for age, income, education, ethnicity, and presence of children in the household as well as gender. Again, we first performed MANOVAs on the three sets of variables, followed by separate univariate general linear models on each outcome variable.

Results

Descriptive statistics

Descriptive statistics for the main food consumption variables for the UK sample and the pooled data from the NHANES 2013-14 cycle are shown in Table 1.

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239 Table 1. Variables extracted from the food recalls for the current study and NHANES pooled data

	Variable name	Definition	Units	UK data Mean (sd)	NHANES 2013-4 Mean (sd)
Consumption amounts	Energy intake	Total energy intake per day	kcal	1759 (680)	2056 (878)
	Carbohydrate	Carbohydrate	g	218.92 (95.21)	247.89 (112.52)
	Protein	Protein	g	67.22 (28.2)	81.96 (39.48)
	Fat	Fat	g	69.8 (30.93)	78.5 (40.07)
	Fibre	Fibre	g	16.48 (8.61)	16.9 (9.54)
Intraday patterns	First CE	Time of first CE	Hours from midnight	9.3 (1.9)	7.9 (2.3)
	Number of CE	Mean number of CE per day	Number	4.07 (1.08)	5.47(1.63)
	Mean foods per CE	Mean number of distinct foods per CE	Number	3.41 (1.02)	9.63 (3.3)
	Variability foods per CE	Intraday standard deviation number of distinct foods per CE	Number	1.47 (0.68)	5.34(1.94)
	Variability time gap	Intraday standard deviation in time gap between CEs	Minutes	93.38 (45.3)	109.42 (55.88)
Interday variability ¹	Variability energy per CE	Intraday standard deviation Kcal per CE	kcal	334.23 (247.19)	407.38 (195.52)
	IDSD energy intake	Interday standard deviation energy intake	Kcal	587 (614.94)	736.11 (688.83)
	IDSD first CE	Interday standard deviation time of first CE	Hours	1.42 (1.52)	1.83 (2.40)
	IDSD number of foods	Interday standard deviation number of foods	Number	0.68(0.4)	4.62 (3.90)
	IDSD number of CEs	Interday standard deviation number of CEs	Number	0.74 (0.6)	1.51 (1.33)
	IDSD mean time gap	Interday standard deviation mean time gap between CEs	Minutes	47.78 (34.49)	68.69 74.60)

240 1. These variables represent standard deviations for the UK data, but difference scores for the NHANES data where there are only two recall days per
241 participant. Hence, the descriptive statistics are not directly comparable. CE = Consumption event. IDSD = Interday standard deviation.

Main analyses

Results of the main analyses for both the UK and NHANES datasets are summarized in Table 2.

UK dataset

There was no significant effect of FI overall for the five food consumption variables. Follow up univariate analysis of the individual variables showed that food insecure adults consumed significantly more carbohydrate but less protein relative to their total energy intake than their food secure counterparts. There was no significant difference by FI status in total energy intake or relative fat and fibre consumption. There was a significant overall effect of FI on intraday patterns of eating. Food insecure adults consumed a significantly smaller and less variable number of foods per CE and had larger and more variable time gaps between CEs. However, there was no significant difference in the time of the first meal, the number of meals consumed, or the amount of energy consumed at each meal. There was no significant effect of FI on the interday patterns of eating, either in the MANOVA nor in relation to any of the individual variables.

Standardized parameter estimates, plus 95% confidence intervals, from the univariate analyses are shown in figure 2. The variables are ordered from the largest to the smallest absolute parameter estimate in Nettle and Bateson (2019), rather than the order of their size in the UK dataset.

Table 2. Parameter estimates for the difference between food-secure and food insecure participants. Food secure is the reference category, the parameter estimates represent the deviation of the food insecure participants from the food secure participants

	UK dataset		NHANES pooled dataset	
	<i>B (se)</i>	<i>p</i> -value	<i>B (se)</i>	<i>p</i> -value
<i>Consumption variables</i>	MANOVA F(5,387) = 1.25,	0.28	MANOVA F(5, 4947) = 36.18	<0.001
Energy intake per day	-49.68 (66.04)	0.45	18.03 (30.17)	0.50
Relative carbohydrate	8.32 (4.13)	0.04	5.52 (1.36)	<0.001
Relative protein	-3.42 (1.69)	0.04	-3.35 (0.95)	<0.001
Relative fat	-1.45 (1.48)	0.33	-1.14 (0.79)	0.14
Relative fibre	-1.16 (0.69)	0.09	-1.02 (0.25)	<0.001
<i>Intraday pattern variables</i>	MANOVA F(8,373) = 2.50	0.01	MANOVA (F6,4727) = 47.12	<0.001
First CE	2.24 (11.75)	0.85	-0.02 (0.08)	0.77
Number of CE	-0.11 (0.11)	0.32	-0.13 (0.06)	<0.05
Mean foods per CE	-0.28 (0.10)	0.01	-0.41 (0.12)	<0.001
Variability foods per CE	-0.23 (0.07)	<0.001	-0.29 (0.07)	<0.001
Variability time gap	9.09 (4.58)	0.048	8.31 (2.01)	<0.001
Variability energy per CE	-0.92 (24.60)	0.97	6.56 (6.71)	0.32
<i>Interday variability variables</i>	MANOVA F(5,366) = 1.23	0.30	MANOVA F(5,4365) = 15.48	<0.001
IDSD energy intake	26.04 (62.14)	0.68	45.38 (26.08)	0.08
IDSD first CE	16.87(9.21)	0.07	0.11 (0.09)	0.24
IDSD number of foods	-0.04 (0.04)	0.37	0.18 (0.16)	0.27
IDSD number of CEs	0.04 (0.04)	0.35	0.05 (0.05)	0.32
IDSD mean time gap	6.70 (3.56)	0.06	3.76 (2.88)	0.19

Figure 2. Standardized associations (plus 95% confidence interval) of the sixteen dietary variables with food insecurity status in the UK dataset. The order in which the variables appear is for direct comparability against figure 1 of Nettle and Bateson (2019).

NHANES dataset

For the five food consumption variables, there was a significant effect of FI overall. Food insecure adults in the NHANES sample consumed significantly more carbohydrate, but less protein and less fibre relative to energy intake than food secure adults. There was a significant effect of FI overall on intraday patterns of eating. Food insecure adults had fewer CEs each day, ate a smaller and less variable number of foods at each CE and had fewer distinct foods at each CE with more variable time gaps between CEs. There was no significant difference in the time of the first CE, nor in the total amount of energy consumed at each CE. There was a significant effect overall of FI on interday variation in patterns of eating. However, in the follow up analyses, none of the individual variables differed significantly by FI status.

Comparison of associations with FI in UK and NHANES datasets

Comparing which associations are significant in the UK and NHANES data is a poor way of assessing the similarity of patterns, since the much smaller sample from the UK means that associations are estimated with much less statistical power. Therefore, to investigate the extent to which being food insecure is associated with the same patterns of eating in our UK sample as in the NHANES sample, we compared the standardized parameter estimates related to FI status for each of the sixteen consumption variables. The pattern of associations was extremely similar for the two samples (correlation of parameter estimates between UK sample and NHANES, $r = 0.86$, $p < 0.001$; see figure 3).

Figure 3. Standardized associations with food insecurity status in the NHANES 2013-4 dataset against those in the UK dataset. Each point represents one variable. Error bars represent one standard error in the corresponding dataset.

Association between FI and BMI

There was no significant association between BMI and FI status in the UK sample, even including an expected interaction with gender: $B_{\text{female}} = 1.19$, $se = 1.12$, $t = -1.06$, $p = 0.29$; $B_{\text{FI}} = 0.10$, $se = 1.13$, $t = 0.08$, $p = 0.94$; $B_{\text{interaction}} = 0.19$, $se = 0.91$, $p = 0.91$). Thus, we did not investigate mediation of the FI-BMI association by food consumption variables.

Discussion

The aim of the current study was to determine whether, in a sample of UK adults, FI as measured by questionnaire was associated with the same patterns of dietary intake as it was in the larger US NHANES sample studied by Nettle and Bateson (2019). It was, to a quite striking extent. Just as in the NHANES dataset, food insecure individuals differed from food secure individuals in the composition of what they ate, and the temporal patterning of their eating, but not in the total number of calories they ate. In some cases, the UK results differed in significance from the NHANES results, but this may be attributed to the very much smaller sample size: the parameter estimates were in all cases extremely similar between the two datasets. In terms of macronutrient composition, food insecure individuals in the UK dataset ate relatively more carbohydrate and less protein. They tended to eat less fibre as well, though this trend was not significant in the UK dataset. In terms of temporal patterning, notably, they ate fewer distinct foods per meal, and with more variable time gaps between meals. These were two of the key patterns also found by Nettle and Bateson (2019). Thus, despite a different population, several years between the two studies, and several important methodological and contextual differences, the two studies reach convergent conclusions about how the eating behaviour of people exposed to food insecurity differs from that of those who are not.

Our finding of fewer distinct foods at each meal and more relative energy from carbohydrate and less from protein is consistent with prior research that shows that the dietary intake of people who experience FI contains low diversity but high amounts of cheaper carbohydrate based foods and lower amounts of quality protein (Dixon et al., 2001; Hanson & Connor, 2014; Tingay et al., 2003). Accessibility, cost, value for money, how satiating food is and the amount of food relative to the amount of money available to spend all play an important role in the decisions made by food insecure adults when shopping for food (Burns et al., 2013; Caraher et al., 1998; Dawson et al., 2008; A Drewnowski & Specter, 2004; Tinkler & Ritchie, 2016). Recent research in the UK for example shows that low income families cannot afford to meet dietary recommendations for good health (Taylor & Loopstra, 2016). The alternative therefore for low-income families who have less money to spend on food, is to buy cheap, energy dense but nonetheless highly palatable foods (Bocquier et al., 2015; Burns et al., 2013; Drewnowski & Specter, 2004; Drewnowski, 2010; Kirkpatrick & Tarasuk, 2007, 2008; Leung et al., 2014). However, other factors in addition to availability of money may influence food choices. The high fat, sugar and salt content of convenience foods make

these foods highly palatable and therefore potentially more psychologically rewarding (Drewnowski & Specter, 2004; Gearhardt et al., 2011).

Prior research has shown that high carbohydrate/low protein diets and high intakes of ultra-processed foods are associated with high energy intake (Couteur et al., 2016; Drewnowski & Specter, 2004; Lawrence & Baker, 2019; Morrison & Laeger, 2015; Rico-campà et al., 2016). However, although we found that food insecure adults consumed more carbohydrate and less protein relative to their energy intake, we found no significant difference in total energy intake itself. This accords with most previous studies of FI (Basiotis & Lino, 2002; Burns et al., 2013; Leung et al., 2014; Zizza et al., 2008), though some have found reduced energy intake associated with FI (Dixon et al., 2001; Kirkpatrick & Tarasuk, 2008). Observational studies have not found evidence for increased energy intake in association with FI in everyday life (Nettle et al., 2019; experimental studies where participants are given staged access to free food may be a different matter; Stinson et al., 2018). This means that the higher BMI that is robustly associated with FI in women (Nettle et al., 2017) is not apparently driven by increased habitual calorie consumption. Rather, differences in energy expenditure, or different obesogenic potential of foods consumed on different temporal schedules (Alhussain et al., 2016; Farshchi et al., 2004), must be implicated. We found no evidence for higher BMI in food insecure women in the current UK sample, but we note that our study was only modestly powered to detect such an association given the expected effect size (Nettle et al., 2017).

A key finding of Nettle and Bateson (2019) was that FI was associated with more variable time gaps between food consumption. They used this to justify connecting FI as studied in the social sciences and routinely measured by questionnaire with a rich experimental tradition in birds, in which time gaps between periods of food access are made more variable and/or unpredictable (Bateson et al., 2021; Bauer et al., 2011; Bednekoff & Krebs, 1995; Cuthill et al., 2000; Witter et al., 1995; Witter & Swaddle, 1997). Those studies show that FI leads to weight gain in birds, often without a concomitant increase in energy intake. Moreover, experimentally increasing variability in time gaps between food in humans causes metabolic changes that would, if sustained over the long term, lead to weight gain (Alhussain et al., 2016; Farshchi et al., 2004). The fact that we found the same association between FI and variable time gaps between food in the UK sample further buttresses connecting these experimental literatures with the study of FI in human populations.

The UK study had several limitations. First, the sample was small: the small number of participants compared to NHANES is not completely offset by the greater precision that arises from having more than two 24-hour food recalls per participant. Second, we relied on an opportunity sample. Although we restricted screening to low-income participants to draw from a relatively homogenous pool and used matching to remove variability due to age and gender, unmeasured socioeconomic or contextual differences between our food secure and food insecure groups may remain, and generalizability to the wider UK food insecure population is unknown. Third, our data collection took place during the coronavirus pandemic of 2020. This has a number of implications. It meant we had to assess FI with respect to the pre-pandemic period, but the dietary recalls themselves took place during the pandemic-affected period. Respondents were more likely to have been at home than usual, may have had routines disrupted, and many were affected by economic hardship. These uncertainties militated against finding stable associations of dietary intake patterns with (pre-pandemic) exposure to FI. Given these uncertainties, it is, perhaps, all the more remarkable that we found significant associations between FI status and dietary intake patterns, and in particular that these would be so strikingly similar to those of the earlier study in a different population unaffected by the pandemic. This does suggest that the FI questionnaire proxies some repeatable, systematic, general differences in patterns of dietary intake.

A further limitation is the possibility of biased reporting or under-reporting in dietary recalls. We are not concerned with whether the total energy intake was reported accurately, merely with the difference by FI status. Thus, for under-reporting to affect our conclusions, there would have to be differential under-reporting by FI status. This is certainly possible. Under-reporting in nutritional intake studies is often associated with social desirability, low income and high BMI (Maukonen et al., 2018; Orcholski et al., 2015; Scagliusi et al., 2009; Schoch & Raynor, 2012; Shields et al., 2015). Thus, it could also be associated with FI status. Under-reporting has been particularly highlighted in relation to total energy intake. Most of our statistically significant findings concern other variables, such as temporal gaps, and the extent to which these are affected by under-reporting or biased reporting is not known.

Conclusion

The current study adds to findings in the literature that suggest no difference in total energy intake of food secure and food insecure adults in their everyday diets. However, in line with a very different study in the USA, we found that FI is associated with a suite of changes to dietary intake, consisting of more reliance on carbohydrate at the expense of other

macronutrient groups, less dietary diversity, and more variable time gaps between eating episodes. In view of rising concern about the prevalence of FI in the UK (Department for Work and Pensions, 2021), and the potential health impacts of FI, these patterns are timely and important to understand.

Data availability

The data and code required to reproduce all analyses reported in this paper are freely available via the Zenodo repository at: <https://doi.org/10.5281/zenodo.4668564>

Supplementary materials

Table S1 Demographic information on participants recruited to phase 1 of the study.

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601 Table S1. Demographic profile of phase 1 screening exercise participants, by gender and food
 602 insecurity status.

Characteristic	Male		Female		Other
	Food secure	Food insecure	Food secure	Food insecure	Food secure
N	500	98	764	134	4
Mean age (SD)	38 (13)	35 (11)	38 (13)	34 (10)	29 (3)
Employed	339	59	525	82	2
Unemployed/Furloughed/ Retired/Ill health etc.	161	39	243	52	2
Household type					
Homeowner	221	12	339	35	
Rent	153	54	225	73	
Live with parents	126	32	144	28	4
Number of people living in the household (SD)	2.6 (1.2)	2.8 (1.3)	2.8 (1.1)	3.1 (1.4)	3.2 (1.9)

603