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High-risk environments for eating foods surplus to requirements: a multilevel analysis of adolescents' non-core food intake in the National Diet and Nutrition Survey (NDNS).

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Conflict of interest

None.

Authorship

The present work was designed by Z.T., A.H. and L.J.; analysis was conducted by Z.T., L.J. and K.T.; initial manuscript preparation and drafts were prepared by Z.T.; the final manuscript was revised by all authors. The authors declare that there are no conflicts of interest.

Abstract

Objective: Interventions to reduce adolescents' non-core food intake, i.e. foods high in fat and sugar, could target specific people or specific environments, but the relative importance of environmental contexts vs. individual characteristics is unknown.

Design: Cross-sectional.

Setting: Data from 4-day food diaries in the UK National Diet and Nutrition Survey (NDNS) 2008-2012 were analysed. NDNS food items were classified as 'non-core' based on fat and sugar cut-off points per 100g of food. Linear multilevel models investigated associations between 'where' (home, school, etc.) and 'with whom' (parents, friends, etc.) eating contexts and non-core food energy (kcal) per eating occasion (EO), adjusting for variables at the EO e.g. time of the day, and adolescent level, e.g. gender.

Subjects: Adolescents (n=884) aged 11-18 years.

Results: Only 11% of variation in non-core energy intake was attributed to differences between adolescents. In adjusted models, non-core food intake was 151% higher in EOs at 'Eateries' (2.51 95% CI 2.14, 2.95) and 88% higher at 'School' (1.88 95% CI 1.65, 2.13) compared to 'Home'. EOs with 'Friends' (1.16 95% CI 1.03, 1.31) and 'Family & friends' (1.21 95% CI 1.07, 1.37) contained 16-21% more non-core food compared with eating 'Alone'. At the individual level, total energy intake and BMI, but not social class, gender or age, were weakly associated with more non-core energy intake.

Conclusions: Regardless of individual characteristics, adolescents' non-core food consumption was higher outside of the home, especially at 'Eateries'. Targeting specific eating contexts, not individuals, may contribute to more effective public health interventions.

Introduction

Poor diets account for 10% of the global burden of disease (1). Adolescence represents a time when dietary intakes are at their worst (2, 3) and a trajectory is set for inadequate dietary intake in adulthood. Interventions to improve diet and reduce the burden of disease are urgently required. In the UK, adolescents' diet is not optimal and according to the most recent National Diet and Nutrition Survey (NDNS), their intake of saturated fats and added sugars is excessive (4). Few policies in the UK have tried to improve adolescents' food consumption, such as the implementation of school food standards to improve school meals (5). Consumption of energy-dense nutrient-poor foods at this age is an issue of public health concern and comprises one of the key strategies to prevent childhood obesity (6).

Core foods provide the body with all the essential nutrients required for health and should form the basis of everyday diet. Whereas non-core or discretionary foods are surplus to requirements and should have limited consumption. In the UK, non-core foods like regular soft drinks, crisps and savoury snacks, chips and potato products, chocolate and biscuits, make up 40% of adolescents' total energy intake (7) vastly exceeding recommendations (8, 9).

Understanding the context of non-core energy consumption, in terms of where and with whom adolescents eat non-core foods, could help identify high-risk environments where interventions can be focussed. In descriptive analyses we have shown that a greater proportion of calories eaten in eateries or with friends is non-core, thus these contexts may represent high-risk environments for eating surplus to requirements (7). However, these analyses did not consider the interrelations between characteristics of eating contexts, for example, eating occasions (EOs) with parents are more likely to be an evening meal (10). Furthermore, potential confounding by individual adolescent characteristics, such as age, sex, or socio-economic status (SES) could explain associations (11). It is unclear if greater non-core food intake occurs in eateries and with friends because of those physical and social contexts per se or because the type of people that eat in those contexts more often generally eat more non-core food.

A way to overcome this is the use of Ecological Momentary Assessment (EMA), i.e. collecting real-time information on people's behaviours in natural environments, which has had limited application in nutritional research (12). EMA can be combined with dietary assessment using multiday diet diaries, which offer data on many EOs in multiple different contexts for the same person. This will allow associations of specific contexts with non-core food intake to be estimated within-person whilst holding variation in individual characteristics constant. Multilevel modelling (MLM) can partition variation in the amount of non-core food eaten in an EO to within- and between-person sources to explore the relative contribution of the individual characteristics vs. the environment.

A couple of analyses have explored the association of eating context with food intake by accounting for within and between people variation or the use of EMA (12, 13). Both these studies highlighted specific environments that could benefit from the provision of healthier food choices to improve children's and adults' food intake, suggesting similar environmental targets could be identified to reduce adolescent non-core food consumption, but to our knowledge no studies in adolescents have yet been conducted.

We aimed to determine the independent relationship between specific eating contexts and non-core energy consumption in an EO, by focussing on variation in the characteristics of different EOs within adolescents whilst holding between adolescent variation constant.

Methods

Study sample

Dietary data were used from 884 adolescents aged 11-18 years old from Years 1-4 (2008/09 – 2011/12) of the UK NDNS rolling programme. Details about the design of NDNS can be found elsewhere (4), relevant details to this analysis are described below. The NDNS was conducted according to the Declaration of Helsinki and was approved by the Oxforshire A Research Ethics Committee. (4). Data for the present analysis was downloaded from the UK data archive (14).

Dietary data

Participants completed a 4-day food diary recording details of all EOs including food and drinks consumed, while a form of EMA was used to collect information on 'where' and 'with whom' the EO occurred. Further description about the dietary assessment can be found elsewhere (15). Foods and food groups (16) were classified as non-core using specific fat and sugar cut off points per 100 g of food (17), following a previously used approach(18). A total of 20 food groups containing non-core foods was determined. Further information about the allocation of foods to non-core can be found elsewhere (7). Raw data represented one food item consumed by one adolescent within one EO in each row. EOs were defined as all food and drink items consumed together by the same person, on the same day, at the same time. Total non-core energy intake (kcal) per EOs was the sum of energy from all non-core foods and drinks reported.

Definition of eating context

NDNS used EMA to collect real-time information on where and with whom food consumption occurred. Thirty six locations of EOs were collapsed into 7 categories (Home, Friend's/Relative's House, School, Eateries, such as restaurants, cafes and fast food places, On the Go, Activity/Other Places, Work) and 19 'with whom' categories were collapsed into 5 groups (Alone, Parents/Carers, Parents & Siblings, Family & Friends, Friends, Not Specified) for analysis (7). For the 'where' and 'with whom' categories, 'Home' and 'Alone' were the reference groups respectively.

Potential confounders

A review of the literature and the availability of data in the survey informed the selection of potential confounders, which included; 1) Time (hours) of each EO; 2) Day of each EO (weekday (Monday – Friday) or weekend day (Saturday – Sunday)); 3) TV watching, 4) sex; 5) age (years); 6) Body Mass Index (BMI) (kg/m^2), computed from measured weight and height and standardised for age and sex using 1990 British Growth Reference (19). BMI categories, i.e. underweight, normal weight, overweight and obese, based on International Obesity Task Force (IOTF) criteria were also created and were used in interaction models; 7) adolescent SES indicated by parental occupation (high, intermediate, or low (reference category)) based on the National Statistics Socio-Economic Classification (NSSEC) (20); and 8) adolescents' average total daily energy intake (EI) (per 1000 kcal/day).

Data analysis

The frequency (%) of all EOs and characteristics of EOs in specific 'where' and 'with whom' eating contexts were reported at the survey level. Mean and standard deviations (SD) described total and non-core EOs per day consumed by adolescents overall and in specific contexts. Individual characteristics of adolescents reporting EOs overall and in specific contexts are described using frequencies and percentages (for categories) and in means and standard deviations (for continuous). Pearson chi-square tests were used to examine simple associations between eating contexts and categorical characteristics of EOs or adolescents. Differences between eating contexts and continuous variables were examined using Kruskal-Wallis tests for non-normal and ANOVA for normally distributed variables.

Multilevel modelling (MLM)

MLM (21) investigated the relationship of eating contexts with non-core energy consumption. Level 1 variation was in characteristics of EOs (where, with whom, time and day of the week of each EO and TV watching) and level 2 variation was in characteristics of adolescents (age, sex, SES, BMI and total EI). EOs are nested within adolescents hence, MLM allowed us to explore whether non-core energy intake varies within and between adolescents, as well as factors that explain this variability. Non-core kilocalories (kcal) per EO was not normally distributed, owing to non-consumption of non-core foods in 31% of EOs, and was logged to approximate the normal distribution.

A series of models were run: Model 1, was the null intercept model, which included just the adolescent identifier in the random part of the model, to explore the extent to which differences in non-core energy intake were bigger between adolescents vs. within adolescents. Model 1.1 to 1.9 are random intercept univariable models, where each model included adolescent identifier and an additional single explanatory variable from either the EO or adolescent level entered separately in their own model. These models examined the individual effect of each EO related variable on non-core energy. Model 2 is a random intercept model and included all explanatory variables at the EO level from models 1.1 to 1.4 simultaneously to explore the independent effect of each eating context on non-core energy consumption, accounting for time of the day and day of the week. Model 3 was Model 2 plus all adolescent related variables from models 1.5-1.9. to explore the independent effect of each eating context on non-core energy consumption accounting for time of the day, day of the week and between adolescent differences, i.e. sex, age, SES, EI and BMI. Coefficients from Model 3 were also converted to non-core calories by multiplying the adjusted ratios by the intercept of the model, to provide meaningful units for public health nutrition. The description and purpose of all different models are illustrated in Supplementary Table 1.

For each model, we calculated the change in proportion of variance explained in the outcome within adolescents, between adolescents and in total compared with variance estimated by Model 1. For Models 1-3 the intra-class correlation (ICC) (between adolescents' variance/total variance), represented the proportion of variance in non-core energy intake attributable to differences between adolescents. Model fit was assessed using a likelihood ratio test.

Sensitivity analyses

Misreporting for EI was assessed, using an individualised method (22, 23), where the ratio of reported EI to estimated energy requirements (EER) (EI:EER) was calculated and plausible reports were identified using cut-offs of 0.66-1.34. In total, 53% of the total sample were under-reporters and 4% adolescents were over-reporters. The final model 3 was re-run with the inclusion of a categorical misreporting variable (under-, plausible- or over-reporters), however ratios were identical to Model 3 and are therefore not reported. Interactions between eating contexts with sex, SES and BMI were tested in Models 4, 5 and 6 respectively. Stratified MLMs were run for any statistically significant interactions. Individual level-2 survey weights, available from NDNS, were used to account for selection and non-response bias. Analyses was done in Stata 13 (College Station, TX:StataCorp LP).

Results

Characteristics of EOs

Table 1 describes the characteristics of EOs overall and within specific eating contexts. The majority of EOs were consumed at Home (68%) and on a weekday (70%) but were broadly spread throughout the day. Adolescents ate 'Alone' (24%) as much as with 'Friends' (23%). Overall 69% of EOs contained non-core food. Similar to all EOs most non-core EOs occurred at home (66%), on weekdays (67%) and were spread throughout the day. EOs at 'Home' (68%) were less likely to be with 'Friends' (5%) and more likely to occur 'Alone' (33%) (data not shown). While 3% of all EOs occurred in eateries (Supplementary Table 2), 89% contained non-core food. EOs at 'Eateries' were more likely to occur with 'Friends' (51%) and less likely to occur with 'Parents/carers' (9%) (data not shown). Eating 'Alone', was less likely to contain non-core food (60%) and was more common in the morning (34% 06:00-12:00). EOs with friends were more likely to contain non-core food (77%) and occur on a weekday (78%) lunch time (35% 12:00-14:00).

Characteristics of adolescents

Table 2 describes individual characteristics of adolescents reporting EOs overall and within different physical and social eating contexts. All adolescents reported eating at home and 63% ate at school. Fewer adolescents reported eating in other locations, ranging from 12-50% reporting eating at 'Work' or 'On the Go'. Overall the mean age of adolescents was 14.5 years, mean BMI was 21.0, BMI z-score was 0.7 and mean total EI was 1785 kcal/day. Adolescents reported on average 6.4 EOs per person per day.

Adolescents who ate at eateries were mostly females, older, of higher SES and had greater total EI (1905 kcal/day) compared to the overall sample. On the contrary, their BMI z-score was lower compared to the children of the UK child growth standards (0.5 vs. 0.7).

Adolescents had on average 0.2 EOs per person per day at eateries. Finally, adolescents who ate with ‘Friends’ had 1.3 EOs per day on average eating with them and did not differ from the overall sample in terms of their overall characteristics.

Compared to the overall sample of adolescents, boys were less likely to eat at a ‘Friend’s/Relative’s house’, ‘Eateries’, ‘Work’ and with ‘Family & Friends’ and more likely to eat at ‘Activity/Other places’ and with people ‘Not specified’ (Supplementary Table 3). Adolescents from high SES groups were more likely to eat at ‘Eateries’ and ‘Activity/Other places’ and with ‘Parents/Carers’ compared to the overall sample (Supplementary Table 3)., while adolescents from intermediates SES groups were more likely to eat at ‘Work’ and with ‘Parents/siblings/ compared to the overall sample (Supplementary Table 3).

Within and between adolescent variation in non-core energy intake

In Model 1, including random effects for adolescents, the intra-class correlation (ICC) showed that only 11% of the total variance in non-core energy intake was attributed to differences between adolescents (Table 3). The remaining 89% of the differences in non-core energy intake were attributed to within person variability in different EOs.

Including level 1 variables (characteristics of EOs), explained 4.8% of the total variation and 5.1% of the variation within adolescents in non-core energy intake (Model 2, Table 3). Further adjusting for adolescents’ characteristics in Model 3, we explained 20.2% of the between adolescents’ variation in non-core EI and 6.5% of the total variance compared to Model 1 (Model 3, Table 3). Only sex, total EI and BMI showed evidence of an association with non-core EI, which individually explained 0.3%, 2.3% and 0.3% of the total variation respectively (Table 4). The association of sex with non-core EI was attenuated by the inclusion of covariates in model 3, but associations for total EI and BMI z-score remained (data not shown). In Model 3, each 1000kcal of total EI was associated with 42% (95% CI 30, 55%) more non-core energy, while each standard deviation of BMI was associated with 4% (95% CI 0, 7%) fewer non-core calories in an EO. The ICC in Model 3 decreased to 9.3%, suggesting that by including the above adolescent characteristics, 9.3% of the differences in non-core energy are now attributed to differences between adolescents. The fit of the models significantly improved (Table 3).

Associations of physical (‘where’) contexts with non-core energy intake

The effect estimates and variation explained for physical eating contexts in Model 1.1 are displayed in Table 4. Eating at Eateries' was associated with the largest non-core EI with intakes more than double the amount eaten at 'Home' (2.79, 95% CI 2.41, 3.24). All the remaining locations showed evidence, to a much lesser extent, of higher non-core EI compared to 'Home'. Collectively 'where' EOs explained 4.1% of the total variance in non-core energy (Table 4).

After adjusting for EO and adolescent characteristics (Model 3), evidence for higher non-core EI in all out-of-home locations was robust (Table 5). The effect size of all locations on non-core EI was broadly similar in Model 3 compared to the unadjusted Model 1.1 (Table 4). After these adjustments, 'Eateries' remained associated with the highest non-core EI (2.51, 95% CI 2.12, 2.96), followed by 'School' (1.88, 95% CI 1.65, 2.13).

Associations of locations with non-core calories are presented in Figure 1 in units of kcal/EO. Assuming all else is equal when adolescents eat in eateries, rather than at home, they consume 101 kcal (168, 95% CI 102, 278) more non-core energy.

Associations of social ('with whom') contexts with non-core energy intake

The effect estimates and variation explained for social eating contexts in Model 1.2 are displayed in Table 4. In the unadjusted models (Table 4), when eating with 'Friends' adolescents consumed 80% more non-core EI (1.80, 95% CI 1.63, 1.99) compared to eating 'Alone'. On the contrary, eating with 'Parents & siblings' adolescents reported eating 15% (1.15, 95% CI 1.02, 1.29) fewer non-core calories compared to eating 'Alone'. Collectively 'with whom' adolescents ate explained 2.1% of the variance in non-core energy (Table 4).

After adjusting for EO and adolescent characteristics (Model 3, Table 5), eating with 'Family & friends' was the social context with the highest non-core EI compared to eating 'Alone' (21%, 95% CI 7%, 37%), whereas the association with 'Friends' was greatly attenuated to just 16% (95% CI 3%, 31%) more non-core energy intake.

Associations of social eating contexts with non-core calories represent adolescents consuming an extra 14 (81, 95% CI 30, 47) and 10 (78, 95% CI 29, 45) more non-core calories when with 'Family & friends' and 'Friends' adolescents compared to eating 'Alone' respectively (Figure 1).

Interactions between sex and eating contexts on non-core energy intake

Evidence of interaction was observed only for sex and 'Activity Places' (p=0.045) as well as 'Family & Friends' (p=0.028). Boys consumed 48% more non-core energy at 'Activity places' compared to girls (boys, 1.56, 95% CI 1.22, 1.98 vs. girls, 1.08, 95% CI 0.83, 1.42), whereas girls consumed 29% more non-core energy compared to boys when eating with 'Family & friends' (girls, 1.35, 95% CI 1.14, 1.59 vs. boys, 1.06, 95% CI 0.90, 1.25).

Discussion

This is the first study assessing the associations between eating contexts and non-core energy consumption independent of other features of EOs and individual adolescent characteristics. Only 11% of the variation in non-core energy intake was attributed to differences between adolescents, while the remaining 89% occurred because of differences from one EO to another within the same person. 'Eateries', such as restaurants, cafes and fast food places, were independently associated with the highest non-core EI, where adolescents consume 101 kcal/occasion more non-core energy than comparable EOs at home. Analyses to date have only captured how differences between people are associated with non-core energy intake, such as food preferences or amounts of TV watching (24, 25). By using MLM, the association of eating contexts independent of between individual differences was estimated and thus potential confounding associated with adolescents' specific characteristics was ruled out.

As our analysis is novel there are no other studies with which to directly compare the results. Previous research has either focused on the associations of different food environments with overall consumption, without distinguishing between 'healthy' and 'unhealthy' foods (26, 27), or has only examined younger children's individual characteristics in relation to non-core energy consumption (24, 25, 28). Mak et al. (2012) (12) have examined associations of eating context with fruit and vegetable consumption in a younger age group showing lower odds of fruit and vegetable consumption at home compared to school and care outside home settings. In addition, Liu et al. (2015) (13) showed that adults had higher odds for consuming SSB outside of the home and especially in sit-down restaurants and fast food/convenience stores, similarly to our findings. However, none of these studies reported on the relative contribution of within and between person variation in food intake unlike our findings. Our analyses showed greater within person variability in non-core food intake, suggesting that interventions should target environmental contexts rather than individual characteristics to reduce adolescents' non-core food consumption.

Non-core energy intake was more variable from one EO to another (within adolescents) than it was from one person to another (between adolescents), suggesting that all adolescents eat non-core energy to some extent. The amount of non-core energy they eat is better predicted by characteristics of EOs, e.g. where and with whom the EO occurred, rather than characteristics of the individual, e.g. their age or SES. Future research should therefore focus on identifying factors affecting within person variability in EOs rather than the characteristics of people, e.g. food advertising, product placement and number of people present. These factors, amongst others, can vary between eating occasions, however they are typically measured in laboratory settings. Collecting information on these factors real-life settings may help us explain a greater proportion of within-people variation in non-core energy intake and identify novel targets for interventions. Changing individuals' eating behaviour can be notoriously hard, interventions could instead target particular eating environments to help everyone reduce non-core energy in those contexts (29). The focus of policies could be further guided by understanding the source of non-core energy, for example if most non-core energy eaten at school is bought from nearby food outlets then policies improving the food environment of those outlets would be beneficial.

Eateries were the eating contexts associated with the highest non-core energy consumption in adolescents. On average adolescents had 0.2 non-core EOs at eateries per day and ate 101 kcal more non-core energy in each EO, which translates to 141 extra calories per week of non-core energy compared to eating at home. Although most eating occasions take place at home and therefore in absolute terms more non-core food is consumed at home, adolescents are less likely to consume non-core food at home compared to eating in eateries. In addition, our analyses did not consider food purchased from eateries but consumed elsewhere, which is likely to have increased non-core food consumed at/from eateries. Adolescents choose to eat at eateries, e.g. fast food places, because they are quick, easy to get to and they serve tasty food (30). Foods consumed in eateries are usually higher in fat and sugar compared to foods consumed at home (31), which is in concordance with our work showing higher non-core energy intake in these settings. In addition, portion sizes served at eateries in the UK have increased over the years (32). Hence, factors such as an increased availability of non-core foods at eateries, larger portion sizes and the frequency with which adolescents eat there, may explain the increased non-core energy intake at these places. Reformulating non-core foods, offering a different range of foods, e.g. fruit and vegetables as side dishes rather than chips (33), and decreasing portion sizes, have been suggested as strategies in order to decrease non-core food consumption (34). Few of these strategies have been tried among adolescents and were shown to be successful (35, 36), thus future studies should further explore their use in real-life settings.

Despite existing policies to improve the quality of food in schools (37), our findings highlighted greater amounts of non-core foods consumed in school compared to home. School food standards have generally improved the quality of schools meals provided in secondary schools(38), however, nutrients such as fibre, vitamins and iron were still below recommended standards (38). In addition, some academies and free schools are still exempt, hence the quality of food provided there cannot be ensured. A substantial source of food consumed in schools are packed lunches, whose nutritional quality is considered to be poorer compared to school meals (38-40). Furthermore, adolescents often buy non-core foods, such as soft drinks, and confectionery, from supermarkets, fast food places and convenience shops(41), typically found around school premises (42). Future studies should also explore where the majority of non-core food consumed in schools is obtained from, to better guide the focus of school interventions and policies.

Eating with ‘Family & friends’ and with ‘Friends’ were the only social eating contexts associated with increased non-core energy intake compared to eating ‘Alone’. Previous research has shown increased EI with familiar others compared to strangers (43), i.e. greater meal size (calories) when eating with family/spouse and friends, compared to co-workers and other unfamiliar people (44). Social facilitation was suggested as the operating mechanism, i.e. people consume more food in the presence of familiar others (44, 45). In addition, eating with family and friends more often than not occurs in eateries compared to when eating alone or with parents and siblings, i.e. 7% vs. 0.2-2% (data not shown). Eating with family and friends represents a social occasion which is considered to be a ‘treat’ for the whole family(46), hence non-core food choices become more acceptable compared to the home environment. Future studies should explore ways to normalise core food consumption when eating out in the company of family and friends.

Our findings highlighted high-risk eating environments, such as eateries and school, however the majority of EOs and subsequently non-core food still occur within the home environment. To improve the home eating environment, we need to understand the sources of non-core food consumed at home, which will enable us to identify additional targets for home-based interventions. Evidence shows that British adolescents obtain most of their fat and sugar intake from fast food places, bakeries, convenience shops and vending machines (47), while US data from four national representative surveys from 1977-2006 have shown that most of the energy adolescents consumed at home was obtained from supermarkets and grocery shops (48). Future studies should investigate place of consumption and place of purchase concurrently, in order to more efficiently target and change high-risk eating environments.

Strengths and limitations

Our findings should be interpreted carefully in light of the study's strengths and limitations. A major strength is that data are from a representative adolescent sample in the UK and that foods were classified to core and non-core with the use of a simple and explicit tool. The use of MLMs allowed us to investigate the independent association of eating context within person, while holding between-person confounding factors constant. Food diaries offer a more accurate dietary assessment method compared with a Food Frequency Questionnaire or a single 24hr recall (49), while their combination with EMA allowed the collection of real-time data and the simultaneous measure of contextual factors alongside food intake. All self-reported dietary assessment can be affected by mis-reporting, however, we quantified and adjusted for plausible reporting in our analyses (22, 50) and the results were unchanged.

On the other hand, the use of cross-sectional data limits causal inference. The study did not investigate the combined association of physical and social eating contexts, e.g. eating with friends at school, as this type of analysis would decrease the power to detect interactions owing to the small numbers in some contextual combinations. Eating location was defined as the place of consumption, however looking at the place of purchase may have identified different eating contexts, e.g. convenience stores. The total variance of non-core energy intake explained in the models was relatively small, i.e. 6.7%, hence future research should explore further within person variability by measuring additional factors, (51) e.g. food availability and accessibility of food outlets. These are typically perceived to vary between people but could also be measured at that EO level. Finally, the definition of eateries in the current study included both sit-down restaurants and fast food places, although poor diet quality has been mainly attributed to fast food outlets rather than sit-down restaurants or cafes(52). However, EOs at fast food outlets in our data represented a very small proportion of total EOs, i.e. 0.8%, hence associations of fast food restaurants only would unlikely to be different compared to overall eateries.

Conclusion

The present study is the first to analyse associations of eating context with UK adolescents' non-core energy consumption, independent of their individual characteristics. Variability in non-core energy intake is better explained by differences between EOs rather than between individuals, hence targeting specific high-risk food environments and not specific people may be more beneficial for improving adolescents' eating behaviour and subsequently their diet during adulthood. More specifically, our findings highlight the potential for targeting eateries in future interventions to reduce non-core energy intake, through reformulation of existing non-core foods, the provision of smaller portion sizes or increasing the availability of healthier food choices. By improving the food environment of eateries, as well as other high-risk eating environments, e.g. school, consumption of healthier options becomes easier, while diet inequalities are more likely to reduce since change occurs for everyone (29). A great proportion of unexplained within-person variability in non-core energy intake was highlighted which suggests that future research should focus on identifying factors affecting EOs rather than individual characteristics.

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Table 1: Characteristics of EOs in the survey and across 'where' and 'with whom' eating contexts, in absolute frequencies and percentages.

	Total EOs	Non-core EOs[ac**]	Weekday[c**]	Meal slots[bc**]				
				06:00-12:00	12:00-14:00	14:00-17:00	17:00-20:00	20:00-06:00
	n (%[¥])	**n (%[¥])**	**n (%[¥])**	**n (%[¥])**	**n (%[¥])**	**n (%[¥])**	**n (%[¥])**	**n (%[¥])**
Survey	19827 (100)	13723 (69)	13816 (70)	5064 (26)	3424 (17)	3259 (16)	4164 (21)	3916 (20)
WHERE	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**
Home	13517 (68)	8909 (66)	9093 (67)	3502 (26)	1342 (10)	2161 (16)	3400 (25)	3112 (23)
Friend's/Relative's house	932 (5)	739 (79)	496 (53)	137 (15)	108 (12)	152 (16)	247 (27)	288 (31)
School	2359 (12)	1713 (73)	2329 (99)	933 (40)	1274 (54)	129 (5)	17 (1)	6 (0)
Eateries	731 (4)	648 (89)	403 (55)	52 (7)	181 (25)	148 (20)	136 (19)	214 (29)
On the go	1069 (5)	878 (82)	716 (67)	188 (18)	234 (22)	396 (37)	154 (14)	97 (9)
Activity/Other places	816 (4)	572 (70)	470 (58)	131 (16)	146 (18)	182 (22)	172 (21)	185 (23)
Work	403 (2)	264 (66)	309 (77)	121 (30)	139 (34)	91 (23)	38 (9)	14 (3)
WITH WHOM	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**	**n (%[†])**
Alone	4808 (24)	2897 (60)	3391 (71)	1615 (34)	561 (12)	905 (19)	653 (14)	1074 (22)
Parents/Carers	2877 (15)	1995 (69)	1957 (68)	752 (26)	295 (10)	471 (16)	797 (28)	562 (20)
Parents & Siblings	2871 (14)	2011 (70)	1932 (67)	628 (22)	278 (10)	457 (16)	987 (34)	521 (18)
Family & Friends	2350 (12)	1754 (75)	1404 (60)	387 (16)	275 (12)	358 (15)	835 (36)	495 (21)
Friends	4618 (23)	3564 (77)	3605 (78)	1158 (25)	1632 (35)	642 (14)	515 (11)	671 (15)
Not specified	2303 (12)	1502 (65)	1527 (66)	524 (23)	383 (17)	426 (18)	377 (16)	593 (26)

Abbreviations: EOs – Eating Occasions

[a] EOs containing at least one non-core food

[b]Meal slots are based on NDNS categories

[c] Pearson chi-square test was performed between this variable and with all 'where' and 'with whom' eating contexts

[¥]These are percentages of all EOs in the whole survey

[†]These are percentages of all EOs in the specific context

**p<0.001 across all 'where' and 'with whom' eating context

Table 2: Characteristics of adolescents 11-18 years old in NDNS (2008-2011/12)

	Adolescents	Boys[e]	High SES[f]	Intermediate SES	Mean age[af] (SD)	Mean BMI[bf] (SD)	Mean BMI z-score[cf] (SD)	Mean total energy intake (SD)[df]	Mean total EOs per person/day[f] (SD)
	n (%)	**n (%)**	**n (%)**	**n (%)**					
Survey	884 (100)	445 (50)	362 (41)	167 (19)	14.5 (2.2)	21.9 (4.4)	0.7 (1.2)	1785 (520)	6.4 (2.5)
WHERE	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**Mean age (SD)**	**Mean BMI (SD)**	**Mean BMI z-score (SD)**	**Mean total energy intake (SD)**	**Mean total EOs per person/day (SD)**
Home	883 (100)	444 (50)	362 (41)	167 (19)	14.5 (2.2)	21.9 (4.4)	0.7 (1.2)	1786 (520)	3.8 (2.0)
Friend's/Relative's house	315 (36)	148 (47)	134 (43)	55 (17)	14.6 (2.2)	21.8 (4.1)	0.6 (1.2)	1791 (513)	0.3 (0.8)
School	554 (63)	286 (52)	238 (43)	105 (19)	13.8 (2.1)	21.6 (4.4)	0.7 (1.2)	1788 (498)	0.7 (1.1)

Eateries	324 **(**37**)**	155 (48)	145 (45)	62 (19)	15.0 (2.2)	21.9 (4.1)	0.6 (1.2)	1905 (525)	0.2 (0.7)
On the go	445 **(**50**)**	218 (49)	185 (42)	82 (18)	14.6 (2.2)	22.1 (4.7)	0.7 (1.2)	1872 (541)	0.3 (0.7)
Activity/Other places	337 **(**38**)**	177 (53)	156 (46)	63 (19)	14.5 (2.2)	21.9 (4.2)	0.8 (1.1)	1858 (520)	0.2 (0.7)
Work	108 **(**12**)**	45 (42)	42 (39)	27 (25)	16.4 (2.0)	23.1 (4.6)	0.7 (1.3)	1798 (564)	0.1 (0.6)
WITH WHOM	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**Mean age (SD)**	**Mean BMI (SD)**	**Mean BMI z-score (SD)**	**Mean total energy intake (SD)**	**Mean total EOs per person/day (SD)**
Alone	776 **(**88**)**	388 (50)	334 (43)	146 (19)	14.7 (2.2)	21.9 (4.4)	0.7 (1.2)	1792 (537)	1.4 (1.5)
Parents/Carers	596 **(**67**)**	293 (49)	253 (42)	109 (18)	14.4 (2.2)	21.8 (4.5)	0.7 (1.2)	1804 (535)	0.8 (1.3)
Parents & Siblings	496 **(**56**)**	245 (49)	203 (41)	98 (20)	14.2 (2.2)	21.6 (4.2)	0.7 (1.2)	1785 (511)	0.8 (1.4)
Family & Friends	508 **(**57**)**	245 (48)	205 (40)	98 (19)	14.4 (2.2)	21.8 (4.3)	0.7 (1.2)	1797 (506)	0.7 (1.2)
Friends	773 **(**87**)**	382 (49)	321 (42)	148 (19)	14.5 (2.2)	21.9 (4.5)	0.7 (1.2)	1797 (526)	1.3 (1.7)
Not specified	464 **(**52**)**	244 (53)	168 (36)	95 (20)	14.5 (2.3)	21.9 (4.3)	0.7 (1.2)	1813 (522)	0.7 (1.3)

Abbreviations: EO – Eating occasion, SES – Socio-economic status SD – standard deviation

[a]Age is measured in years

[b] BMI is measured in kg/m^2

[c]BMI z-score was created by standardising BMI for sex and age based on the 1990 British Growth Reference (UK90) (19)

[d]Total energy intake is measured in kcal/day

Pearson chi-square test was performed between sex, High SES, Intermediate SES and all ‘where’ and ‘with whom’ eating contexts.

Kruskal Wallis test was performed between age, BMI, BMI z-score, mean and total EOs per person/day with all ‘where’ and ‘with whom’ eating contexts

[e]Evidence of association only for ‘with whom’ eating contexts ($p<0.001$)

[f]Evidence of association for both ‘where’ and ‘with whom’ eating contexts ($p<0.001$)

Table 3: Within, between and total adolescents' variance explained across the different models

				Interaction models		
	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Model 5[e]	Model 6[f]
Within adolescents' variance explained† (%)	NA	5.1	4.9	5.1	5.6	5.0
Between adolescents' variance explained† (%)	NA	1.7	20.2	19.8	21.5	20.4
Total variance explained† (%)	NA	4.8	6.5	6.7	7.4	6.6
Intra-class correlation¥ (%)	10.9	11.3	9.3	9.4	9.3	9.3
Log-maximum likelihood	22639	22310**	21235**	21219**	21572	21228**

**p<0.001: A likelihood ratio test was conducted by comparing the deviance across the models. The difference in deviance follows a chi-square distribution with degrees of freedom (df) the increase in the number of parameters estimated in each successive model (df=1).

† Computed as the % of change in variance compared to Model 1.

[a] Model 1: Includes just adolescents ID to model random effects within and between people. No explanatory variables are included

[b] Model 2 is adjusted for within adolescents' variables, i.e. 'where and 'with whom' eating contexts, time of the day and day of the week

[c] Model 3 is adjusted for within adolescents' variables (from Model 2) and for between adolescents' variables, i.e. sex, age, BMI, energy intake and SES.

[d]Model 4 is adjusted for within and between adolescents' variables (Model 3) and sex-eating contexts interactions

[e]Model 5 is adjusted for within and between adolescents' variables (Model 3) and SES-eating contexts interactions

[f]Model 6 is adjusted for within and between adolescents' variables (Model 3) and BMI-eating contexts interactions

¥ICC represents the % of variation in non-core energy intake in an eating occasion attributed to differences between adolescents. Computed from ICC= Between adolescents' variance/Total variance.

Table 4: Relationship between non-core energy intake, EO and adolescent variables and percentage of total variance explained.

		Model	Ratio	95% CI	p-value	Total variance explained (%)†
EO level	Friend's/Relative's house[a]	Model 1.1.	1.39	(1.21, 1.59)	0.001	4.1
	School[a]		1.82	(1.65, 1.99)	0.001	
	Eateries[a]		2.79	(2.41, 3.24)	0.001	
	On the go[a]		1.77	(1.60, 1.97)	0.001	
	Activity Places[a]		1.38	(1.16, 1.64)	0.001	
	Work[a]		1.29	(1.06, 1.57)	0.013	
	Parents/Carers[b]	Model 1.2.	1.06	(0.95, 1.18)	0.322	2.1
	Parents & siblings[b]		1.15	(1.02, 1.29)	0.018	
	Family & friends[b]		1.37	(1.22, 1.54)	0.001	
	Friends[b]		1.80	(1.63, 1.99)	0.001	
	Not specified[b]		1.19	(1.05, 1.35)	0.008	
	Time of the day (per hour)	Model 1.3.	1.01	(1.00, 1.02)	0.001	0.1
	Day of the week	Model 1.4.	1.04	(0.98, 1.10)	0.234	0.0
Adolescent level	Sex	Model 1.5.	0.85	(0.78, 0.92)	0.001	0.3
	Age	Model 1.6.	1.02	(1.00, 1.04)	0.069	0.1
	BMI z-score	Model 1.7.	0.95	(0.92, 0.99)	0.008	0.3
	Energy intake (per 1000 kcal)	Model 1.8.	1.53	(1.42, 1.66)	0.001	2.3
	High SES	Model 1.9.	0.98	(0.89, 1.07)	0.611	0.0
	Intermediate SES		0.92	(0.81, 1.05)	0.226	

Abbreviations: EO – Eating Occasion, CI – Confidence Interval

[a]Reference category is 'Home'

[b]Reference category is 'Alone'

Ratios come from linear variance component multilevel models (Model 1.1-1.9), with non-core energy intake (non-core kcal) as the outcome variable. Models 1.1 and 1.2 with eating contexts contain all dummy variables for the physical or the social contexts examined. For example, Model 1.1. includes all the dummy variables for the 'where' variable, e.g.

Friend's/Relative's house, school, eateries, on the go, activity places and work, with the reference category being home. Similarly, Model 1.2. includes parents/carers, parents & siblings, family & friends, friends and not specified, with the reference category being alone. All the remaining models contain one

independent variable. Ratios are the exponentiated values of the log-transformed coefficients and represent changes in the ratio of the mean non-core energy intake (kcal) in an eating occasion (the intercept). For example, an exponentiated value of 1.39 for an eating context represents a 39% difference in non-core energy intake between the specified eating context and its reference category.

†Computed as the % of change in total variance compared to Model 1.

Table 5: Ratios of the change in the mean non-core energy intake at each 'where' and 'with whom' eating context.

	Estimate[c]	**95%CI**	**p-value**
Intercept	67.0	(47.84, 93.93)	0.001
	Ratio[c]	**95%CI**	**p-value**
Friend's/Relative's house[a]	1.25	(1.07, 1.46)	0.004
School[a]	1.88	(1.65, 2.13)	0.001
Eateries[a]	2.51	(2.12, 2.96)	0.001
On the go[a]	1.75	(1.56, 1.96)	0.001
Activity Places[a]	1.34	(1.12, 1.61)	0.002
Work[a]	1.28	(1.05, 1.57)	0.015
Parents/Carers[b]	1.01	(0.91, 1.13)	0.816
Parents & siblings[b]	1.10	(0.98, 1.23)	0.122
Family & friends[b]	1.21	(1.07, 1.37)	0.002
Friends[b]	1.16	(1.03, 1.31)	0.014
Not specified[b]	0.93	(0.82, 1.06)	0.296

Abbreviations: SE – Standard Error, CI – Confidence Interval

[a]Reference category is 'Home'

[b]Reference category is 'Alone'

[c]Estimate and ratios come from Model 3 (adjusted for 'where and 'with whom' eating contexts, time of the day, day of the week, sex, age, BMI, energy intake and SES). Ratios are the exponentiated values of the log-transformed coefficients and represent changes in the

ratio of the mean non-core energy intake (kcal) in an eating occasion (the intercept). For example, an exponentiated value of 1.25 for an eating context represents a 25% difference in non-core energy intake between the specified eating context and its reference category.

Figure 1: Associations of eating contexts with adolescents' non-core energy intake (kcal/eating occasion).

[a] Predicted estimates come from Model 3, adjusted for time of the day, day of the week, sex, age, BMI, energy intake and SES. Computed from Table 5 (Estimate=Intercept*Ratio), they show non-core energy (kcal/eating occasion) that adolescents consume in all eating contexts.

------- Dashed line shows non-core energy intake at Home & Alone (intercept), adjusted for factors in Model 3 (mentioned above).