Breakfast consumption and daily physical activity in 9–10-year-old British children

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Abstract

Objective: To examine the association between breakfast consumption and physical activity in a well-characterised sample of English children.
Design: Cross-sectional study using food diaries to record breakfast consumption and accelerometry to assess physical activity.
Setting: Norfolk county, England.
Subjects: Children (*n* 1697) aged 9–10 years from the SPEEDY (Sport, Physical Activity and Eating behaviour: Environmental Determinants in Young people) study.
Results: Boys who consumed a poor-quality breakfast based on dairy product, cereal and fruit intakes spent approximately 7 min more time in moderate-to-vigorous physical activity (MVPA) during weekday afternoons and evenings compared with those who did not consume breakfast ($P < 0{\cdot}05$). On weekend days, boys who consumed a poor- or good-quality breakfast spent approximately 6 and 5 min less time respectively being sedentary during the mornings compared with breakfast non-consumers ($P < 0{\cdot}05$). Boys who consumed a good-quality breakfast spent almost 3 min more in MVPA during the morning on weekend days compared with non-consumers, and boys who consumed a poor- or good-quality breakfast were 22 % and 16 % more active overall respectively than breakfast non-consumers ($P < 0{\cdot}05$). During the rest of the day, boys who consumed a good-quality breakfast spent about 11 min less time being sedentary ($P < 0{\cdot}05$) and 7 min more time in MVPA ($P < 0{\cdot}01$).
Conclusions: Although some associations between breakfast consumption and physical activity were detected for boys, the present study does not provide strong evidence that failing to consume breakfast, or having a low energy intake at breakfast time, is detrimental to children's physical activity levels.

Keywords
Breakfast consumption
Physical activity
Sedentary behaviours
Children

Regular breakfast consumption has been found to be associated with improved overall diet, including greater micronutrient intakes and better diet quality, in school-aged children[1–4]. For example, in Belgian 13–18-year-olds, higher intakes of fruit, vegetables, bread, milk, milk products and fruit juices have been associated with the consumption of a high-quality breakfast, while soft drinks intake has been shown to be significantly lower compared with consumers of a less nutritious breakfast[4]. Missing breakfast has also been associated with decreases in attention, memory and school performance[5,6], all important factors in children's development. In addition, there are indications that breakfast patterns are linked to overweight and obesity[7–12].

It is of concern that a decline in breakfast consumption has been observed in recent years. For example, between 1965 and 1991, there is evidence of decreasing rates of breakfast consumption among American children. Declines were highest among older adolescents (15–18-year-olds), with daily consumption rates decreasing by 14·8 % and 19·7 % in boys and girls, respectively[9]. In a recent multi-country study, over 30 % of 11–15-year-old children did not eat breakfast in all but four of forty-one countries studied[13]. There is also evidence from the UK that approximately 8 % of 8–16-year-old children do not eat breakfast daily, with this prevalence increasing with age[14]. To address the decline in breakfast consumption in the UK, the Department of Health provided funding to implement breakfast clubs in schools in deprived areas, which serve food to children who arrive early at school before formal lessons begin[15]. An evaluation of the breakfast club programme in England showed attendees exhibited better concentration, higher rates of school attendance and higher intakes of fruit consumed at breakfast[16].

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A number of cross-sectional studies in children and adults have reported a negative association between breakfast consumption and body weight[7–12], and in UK boys and girls, not consuming breakfast has been associated with an approximate doubling of obesity risk[17]. Next to diet quality, a possible pathway linking breakfast consumption and weight status could be through physical activity if children who do not eat breakfast are less physically active as a result.

It may be that not consuming breakfast or consuming one of poor dietary quality results in low energy levels, thereby reducing the likelihood of children being physically active, especially during the morning. In before-lunch physical endurance tests among 10-year-old children, those consuming a breakfast that provided over 20 % of their estimated daily energy requirement performed significantly better than those consuming a breakfast that provided only 10 % of the requirement[18]. Furthermore, Vermorel *et al.* illustrated that the consumption of an inadequate breakfast does not meet the energy expenditure requirements of adolescents participating in morning physical activity sessions at school[19]. There is also evidence of associations between short-term macronutrient intake and physical performance, as intakes of carbohydrate, protein and amino acids within 4 h prior to exercise have all been associated with subsequent measures of physical performance[20]. Despite these observations, rather little attention has been paid to potential associations between breakfast consumption and physical activity in free-living children.

The evidence that is available comes predominantly from studies that focus on dietary patterns and general lifestyle, using self-reported measures of physical activity. Among 11–12-year-old Swedish children it was found that those who seldom ate breakfast tended to be more sedentary[21], with a similar association being reported in 16-year-old Finnish children[7]. Never reporting eating breakfast was recently associated with approximately a doubling of the risk of being classified as 'inactive' among a sample of 4337 children aged 9–16 years[22]. In another study, conducted in 14-year-old English children, less frequent self-reported breakfast intake was associated with lower physical activity levels during the morning in girls but not boys[23]. However, no associations with breakfast consumption were detected among studies of children's physical activity in New Zealand[24] and Portugal[25].

In summary, the evidence regarding breakfast consumption and physical activity in children is limited and equivocal. In addition, most information on dietary intakes and physical activity in the studies that are available has been collected using food frequency and physical activity questionnaires[26,27]. Using a well-characterised sample of 9–10-year-old British children, the present study was undertaken to provide new evidence on the relationship between breakfast consumption and physical activity. Four-day food diaries were used to assess breakfast intake, while corresponding daily physical activity was measured using accelerometry to provide objective measures of both behaviours. The application of these methods has meant that we have been able to examine daily associations between breakfast consumption and physical activity levels. To our knowledge, this is novel and we hypothesise that breakfast consumption behaviours during the early morning are associated with subsequent patterns of physical activity during the rest of the day.

Experimental methods

Study sample and analytical design

A cross-sectional study was conducted using data from the SPEEDY (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young People) study, which examined physical activity and dietary behaviours in a large population-based sample of Year 5 children (aged 9–10 years) in the county of Norfolk, Eastern England. The data collection procedures and sample characteristics are described in detail elsewhere[28] and are thus only briefly recounted here. In total, ninety-two schools, each with at least twelve Year 5 children, took part and from these schools 2064 children were recruited (59·0 % response rate). The SPEEDY study received full ethical approval from the University of East Anglia ethics committee and only those children who returned consent forms completed by themselves and a parent or guardian were allowed to participate.

Each school was visited by a team of trained research associates who undertook anthropometric measurements on participating children and distributed a home pack containing (of relevance to the present study) a 4 d food diary, an accelerometer and a questionnaire for parents. The children were instructed on how to complete the diary and on wearing the accelerometer. They were requested to return the home pack to school 8 d after the measurement day where it was collected by research assistants.

Physical activity

Free-living physical activity was assessed using an accelerometer: the Actigraph activity monitor (GT1 M; Actigraph LCC, Pensacola, FL, USA). The children wore the monitor for 7 d on their right hip during waking hours, except while bathing or during other aquatic activities. Activity data were stored at 5 s intervals. During processing, all data recorded between 23.00 and 6.00 hours were discarded, periods of 10 min of zero counts were considered as non-worn time. The outcome variables were daily average counts per minute (CPM), minutes spent in sedentary time (<100 CPM) and time spent in moderate-to-vigorous physical activity (MVPA; >2000 CPM)[29,30]. As previous work has shown that physical activity patterns are different during the morning and afternoon for boys and girls on schooldays[31], and because food consumed at lunch time may influence physical activity in the afternoon, we divided the physical activity outcomes into morning physical activity (09.00 to 12.00 hours) and that undertaken during the rest of the day (12.00 to 21.00 hours). The 09.00 hours start time was chosen to exclude the period during which breakfast likely was actually being consumed.

Breakfast intake

Dietary intake was assessed using a 4 d food diary. Children recorded, with assistance of their parents, foods and drinks consumed and estimated the portion size of each recorded item. The weights of the portions were then estimated using published values for children[32–34]. Daily energy intakes were estimated using the WISP nutritional analysis software version 3·0 (Tinuviel Software, Warrington, UK) using values from McCance and Widdowson's *The Composition of Foods*, 6th edition[35]. Reporting duration of at least 3 d, including one weekend day, were the criteria we used to define valid reporting of food intake and hence inclusion in the present analysis.

Two measures of breakfast consumption were derived. The first was a breakfast quality score developed to assess the quality of breakfast consumption on a given day. In this measure, children who ate less than 209 kJ (50 kcal) between 06.00 hours and 09.00 hours were defined as consuming no breakfast, as previously used by Gleason *et al.*[36]. Children who exceeded this threshold were classified as having a breakfast of 'poor' or 'good' quality based on the consumption of dairy products, cereal/grain products and fruits. A poor-quality breakfast was defined as eating none or one of the specified food items, while a good-quality breakfast was defined as eating two or three. The classification used was developed by Van den Boom *et al.*[37]. The second measure was of breakfast energy intake, which was analysed according to quartile of energy intake (kJ/kcal) between 06.00 hours and 09.00 hours, calculated within boys and girls separately. To control for the effects of overall diet quality in our analysis, we also extracted information on the mean daily portions of fruit and vegetables that were reported consumed over the whole period of diary completion for each child.

Anthropometry

Anthropometric measurements were taken by research assistants during the school visit using standardized methods. Height was measured to the nearest millimetre using a portable Leicester height measure. A non-segmental bio-impedance scale (Tanita type TBF-300A) was used to assess body weight (to the nearest 0·1 kg) and impedance. Fat mass (FM) was derived from the impedance value using previous validated and published equations[38]. Fat mass index ($FMI = FM\ (kg)/[height\ (m)]^2$) was then calculated for each child for whom height and impedance measures were available. FMI was found to be associated with both exposure and outcome measures and therefore included in analyses. The measure was used in preference to BMI as it has been shown to provide a better measure of body fat[39] and was more correlated to measures of physical activity than other adiposity measures such as BMI in this sample[40].

Statistical analysis

Dietary data were matched on a daily basis to the physical activity data. The association between breakfast consumption and physical activity was analysed using different sets of regression models. All models were fitted with the physical activity outcomes (sedentary time, MVPA or CPM) in the morning or during the rest of the day as the dependent variable. Either the categorical variable of breakfast quality or quartiles of energy intake at breakfast were fitted as the independent variable. As the physical activity levels of young people have also been associated with family socio-economic status[41], analyses were adjusted for the highest educational qualification attained by the parent (usually the mother) completing the home pack questionnaire. Other covariates in the model were age, calculated using the date of birth and the date of measurement, mean daily fruit and vegetable consumption and FMI. To account for any artefacts associated with wear time, the time each child spent wearing the accelerometer between 09.00 hours and 21.00 hours each day was fitted as an additional covariate in the models of sedentary time and MVPA. In order to control for potential under- or over-reporting of energy intakes, we calculated the ratio of reported energy intake (EI) to estimated energy requirement (EER) using the methodology of the FAO/WHO/United Nations University Expert Consultation Report on Human Energy Requirements[42], and this was adjusted for in our models that included energy intake at breakfast time.

A hierarchical structure was present in the data set with measurement days nested within children nested within schools. To account for this, multilevel regression models were developed in which school was defined as the third, child as the second and measurement day as the first level. All models were fitted using MLwiN software version 2·18 (Centre for Multilevel Modelling, University of Bristol, Bristol, UK)[43]. Fixed coefficients from the models were converted to predicted means of the different physical activity outcomes in the morning or during the rest of the day, holding the other covariates in the model to their means. Estimated means of the physical activity measures of poor- and good-quality breakfast consumers were compared with those of breakfast non-consumers and tested for statistical significance. To identify whether any trends were apparent in the association between energy intake at breakfast and the physical activity measures, a test for trend was conducted on the regression coefficients across quartiles of energy intake. A P value of $<0·05$ was regarded as statistically significant.

Gender differences in breakfast consumption, physical activity and other characteristics of the study sample were assessed using the Student's t test or the χ^2 test. After fitting

Table 1 Characteristics of the sample: British children (*n* 1697) aged 9–10 years from the SPEEDY (Sport, Physical Activity and Eating behaviour: Environmental Determinants in Young people) study

	Boys (*n* 741)		Girls (*n* 956)		Overall (*n* 1697)	
	Mean	SD	Mean	SD	Mean	SD
Personal characteristics						
Age (years)	10·2	0·3	10·3	0·3	10·3	0·3
FMI (kg/m^2)	5·1**	2·4	6·4	2·6	5·8	2·6
Weekday						
Breakfast						
Breakfast quality score (%)						
No breakfast consumed	6·7*††		8·7††		7·9††	
Poor-quality breakfast consumed	19·7**		23·7		22·0	
Good-quality breakfast consumed	73·6**††		67·6††		70·1††	
Energy intake (kJ) between 06.00 and 09.00 hours	1172**††	633	1026†	564	1089††	599
Energy intake (kcal) between 06.00 and 09.00 hours	280·0**††	151·2	245·2†	134·7	260·3††	143·1
Physical activity – 09.00 until 12.00 hours						
Sedentary time (min)	123·9**††	20·9	127·9††	20·4	126·2††	20·7
MVPA (min)	11·1**††	6·9	8·3††	6·2	9·5††	6·7
CPM	404·7**††	218·4	333·4††	197·2	364·3††	209·6
Physical activity – 12.00 until 21.00 hours						
Sedentary time (min)	291·3**	53·4	302·9	50·9	297·9	52·3
MVPA (min)	61·9**	26·7	49·1	21·8	54·6	24·9
CPM	760·1**	324·5	665·9‡	322·9	706·6‡	326·9
Weekend day						
Breakfast						
Breakfast quality score (%)						
No breakfast consumed	22·9*		27·0		25·2	
Poor-quality breakfast consumed	21·0*		24·3		22·9	
Good-quality breakfast consumed	56·1**		48·6		51·9	
Energy intake (kJ) between 06.00 and 09.00 hours	1056**	850	964	818	1004	833
Energy intake (kcal) 06.00 and 09.00 hours	252·3**	203·2	230·4	195·6	240·0	199·2
Physical activity – 09.00 until 12.00 hours						
Sedentary time (min)	87·4	33·0	88·5	33·2	88·0	33·1
MVPA (min)	19·1**	16·6	13·6	11·5	16·0	14·2
CPM	760·6**	577·0	626·8	490·8	685·5	534·5
Physical activity – 12.00 until 21.00 hours						
Sedentary time (min)	291·2**	61·8	301·2	56·6	296·8	59·1
MVPA (min)	61·2**	35·1	49·3	27·6	54·5	31·6
CPM	774·5**	480·0	711·4	496·6	739·1	490·3

FMI, fat mass index; MVPA, moderate-to-vigorous physical activity; CPM, counts per minute.
Results are reported as means and SD unless stated otherwise.
Statistically significantly different from girls within week or weekend day: *$P<0·05$, **$P<0·01$.
Statistically significantly different from weekend day within boys or girls: †$P<0·05$, ††$P<0·01$.

gender as an interaction term in an unstratified model, it was found to be an effect modifier so all results were stratified by gender. Physical activity patterns of children of this age are known to differ between weekdays and weekend days, and there is evidence that different foods are eaten at weekends[44]. Therefore, results are presented further stratified between weekdays and weekend days.

Results

Baseline characteristics of the study population

Out of the 2064 children participating in the SPEEDY study, 1859 (90·0 %) recorded valid food diary data on at least 3 d. After matching physical activity and dietary data on a daily basis, 1697 (82·2 %) children (956 girls and 741 boys) provided concurrent diet and physical activity data for at least 1 d, and these children formed the sample analysed. The included children did not differ in either age (10·3 (SD 0·3) years *v.* 10·3 (SD 0·3) years, $P=0·61$) or FMI (5·8 (SD 2·6) kg/m^2 *v.* 5·6 (SD 2·6) kg/m^2, $P=0·20$) from those who were excluded. However, there was a lower percentage of boys among the included compared with the excluded sample (43·7 % *v.* 50·4 %, $P=0·02$).

Baseline characteristics of the sample are shown in Table 1. Boys consumed breakfast more often and the quality generally scored more highly compared with girls. Furthermore, boys had a higher energy intake (kJ/kcal) at breakfast. For both sexes, breakfast was less often consumed, of poorer quality and lower in energy at weekends. Boys generally spent less time in sedentary behaviour, more time in MVPA and had a higher CPM. For both sexes, activity patterns in the morning were significantly different on weekdays compared with weekend days.

Table 2 Differences in physical activity between those who never, sometimes and always consumed breakfast: British children (*n* 1697) aged 9–10 years from the SPEEDY (Sport, Physical Activity and Eating behaviour: Environmental Determinants in Young people) study

	Children who always eat breakfast (*n* 1075)		Children who sometimes eat breakfast (*n* 591)		Children who never eat breakfast (*n* 31)	
	Mean	SD	Mean	SD	Mean	SD
Physical activity – 09.00 until 12.00 hours						
Sedentary time (min)	111·4	17·6	106·2**	17·5	109·1	29·0
MVPA (min)	12·7	7·1	11·5**	6·2	9·6**	5·7
CPM	505·5	245·3	493·7	228·0	472·3	370·1
Physical activity – 12.00 until 21.00 hours						
Sedentary time (min)	291·5	42·3	302·2**	35·7	288·2	75·7
MVPA (min)	54·8	20·9	53·6	18·5	47·3*	18·7
CPM	721·7	274·23	717·9	291·3	716·4	284·4

MVPA, moderate-to-vigorous physical activity; CPM, counts per minute.
Statistically significantly different from children who always eat breakfast: *$P<0·05$, **$P<0·01$.

Associations with breakfast consumption

Table 2 shows aggregate unadjusted associations between physical activity levels and breakfast consumption over the whole measurement period, with children being classified into those who always, sometimes or never reported eating breakfast based on diary entries. Particularly for MVPA, there is some evidence of a trend whereby those who sometimes or never ate breakfast were less active than those who always did, although the sample size of the non-consumers was small (*n* 31).

Results of the multilevel regression models of daily physical activity *v.* the categorical breakfast quality scores are shown in Table 3. In boys, no significant associations were found between scores and physical activity outcomes during the morning on weekdays. However, during the rest of the day, boys who consumed a poor-quality breakfast spent approximately 7 (95 % CI 1, 13) min more time in MVPA compared with those who did not consume breakfast, although differences were not apparent for those consuming a good-quality breakfast. On weekend days, boys who consumed a poor- or good-quality breakfast spent approximately 6 (95 % CI 2, 10) min and 5 (95 % CI 1, 8) min respectively less time being sedentary during the mornings compared with breakfast non-consumers. Boys who consumed a good-quality breakfast spent almost 3 (95 % CI 0·2, 5) min more in MVPA during the morning on weekend days compared with non-consumers, and boys who consumed a poor- or good-quality breakfast were 22 % (95 % CI 7 %, 38 %) and 16 % (95 % CI 4 %, 29 %) more active respectively (measured by CPM) during this time than breakfast non-consumers. During the rest of the day at weekends, boys who consumed a good-quality breakfast spent significantly less (11 (95 % CI 2, 19) min) time being sedentary and more (7 (95 % CI 2, 13) min) time in MVPA. In girls, no significant associations were found between breakfast quality scores and physical activity outcomes.

Tables 4 and 5 present the results of the models for quartiles of energy intake at breakfast on weekdays and weekend days, respectively. No statistically significant associations were found in either boys or girls between energy intake at breakfast and physical activity. Furthermore, neither maternal education nor fruit and vegetable consumption was found to be associated with any of the outcomes.

Discussion

In this sample of 9–10-year-old British children, breakfast consumption was not unequivocally associated with physical activity on weekdays. Overall there was some evidence that children who never or only sometimes consumed breakfast were less active than those who always did, especially for MVPA. When daily variations were examined, the key findings were that boys who consumed breakfast were generally less sedentary, spent more time in MVPA and had a higher CPM compared with non-consumers. However, physical activity was not clearly associated with breakfast quality, and in girls, no significant associations were detected. Hence the present study does not provide strong evidence that failing to consume breakfast, having a nutritionally poor-quality breakfast or low energy intake at breakfast time is detrimental to children's physical activity levels.

The fact that the associations between daily breakfast consumption and physical activity that we did find were for weekends only may be associated with the times children rose from bed. Children who stay in bed longer at weekends are likely to be less active, at least in the morning, and might be less likely to consume breakfast before 09.00 hours, our threshold to classify food intake as constituting breakfast. Why associations were only apparent in boys is not known. We do not have information on the times children rose from bed on each day, and it may be that boys are more variable than girls, although patterns of physical activity between weekday and weekend mornings were similar for both sexes.

Table 3 Estimated means and 95 % confidence interval of the physical activity outcomes by daily breakfast quality score, holding the other covariates in the model to their means: British children (*n* 1697) aged 9–10 years from the SPEEDY (Sport, Physical Activity and Eating behaviour: Environmental Determinants in Young people) study

		Boys						Girls					
		Breakfast score						Breakfast score					
		No breakfast consumed (348 d)		Poor-quality breakfast consumed (499 d)		Good-quality breakfast consumed (1612 d)		No breakfast consumed (542 d)		Poor-quality breakfast consumed (765 d)		Good-quality breakfast consumed (1883 d)	
Time period	Outcome	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI
Weekdays													
Morning (09.00–12.00 hours)	Sedentary time (min)‡,§	124·4	121·0, 127·7	123·5	121·3, 125·8	123·6	122·0, 125·3	128·0	125·4, 130·6	128·2	126·3, 130·1	127·5	125·9, 129·0
	MVPA (min)‡,§	11·4	9·9, 12·9	11·4	10·4, 12·4	11·4	10·6, 12·2	8·0	6·8, 9·2	8·0	7·2, 8·8	8·4	7·8, 9·0
	CPM‡	420·7	371·1, 471·3	408·0	376·4, 440·0	410·7	385·8, 433·5	325·3	287·2, 362·0	323·4	296·2, 349·5	338·9	317·6, 361·0
Rest of the day (12.00–21.00 hours)	Sedentary time (min)‡,§	294·2	285·1, 303·8	289·3	283·6, 295·2	291·0	287·4, 294·6	300·8	294·3, 307·2	300·0	295·7, 304·5	303·1	300·0, 306·0
	MVPA (min)‡,§	56·9	51·4, 62·6	64·1*	60·7, 67·4	62·0	60·1, 64·0	47·9	44·3, 51·7	50·9	48·5, 53·3	48·6	46·8, 50·3
	CPM‡	704·2	635·0, 780·2	778·9	735·2, 828·1	764·2	738·8, 789·8	670·9	612·0, 732·5	688·4	650·4, 727·7	662·5	636·4, 688·1
Weekend days													
Morning (09.00–12.00 hours)	Sedentary time (min)‡,§	90·9	87·5, 94·3	84·9**	81·5, 88·3	86·2*	83·9, 88·6	90·1	87·9, 92·2	87·6	85·3, 89·9	87·8	86·0, 89·6
	MVPA (min)‡,§	17·4	15·2, 19·7	19·8	17·6, 22·0	20·1*	18·6, 21·5	13·2	12·0, 14·4	13·7	12·5, 14·9	13·7	12·8, 14·6
	CPM‡	678·8	597·8, 762·1	822·8**	744·5, 908·8	784·0*	726·5, 840·8	610·8	553·1, 668·7	659·7	602·6, 717·4	627·7	585·5, 672·1
Rest of the day (12.00–21.00 hours)	Sedentary time (min)‡,§	298·3	290·8, 306·1	291·5	283·4, 299·3	287·5*	282·3, 293·0	303·4	297·7, 308·9	299·6	293·6, 305·4	301·0	296·0, 305·7
	MVPA (min)‡,§	56·4	51·6, 61·2	61·0	56·4, 65·8	63·4**	60·2, 66·8	48·8	45·8, 51·9	49·9	46·7, 53·1	48·8	46·3, 51·4
	CPM‡	755·0	686·6, 823·7	767·6	698·7, 839·6	782·3	738·9, 827·6	689·3	633·2, 746·6	736·5	675·3, 793·1	704·1	656·9, 749·0

MVPA, moderate-to-vigorous physical activity; CPM, counts per minute.
Statistically significantly different from breakfast non-consumers: *$P < 0·05$, **$P < 0·01$.
‡Adjusted for fat mass index, age, parental education, fruit and vegetable intake.
§Additionally adjusted for accelerometer wear time.

Table 4 Estimated means and 95 % confidence interval of the physical activity outcomes on weekdays by quartiles of daily mean energy intake at breakfast, holding the other covariates in the model to their means: British children (*n* 1697) aged 9–10 years from the SPEEDY (Sport, Physical Activity and Eating behaviour: Environmental Determinants in Young people) study

	Boys								
	Q1 (≤ 742 kJ (≤ 177·25 kcal))		Q2 (743–1048 kJ (177·26–250·50 kcal))		Q3 (1049–1460 kJ (250·51–349·00 kcal))		Q4 (≥ 1461 kJ (≥ 349·01 kcal))		Test for trend (*P* value)
	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	
09.00–12.00 hours									
Sedentary time (min)‡,§	123·7	121·4, 126·0	123·3	120·9, 125·5	123·4	121·3, 125·6	123·4	121·3, 125·6	0·87
MVPA (min)‡,§	11·7	10·7, 12·7	11·3	10·3, 12·3	11·6	10·6, 12·6	11·1	10·2, 12·0	0·42
CPM‡	417·7	384·3, 448·9	409·1	376·8, 440·3	422·4	391·2, 452·9	401·8	373·1, 433·2	0·60
12.00–21.00 hours									
Sedentary time (min)‡,§	292·5	286·9, 298·1	289·4	284·0, 294·8	291·4	286·1, 296·7	291·0	285·5, 296·3	0·81
MVPA (min)‡,§	61·7	58·5, 64·9	63·7	60·5, 67·0	62·6	59·6, 65·9	61·1	58·1, 64·1	0·72
CPM‡	755·9	714·8, 800·9	770·5	729·0, 812·0	773·5	734·5, 812·6	754·1	715·2, 796·5	1·00

	Girls								
	Q1 (≤ 707 kJ (≤ 160·90 kcal))		Q2 (708–911 kJ (160·91–217·75 kcal))		Q3 (912–1247 kJ (217·76–297·96 kcal))		Q4 (≥ 1248 kJ (≥ 297·97 kcal))		Test for trend (*P* value)
	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	
09.00–12.00 hours									
Sedentary time (min)‡,§	127·6	125·7, 129·6	127·2	125·2, 129·0	127·0	125·0, 128·8	127·9	126·2, 129·8	0·83
MVPA (min)‡,§	8·4	7·6, 9·2	8·4	7·6, 9·3	8·6	7·8, 9·4	8·1	7·3, 8·9	0·56
CPM‡	336·4	310·6, 363·0	349·7	323·0, 376·4	339·8	314·5, 365·5	330·6	304·9, 356·4	0·58
12.00–21.00 hours									
Sedentary time (min)‡,§	302·1	297·3, 306·6	302·0	297·3, 306·5	301·2	297·1, 305·7	303·4	299·2, 307·7	0·74
MVPA (min)‡,§	49·4	47·0, 51·8	49·7	47·3, 52·2	50·3	48·1, 52·7	48·5	46·2, 51·0	0·73
CPM‡	687·2	648·9, 726·4	683·8	646·2, 723·2	680·8	643·1, 718·2	664·8	629·2, 702·5	0·38

MVPA, moderate-to-vigorous physical activity; CPM, counts per minute.
‡Adjusted for fat mass index, energy reporting quality, age, fruit and vegetable intake and parental education.
§Additionally adjusted for accelerometer wear time.

Table 5 Estimated means and 95 % confidence interval of the physical activity outcomes on weekend days by quartiles of daily mean energy intake at breakfast, holding the other covariates in the model to their means: British children (*n* 1697) aged 9–10 years from the SPEEDY (Sport, Physical Activity and Eating behaviour: Environmental Determinants in Young people) study

	Boys								
	Q1 (≤ 607 kJ (≤ 145·00 kcal))		Q2 (608–892 kJ (145·01–213·10 kcal))		Q3 (893–1433 kJ (213·11–342·60 kcal))		Q4 (≥ 1434 kJ (≥ 342·61 kcal))		Test for trend (*P* value)
	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	
09.00–12.00 hours									
Sedentary time (min)‡,§	89·0	85·8, 92·5	84·7	81·3, 87·9	86·3	83·1, 89·6	87·8	84·5, 91·0	0·74
MVPA (min)‡,§	18·5	16·5, 20·7	20·9	18·7, 23·1	19·5	17·4, 21·6	19·0	17·0, 21·2	0·96
CPM‡	714·5	634·5, 788·3	848·7	771·2, 929·8	732·9	657·6, 809·1	772·7	699·0, 846·9	0·67
12.00–21.00 hours									
Sedentary time (min)‡,§	296·4	288·4, 304·3	283·8	276·0, 291·8	285·5	278·6, 293·2	294·2	286·9, 301·9	0·68
MVPA (min)‡,§	57·3	52·4, 62·1	66·2	61·4, 71·0	63·1	58·4, 67·7	60·0	55·5, 64·8	0·53
CPM‡	736·2	672·6, 802·4	852·9	785·1, 920·4	763·4	696·3, 827·8	748·8	684·9, 815·3	0·82
	Girls								
	Q1 (≤ 437 kJ (104·40 kcal))		Q2 (438–820 kJ (104·41–195·88 kcal))		Q3 (821–1356 kJ (195·89–324·08 kcal))		Q4 (≥ 1357 kJ (≥ 324·09 kcal))		Test for trend (*P* value)
	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	Mean	95 % CI	
09.00–12.00 hours									
Sedentary time (min)‡,§	90·3	88·1, 92·6	87·1	84·8, 89·4	89·0	86·8, 91·3	86·9	84·6, 89·1	0·08
MVPA (min)‡,§	13·3	12·1, 14·6	13·9	12·7, 15·2	12·8	11·5, 14·0	14·5	13·3, 15·7	0·34
CPM‡	629·1	572·3, 692·0	674·7	614·5, 734·5	584·8	529·0, 642·9	660·0	605·2, 718·6	0·92
12.00–21.00 hours									
Sedentary time (min)‡,§	303·4	297·2, 309·2	300·9	294·9, 307·2	303·7	297·7, 309·5	300·4	294·6, 306·2	0·58
MVPA (min)‡,§	48·7	45·2, 51·9	49·8	46·4, 53·0	46·6	43·5, 49·8	50·4	47·4, 53·7	0·73
CPM‡	688·2	626·2, 746·8	734·2	668·2, 796·3	663·1	605·5, 725·8	727·9	668·2, 788·0	0·66

MVPA, moderate-to-vigorous physical activity; CPM, counts per minute.
‡Adjusted for fat mass index, energy reporting quality, age, fruit and vegetable intake and parental education.
§Additionally adjusted for accelerometer wear time.

Therefore, the lack of associations in girls is unlikely to be associated with differences in the variability of our outcomes. Boys in our sample were generally more physically active than girls and it may therefore be that breakfast consumption is more important in this group, although further studies are required to confirm this finding in different settings.

To our knowledge, the present study is the first one to address the association between breakfast consumption and physical activity in children on a daily basis. It is noteworthy that there exists no clear definition of what constitutes ‘breakfast’ in the literature and the variety of definitions employed could contribute to the equivocal nature of the body of evidence. Previously conducted studies that did report an association assessed more habitual aspects of breakfast consumption and physical activity with questionnaires, and this may explain differences in their findings compared with ours. Other strengths of our study include its large population-based study sample and valid assessment of breakfast quality and energy intake and physical activity. A comparable accelerometer to that used here has been validated against energy expenditure estimated by the doubly labelled water method in 9-year-old children[29]. Dietary intake was assessed with a 4 d food diary which has been shown to exhibit better agreement between observed and reported dietary intake than 24 h recall and 5 d FFQ in 9–10-year-old girls[45]. Furthermore, since diet and physical activity measurements were conducted in the same period for each child, data could be matched on measurement date. In addition, the measurements of all children were conducted during the summer term which is likely to reduce the influence of poor weather conditions on the physical activity measurements.

A limitation of our study is its cross-sectional study design which means that no causal relationship can be established from the observed associations. The large number of tests we undertook raises the possibility of spurious associations being detected. Another limitation of the study is that, despite the benefits of food diaries, there is evidence that their use can alter habitual dietary intakes when participants, for example, eat or record certain foods for ease of completion[46]. It may also be that children inaccurately reported their true breakfast consumption patterns. Although our analysis of energy intake at breakfast did adjust for under- or over-reporting of total dietary intakes, this does not eliminate the possibility that our findings are affected by reporting bias. The time-bounded nature of the breakfast variables that we used could also have influenced the findings as it is possible that, especially on weekend days, breakfast was not consumed before 09.00 hours. Furthermore, it could be that additional morning snacks eaten before 09.00 hours were included as ‘breakfast consumption’ in our measure of energy intake. Because physical activity before 09.00 hours was excluded from this analysis, we may also not have captured associations with travel mode to school on weekdays. A further limitation is that the participating children were all recruited from Norfolk. While the environment of the county is varied, with both urban and rural areas, Norfolk is more affluent than the national average and has a low percentage non-white population. The SPEEDY sample also contains a lower percentage of boys and obese children than the county population[28]. These factors may limit the generalisability of our findings to other settings.

In the present study, no clear association was found between breakfast consumption and physical activity in British 9–10-year-old children. Our results do not provide strong evidence to suggest that interventions based around breakfast eating would be efficacious in terms of increasing physical activity in children of this age.

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