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Lifestyle Behaviors Associated With Body Fat Percent in 9- to 11-Year-Old Children

Lifestyle behaviours associated with body fat percent in 9-11-year-old children

Abstract

Purpose

To examine [1] associations between body fat percent (BF) and lifestyle behaviours in children aged 9-11 years, and [2] the consistency of these associations over a 10-year period.

Methods

In this repeat, cross-sectional study, 15,977 children aged 9-11 years completed an anthropometric assessment and the SportsLinx Lifestyle survey between 2004 and 2013. Body fat was estimated according to the sum of the tricep and subscapular skinfold measurements. Multilevel models were utilized to examine associations between BF and responses to the lifestyle survey, while controlling for known covariates.

Results

Lifestyle behaviours explained 8.6% of the total variance in body fat. Specifically, negative associations were found between BF and active transport to school (β=-0.99±0.19 $p<0.001$), full-fat milk (-0.07±0.15 $p<0.001$) and sweetened beverage consumption (-0.40±0.15 $p=0.007$). Relative to the reference group of ≤8:00pm, later bedtime was positively associated with BF; 8:00-8:59pm (β=1.60±0.26 $p<0.001$); 9:00-10:00pm (β=1.04±0.24 $p<0.001$); ≥10:00pm (β=1.18±0.30 $p<0.001$). Two-way interactions revealed opposing associations between BF and the consumption of low-calorie beverages for boys (β=0.95 ± 0.25 = $p<0.001$) and girls (β=-0.85±0.37 $p=0.021$). There was no significant change in these associations over a 10-year period.

Conclusions

In this population-level study covering a decade of data collection, lifestyle behaviours were associated with BF. Policies and interventions targeting population-level behaviours change,

such as active transport to school, sleep time and consumption of full-fat milk, may offer an opportunity for improvements in BF.

Key Words: Body fat, child, lifestyle behaviour, skinfold, obesity, active transport, bedtime.

Introduction

Childhood obesity is a significant public health concern, with a third of children in the UK being affected by overweight or obesity (1). Excess body weight increases the risk of developing type 2 diabetes, cardiovascular disease, hypertension, and sleep apnoea (2). Childhood obesity is also related to emotional problems and reduces quality of life (3). Moreover, excess weigh at this age and during adolescents tends to persist into adulthood (4). Given that excess BF result from long-term energy imbalance, efforts to prevent obesity must promote lifestyle behaviours that reduce energy intake and promote energy expenditure.

In 2009, data from the SportsLinx study showed the increase in prevalence of overweight and obesity had slowed among children across Liverpool (5). These changes may reflect a combined impact of the initiatives delivered in Liverpool at the time including interventions delivered by the SportsLinx programme such as after school clubs and taster sessions, and Liverpool City Council's campaigns such as Active City and A Taste for Health, part of the city's obesity agenda that aimed to halt the rise in obesity by targeting physical activity and healthy eating (6). In the same period, the SportsLinx study reported an improvement in children's food intake with an increase in fruit, vegetable and salad intake over a 10-year period (7). Despite these changes, it is unclear how specific behaviours relate to adiposity and whether this has changed over time. Diet, physical activity and sedentary behaviours such as skipping breakfast, screen time, and the consumption of sugar sweetened beverages, have been implicated in the development of obesity in children (8,9). Conversely, increased fruit and vegetable consumption and physical activity are linked with reduced risk of overweight and obesity in children (10). However, associations are inconsistent, for example, in a large international study of 10–16 year olds, obesity was associated with low physical activity levels and television viewing but not with the fruit and vegetable intake, soft drink consumption or the time spent using computers, yet a negative association was found between the frequency of the consumption of sweets (candy in the USA) and obesity (11,12). Furthermore, the ISCOLE study including 6,025 children (9-12 years) from 12 countries, failed to find an association between dietary patterns and obesity (11), in accord with population-level studies in the UK (13,14). It is therefore unclear which behaviours are related to obesity and should be the target of interventions. Associations between specific foods and obesity are not always intuitive. For example, the intake of fat from dairy is negatively associated with obesity during childhood (15,16) despite its energy content. Similarly, the relationship between sugar sweetened beverages and BF is not straightforward as might be assumed. Data from the SportsLinx study has demonstrated that children with the greatest intake of sugar sweetened beverages had a significantly lower BMI than non-consumers (17). Methodological limitations to population-level studies such as the pooling of responses to a food frequency questionnaire to produce a “healthy” and “unhealthy” score (13,14), may mask associations between specific foods and obesity and precludes further interpretation of these findings.

Over the past decade there has been a year-on-year shift from full-fat to skimmed milk varieties and an increase of wholemeal bread (18). Moreover, between 2004 and 2008, the percentage soft drinks consumed by children with no added sugar increased by 9 percent (19).

Likewise, over the past 15 years screen behaviour has changed, TV viewing has decreased, while computer use has sharply increased (20). Despite these changes, it is unclear whether lifestyle behaviours and food choices positively impact on adiposity over time.

Exploring the lifestyle behaviours that influence childhood overweight and obesity and how these have altered among changing technology use, food composition and public health policy and campaigns is essential for the development of effective interventions. To our knowledge, no studies have reported long-term changes to cross-sectional associations between lifestyle behaviours and BF.

The aim of this study was to examine the associations between BF and dietary and physical activity behaviours in primary school children over a 10-year period.

Methods

Participants and Settings

Participants included children aged 9-11 years that took part in the SportLinx program between 2004 and 2013. The SportsLinx program has been described in more detail elsewhere (7,21). Briefly, SportsLinx was a repeat, cross-sectional physical activity, nutrition and health program conducted in primary schools within the Liverpool Local Education Authority (UK). All year 5 pupils (9-10 years) were invited to take part annually resulting in 15,977 children who completed an anthropometric assessment and lifestyle survey (7). On average, 105 primary schools took part every year, representing 90% of all primary schools in the area.

Measures and Procedures

The SportsLinx Lifestyle Survey was used to assess sport participation, screen time, diet and sleep. Participants specified, on a 5-point Likert scale, how much time during week and weekend days they typically spent watching TV/DVDs/videos, playing video games, using the internet, and participating in sport. Given that spending ≥2 hours in sedentary pursuits, is unfavourable associated with body composition (22), data were categorized into dichotomous levels for each variable to reflect participation in each sedentary activity for above or below 2 hour per day. Children were asked to select what time they went to bed (1: Before 8pm; 2: 8-8:59pm; 3: -9:59pm; 4: After 10pm). The food intake questionnaire was designed to measure eating habits at the population level based on the recall of foods consumed on the previous day. A series of 'yes/no' questions indicated which foods were consumed from a list of 44 items. The survey has acceptable validity (23) and reliability (24), in children of a similar age. For this study, all foods, dietary patterns or behaviours that may have affected energy balanced were considered in the analysis (List in supplementary material).

Socioeconomic status (SES) was calculated using the 2007 Indices of Multiple Deprivation (IMD) (25) based on participants home postcode.

Skinfold thicknesses at the triceps and subscapular were measured by the same ISAK qualified anthropometrist using standardised procedures (26). The Slaughter equations (27) which have been validated in this age group (28) were used to estimate BF from the skinfold thicknesses.

Height was measured to the nearest 0.1 cm using a Leicester Height Measure (Seca, Birmingham, UK), and weight was measured using calibrated analogue scales (model 873, Seca, Birmingham, UK) to the nearest 0.1 kg.

The 20 meter multi-stage fitness test (MSFT) which has previously been validated in this age group (29), was used to estimate the children's aerobic fitness. Given cardio-respiratory fitness is negatively associated with BF (30), BMI (31) and sedentary time (32) and positively associated with physically active (33) it was controlled for in the analysis.

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by xxxxx University ethics committee [xxxxx]. All participating children and their parents provided informed written assent and consent.

Statistical analyses

Descriptive statistics, independent samples t-test, and Pearson's chi-squared tests were used to examine differences in the basic characteristics and questionnaire responses between sexes. The proportion of children reporting each behaviour was also compared between years using chi-square tests followed by pairwise comparisons using the z-test of two proportions with a Bonferroni correction, to determine which years were different. The statistical package IBM SPSS statistics, version 22.0 (IBM Corp., Armonk, NY, USA) was used for these analyses.

As data were collected from schools across Liverpool, a two-level multi-level model (participant, school) was constructed using MLwiN v.3.01 software (Centre for Multilevel Modelling, University of Bristol, UK) to examine associations between lifestyle survey responses and BF. The model was constructed in three stages. Firstly, a backwards stepwise deletion approach was used to identify all predictor variables that were significantly associated with the outcome variable. Regression coefficients were assessed for significance using the Wald statistic and a Chi-square distribution (34). All significant predictor variables were entered into a crude model (model 1). Secondly, to control for confounders, sex, year, MSFT and SES were entered into the model (model 2). Finally, two-way interactions were explored to establish whether predictors differed by sex or year of data collection (model 3). Alpha was set at $p < .05$ for main effects and $p < 0.1$ for interaction terms (34). The explained variance was calculated by comparing the variance in each model to the variance in the null model containing no independent variables.

Multiple imputation was used to address the potential bias and loss of precision that can result from complete-case analysis. REALCOM-IMPUTE software with MLwiN (35) was used to generate 10 imputed datasets with missing values replaced by plausible values based on known covariates and distributional information. After a total of 6,500 iterations the model of interest was fitted to each imputed dataset and the results were combined using Rubin's rule (36).

Results

Participant characteristics are presented in Table 1. Girls (n=7,949) had a greater prevalence of overweight and obesity than boys (n=7,955; $p<0.001$) and a higher percent BF ($p<0.001$). Responses to the lifestyle survey are presented in the supplementary materials.

Results of the multilevel models are presented in Table 2. The estimated variance at the school level, indicated by the null model, suggests a significant inter-individual difference across schools in BF (χ^2 = 2,141 $p < 0.001$). The interclass correlation coefficient revealed that 16.4% of the variability in BF was explained by the school-level and 83.6% was explained by individual level factors.

The crude model which contained all lifestyle behaviours that were significantly associated with BF explained approximately 8.6% of the variance in BF. The adjusted model, which adjusted for relevant covariates, accounted for 15.3% of the variance. Associations, between bedtime, active transport, sugar sweetened cereals, sugar sweetened beverage, low calorie beverage and full-fat milk were not attenuated by covariates. The final model with interaction terms explained 15.5% of the total variation in BF.

After adjusting confounders, significant positive associations were observed between bedtime and BF (Table 2). All bedtimes later than 8pm were positively associated with BF. The use of an active mode of transport to get to school was negatively associated with BF. Intake of full-fat milk was negatively associated BF as were sugar sweetened cereal and sugar sweetened beverage intake. Low calorie beverages were positively associated with BF. Two-way interactions indicated that the positive association between low calorie beverages and BF was moderated by sex, with a negative association for girls. The main effects of year indicate that BF in 2010 and 2011 was significantly lower than 2004. However, two-way interactions between year and lifestyle behaviours were not significant. Some significant differences in lifestyle behaviours were found between years (supplementary material). However, these differences did not coincide with differences in BF.

Discussion

The aim of this study was to investigate the associations between BF, and lifestyle behaviours in a large population of children in one city and to test the consistence of these associations over a 10 -year period. Lifestyle behaviours explained 8.6% of the variation in BF and remained significant after adjustment for confounding variables. Despite alterations in behaviour, the composition of foods, nutritional policies and obesity prevention strategies, associations with childhood adiposity have not significantly changed over a 10-year period.

Retiring to bed later than 8pm was positively associated with adiposity. This is consistent with literature that has shown short sleep and late bedtimes are associated with an unhealthy body weight (37,38). Insufficient sleep has been shown to effect dietary patterns, resulting in food cravings and a greater consumption of energy dense foods (39). Further explanations for this association may be that sleep is negatively impacted by sedentary pursuits, such as television watching (40), and positively affected by exercise (41). However, no association was found between television watching and BF in the present study. Current sleep guidelines suggest children should achieve between 9-11 hours of sleep every 24-hours (42). In the present study, the bedtimes associated with BF were relatively early; guidelines could be achieved while going to bed beyond 8pm. This may reflect a discrepancy between bedtime and sleep onset which are not always synonymous and may be influenced by media use (43). None the less, bedtime and sleep duration are important considerations when planning lifestyle interventions for the prevention of obesity.

Active transport to school was negatively associated with BF, likely because active commuters expend more energy than children who use motorised transport (44). This finding is consistent with results from a study of children of the same age from 12 counties (45) which also found that active transport increases daily physical activity levels (46). These findings suggest that commuting to school may offer an effective approach to reducing BF by increasing daily physical activity and energy expenditure.

The consumption of free sugars is a determinant of body weight. Consequently, guidelines recommend an intake of below 5% of total energy intake (47). In the present study, no association was found between reporting the intake of biscuits, cakes, chocolate bars, fizzy drinks or added sugar, but a negative association was found between BF and sugar-sweetened cereals and sweetened beverages, similar to the findings of Janssen et al (12). As we could not establish portion size from our data, it is possible that overweight children consumed greater quantity of sugar-sweetened cereals and sweetened soft drinks. Another possible explanation is that overweight children are more likely to under-report unhealthy food intake than their normal weight counterparts (48). We found that the consumption of low-calorie soft drinks was positively and negatively associated with BF in boys and girls respectively. The result for boys was unexpected but are in agreement with previous findings that diet soft drinks are positively associated with body weight, suggesting that calorie content is not solely responsible for this association (49). It may be that soft drinks, regardless of their sugar content, are regularly consumed alongside high-energy snacks or during sedentary behaviours, such as television watching. Conversely, soft drinks, including sports drinks, are frequently sold at sports centres and may be consumed while also participating in exercise (50). It is also possible that flowing weight gain, children consume diet soft drinks in an attempt to reduce their calorie intake (51). However, prospective studies have shown that these associations remain significant after controlling for BMI at baseline or when studying normal weight adults separately (52). Repeatedly consuming sweet tasting foods with no energy content may lead to the failure to anticipate calories from sugar when they are consumed, disrupting the signals that lead to satiety (53). Independent of underlying mechanisms, we found that the association between low-calorie beverages and BF differs between boys and girls. Very few studies have distinguished between regular and sugar-free or diet drinks when investigating association with BF or obesity; this is the first study to show a sex difference in the associations with BF in a large population over time. Further research is required to establish the wider context in which diet and low-calorie soft drinks relate to BF. Based on our findings, future studies should analyse data dependent on sex.

Breakfast cereals are a major contributor to free sugar intake among children in the UK, which are in-turn associated with over-eating and weight gain (47). Despite this link, a negative association was found between BF and sugar-sweetened cereals. This finding agrees with outcomes from the NHANES study which found children who ate cereal, regardless of sugar content, had significantly lower BMI compared with children who did not. Furthermore, cereal consumption was associated with lower fat intake, a higher intake of carbohydrates, whole grains, and a range of vitamins (54). Similarly, a recent Australian study found no association between anthropometric measures and the choice of non-sweetened or sweetened breakfast cereal. Furthermore, added and free sugar intake was similar between cereal and no-cereal consumers (55). These findings might be explained by a lower Glycaemic index (GI) diet in participants who consumed breakfast cereals. Although no association was found between high fibre cereals and BF, the energy density and GI of breakfast cereals is not solely dependent on sugar content but also processing techniques and the quantity and type of fibre (56,57). Research has shown higher dietary fibre intake in participants consuming breakfast cereals regardless of sugar content (54,55).

Full-fat milk was negatively associated with BF, no association was found between low fat milk varieties. Previous studies have provided inconsistent reports of the relationship between milk/dairy intake in children and adiposity with studies reporting negative association (58), no association (9) or positive associations (15). Several studies have shown that soft drink consumption displaces milk consumption in children and adolescents (59), however, the associations between soft drink consumption and BF were inconclusive and could not explain the lack of association for low fat milk in this study. Few studies have distinguished between low and full-fat dairy products in children in relation to BF; However while the consumption skimmed milk was associated with weight gain, dairy fat was not (15). In a cohort of children up to 3-years of age, a higher milk fat consumption was associated with lower odds of obesity (16). Mechanisms for the adverse association between dairy fat and obesity are unclear but may include bioactive effects of the fatty acids contained in milk which have been shown to have an effect on low grade inflammation, oxidative stress (60) and insulin resistance (61) particularly in adults. Existing evidence from prospective studies reported that full-fat milk may be protective of weight gain and obesity (61,62). The findings of the present study add to this evidence by showing that at a population level, the consumption of full-fat milk is negatively associated with BF in 9-11 years old children.

Despite alterations in behaviour, the composition of foods, nutritional policies and obesity prevention strategies, associations between lifestyle behaviours and BF have not significantly changed over a 10-year period. This may reflect the fact that very few programmes and policies have successfully influenced childhood obesity and that any positive effects have been modest in relation to population trends (63). This may in turn be due to the lack of clarity about the relative importance of possible causative factors such as changes in dietary patterns, increases in soft drink consumption, portion size, screen time, physical activity and sedentary behaviours or most likely, a combination of all these factors. It is important to acknowledge that although significant associations between lifestyle behaviours and BF were found, combined, they explained only a small proportion of the variance in BF indicating the potential for other important contributing factors.

This study has several strengths. First, the large sample size and the duration of study spanning 10 years has allowed us to test consistency of associations between BF and lifestyle behaviours over time. To our knowledge, this is the first study to examine a near complete cross-section of children (aged 9-11 years) from a UK city. Secondly, the pathogenic processes associated with obesity are related to BF. BMI is a composite measure using height and weight and is not a measure of body composition. Skinfold measures on the other hand are a 2-compartment model and allow fat mass and fat free mass to be estimated. Finally, the use of multilevel analyses and multiple imputation techniques add to the rigour of our methodology by accounting for clustering between schools and by handling missing data respectively.

Limitations of this study include the cross-sectional design which precluded the inference of causality. Further, the lifestyle behaviours were captured with a self-report questionnaire that may be susceptible to social desirability and recall bias. Furthermore, some items on the survey had not been previously validated. However, single-item measures to measure screen time are common in large pollution studies and show high levels of validity among available methodologies (64), Similarly, comparable items on frequency of sports participation and club membership have shown good validity in this age group (65).

Previous studies investigating associations between lifestyle behaviours and BF or BMI have shown negative associations between physical activity and markers of obesity (11,13,14). In the present study, we did not have a direct measure for physical activity, instead we reported aerobic fitness. Although we recognize that aerobic fitness is partially genetic in origin, it can also be a reflection of recent physical activity levels (33,66). Finally, we were unable to control for maturation, given the age range of the participants it is possible that some, particularly girls, were going through puberty which may have affected their behaviour and BF.

Conclusions

In a large population of children, lifestyle behaviours were associated with adiposity but no significant change in these associations were found over a 10-year period. Policies and interventions targeting population shifts in behaviours, such as active transport to school, sleep time and consumption of full-fat milk may offer an opportunity for public health improvement. Further research is required to establish the wider context in which low calorie soft drink are linked with BF, future studies should consider different mechanisms for boys and girls.

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Table 1 **Participant characteristics**

	Boys (n=7,955)		Girls (n=7,949)		P-*value*
Age (years)	9.7	(0.4)	9.7	(0.4)	0.84
Height (cm)	137.8	(6.2)	137.5	(7.8)	**0.001**
Weight (kg)	39.2	(13.9)	39.4	(13.7)	0.223
BMI ($kg \cdot m^{-2}$)	20.4	(6.9)	20.7	(6.8)	**0.024**
BMI z-score [a]	0.8	(1.5)	0.9	(1.4)	**0.004**
Fat percent	23.8	(8.9)	27.2	(8.6)	**<0.0005**
Prevalence of overweight [b] (%)	17.7		21.0		**<0.0005**
Prevalence of obese [b] (%)	11.4		13.5		**<0.0005**

Data are means and standard deviations unless stated otherwise. [a]BMI Z-score denotes the standard deviation score calculated from International Obesity Task Force values. [b] Overweight and obesity were defined by using the International Obesity Task Force criteria.

Table 2 **Associations between lifestyle behaviours and body fat percentage**

	Crude model (model 1)				Adjusted model (model 2)				Model 2 plus two-way interactions			
	Beta	95% CI		p-*value*	Beta	95% CI		p-*value*	Beta	95% CI		p-*value*
		Low	High			Low	High			Low	High	
Constant	27.025	26.44	27.61	<0.0005	25.96	24.87	27.05	<0.0005	25.88	24.79	26.96	<0.0005
Sugar sweetened cereals	-0.70	-1.02	-0.37	<0.0005	-0.62	-0.94	-0.29	<0.0005	-0.62	-0.95	-0.29	<0.0005
High fibre cereals	-0.31	-0.66	0.03	0.071	-0.19	-0.52	0.15	0.285	-0.19	-0.53	0.15	0.272
Ordinary sausages	-0.52	-0.90	-0.14	0.007	-0.28	-0.66	0.11	0.157	-0.27	-0.65	0.11	0.163
Full fat milk	-1.10	-1.41	-0.79	<0.0005	-0.97	-1.27	-0.67	<0.0005	-0.97	-1.27	-0.67	<0.0005
Sugar sweetened beverages	-0.37	-0.66	-0.08	0.013	-0.39	-0.68	-0.10	0.009	-0.40	-0.70	-0.11	0.007
Low calorie beverages	0.54	0.16	0.91	0.005	0.54	0.19	0.89	0.003	0.95	0.46	1.44	<0.0005
Active Transport	-1.34	-1.71	-0.97	<0.0005	-1.00	-1.37	-0.62	<0.0005	-0.99	-1.37	-0.61	<0.0005
Week Sport	-0.50	-0.78	-0.22	<0.0005	-0.13	-0.41	0.14	0.339	-0.14	-0.41	0.14	0.331
Usual bed time during the week ≤*8:00pm (Ref)*												
8:00-8:59pm	1.66	1.15	2.18	<0.0005	1.59	1.08	2.10	<0.0005	1.59	1.09	2.10	<0.0005
9:00-10:00pm	1.09	0.62	1.56	<0.0005	1.04	0.57	1.50	<0.0005	1.03	0.57	1.49	<0.0005
≥*10:00pm*	0.92	0.33	1.50	0.002	1.18	0.60	1.76	<0.0005	1.18	0.60	1.76	<0.0005
Computer on the weekend	-0.74	-1.02	-0.46	<0.0005	0.18	-0.12	0.47	0.241	0.18	-0.11	0.47	0.232
IMD Score					0.01	0.00	0.02	0.003	0.01	0.00	0.02	0.003
MSFT					-0.04	-0.04	-0.03	<0.0005	-0.04	-0.04	-0.03	<0.0005
Sex (girl)					3.06	2.78	3.35	<0.0005	3.25	2.94	3.56	<0.0005
Year *2004 (ref)*												
2005					-0.40	-1.45	0.66	0.461	-0.39	-1.44	0.66	0.467
2006					0.05	-1.03	1.12	0.932	0.05	-1.03	1.12	0.930
2007					0.45	-0.62	1.51	0.410	0.45	-0.62	1.51	0.412
2008					0.42	-0.69	1.53	0.456	0.42	-0.69	1.53	0.455
2009					-0.15	-1.21	0.91	0.783	-0.15	-1.21	0.91	0.783

2010	-6.89	-8.22	-5.55	<0.0005	-6.90	-8.23	-5.56	<0.0005
2011	-3.13	-4.25	-2.01	<0.0005	-3.13	-4.26	-2.01	<0.0005
2012	0.39	-0.80	1.57	0.522	0.40	-0.79	1.58	0.514
2013	-0.35	-3.48	2.79	0.829	-0.36	-3.49	2.78	0.823
Two-way interactions								
*Sex * low calorie beverages (girl)*					-0.84	-1.57	-0.12	0.023

Random	**Null model**	**Crude model**	**Adjusted model (model 2)**	**Model 2 plus two-way interactions**
Total variance	78.42	68.62	65.09	65.06
ICC	16.4	5.8	4.9	4.8
Deviance	101592.084	60334.059	47145.847	47138.582
Variance explained				
Total		8.6%	15.3%	15.5%
School level		7.4%	10.7%	10.8%
Individual level		1.2%	4.6%	4.7%

IMD, Indices of Multiple Deprivation; MSFT, Multi Stage Fitness Test; ICC Intraclass Correlation Coefficient. Beta values are unstandardized beta coefficients.
Model 1 Contained all lifestyle behaviours associated with body fat percentage
Model 2 Contained all variables in model 1 plus confounding variables: IMD, MSFT, sex and year
Model 3 Contained all variables in model 2 plus 2-way interactions between sex and the consumption of low calories beverages