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 ($\beta=-0.99\pm0.19$ $p<0.001$), 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 $\leq$8:00pm, later bedtime was positively associated with BF; 8:00-8:59pm ($\beta=1.60\pm0.26$ $p<0.001$); 9:00-10:00pm ($\beta=1.04\pm0.24$ $p<0.001$); $\geq$10:00pm ($\beta=1.18\pm0.30$ $p<0.001$). Two-way interactions revealed opposing associations between BF and the consumption of low-calorie beverages for boys ($\beta=0.95 \pm 0.25 = p<0.001$) and girls ($\beta=-0.85\pm0.37$ $p=0.021$). 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,

26 such as active transport to school, sleep time and consumption of full-fat milk, may offer an

27 opportunity for improvements in BF.

28

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

30

31 **Introduction**

32 Childhood obesity is a significant public health concern, with a third of children in the UK

33 being affected by overweight or obesity (1). Excess body weight increases the risk of

34 developing type 2 diabetes, cardiovascular disease, hypertension, and sleep apnoea (2).

35 Childhood obesity is also related to emotional problems and reduces quality of life (3).

36 Moreover, excess weigh at this age and during adolescents tends to persist into adulthood (4).

37 Given that excess BF result from long-term energy imbalance, efforts to prevent obesity must

38 promote lifestyle behaviours that reduce energy intake and promote energy expenditure.

39 In 2009, data from the SportsLinx study showed the increase in prevalence of overweight and

40 obesity had slowed among children across Liverpool (5). These changes may reflect a

41 combined impact of the initiatives delivered in Liverpool at the time including interventions

42 delivered by the SportsLinx programme such as after school clubs and taster sessions, and

43 Liverpool City Council's campaigns such as Active City and A Taste for Health, part of the

44 city's obesity agenda that aimed to halt the rise in obesity by targeting physical activity and

45 healthy eating (6). In the same period, the SportsLinx study reported an improvement in

46 children's food intake with an increase in fruit, vegetable and salad intake over a 10-year period

47 (7). Despite these changes, it is unclear how specific behaviours relate to adiposity and whether

48 this has changed over time. Diet, physical activity and sedentary behaviours such as skipping

49 breakfast, screen time, and the consumption of sugar sweetened beverages, have been

50 implicated in the development of obesity in children (8,9). Conversely, increased fruit and

51 vegetable consumption and physical activity are linked with reduced risk of overweight and

52 obesity in children (10). However, associations are inconsistent, for example, in a large

53 international study of 10–16 year olds, obesity was associated with low physical activity levels

54 and television viewing but not with the fruit and vegetable intake, soft drink consumption or

55 the time spent using computers, yet a negative association was found between the frequency of

56 the consumption of sweets (candy in the USA) and obesity (11,12). Furthermore, the ISCOLE

57 study including 6,025 children (9-12 years) from 12 countries, failed to find an association

58 between dietary patterns and obesity (11), in accord with population-level studies in the UK

59 (13,14). It is therefore unclear which behaviours are related to obesity and should be the target

60 of interventions. Associations between specific foods and obesity are not always intuitive. For

61 example, the intake of fat from dairy is negatively associated with obesity during childhood

62 (15,16) despite its energy content. Similarly, the relationship between sugar sweetened

63 beverages and BF is not straightforward as might be assumed. Data from the SportsLinx study

64 has demonstrated that children with the greatest intake of sugar sweetened beverages had a

65 significantly lower BMI than non-consumers (17). Methodological limitations to population-

66 level studies such as the pooling of responses to a food frequency questionnaire to produce a

67 "healthy" and "unhealthy" score (13,14), may mask associations between specific foods and

68 obesity and precludes further interpretation of these findings.

69 Over the past decade there has been a year-on-year shift from full-fat to skimmed milk varieties

70 and an increase of wholemeal bread (18). Moreover, between 2004 and 2008, the percentage

71 soft drinks consumed by children with no added sugar increased by 9 percent (19).

72 Likewise, over the past 15 years screen behaviour has changed, TV viewing has decreased,

73 while computer use has sharply increased (20). Despite these changes, it is unclear whether

74 lifestyle behaviours and food choices positively impact on adiposity over time.

75 Exploring the lifestyle behaviours that influence childhood overweight and obesity and how

76 these have altered among changing technology use, food composition and public health policy

77 and campaigns is essential for the development of effective interventions. To our knowledge,

78 no studies have reported long-term changes to cross-sectional associations between lifestyle

79 behaviours and BF.

80 The aim of this study was to examine the associations between BF and dietary and physical

81 activity behaviours in primary school children over a 10-year period.

82

83 **Methods**

84 *Participants and Settings*

85 Participants included children aged 9-11 years that took part in the SportLinx program between

86 2004 and 2013. The SportsLinx program has been described in more detail elsewhere (7,21).

87 Briefly, SportsLinx was a repeat, cross-sectional physical activity, nutrition and health program

88 conducted in primary schools within the Liverpool Local Education Authority (UK). All year

89 5 pupils (9-10 years) were invited to take part annually resulting in 15,977 children who

90 completed an anthropometric assessment and lifestyle survey (7). On average, 105 primary

91 schools took part every year, representing 90% of all primary schools in the area.

92

93 *Measures and Procedures*

94 The SportsLinx Lifestyle Survey was used to assess sport participation, screen time, diet and

95 sleep. Participants specified, on a 5-point Likert scale, how much time during week and

96 weekend days they typically spent watching TV/DVDs/videos, playing video games, using the

97 internet, and participating in sport. Given that spending ≥ 2 hours in sedentary pursuits, is

98 unfavourable associated with body composition (22), data were categorized into dichotomous

99 levels for each variable to reflect participation in each sedentary activity for above or below 2

100 hour per day. Children were asked to select what time they went to bed (1: Before 8pm; 2: 8-

101 8:59pm; 3: -9:59pm; 4: After 10pm). The food intake questionnaire was designed to measure

102 eating habits at the population level based on the recall of foods consumed on the previous day.

103 A series of 'yes/no' questions indicated which foods were consumed from a list of 44 items.

104 The survey has acceptable validity (23) and reliability (24), in children of a similar age. For

105 this study, all foods, dietary patterns or behaviours that may have affected energy balanced

106 were considered in the analysis (List in supplementary material).

107 Socioeconomic status (SES) was calculated using the 2007 Indices of Multiple Deprivation

108 (IMD) (25) based on participants home postcode.

109 Skinfold thicknesses at the triceps and subscapular were measured by the same ISAK qualified

110 anthropometrist using standardised procedures (26). The Slaughter equations (27) which have

111 been validated in this age group (28) were used to estimate BF from the skinfold thicknesses.

112 Height was measured to the nearest 0.1 cm using a Leicester Height Measure (Seca,

113 Birmingham, UK), and weight was measured using calibrated analogue scales (model 873,

114 Seca, Birmingham, UK) to the nearest 0.1 kg.

115 The 20 meter multi-stage fitness test (MSFT) which has previously been validated in this age

116 group (29), was used to estimate the children's aerobic fitness. Given cardio-respiratory fitness

117 is negatively associated with BF (30), BMI (31) and sedentary time (32) and positively

118 associated with physically active (33) it was controlled for in the analysis.

119 The study was conducted according to the guidelines laid down in the Declaration of Helsinki

120 and all procedures involving human subjects/patients were approved by xxxxx University

121 ethics committee [xxxxx]. All participating children and their parents provided informed

122 written assent and consent.

123 ***Statistical analyses***

124 Descriptive statistics, independent samples t-test, and Pearson's chi-squared tests were used to

125 examine differences in the basic characteristics and questionnaire responses between sexes.

126 The proportion of children reporting each behaviour was also compared between years using

127 chi-square tests followed by pairwise comparisons using the z-test of two proportions with a

128 Bonferroni correction, to determine which years were different. The statistical package IBM

129 SPSS statistics, version 22.0 (IBM Corp., Armonk, NY, USA) was used for these analyses.

130 As data were collected from schools across Liverpool, a two-level multi-level model

131 (participant, school) was constructed using MLwiN v.3.01 software (Centre for Multilevel

132 Modelling, University of Bristol, UK) to examine associations between lifestyle survey

133 responses and BF. The model was constructed in three stages. Firstly, a backwards stepwise

134 deletion approach was used to identify all predictor variables that were significantly associated

135 with the outcome variable. Regression coefficients were assessed for significance using the

136 Wald statistic and a Chi-square distribution (34). All significant predictor variables were

137 entered into a crude model (model 1). Secondly, to control for confounders, sex, year, MSFT

138 and SES were entered into the model (model 2). Finally, two-way interactions were explored

139 to establish whether predictors differed by sex or year of data collection (model 3). Alpha was

140 set at $p < .05$ for main effects and $p < 0.1$ for interaction terms (34). The explained variance

141 was calculated by comparing the variance in each model to the variance in the null model

142 containing no independent variables.

143 Multiple imputation was used to address the potential bias and loss of precision that can result

144 from complete-case analysis. REALCOM-IMPUTE software with MLwiN (35) was used to

145 generate 10 imputed datasets with missing values replaced by plausible values based on known

146 covariates and distributional information. After a total of 6,500 iterations the model of interest

147 was fitted to each imputed dataset and the results were combined using Rubin's rule (36).

148

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 ($\chi^2 = 2,141$ 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

173   lifestyle behaviours were found between years (supplementary material). However, these

174   differences did not coincide with differences in BF.

175   **Discussion**

176

177   The aim of this study was to investigate the associations between BF, and lifestyle behaviours

178   in a large population of children in one city and to test the consistence of these associations

179   over a 10 -year period. Lifestyle behaviours explained 8.6% of the variation in BF and remained

180   significant after adjustment for confounding variables. Despite alterations in behaviour, the

181   composition of foods, nutritional policies and obesity prevention strategies, associations with

182   childhood adiposity have not significantly changed over a 10-year period.

183   Retiring to bed later than 8pm was positively associated with adiposity. This is consistent with

184   literature that has shown short sleep and late bedtimes are associated with an unhealthy body

185   weight (37,38). Insufficient sleep has been shown to effect dietary patterns, resulting in food

186   cravings and a greater consumption of energy dense foods (39). Further explanations for this

187   association may be that sleep is negatively impacted by sedentary pursuits, such as television

188   watching (40), and positively affected by exercise (41). However, no association was found

189   between television watching and BF in the present study. Current sleep guidelines suggest

190   children should achieve between 9-11 hours of sleep every 24-hours (42). In the present study,

191   the bedtimes associated with BF were relatively early; guidelines could be achieved while

192   going to bed beyond 8pm. This may reflect a discrepancy between bedtime and sleep onset

193   which are not always synonymous and may be influenced by media use (43). None the less,

194   bedtime and sleep duration are important considerations when planning lifestyle interventions

195   for the prevention of obesity.

196   Active transport to school was negatively associated with BF, likely because active commuters

197   expend more energy than children who use motorised transport (44). This finding is consistent

198   with results from a study of children of the same age from 12 counties (45) which also found

199   that active transport increases daily physical activity levels (46). These findings suggest that

200   commuting to school may offer an effective approach to reducing BF by increasing daily

201   physical activity and energy expenditure.

202   The consumption of free sugars is a determinant of body weight. Consequently, guidelines

203   recommend an intake of below 5% of total energy intake (47). In the present study, no

204   association was found between reporting the intake of biscuits, cakes, chocolate bars, fizzy

205   drinks or added sugar, but a negative association was found between BF and sugar-sweetened

206   cereals and sweetened beverages, similar to the findings of Janssen et al (12). As we could not

207   establish portion size from our data, it is possible that overweight children consumed greater

208   quantity of sugar-sweetened cereals and sweetened soft drinks. Another possible explanation

209   is that overweight children are more likely to under-report unhealthy food intake than their

210   normal weight counterparts (48). We found that the consumption of low-calorie soft drinks was

211   positively and negatively associated with BF in boys and girls respectively. The result for boys

212   was unexpected but are in agreement with previous findings that diet soft drinks are positively

213   associated with body weight, suggesting that calorie content is not solely responsible for this

214   association (49). It may be that soft drinks, regardless of their sugar content, are regularly

215   consumed alongside high-energy snacks or during sedentary behaviours, such as television

216   watching. Conversely, soft drinks, including sports drinks, are frequently sold at sports centres

217   and may be consumed while also participating in exercise (50). It is also possible that flowing

218   weight gain, children consume diet soft drinks in an attempt to reduce their calorie intake (51).

219   However, prospective studies have shown that these associations remain significant after

220   controlling for BMI at baseline or when studying normal weight adults separately (52).

221   Repeatedly consuming sweet tasting foods with no energy content may lead to the failure to

222   anticipate calories from sugar when they are consumed, disrupting the signals that lead to

223   satiety (53). Independent of underlying mechanisms, we found that the association between

224 low-calorie beverages and BF differs between boys and girls. Very few studies have

225 distinguished between regular and sugar-free or diet drinks when investigating association with

226 BF or obesity; this is the first study to show a sex difference in the associations with BF in a

227 large population over time. Further research is required to establish the wider context in which

228 diet and low-calorie soft drinks relate to BF. Based on our findings, future studies should

229 analyse data dependent on sex.

230 Breakfast cereals are a major contributor to free sugar intake among children in the UK, which

231 are in-turn associated with over-eating and weight gain (47). Despite this link, a negative

232 association was found between BF and sugar-sweetened cereals. This finding agrees with

233 outcomes from the NHANES study which found children who ate cereal, regardless of sugar

234 content, had significantly lower BMI compared with children who did not. Furthermore, cereal

235 consumption was associated with lower fat intake, a higher intake of carbohydrates, whole

236 grains, and a range of vitamins (54). Similarly, a recent Australian study found no association

237 between anthropometric measures and the choice of non-sweetened or sweetened breakfast

238 cereal. Furthermore, added and free sugar intake was similar between cereal and no-cereal

239 consumers (55). These findings might be explained by a lower Glycaemic index (GI) diet in

240 participants who consumed breakfast cereals. Although no association was found between high

241 fibre cereals and BF, the energy density and GI of breakfast cereals is not solely dependent on

242 sugar content but also processing techniques and the quantity and type of fibre (56,57).

243 Research has shown higher dietary fibre intake in participants consuming breakfast cereals

244 regardless of sugar content (54,55).

245 Full-fat milk was negatively associated with BF, no association was found between low fat

246 milk varieties. Previous studies have provided inconsistent reports of the relationship between

247 milk/dairy intake in children and adiposity with studies reporting negative association (58), no

248 association (9) or positive associations (15). Several studies have shown that soft drink

249 consumption displaces milk consumption in children and adolescents (59), however, the

250 associations between soft drink consumption and BF were inconclusive and could not explain

251 the lack of association for low fat milk in this study. Few studies have distinguished between

252 low and full-fat dairy products in children in relation to BF; However while the consumption

253 skimmed milk was associated with weight gain, dairy fat was not (15). In a cohort of children

254 up to 3-years of age, a higher milk fat consumption was associated with lower odds of obesity

255 (16). Mechanisms for the adverse association between dairy fat and obesity are unclear but

256 may include bioactive effects of the fatty acids contained in milk which have been shown to

257 have an effect on low grade inflammation, oxidative stress (60) and insulin resistance (61)

258 particularly in adults. Existing evidence from prospective studies reported that full-fat milk

259 may be protective of weight gain and obesity (61,62). The findings of the present study add to

260 this evidence by showing that at a population level, the consumption of full-fat milk is

261 negatively associated with BF in 9-11 years old children.

262
263 Despite alterations in behaviour, the composition of foods, nutritional policies and obesity

264 prevention strategies, associations between lifestyle behaviours and BF have not significantly

265 changed over a 10-year period. This may reflect the fact that very few programmes and policies

266 have successfully influenced childhood obesity and that any positive effects have been modest

267 in relation to population trends (63). This may in turn be due to the lack of clarity about the

268 relative importance of possible causative factors such as changes in dietary patterns, increases

269 in soft drink consumption, portion size, screen time, physical activity and sedentary behaviours

270 or most likely, a combination of all these factors. It is important to acknowledge that although

271 significant associations between lifestyle behaviours and BF were found, combined, they

272 explained only a small proportion of the variance in BF indicating the potential for other

273 important contributing factors.

274 This study has several strengths. First, the large sample size and the duration of study spanning

275 10 years has allowed us to test consistency of associations between BF and lifestyle behaviours

276 over time. To our knowledge, this is the first study to examine a near complete cross-section

277 of children (aged 9-11 years) from a UK city. Secondly, the pathogenic processes associated

278 with obesity are related to BF. BMI is a composite measure using height and weight and is not

279 a measure of body composition. Skinfold measures on the other hand are a 2-compartment

280 model and allow fat mass and fat free mass to be estimated. Finally, the use of multilevel

281 analyses and multiple imputation techniques add to the rigour of our methodology by

282 accounting for clustering between schools and by handling missing data respectively.

283 Limitations of this study include the cross-sectional design which precluded the inference of

284 causality. Further, the lifestyle behaviours were captured with a self-report questionnaire that

285 may be susceptible to social desirability and recall bias. Furthermore, some items on the survey

286 had not been previously validated. However, single-item measures to measure screen time are

287 common in large pollution studies and show high levels of validity among available

288 methodologies (64), Similarly, comparable items on frequency of sports participation and club

289 membership have shown good validity in this age group (65).

290 Previous studies investigating associations between lifestyle behaviours and BF or BMI have

291 shown negative associations between physical activity and markers of obesity (11,13,14). In

292 the present study, we did not have a direct measure for physical activity, instead we reported

293 aerobic fitness. Although we recognize that aerobic fitness is partially genetic in origin, it can

294 also be a reflection of recent physical activity levels (33,66). Finally, we were unable to control

295 for maturation, given the age range of the participants it is possible that some, particularly girls,

296 were going through puberty which may have affected their behaviour and BF.

297
298 **Conclusions**

299   In a large population of children, lifestyle behaviours were associated with adiposity but no

300   significant change in these associations were found over a 10-year period. Policies and

301   interventions targeting population shifts in behaviours, such as active transport to school, sleep

302   time and consumption of full-fat milk may offer an opportunity for public health improvement.

303   Further research is required to establish the wider context in which low calorie soft drink are

304   linked with BF, future studies should consider different mechanisms for boys and girls.

305

306   References

307   1.   Conolly A, Neave A. Health Survey for England 2015 Children ' s body mass index ,

308   overweight and obesity [Internet]. NHS Digitial. 2016 [cited 2018 Feb 2]. p. 1–18.

309   Available from: https://digital.nhs.uk/catalogue/PUB22610

310   2.   Biro FM, Wien M. Childhood obesity and adult morbidities. Am J Clin Nutr.

311   2010;91:1499–505.

312   3.   Tsiros MD, Olds T, Buckley JD, Grimshaw P, Brennan L, Walkley J, et al. Health-

313   related quality of life in obese children and adolescents. Int J Obes. 2009;33(4):387–

314   400.

315   4.   Singh a S, Mulder C, Twisk JWR, van Mechelen W, Chinapaw MJM. Tracking of

316   childhood overweight into adulthood: a systematic review of the literature. Obes Rev

317   [Internet]. 2008 Sep [cited 2014 Mar 19];9(5):474–88. Available from:

318   http://www.ncbi.nlm.nih.gov/pubmed/18331423

319   5.   Boddy LM, Hackett AF, Stratton G. Changes in BMI and prevalence of obesity and

320   overweight in children in Liverpool, 1998-2006. Perspect Public Health.

321   2009;129(3):127–31.

322   6.   Dawson J, Huikuri S, Armada F. Liverpool active city 2005-2010: Increasing

323   population physical activity levels through intersectoral action. J Phys Act Heal.

324 2015;12(6):749–55.

325 7. Boddy LM, Abayomi J, Johnson B, Hackett AF, Stratton G. Ten-year changes in

326   positive and negative marker food, fruit, vegetables, and salad intake in 9-10 year olds:

327   SportsLinx 2000-2001 to 2010-2011. J Hum Nutr Diet. 2014;27(3):236–41.

328 8. Eloranta A-M, Lindi V, Schwab U, Tompuri T, Kiiskinen S, Lakka H-M, et al. Dietary

329   factors associated with overweight and body adiposity in Finnish children aged 6–8

330   years: the PANIC Study. Int J Obes [Internet]. 2012;36(7):950–5. Available from:

331   http://www.nature.com/doifinder/10.1038/ijo.2012.89

332 9. Noel SE, Ness AR, Northstone K, Emmett P, Newby PK. Milk Intakes Are Not

333   Associated with Percent Body Fat in Children from Ages 10 to 13 Years. J Nutr.

334   2011;141(25):2035–41.

335 10. Ledoux TA, Hingle MD, Baranowski T. Relationship of fruit and vegetable intake

336   with adiposity: A systematic review. Obes Rev. 2011;12(5):143–50.

337 11. Katzmarzyk PT, Barreira T V., Broyles ST, Champagne CM, Chaput JP, Fogelholm

338   M, et al. Relationship between lifestyle behaviors and obesity in children ages 9-11:

339   Results from a 12-country study. Obesity. 2015;23(8):1696–702.

340 12. Janssen I, Katzmarzyk PT, Boyce WF, Vereecken C, Mulvihill C, Roberts C, et al.

341   Comparison of overweight and obesity prevalence in school-aged youth from 34

342   countries and their relationships with physical activity and dietary patterns. Obes Rev.

343   2005;6(2):123–32.

344 13. Wilkie HJ, Standage M, Gillison FB, Cumming SP, Katzmarzyk PT. Multiple lifestyle

345   behaviours and overweight and obesity among children aged 9–11 years: results from

346   the UK site of the International Study of Childhood Obesity, Lifestyle and the

347   Environment. BMJ Open [Internet]. 2016;6(2):e010677. Available from:

348   http://bmjopen.bmj.com/lookup/doi/10.1136/bmjopen-2015-010677

349   14.   Basterfield L, Jones AR, Parkinson KN, Reilly J, Pearce MS, Reilly JJ, et al. Physical

350   activity, diet and BMI in children aged 6-8 years: a cross-sectional analysis. BMJ

351   Open [Internet]. 2014;4(6):e005001–e005001. Available from:

352   http://bmjopen.bmj.com/cgi/doi/10.1136/bmjopen-2014-005001

353   15.   Berkey CS, Rockett HRH, Willett WC, Colditz GA. Milk, Dairy Fat, Dietary Calcium,

354   and Weight Gain. Arch Pediatr Adolesc Med [Internet]. 2005 Jun 1 [cited 2017 Oct

355   23];159(6):543. Available from:

356   http://archpedi.jamanetwork.com/article.aspx?doi=10.1001/archpedi.159.6.543

357   16.   Beck AL, Heyman M, Chao C, Wojcicki J. Full fat milk consumption protects against

358   severe childhood obesity in Latinos. Prev Med Reports [Internet]. 2017;8:1–5.

359   Available from: http://dx.doi.org/10.1016/j.pmedr.2017.07.005

360   17.   Boddy LM, Hackett AF, Stratton G. Sugar-sweetened carbonated drinks consumption,

361   body composition and aerobic fitness in 9–10-year-old schoolchildren. Proc Nutr Soc.

362   2009;68(OCE3):2020.

363   18.   DEFRA. Family Food 2014 [Internet]. 2015. Available from:

364   https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/485982/

365   familyfood-2014report-17dec15.pdf

366   19.   BSDA CR. Children's Consumption of Soft Drinks [Internet]. 2008. Available from:

367   http://www.britishsoftdrinks.com/write/MediaUploads/Publications/BSDA_Consumer

368   _Research_2008_-_Children's_Consumption_of_Soft_Drinks_(final).pdf

369   20.   WHO. Adolescent obesity and related behaviours : trends and inequalities in the WHO

370   region 2002-2014 [Internet]. Who. 2017 [cited 2018 Feb 2]. p. 2002–14. Available

371   from:

372   http://www.euro.who.int/__data/assets/pdf_file/0019/339211/WHO_ObesityReport_20

373   17_v3.pdf

374 21. Taylor, S; Hackett, A; Stratton, G; Lamb L. SportsLinx: Improving the Health and

375   Fitness of Liverpool's Youth. Vol. 22, Education and Health. 2004. p. 11–4.

376 22. Tremblay M, LeBlanc A, Koh M, Saunders T, Larouche R, Colley R, et al. Systematic

377   review of sedentary behaviour and health indicators in school-aged children and youth.

378   Int J Behav Nutr Phys Act. 2011;8(98):1–22.

379 23. Johnson B, Hackett A, Roundfield M, Coufopoulos A. An investigation of the face

380   validity of a food intake questionnaire: lessons for dietary advice. J Hum Nutr Diet.

381   1999;12(6):307–16.

382 24. Johnson B, Hackett A, Roundfield M, Coufopoulos A. An investigation of the validity

383   and reliability of a food intake questionnaire. J Hum Nutr Diet.

384   2008;14(September):457–65.

385 25. Index of Multiple Deprivation (IMD) 2007 - Datasets [Internet]. [cited 2017 Jul 21].

386   Available from: https://data.gov.uk/dataset/index_of_multiple_deprivation_imd_2007

387 26. Lohman TG, Roche AF, Martorell R. Anthropometric standardization reference

388   manual. Hum Kinet Books. 1988;177.

389 27. Slaughter MH, Lohman TG, Boileau R a, Horswill C a, Stillman RJ, Van Loan MD, et

390   al. Summary for Policymakers. In: Intergovernmental Panel on Climate Change,

391   editor. Climate Change 2013 - The Physical Science Basis. Cambridge: Cambridge

392   University Press; 1988. p. 1–30.

393 28. Martín-Matillas M, Mora-Gonzalez J, Migueles JH, Ubago-Guisado E, Gracia-Marco

394   L, Ortega FB. Validity of Slaughter Equations and Bioelectrical Impedance Against

395   Dual-Energy X-Ray Absorptiometry in Children. Obesity. 2020;28(4):803–12.

396 29. Léger LA, Mercier D, Gadoury C, Lambert J. The multistage 20 metre shuttle run test

397   for aerobic fitness The multistage 20 metre shuttle run test for aerobic fitness. J Sports

398   Sci. 1988;6(December):93–101.

399 30. Szmodis M, Szmodis I, Farkas A, Mészáros Z, Mészáros J, Kemper HCG. The

400 relationship between body fat percentage and some anthropometric and physical

401 fitness characteristics in pre-and peripubertal boys. Int J Environ Res Public Health.

402 2019;16(7).

403 31. Frey GC, Chow B. Relationship between BMI, physical fitness, and motor skills in

404 youth with mild intellectual disabilities. Int J Obes. 2006;30(5):861–7.

405 32. Carson V, Tremblay MS, Chaput J-P, Chastin SF, Carson V, Tremblay M, et al.

406 Associations between sleep duration, sedentary time, physical activity, and health

407 indicators among Canadian children and youth using compositional analyses 1. Appl

408 Physiol Nutr Metab. 2016;41(June):294–302.

409 33. Ortega FB, Ruiz JR, Hurtig-wennlöf A, Sjöström M. Physically Active Adolescents

410 Are More Likely to Have a Healthier Cardiovascular Fitness Level Independently of

411 Their Adiposity Status . The European Youth Heart Study. 2008;123–9.

412 34. Twisk JWR. Applied multilevel analysis : a practical guide. Cambridge: Cambridge

413 University Press; 2006. 184 p.

414 35. Carpenter JJR, Goldstein H, Kenward MGM. REALCOM-IMPUTE Software for

415 Multilevel Multiple Imputation with Mixed Response Types. J Stat Softw.

416 2011;45(5):1–12.

417 36. Rubin D. Multiple Imputation for Nonresponse in Surveys [Internet]. JOHN WILEY

418 & SONS New, editor. New York; 1987. Available from:

419 https://books.google.co.il/books?hl=iw&lr=&id=bQBtw6rx_mUC&oi=fnd&pg=PR24

420 &dq=multiple+imputations+rubin&ots=8NuI7M3ZgT&sig=2KWSC4nHl3YlnDtdT1

421 X_WigxW_E&redir_esc=y#v=onepage&q=multiple imputations rubin&f=false

422 37. Hart CN, Cairns A, Jelalian E. Sleep and Obesity in Children and Adolescents. Pediatr

423 Clin North Am. 2012;58(3):715–33.

424 38. Liu J, Zhang A, Li L. Sleep duration and overweight/obesity in children: review and
425 implications for pediatric nursing. J Spec Pediatr Nurs [Internet]. 2012;17(3):193–204.
426 Available from:
427 http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3384999&tool=pmcentrez
428 &rendertype=abstract
429 39. Westerlund L, Ray C, Roos E. Associations between sleeping habits and food
430 consumption patterns among 10–11-year-old children in Finland. Br J Nutr [Internet].
431 2009;102(10):1531. Available from:
432 http://www.journals.cambridge.org/abstract_S0007114509990730
433 40. Padez C, Mourao I, Moreira P, Rosado V. Long sleep duration and childhood
434 overweight/obesity and body fat. Am J Hum Biol. 2009;21(3):371–6.
435 41. Chen M-Y, Wang EK, Jeng Y-J. Adequate sleep among adolescents is positively
436 associated with health status and health-related behaviors. BMC Public Health
437 [Internet]. 2006;6(1):59. Available from:
438 http://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-6-59
439 42. Tremblay MS, Carson V, Chaput J-P, Connor Gorber S, Dinh T, Duggan M, et al.
440 Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of
441 Physical Activity, Sedentary Behaviour, and Sleep. Appl Physiol Nutr Metab.
442 2016;41(6 (Suppl. 3)):S311–27.
443 43. Cain N, Gradisar M. Electronic media use and sleep in school-aged children and
444 adolescents: A review. Sleep Med [Internet]. 2010;11(8):735–42. Available from:
445 http://dx.doi.org/10.1016/j.sleep.2010.02.006
446 44. Faulkner GEJ, Buliung RN, Flora PK, Fusco C. Active school transport, physical
447 activity levels and body weight of children and youth: A systematic review. Prev Med
448 (Baltim) [Internet]. 2009;48(1):3–8. Available from:

449   http://dx.doi.org/10.1016/j.ypmed.2008.10.017

450   45.   Sarmiento OL, Lemoine P, Gonzalez SA, Broyles ST, Denstel KD, Larouche R, et al.

451   Relationships between active school transport and adiposity indicators in school-age

452   children from low-, middle- and high-income countries. Int J Obes Suppl.

453   2015;5(S2):S107–14.

454   46.   Denstel KD, Broyles ST, Larouche R, Sarmiento OL, Barreira T V, Chaput J-P, et al.

455   Active school transport and weekday physical activity in 9–11-year-old children from

456   12 countries. Int J Obes Suppl. 2015;5(S2):S100–6.

457   47.   Morenga L., Mallard S, Mann J. Dietary sugars and body weight: systematic review

458   and meta-analyses of randomised controlled trials and cohort studies. Bmj [Internet].

459   2012;346(jan15 3):e7492–e7492. Available from:

460   http://www.bmj.com/cgi/doi/10.1136/bmj.e7492

461   48.   Heitmann BL, Lissner L. Dietary underreporting by obese individuals-is it specific or

462   non-specific? BMJ Br Med J. 1995;311:986–9.

463   49.   Giammattei J, Blix G, Marshak HH, Wollitzer AO, Pettitt DJ. Television Watching

464   and Soft Drink Consumption. Arch Pediatr Adolesc Med [Internet]. 2003;157(9):882.

465   Available from:

466   http://archpedi.jamanetwork.com/article.aspx?doi=10.1001/archpedi.157.9.882

467   50.   Kelly B, Baur LA, Bauman AE, King L, Chapman K, Smith BJ. Examining

468   opportunities for promotion of healthy eating at children's sports clubs. Aust N Z J

469   Public Health. 2010;34(6):583–8.

470   51.   Mattes RD, Popkin BM. Nonnutritive sweetener consumption in humans: Effects on

471   appetite and food intake and their putative mechanisms. Am J Clin Nutr.

472   2009;89(1):1–14.

473   52.   Fowler SP, Williams K, Resendez RG, Hunt KJ, Hazuda HP, Stern MP. Fueling the

474   Obesity Epidemic? Artificially Sweetened Beverage Use and Long-term Weight Gain.

475   Obesity [Internet]. 2008;16(8):1894–900. Available from:

476   http://doi.wiley.com/10.1038/oby.2008.284

477 53. Woods SC. Signals that influence food intake and body weight. Physiol Behav.

478   2005;86(5):709–16.

479 54. Albertson AM, Thompson DR, Franko DL, Holschuh NM. Weight indicators and

480   nutrient intake in children and adolescents do not vary by sugar content in ready-to-eat

481   cereal: Results from National Health and Nutrition Examination Survey 2001-2006.

482   Nutr Res [Internet]. 2011;31(3):229–36. Available from:

483   http://dx.doi.org/10.1016/j.nutres.2011.03.004

484 55. Fayet-Moore F, McConnell A, Tuck K, Petocz P. Breakfast and breakfast cereal

485   choice and its impact on nutrient and sugar intakes and anthropometric measures

486   among a nationally representative sample of Australian children and adolescents.

487   Nutrients. 2017;9(10).

488 56. Shrapnel B. Amount of sugar in Australian breakfast cereals is not associated with

489   energy density or glycaemic index: Results of a systematic survey. Nutr Diet.

490   2013;70(3):236–40.

491 57. Brennan MA, Derbyshire E, Tiwari BK, Brennan CS. Ready-to-eat snack products:

492   The role of extrusion technology in developing consumer acceptable and nutritious

493   snacks. Int J Food Sci Technol. 2013;48(5):893–902.

494 58. Crichton GE, Alkerwi A. Whole-fat dairy food intake is inversely associated with

495   obesity prevalence: Findings from the Observation of Cardiovascular Risk Factors in

496   Luxembourg study. Nutr Res [Internet]. 2014;34(11):936–43. Available from:

497   http://dx.doi.org/10.1016/j.nutres.2014.07.014

498 59. Mrdjenovic G, Levitsky DA. Nutritional and energetic consequences of sweetened

499   drink consumption in 6- to 13-year-old children. J Pediatr. 2003;142(6):604–10.

500   60.   Wang H, Steffen LM, Vessby B, Basu S, Steinberger J, Moran A, et al. Obesity

501   Modifies the Relations Between Serum Markers of Dairy Fats and Inflammation and

502   Oxidative Stress Among Adolescents. Obesity [Internet]. 2011;19(12):2404–10.

503   Available from: http://doi.wiley.com/10.1038/oby.2011.234

504   61.   Kratz M, Baars T, Guyenet S. The relationship between high-fat dairy consumption

505   and obesity, cardiovascular, and metabolic disease. Eur J Nutr. 2013;52(1):1–24.

506   62.   Holmberg S, Thelin A. High dairy fat intake related to less central obesity: a male

507   cohort study with 12 years' follow-up. Scand J Prim Health Care [Internet].

508   2013;31(2):89–94. Available from:

509   http://www.tandfonline.com/doi/full/10.3109/02813432.2012.757070#.VvXcGPkrKU

510   k

511   63.   Birch LL, Ventura AK. Preventing childhood obesity: What works? Int J Obes.

512   2009;33:S74–81.

513   64.   Bryant MJ, Lucove JC, Evenson KR, Marshall S. Measurement of television viewing

514   in children and adolescents: A systematic review. Obes Rev. 2007;8(3):197–209.

515   65.   Moeijes J, van Busschbach JT, Bosscher RJ, Twisk JWR. Sports participation and

516   health-related quality of life: a longitudinal observational study in children. Qual Life

517   Res [Internet]. 2019;28(9):2453–69. Available from: https://doi.org/10.1007/s11136-

518   019-02219-4

519   66.   Baquet G, Praagh E Van, Berthoin S. Endurance Training and Aerobic Fitness in

520   Young People. 2003;33(15):1127–43.

521

522

523

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·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

524