

The complexity of obesity in UK adolescents: relationships with quantity and type of technology, sleep duration and quality, academic performance and aspiration

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Received 30 July 2012; revised 27 September 2012; accepted 18 October 2012

What is already known about this subject

- Technology use and ownership is highly prevalent in adolescents and has been previously linked to obesity, but bedtime use of contemporary, original and multiple device use is currently unexplored.
- Sleep duration is a potentially important contributor to obesity development, but other sleep parameters may be crucial and may contribute to a better understanding of obesity, although these are currently limited in adolescent samples.
- Adolescent obesity may have a negative impact on academic performance, but data are heterogeneous. Body mass index may also influence academic aspiration, but little is known about this potential relationship.

What this study adds

- Frequent use of contemporary (video games) and long-standing technologies (television) as well as multiple quantities of technology during the week at bedtime is positively associated with body mass index emphasizing the complex relationships between lifestyle choices during adolescence and obesity.
- We show that sleep duration and sleep onset latency are important aspects associated with elevated body mass index. Considering the physiological changes commonly associated with sleep alterations during adolescence, it is possible that incorporating sleep education into the curriculum and improving sleep hygiene may help to improve the current obesity epidemic, which impacts on many aspects of an individual's life.
- Increased body mass index is negatively associated with academic performance, but not aspiration, demonstrating the importance of tackling adolescent obesity for future health, well-being and success.

Summary

Background: Contemporary technology and multiple device use may link to increased body mass index (BMI). The sleep–obesity relationship is inconsistent in adolescents. Sleep duration and quality may have crucial connections to obesity development, particularly in adolescents where sleep alterations are common. Elevated BMI in adolescents may influence academic performance and aspiration, but data are limited.

Objectives: The objectives of this study was to assess the linear associations between BMI z-score and (i) quantity/type of technology used; (ii) sleep quantity/quality and (iii) academic performance/aspiration.

Methods: Consenting adolescents ($n = 624$; 64.9% girls, aged 11–18 years) were recruited. The Schools Sleep Habits Survey and Technology Use Questionnaire were administered. Objective measures of height/weight were obtained.

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Results: Quantity of technology was positively associated with BMI z-score $\beta = 0.10$, $P < 0.01$. Those who always engaged in video gaming had significantly higher BMI z-score vs. never-users, $\beta = 1.00$, $P < 0.001$. Weekday sleep duration and sleep onset latency were related to BMI z-score, $\beta = -0.24$, $P < 0.001$ and $\beta = 0.01$, $P < 0.001$, respectively. An inverse linear association was observed between BMI z-score and academic performance, $\beta = -0.68$, $P < 0.001$.

Conclusions: If confirmed prospectively, reducing bedtime use of technology and improving sleep hygiene in adolescents could be an achievable intervention for attenuating obesity with potentially positive effects on academic performance.

Keywords: Adolescence, BMI, sleep, technology.

Introduction

The prevalence of obesity has risen rapidly in recent decades, making obesity a major global health problem. Of great concern is the increasing prevalence of obesity in childhood and adolescence resulting in continuation of obesity into adulthood, and earlier occurrence of obesity complications (1,2).

Adolescence is an important developmental period associated with increased vulnerability to obesity (3). Adolescents exercise greater autonomy in preparation for adulthood, and lifestyle decisions during adolescence may pave the foundation for later health behaviours and outcomes. Several potentially modifiable factors have emerged as contributors to obesity in adolescence. For example, frequent television (TV) viewing during adolescence has been prospectively associated with later obesity (4). While the impact of TV viewing on obesity has been extensively reported, the effect of multiple technology use, or more modern types of technology, has not yet been examined in adolescents where ownership and usage of technology devices is extensive.

Adolescents are vulnerable to sleep loss, because of physiological alterations exacerbated by compulsory school attendance (5). Recently, short sleep duration has emerged as a potential contributor of obesity (6) in adults and children, but data in adolescents are either limited to smaller samples (7) or show no relationship when examined prospectively (8). Sleep duration may not be the only aspect of sleep that is important in relation to obesity, although evidence for other sleep parameters is limited. Poor overall sleep quality has been associated with overweight and obesity in adults (9) and, while one adolescent study reported similar findings (10), others suggest no relationship between sleep quality and body weight in adolescents (7,11).

The health and psychological effects of obesity are well established and include chronic disease (12), mental health problems (13) and reduced quality of life

(14). Obesity has also been associated with reduced productivity in the workplace (15). Indeed, the indirect costs of obesity are higher than its direct costs. Adolescence is a critical period where academic attainment underpins the future of the individual. Obesity may, however, hinder academic performance through peer victimization (16), although one study reported no relationship between obesity and academic performance (17). Furthermore, academic aspirations of obese individuals may differ to non-obese, but evidence for this is currently limited and requires investigation.

To gain a greater understanding of putative factors associated with obesity in adolescence, we examined the associations among technology use (quantity and type), sleep (duration and quality), academic performance and aspiration, and BMI z-score in adolescents. We hypothesized that the following would be independently associated with increased BMI z-score: (i) quantity of technology devices used at bedtime on weekdays; (ii) use of specific technology at bedtime on weekdays, both contemporary and older types; (iii) weekday sleep duration; (iv) sleep onset latency (SOL) and (v) number of night-time awakenings. We further hypothesized that increased BMI z-score would be independently associated with (i) academic performance and (ii) academic aspiration.

Methods

Study population

Survey data were drawn from six randomly selected schools across the Midlands region of the UK. This region is of particular importance, as statistics show that the West Midlands has a higher than national average prevalence of paediatric obesity (18). Students ($n = 1043$; aged 11–18 years) were invited to participate in the study, but were excluded if they did not provide written consent, had a diagnosed sleep disorder, were taking sleep medication or had

travelled to a different time zone 4 weeks prior to the time of data collection. Of those invited to participate, 759 (72.8%) volunteers met all inclusion criteria and attended data collection sessions to provide survey data in 2009. All participants were registered Year 7–13 students in UK secondary education. School type (secondary, grammar, independent) at which participants were registered was used as a proxy for socioeconomic status (19) and for potential variation in teaching standards. The study sample comprised of 55.1% from secondary schools, the main school type in England, 24.0% were registered at grammar school and 20.9% were from an independent school. Self-reported ethnicity (35.9% Caucasian, 46.3% Asian, 9.9% Black, 7.9% other), gender (64.9% girls) and bedroom sharing (74.4% non-sharing bedroom) were also identified.

Exposure and outcome measures

Weight (kg) and height (cm) were measured using scales and stadiometers, calibrated regularly, allowing BMI z-score calculation. Height and weight were measured for each student without shoes and in light indoor clothing. All students were asked to remove any items from their pockets prior to being weighed. A secure online survey combining the validated School Sleep Habits Survey (SSHS) (20) and a Technology Use Questionnaire (21), developed previously for a cohort study, were then completed immediately after height and weight were obtained. All these measures were self-reported; information was gained on weekday sleep duration, SOL and the number of night-time awakenings through the SSHS. Adolescents were asked the following questions: 'Work out how long you USUALLY sleep on a normal school night and fill it in here. Do not include time you spend awake in bed'. Respondents estimated the number of hours and minutes that they slept for on a weekday, and sleep duration (h) was then calculated. We assessed weekday sleep duration as sleep loss may be more prevalent on weekdays because of early compulsory school attendance. Adolescents were also asked the following questions concerning sleep quality: 'On a weekday, how long does it USUALLY take you to fall asleep (in minutes)?' and 'Some people wake up in the night, others never do. How many times do you USUALLY wake up in the night?' (never, once, two or three times, more than three times). Technology use of four technology types (TV viewing, video gaming, Internet/laptop, mobile telephone) at bedtime was obtained (never, sometimes, usually, always). We then calculated the quantity of technology used on weekdays at bedtime (non-user/

any one type/any combinations of two types/any combinations of three types/all four types of technology [0–4]). Self-reported academic achievement was acquired through the SSHS, ranging from mostly A*s (highest) to mostly Ds and Es (lowest) grades. We also asked about academic aspiration: 'What is the highest level of education you expect to complete?' Response options were General Certificate in Secondary Education (GCSE) (lowest aspiration), A-level, degree, postgraduate (highest aspiration). The study received ethical approval from the University of Birmingham Research Ethics Committee (ERN_08–437).

Other measures

Participant's method of travel to school was obtained and categorized for estimation of activity level (inactive [public transport or car], active [walk, cycle]). Assessment of snacking before bedtime was obtained for dietary measures (never, sometimes, usually, always). The SSHS identified symptoms of depression by asking the adolescents 'In the past 2 weeks, how often were you bothered by feeling unhappy, sad or depressed?' (a lot, somewhat, not at all). Participants were asked: 'In the past 2 weeks, how often have you stopped breathing while you sleep or woke up gasping for breath?' to identify those with potential obstructive sleep apnoea (OSA). Information regarding bedroom sharing was obtained (yes, no) along with tendencies for morningness–eveningness.

Statistical analysis

Data analyses were performed using IBM Statistical Package for the Social Sciences (SPSS, version 20.0 SPSS Inc., Chicago, IL, USA). Independent *t*-tests and one-way analyses of variance were used to assess mean differences in BMI z-score for binary and categorical variables, respectively. Cronbach's alpha was calculated to assess the internal consistency of the Technology Use Questionnaire.

A series of linear regression analyses were performed to examine the effect of quantity of weekday technology (0–4) as well as the four technology types (TV, video games, PC/laptop, mobile telephone) on BMI z-score. Dummy variables were created to assess the extent of use (sometimes, usually, always) for each of the four technology types, and 'never' was taken as the referent. Three models were developed, and unstandardized coefficients and standard errors for each are presented. Model 1 shows the unadjusted model; model 2 adjusted for age, sex and ethnicity; model 3 further adjusted for activity,

school, snacking, depression, bedroom sharing and morningness–eveningness.

Linear regression was then used to assess the relationships between weekday sleep duration (h), weekday SOL (min), number of night-time awakenings and BMI z-score. All sleep parameters were treated as continuous variables in the models developed. Model 1 unadjusted; model 2 adjusted for age, sex and ethnicity; model 3 adjusted for quantity of weekday technology, snacking, activity, school, depression, potential OSA, bedroom sharing, morningness–eveningness and academic performance, in addition to the aforementioned factors.

Finally, linear regression was used to investigate the relationship between BMI z-score and academic achievement as well as academic aspiration. Grades were reversed for this analysis and treated as a continuous variable. Three models are presented for each analysis: model 1 unadjusted, model 2 adjusted for age, sex and ethnicity and model 3 further adjusted for quantity of weekday technology, snacking, school, depression, bedroom sharing, weekday sleep duration, potential OSA and morningness–eveningness. Dummy variables were created for academic aspiration, and GCSE was considered as the referent.

Results

Of the 759 volunteers who participated in the study, 135 (17.8%) were excluded because of incomplete data, leaving a total of 624 (82.2%) with data on all variables of interest available for subsequent analysis. There were no significant differences between included and excluded participants for all sleep, academic and technology parameters as well as BMI z-score (data not shown). Descriptive statistics are presented in Table 1 and show that boys had significantly higher BMI z-scores compared with girls, $P = 0.012$, but no differences were found for BMI z-score according to school type. Significant differences of BMI z-scores were also found for weekday sleep duration, quantity of weekday technology and academic performance, all $P < 0.001$. The Technology Use Questionnaire consisted of four technology items ($\alpha = 0.68$) showing good internal consistency.

The linear relationship between quantity of weekday technology and BMI z-score shows that for each additional technology used at bedtime, BMI z-score increases by 0.10, $P < 0.01$, after adjustment for a range of potential confounders (see Table 2). High frequency (usually, always) of TV and video gaming at bedtime had a significant positive association with BMI z-score, after adjustment.

Table 1 The characteristics of 624 participating UK adolescents according to BMI z-score

	BMI z-score	P-value
Age, <i>n</i> (%)		0.009
Younger adolescent, 377 (60.4)	−0.08 ± 1.02	
Older adolescent, 247 (39.6)	0.13 ± 0.95	
Gender, <i>n</i> (%)		0.012
Male, 219 (35.1)	0.15 ± 1.15	
Female, 405 (64.9)	−0.08 ± 0.90	
Ethnicity, <i>n</i> (%)		0.028
Caucasian, 224 (35.9)	−0.05 ± 0.85	
Asian, 289 (46.3)	−0.05 ± 0.99	
Black, 62 (9.9)	0.14 ± 1.05	
Other, 49 (7.9)	0.37 ± 1.55	
School type, <i>n</i> (%)		0.214
Secondary, 344 (55.1)	0.02 ± 1.11	
Grammar, 150 (24.0)	0.06 ± 0.93	
Independent, 130 (20.8)	−0.13 ± 0.75	
Weekday sleep duration, <i>n</i> (%)		<0.001
<9 h, 385 (61.7)	0.24 ± 1.03	
≥9 h, 239 (38.3)	−0.38 ± 0.81	
Grades, <i>n</i> (%)		<0.001
A*, 35 (5.6)	−0.48 ± 0.75	
A* & A, 156 (25.0)	−0.43 ± 0.69	
A, 71 (11.4)	−0.57 ± 0.59	
A & B, 148 (23.7)	0.03 ± 0.96	
B, 35 (5.6)	0.13 ± 0.63	
B & C, 94 (15.1)	0.37 ± 0.86	
C, 46 (7.4)	1.02 ± 1.30	
C & D, 29 (4.6)	0.64 ± 1.27	
D, 7 (1.1)	1.53 ± 1.42	
D & E, 3 (0.5)	1.32 ± 0.35	
Technology frequency, <i>n</i> (%)		<0.001
Non-user, 95 (15.2)	−0.11 ± 1.08	
One type, 88 (14.1)	−0.35 ± 0.67	
Two types, 138 (22.1)	−0.22 ± 0.74	
Three types, 107 (17.1)	0.06 ± 0.86	
Four types, 196 (31.4)	0.34 ± 1.19	

Data are presented as mean ± standard deviation.

Younger adolescent (11–14 years); Older adolescent (15–18 years).

P-values calculated using independent *t*-test or analysis of variance, as appropriate.

BMI, body mass index.

Video gaming had the greatest positive effect. Mobile telephone use was not related to BMI z-score before or after adjustment.

A negative linear relationship was observed between weekday sleep duration (h), weekday SOL (min) and BMI z-score (Table 3). No association was

	Model 1		Model 2		Model 3	
	Unst.	SE	Unst.	SE	Unst.	SE
Quantity of technology	0.15***	0.03	0.13***	0.03	0.10**	0.03
TV viewing						
Sometimes	-0.24**	0.09	-0.26**	0.08	-0.27**	0.08
Usually	0.78***	0.09	0.75***	0.09	0.71***	0.10
Always	0.44**	0.13	0.44**	0.13	0.33*	0.13
Video gaming						
Sometimes	-0.18	0.10	-0.18	0.10	-0.20*	0.10
Usually	0.48***	0.12	0.51***	0.12	0.42**	0.12
Always	1.07***	0.12	1.07***	0.12	1.00***	0.13
PC/laptop						
Sometimes	-0.10	0.09	-0.14	0.09	-0.13	0.09
Usually	0.62***	0.10	0.57***	0.10	0.48***	0.10
Always	0.29**	0.11	0.27*	0.11	0.15	0.12
Mobiles						
Sometimes	0.04	0.09	0.02	0.08	0.03	0.08
Usually	-0.00	0.11	-0.05	0.10	-0.10	0.10
Always	0.18	0.10	0.14	0.10	0.05	0.10

Table 2 The linear associations between quantity and types of weekday technology use and BMI z-score in 624 UK adolescents

Model 1: unadjusted; model 2: adjusted for age, sex and ethnicity; model 3: further adjusted for activity, school, snacking, depression, bedroom sharing and morningness-eveningness.

P* < 0.05; *P* < 0.01; ****P* < 0.001.

Dummy variables were created for the frequency of use of each technology type and 'never' used as the referent. BMI, body mass index; SE, standard error; PC, personal computer; Unst., unstandardized coefficient.

	Model 1		Model 2		Model 3	
	Unst.	SE	Unst.	SE	Unst.	SE
Weekday sleep duration (h)	-0.32*	0.03	-0.33*	0.03	-0.24*	0.03
Sleep onset latency (min)	0.02*	0.00	0.02*	0.00	0.01*	0.00
Night-time awakenings	0.03	0.04	0.02	0.04	-0.03	0.04

Table 3 The linear associations between weekday sleep duration (h), sleep quality parameters and body mass index z-score in 624 UK adolescents

Model 1: unadjusted; model 2: adjusted for age, sex and ethnicity; model 3: further adjusted for quantity of weekday technology, activity, school, snacking, depression, potential obstructive sleep apnoea, bedroom sharing, morningness-eveningness and academic performance.

**P* < 0.001.

SE, standard error; Unst., unstandardized coefficient.

found between the number of night-time awakenings and BMI z-score in our sample of adolescents.

Finally, BMI z-score was shown to be an independent positive predictor of academic performance, measured by self-reported grades. There was no evidence to suggest that BMI z-score was associated with academic aspiration (Table 4).

Discussion

Our data show that increased use of weekday technology at bedtime is independently associated with increased BMI z-score in adolescents. There are several explanations for this observation. Obesity has

been previously related to victimization and social isolation (22). Using technology may promote sedentariness and replace otherwise active behaviours and may thus contribute to energy imbalance. Technology use has also been associated with increased energy intake despite the absence of hunger, resulting in surplus energy intake in adolescents (23). The advertising of unhealthy food types, sugar-sweetened beverages and fast food restaurant chains, through various technologies, has also been linked to increased consumption of these foods and beverages (24). This type of advertising is no longer restricted to the TV but now appears on the Internet and mobile telephone applications. In recent years,

Table 4 The linear associations between body mass index z-score and academic performance and academic aspiration in 624 UK adolescents

	Model 1		Model 2		Model 3	
	Unst.	SE	Unst.	SE	Unst.	SE
Performance	-0.95*	0.07	-0.91*	0.07	-0.68*	0.08
Aspiration						
A-level	-0.03	0.02	-0.03	0.02	-0.03	0.02
Degree	0.04	0.02	0.03	0.02	0.03	0.02
Postgraduate	-0.03	0.02	-0.02	0.02	-0.02	0.02

Model 1: unadjusted; model 2: adjusted for age, sex and ethnicity; model 3: further adjusted for quantity of weekday technology, snacking, school, depression, bedroom sharing, weekday sleep duration, obstructive sleep apnoea and morningness–eveningness.

* $P < 0.001$.

Dummy variables were created to assess academic aspiration and General Certificate in Secondary Education was used as the referent.

SE, standard error; Unst., unstandardized coefficient.

energy drink manufacturers have become main sponsors of some video games. Adolescents are greatly immersed in these technologies and are the targets of optimal unhealthy foods/beverages promotion. Our data support the notion that greater quantities of technology used at bedtime are associated with increased BMI, but longitudinal assessment is required.

Recent studies have highlighted significant, independent associations between obesity and technology use, including TV viewing, computer/Internet use and video gaming (25–27). While there are data linking TV, computer and video gaming to obesity, and the use of these types of technology may replace more active behaviours, as noted earlier, there are no data available on the use of mobile telephones and body weight status. Our study is the first to examine this, although we observed no relationship between weekday mobile use at bedtime and BMI. It is possible that mobile telephones, because of their portable nature, do not restrict the user to a fixed position and may subsequently result in increased movement and energy expenditure, compared with other technology types. Future studies should, however, continue to investigate the use of mobile telephones as these devices now offer a variety of facilities, which may be used to replace other technology types such as video games, Internet and TV/film viewing.

Sleep and obesity

Two systematic reviews and meta-analyses have linked short sleep duration with obesity in children (6,28) and adults (6). Adolescent findings, however, are inconsistent for prospective and cross-sectional studies (8,29). Our study found that adolescent weekday sleep duration was significantly and inversely related to BMI z-score, after adjustment for a

range of potential confounders. Evidence suggests that short sleep duration in adults is associated with alterations in metabolic hormones that promote energy intake (30). Spiegel and colleagues demonstrated metabolic hormone alterations as a consequence of reduced sleep duration, also related to increases in subjective hunger and appetite for unhealthy foods (31). A more recent study showed that experimental circadian misalignment disrupted hormone metabolism. Adolescent studies investigating either metabolic alterations and/or energy balance in response to sleep duration have produced heterogeneous findings, potentially because of different methodological designs (32–34). Investigation into SOL and obesity, however, has not been previously examined. Our data show that BMI z-score was positively and significantly associated with longer weekday SOL. Because of the cross-sectional nature of our study, the temporal sequence cannot be determined. It is possible, however, that those with elevated BMI take longer to fall asleep with several possible explanations. Firstly, adolescents who have higher BMIs may be more anxious and/or depressed and may therefore have more sleep problems, although a measure of depression was adjusted for in our analyses. Secondly, overweight/obese adolescents may be more likely to use technology to avoid social situations, which may delay SOL. Bedtime technology use, however, was adjusted for in our analyses. Thirdly, it may be excess weight and the physiological symptoms that accompany it, which contributes to delayed sleep onset. While some have shown a relationship between overall sleep quality and overweight (9), others report nocturnal awakenings to be associated with a range of mental and physical disorders (35), including obesity. Our data show no relationship between the number of night awakenings and BMI z-score in adolescents. It is, however, possible that this is affected by poor recall.

Future studies should use more objective measures of sleep quality such as actigraphy.

Obesity and academic performance

Previous research assessing the relationship between obesity and academic performance is heterogeneous. A recent review of the literature, however, concluded a negative association between obesity and academic performance, in line with our findings (16). The relationship between increased BMI and poor academic performance may be a result of peer victimization, including teasing and bullying, and/or absenteeism (16). It is possible that obese children/adolescents may have reduced cognitive abilities as a result of OSA. Our study, however, excluded those with diagnosed sleep disorders and adjusted for potential undiagnosed OSA. It is therefore unlikely that OSA is responsible for the relationship observed in our study, although future studies should incorporate screening for this sleep disorder commonly associated with obesity. Our study is the first to examine the relationship between BMI z-score and academic aspiration in adolescents, but there was no evidence to suggest that BMI was related to aspiration. While those with increased BMI in our sample performed less well academically, there was no indication of lower academic aspiration. Comprehensive cognitive assessments and focus groups, coupled with detailed psychosocial data, will provide a greater understanding of the area and should be included in future prospective studies.

Strengths and limitations

Our study has a number of strengths. Firstly, our study is the first to examine the independent associations between BMI and quantity of weekday technology, specific technology types, weekday sleep duration, SOL, nocturnal awakenings, academic performance and academic aspiration in the same sample of adolescents. Secondly, our large sample of adolescents allowed adjustment for a range of potential confounders for each of the relationships assessed. Thirdly, we have demonstrated the complexity of adolescent obesity showing a multitude of factors associated with this chronic condition. Our study highlights several avenues for exploration in the development of programmes to tackle obesity in adolescents. We have identified potential modifiable factors that can be addressed in obesity prevention and treatment including technology use and sleep. Also, we have identified an association between obesity and academic performance, which may

exacerbate and/or perpetuate obesity and its psychological impact on adolescents.

The limitations of our study include its cross-sectional nature, which does not allow determination of temporal relationships. Self-reported data may be subject to bias, although sleep duration obtained from the SSHS has been previously validated with actigraphy (20). The SSHS has not, however, been validated against the gold-standard of polysomnography, nor has it been authenticated against other sleep parameters assessed in our study (SOL and nocturnal awakenings). Information obtained on physical activity levels and diet/snacking may not provide an accurate overall representation of these important potential confounders. Future studies should obtain objective physical activity levels and administer food diaries to obtain a more comprehensive assessment.

The present findings, if confirmed, could have significant public health implications. Constant advances in available technology promote media use that is easily accessible and available at any time of the day for all age groups, displacing more physical activities, which may be exacerbating the current obesity epidemic. Physiological alterations in adolescence result in sleep loss, but environmental and lifestyle choices may intensify sleep deprivation and contribute to obesity development. Adolescent obesity may hinder academic performance through a number of mechanisms. Should our results be confirmed through longitudinal studies, then (i) the use of technology may need to be better managed in adolescents by reducing overall use directly before bedtime; (ii) educating pre-adolescent children about better sleep habits may provide adolescents with useful tools to optimize sleep during adolescence and may potentially aid obesity reduction and (iii) encouraging healthy lifestyles to reduce and/or prevent obesity may result in better performance in adolescents.

Conflicts of Interest Statement

All authors have no conflicts of interest to disclose.

Acknowledgements

Author contributions include: TA collected and analysed data and drafted the manuscript; MHA and JB assisted with data analysis; GLY supervised data analysis; GNT critically appraised the manuscript and ST contributed to study design and writing of the manuscript. All authors had final approval of the submitted and published versions. The Midlands

Adolescent Schools Sleep Education Study received funding from the Action Medical Research, Aim Higher, UK, the Heart of England Foundation Trust, UK and the University of Birmingham, UK. Drs Shahrads Taheri, Guiqing Lily Yao and Jonathan Bishop receive funding from the National Institute for Health Research (NIHR) through the Collaborations for Leadership in Applied Health Research and Care for Birmingham and Black Country (CLAHRC-BBC) programme. The views expressed in this publication are not necessarily those of the NIHR, the Department of Health, NHS Partner Trusts, University of Birmingham or the CLAHRC-BBC Theme 8 Steering Group. Participating schools were Ashby School, Bishop Vesey's Grammar School, Hamstead Hall Community Learning Centre, Highclare School, Repton School and Sutton Coldfield Grammar School for Girls. We thank all teaching staff for their support, in particular Jane Taylor, Trudi Young, William Potter, Claire Horne, Lawrence Sneary, Ken Morris, Suzanne Gray and Dr Dawn Edwards. We also thank the parents who agreed for their children to participate, sixth form students and students who provided us with data across all recruited schools.

References

1. Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. *Int J Pediatr Obes* 2006; 1: 11–25.
2. Clarke WR, Lauer RM. Does childhood obesity track into adulthood? *Crit Rev Food Sci Nutr* 1993; 33: 423–430.
3. Alberga AS, Sigal RJ, Goldfield G, Prud' Homme D, Kenny GP. Overweight and obese teenagers: why is adolescence a critical period? *Pediatric Obesity* 2012; 7: 261–273.
4. Parsons TJ, Manor O, Power C. Television viewing and obesity: a prospective study in the 1958 British birth cohort. *Eur J Clin Nutr* 2008; 62: 1355–1363.
5. Wolfson AR, Carskadon MA. Understanding adolescents' sleep patterns and school performance: a critical appraisal. *Sleep Med Rev* 2003; 7: 491–506.
6. Cappuccio FP, Taggart FM, Kandala NB, et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep* 2008; 31: 619–626.
7. Gupta NK, Mueller WH, Chan W, Meiningner JC. Is obesity associated with poor sleep quality in adolescents? *Am J Hum Biol* 2002; 14: 762–768.
8. Calamaro CJ, Park S, Mason TB, et al. Shortened sleep duration does not predict obesity in adolescents. *J Sleep Res* 2010; 19: 559–566.
9. Hung HC, Yang YC, Ou HY, Wu JS, Lu FH, Chang CJ. The association between self-reported sleep quality and overweight in a Chinese population. *Obesity (Silver Spring)* 2012; doi: 10.1038/oby.2012.169.
10. Bawazeer NM, Al-Daghri NM, Valsamakis G, et al. Sleep duration and quality associated with obesity among Arab children. *Obesity (Silver Spring)* 2009; 17: 2251–2253.
11. Mota J, Vale S. Associations between sleep quality with cardiorespiratory fitness and BMI among adolescent girls. *Am J Hum Biol* 2010; 22: 473–475.
12. Colditz GA, Willett WC, Rotnitzky A, Manson JE. Weight gain as a risk factor for clinical diabetes mellitus in women. *Ann Intern Med* 1995; 122: 481–486.
13. Luppino FS, de Wit LM, Bouvy PF, et al. Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. *Arch Gen Psychiatry* 2010; 67: 220–229.
14. Swallen KC, Reither EN, Haas SA, Meier AM. Overweight, obesity, and health-related quality of life among adolescents: the National Longitudinal Study of Adolescent Health. *Pediatrics* 2005; 115: 340–347.
15. Loeppke R, Taitel M, Haufle V, Parry T, Kessler RC, Jinnett K. Health and productivity as a business strategy: a multiemployer study. *J Occup Environ Med* 2009; 51: 411–428.
16. Robinson S. Victimization of obese adolescents. *J Sch Nurs* 2006; 22: 201–206.
17. Barrigas C, Fragoso I. Obesity, academic performance and reasoning ability in Portuguese students between 6 and 12 years old. *J Biosoc Sci* 2012; 44: 165–179.
18. NHS. Childhood obesity in West Midlands higher than national average. In: NHS (ed.). *NHS Local Better Health Together*. National Health Services: Birmingham, 2010, [WWW document]. URL <http://nhslocal.nhs.uk/story/news/childhood-obesity-west-midlands-higher-national-average> (accessed 11 November 2012).
19. Piovesan C, Padua MC, Ardenghi TM, Mendes FM, Bonini GC. Can type of school be used as an alternative indicator of socioeconomic status in dental caries studies? A cross-sectional study. *BMC Med Res Methodol* 2011; 11: 37.
20. Wolfson AR, Carskadon MA, Acebo C, et al. Evidence for the validity of a sleep habits survey for adolescents. *Sleep* 2003; 26: 213–216.
21. Ness AR. The Avon Longitudinal Study of Parents and Children (ALSPAC) – a resource for the study of the environmental determinants of childhood obesity. *Eur J Endocrinol* 2004; 151(Suppl. 3): U141–U149.
22. Griffiths LJ, Page AS. The impact of weight-related victimization on peer relationships: the female adolescent perspective. *Obesity (Silver Spring)* 2008; 16(Suppl. 2): S39–S45.
23. Chaput JP, Visby T, Nyby S, et al. Video game playing increases food intake in adolescents: a randomized crossover study. *Am J Clin Nutr* 2011; 93: 1196–1203.
24. Andreyeva T, Kelly IR, Harris JL. Exposure to food advertising on television: associations with children's fast food and soft drink consumption and obesity. *Econ Hum Biol* 2011; 9: 221–233.

25. Vandelanotte C, Sugiyama T, Gardiner P, Owen N. Associations of leisure-time internet and computer use with overweight and obesity, physical activity and sedentary behaviors: cross-sectional study. *J Med Internet Res* 2009; 11: e28.
26. Lazarou C, Soteriades ES. Children's physical activity, TV watching and obesity in Cyprus: the CYKIDS study. *Eur J Public Health* 2010; 20: 70–77.
27. Yi X, Yin C, Chang M, Xiao Y. Prevalence and risk factors of obesity among school-aged children in Xi'an, China. *Eur J Pediatr* 2012; 171: 389–394.
28. Chen X, Beydoun MA, Wang Y. Is sleep duration associated with childhood obesity? A systematic review and meta-analysis. *Obesity (Silver Spring)* 2008; 16: 265–274.
29. Knutson KL, Lauderdale DS. Sleep duration and overweight in adolescents: self-reported sleep hours versus time diaries. *Pediatrics* 2007; 119: e1056–e1062.
30. Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Med* 2004; 1: e62.
31. Spiegel K, Tasali E, Penev P, Van Cauter E. Brief communication: sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Ann Intern Med* 2004; 141: 846–850.
32. Hitze B, Bösy-Westphal A, Bielfeldt F, *et al.* Determinants and impact of sleep duration in children and adolescents: data of the Kiel Obesity Prevention Study. *Eur J Clin Nutr* 2009; 63: 739–746.
33. Al-Disi D, Al-Daghri N, Khanam L, *et al.* Subjective sleep duration and quality influence diet composition and circulating adipocytokines and ghrelin levels in teen-age girls. *Endocr J* 2010; 57: 915–923.
34. Klingenberg L, Chaput JP, Holmback U, Jennum P, Astrup A, Sjodin A. Sleep restriction is not associated with a positive energy balance in adolescent boys. *Am J Clin Nutr* 2012; 96: 240–248.
35. Ohayon MM. Nocturnal awakenings and comorbid disorders in the American general population. *J Psychiatr Res* 2008; 43: 48–54.