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A model linking video gaming, sleep quality, sweet drinks consumption and obesity among children and youth

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What is already known about this subject?

- The prevalence of paediatric obesity is high.
- The prevalence of video gaming among children and youth is high and on the rise.
- Paediatric obesity is associated with video-game use duration.

What does this study add?

- Video-gaming duration before bedtime is associated with reduced sleep quality.
- Average video-gaming session duration is associated with increased sweet drinks consumption while playing video games.
- Poor sleep quality and sweet drinks consumption are linked, and can mediate the association between video-gaming patterns and paediatric obesity.

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Summary

There is a growing need to curb paediatric obesity. The aim of this study is to untangle associations between video-game-use attributes and obesity as a first step towards identifying and examining possible interventions. Cross-sectional time-lagged cohort study was employed using parent–child surveys (t1) and objective physical activity and physiological measures (t2) from 125 children/adolescents (mean age = 13.06, 9–17-year-olds) who play video games, recruited from two clinics at a Canadian academic children's hospital. Structural equation modelling and analysis of covariance were employed for inference. The results of the study are as follows: (i) self-reported video-game play duration in the 4-h window before bedtime is related to greater abdominal adiposity (waist-to-height ratio) and this association may be mediated through reduced sleep quality (measured with the Pittsburgh Sleep Quality Index); and (ii) self-reported average video-game session duration is associated with greater abdominal adiposity and this association may be mediated through higher self-reported sweet drinks consumption while playing video games and reduced sleep quality. Video-game play duration in the 4-h window before bedtime, typical video-game session duration, sweet drinks consumption while playing video games and poor sleep quality have aversive associations with abdominal adiposity. Paediatricians and researchers should further explore how these factors can be altered through behavioural or pharmacological interventions as a means to reduce paediatric obesity.

Keywords: Paediatric obesity, sleep quality, sweet drinks consumption, video games.

Introduction

Video gaming is one of the most popular leisure activities among North American youth; over 72% of teenagers (84% of teen boys) play video games (1). Recent reports indicate that youth (13 years and older) spend an average of 6.3 h per week on video games, and this number has been growing over the last several years, in part, due to the increased availability of smartphones and mobile devices (2). Moreover, only 30% of the 8–18-year-old population segment has parental rules regarding media use (3) and 8.5% of American youth develop addiction-like symptoms to video games and meet common addiction criteria (4).

This pattern of video gaming has been associated with a myriad of academic, social, psychological and physiological problems, including shortened sleep duration, reduced sleep quality, diminished academic performance and increased attention problems (4). It is also associated with increased caloric intake; especially the intake of high-calorie, low-nutritional quality food (5). Furthermore, video gaming has been linked to obesity and especially abdominal adiposity (6); although this association is not direct and may be mediated through sleep, sedentary time and other factors (7). Such associations suggest that video-game use and the mediating variables may be important target metrics for paediatric weight management interventions, as obesity is highly prevalent among North American children and youth and is associated with multiple adverse physical and psychosocial outcomes in childhood and adulthood (8).

Therefore, this study seeks to (i) point to specific video-game use patterns (specific attributes such as timing and duration of video gaming) which may be related to childhood obesity, and (ii) identify variables which may mediate this association. While most studies on this association focus on daily use duration (9) as the driver of the aforementioned problems, we propose to examine more specific video-game use patterns including average (i.e., "typical") video-gaming session duration and timing of video-game use with a focus on the pre-bedtime period. The possible mediating variables we focus on include poor sleep quality and sweet drinks consumption while playing video games. Understanding of these video-game use patterns and possible mediating variables may provide a more nuanced understanding of what constitutes unhealthy video-gaming habits and direct researches towards more focused interventions.

Consistent with prior studies (10,11), this study predicts that abdominal adiposity is positively related to poor sleep quality and consumption of sweet drinks while playing video games, after accounting for physical activity levels. The study then suggests, based on the idea that sugary drinks can inhibit sleep (12,13), that these predictors are not independent and that the intake of sweet drinks while playing video games can be associated with a reduction in sleep quality. Finally, we propose that unique video-game use patterns influence each of these direct predictors of abdominal adiposity. We argue that when one's typical video-game session duration is high, he or she will have more opportunity and stronger motivation to consume sweetened drinks during this session. This is consistent with findings that when unhealthy snacks and drinks are available to video gamers (young adults), they consume them as they keep on playing, which produces an average energy surplus of 655 calories/h in regular games, and 376 calories/h in active (motion-controlled) games (14). In addition, it is proposed that longer video-game use prior to bedtime is a unique contributor to decline in sleep quality, consistent with prior studies (15); presumably through suppressed melatonin release and intrusive thoughts about the video game (6).

Methods

Procedure and participants

A cross-sectional time-lagged study design was employed. Inclusion criteria were age below 18, self-reported video-game player, guardian consent and participant assent. The sample was recruited from children and adolescents who were outpatients of one of two hospital clinics (paediatric lipid clinic and weight management) at McMaster Children's Hospital. It was part of a larger study focusing on children's sleep and physical activity. The protocol was approved by the Hamilton Health Sciences Research Ethics Board. A total of 200 children visiting these clinics were invited during the 2015 school year to voluntarily participate in this study, out of which 157 agreed. After excluding 32 who do not play video games, a paper-based survey was used during the recruitment visit to record self-report video-game use information, sweet drink consumption while playing video games and sleep quality (completed with nurse assistance and no guardian involvement). Guardians completed a demographic questionnaire at this point, which captured their annual income ranges. Fitbit devices were given to participants for a period of 1 week for capturing physical activity; training was provided by a nurse. After 3–10 weeks of survey recording (average of 6 weeks), abdominal obesity measures were collected in a follow-up clinic visit.

Measures

Measures were based on validated established instruments. The primary outcome was abdominal adiposity, measured using the waist-to-height ratio (WtHR). Height was measured with a Harpenden Stadiometer to the nearest 0.5 cm using a standardized approach. Waist circumference was measured on an unclothed abdomen at the midpoint between the costal margin and the iliac crest with a non-stretchable standard tape measure attached to a spring balance. This measure of obesity is advantageous to others (e.g. body mass index) as it better captures central fat distribution, is related to cardiometabolic health indicators and is adjusted to inter-individual differences in body size related to age (16).

Exposures examined included video-game use, subjective evaluation of sleep quality and self-reported nutritional intake – all were completed by questionnaire. Video-game use characteristics examined included session duration, number of days in the week that participants game and video-game use in the 4-h period prior to going to bed. Video-game session duration was measured with one item based on a measure of session duration (17): 'On average, what is the length (in minutes) of a typical video-game playing session?'. The source study reported an average of 1.5 h and standard deviation (SD) = 2 in their sample, which is similar to what we observed in the current study. Hours of video-game use before bedtime was operationalized with an adaptation of a direct question of duration of video-game use: 'How many minutes do you usually use video games in the 4-h period prior to going to bed?' Finally, we also asked how many days per week the child/adolescent played video games: 'Considering your typical behaviour for the previous 4 weeks, how many days per week do you play video games?'.

Sleep quality was measured with the Pittsburgh Sleep Quality Index (PSQI), which has been shown to be valid and reliable (18) including in samples of adolescents (19). This self-report index includes 19 items grouped into seven domains, scored 0–3. The total score can range from 0 to 21, with lower scores consistent with better sleep quality. Sweet drinks consumption while playing video games was adapted from a semi-quantitative food frequency questionnaire (20). It asked respondents to report on how often (from 1 = less than once per month/never to 9 = more than 3 times per day) they consume sugary drinks (soft drinks [Coke, Kool-Aid], sports drinks [Gatorade] and fruit and vegetable juices) when they play video games. Daily intake was calculated based on the responses.

The study controlled for age and sex as sleep and video-game play can be modulated as a function of these factors (2,3). It also controlled for physical activity operationalized as the number of steps participants recorded on their FitBit device, divided by (adjusted for) the number of minutes they wore the device (they wore it for about 1 week, including one weekend, but not all of the time). Family socioeconomic status (family income reported by guardians) was also accounted for as it has been shown to relate to sugar-sweetened drink intake, habits and obesity prevalence.

Statistical analysis

After preliminary analyses, we used the structural equation path modelling facilities of Amos 24. This approach was taken given the complex mediational network of effects we hypothesize. In order to alleviate concerns regarding normality assumptions, we employed bootstrapping with 500 resamples for parameter estimation, an approach that does not make any distributional assumptions (21). Sample size for power of 0.8 and $\varepsilon = 0.1$ for root mean square of approximation (RMSEA) was calculated for a model with 16 degrees of freedom (22). The required sample was 122, which we exceeded in this study. Goodness of fit was assessed with combined fit indices criteria as specified by Hu and Bentler (23).

Results

The sample included 125 children and adolescents. Their characteristics are given in Table 1. The inter-correlations among the model's constructs are included in Table 2 with the control variables on the bottom.

The model was initially estimated with all control variables. It presented good fit ($\chi^2(4) = 7.21$ non-significant with $P < 0.13$, comparative fit index [CFI] = 0.97, incremental fit index [IFI] = 0.98, root mean square error of approximation [RMSEA] = 0.081 with P-close < 0.24 and standardized root mean square residual [SRMR] = 0.025). Hypothesized effects, excluding the effect of sweet drinks consumption while playing video game on abdominal obesity, were statistically significant at least at $P < 0.05$. Several control variables (income, sex, physical activity and days per week of video-game play) had no significant effects on endogenous constructs, and for parsimony reasons, these and non-significant control effects and correlations were removed. The model was re-estimated and presented good fit ($\chi^2(16) = 20.72$ non-significant with $P < 0.19$, CFI = 0.95, IFI = 0.96, RMSEA = 0.049 with P-close < 0.47 and SRMR = 0.063). The standardized path coefficients, P-values (in parentheses) and explained variance in endogenous constructs (SMC, square multiple correlations) are shown in Fig. 1.

As demonstrated in Fig. 1, video gaming before bedtime is associated with lower sleep quality among children and adolescents and longer typical (average) video-gaming sessions is associated with higher consumption of sweet drinks while playing video games. This sweet drinks consumption is associated with reduced sleep quality among children and adolescents. While poor sleep quality is linked to increased abdominal adiposity, sweet drinks consumption while playing video games is not directly linked to obesity. It is indirectly linked to obesity, although, through reduction in one's sleep quality. Physical activity was not associated with sweet drinks consumption, sleep quality or abdominal adiposity.

The model implies that poor sleep quality and sweet drinks consumption while playing video games mediate the association between video-game use patterns and abdominal adiposity. The results also imply that the association between sweet drinks consumption while playing video games and abdominal adiposity is mediated through reduction in sleep quality. To statistically test these proposed mediational mechanisms, confidence intervals (CIs) for and the significance of the indirect associations were calculated using bootstrapping with 500 resamples and bias-corrected significance estimation (21). The standardized indirect

Table 1 Sample characteristics (*n* = 125)*

Characteristics/Clinic	Weight management clinic (*n* = 79)	Lipid clinic (*n* = 46)	All (*n* = 125)
	Range (mean) [SD]		
Age (years)	10–17 (12.86) [2.21]	9–17 (13.39) [2.24]	9–17 (13.06) [2.22]
Male sex, *n* (%)	46 (58%)	38 (83%)	84 (67%)
Height (cm)	138.3–191.5 (160.82) [11.36]	142.0–198.0 (164.39) [12.44]	138.3–198.0 (162.1) [11.85]
Waist circumference (cm)	67.0–140.5 (96.23) [15.88]	54.0–124.0 (83.57) [18.04]	54.0–140.5 (91.57) [17.73]
Waist-to-height ratio	0.43–0.84 (0.60) [0.08]	0.34–0.70 (0.51) [0.10]	0.34–0.84 (0.56) [0.09]
Video-game play before bedtime, Yes, *n* (%)	68 (86.1%)	39 (84.8%)	107 (85.6%)
Video-game play before bedtime (minutes)	0–240 (101.03) [59.83]	0–240 (94.5) [54.87]	0–240 (98.62) [57.92]
Days per week play video games (days)	0.1–7.0 (4.59) [2.19]	1.0–7.0 (5.07) [1.82]	0.1–7.0 (4.76) [2.06]
Typical video-game session duration (minutes)	1–480 (97.52) [95.07]	10–320 (93.70) [63.31]	1–480 (96.12) [84.52]
Sleep Quality Index	0–13 (4.63) [3.02]	1–11 (4.35) [2.25]	0–13 (4.53) [2.76]
Poor sleep quality classification, *n* (%; based on Pittsburgh Sleep Quality Index cutoff of 5)	27 (34.2%)	11 (23.9%)	38 (30.4%)
Physical activity (step count per minute of wearing the device)[†]	6.00–32.83 (13.32) [3.76]	6.91–47.01 (15.00) [6.69]	6.00–47.01 (13.94) [5.08]
Family annual income ($ Canadian)	<49 999 = 14 (17.7%), 50 000–69 999 = 16 (20.3%), 70 000–99 999 = 28 (35.5%), >100 000 = 21 (28.6%)	<49 999 = 6 (13.0%), 50 000–69 999 = 8 (17.4%), 70 000–99 999 = 19 (41.3%), >100 000 = 13 (28.3%)	<49 999 = 20 (16%), 50 000–69 999 = 24 (19.2%), 70 000–99 999 = 47 (37.6%), >100 000 = 34 (27.2%)

*Sample characteristics are presented by clinic in order to illuminate potential similarities and differences.
[†]Can be interpreted as a global measure of level of activity; higher steps per minute indicate more physical activity.

association between duration of video gaming before bedtime and abdominal adiposity was 0.064 (95% CI = [0.013, 0.136], *P*(two-tailed) < 0.02). The standardized indirect association between typical video-gaming session duration and abdominal adiposity was −0.003 (95% CI = [−0.055, 0.046], *P*(two-tailed) < 0.86); and the standardized indirect association between sweet drinks consumption while playing video games and abdominal adiposity was 0.056 (95% CI = [0.015, 0.117], *P*(two-tailed) < 0.016).

These findings indicate that video game play duration before bedtime, typical video-gaming session duration and sweet drinks consumption while playing video games are statistically significantly indirectly linked to abdominal adiposity in this study population. In addition, older children consume more sweet-drinks while video gaming compared with younger children. All of these associations were after controlling for clinic affiliation effects; as expected, patients of the weight management clinic presented higher levels of abdominal adiposity compared with patients of the lipid clinic.

Lastly, a post-hoc analysis of variance comparison of good vs. poor sleepers, using the cutoff suggested by the PSQI (18) was performed. The results are given in Table 3 and suggest that poor and good sleepers significantly differ in their video-gaming time before bedtime, duration of typical video-gaming sessions, sweet drinks consumption while playing video games and abdominal adiposity, all of which are higher among poor sleepers.

Discussion

This study adhered to calls to better understand how children and youth's video-gaming habits may translate into health problems including obesity (14). This was done as a first step in a programme of research aimed at developing interventions targeting the predictors and mediational mechanisms of childhood obesity. It is generally known that excessive video gaming can be associated with obesity (7), but health researchers have an incomplete picture regarding the mechanisms that underlie this association, and they have a narrow view regarding video-gaming use patterns with almost sole focus on video-game duration as the target metric. It has been suggested that reduced sleep (6) and increased calorie intake (14) are important translational mechanisms as both are related to video gaming and can be adversely linked to cardiometabolic processes and indices (14). Addressing these issues, this study sought to examine how specific overlooked video-gaming facets (play duration before bedtime and typical video-gaming session duration) are linked, through sleep quality and sweet drink consumption modulations, with abdominal adiposity, after

Table 2 Descriptive statistics and intervariable correlations (n = 125)[†]

	Mean	SD	1	2	3	4	5	6	7	8	9	10
Video-gaming duration before bedtime (minutes)	58.39	75.65										
Typical video-gaming session duration (minutes)	96.12	84.52	0.11									
Sleep Quality Index	4.53	2.76	0.33**	0.21*								
Sweet drinks consumption while playing video game	1.08	1.79	0.03	0.25**	0.29**							
Abdominal adiposity (waist-to-height ratio)	0.56	0.10	0.10	0.18	0.20*	−0.01						
Age	13.06	2.22	0.27**	0.08	0.29**	0.28**	0.12					
Days per week playing video games	4.76	2.06	0.17	0.24**	0.00	0.01	−0.03	−0.07				
Family annual income	2.71	1.02	−0.08	−0.19*	0.03	0.00	−0.02	−0.04	0.06			
Physical activity (steps/min)	13.94	5.08	−0.28**	0.00	−0.13	0.02	−0.13	0.02	−0.06	0.07		
Sex (0 = male, 1 = female)	NA		0.22*	−0.14	0.04	−0.21*	0.09	−0.16	−0.11	−0.02	−0.02	
Clinic programme (0 = weight management, 1 = lipid)	NA		−0.05	−0.02	−0.05	−0.00	−0.45**	0.12	0.11	0.06	0.06	−0.25**

[†]A higher sleep quality index is indicative of poorer sleep quality.
*P < 0.05; **P < 0.01.
SD, standard deviation.

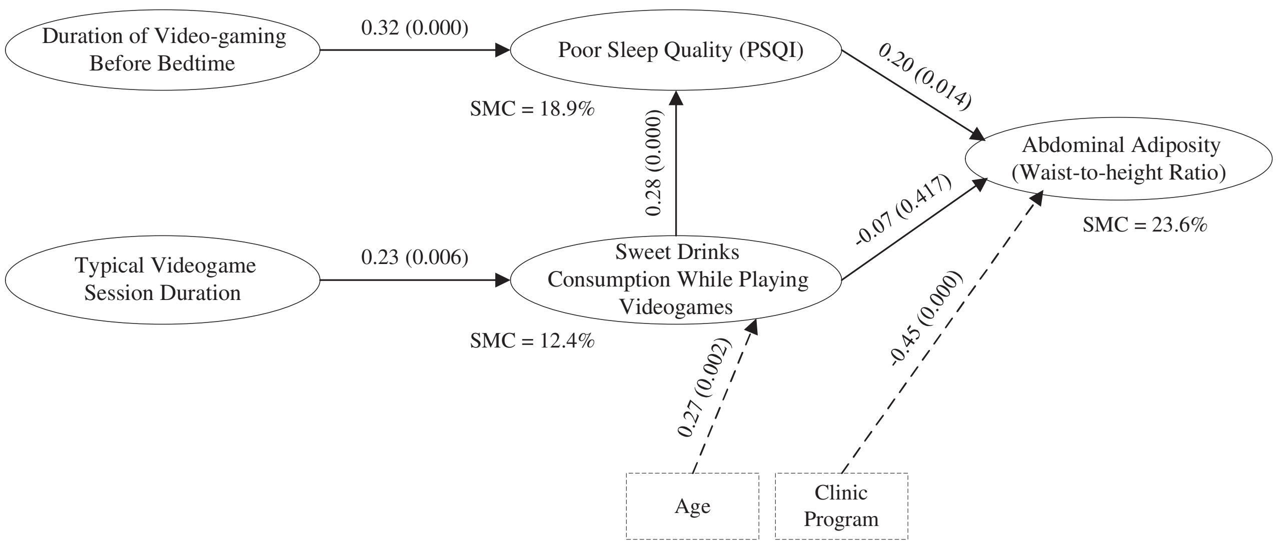

Figure 1 Structural model (n = 125). Model fit indices: ($\chi^2(16)$ = 20.72 non-significant with P < 0.19, comparative fit index = 0.95, incremental fit index = 0.96, root mean square of approximation = 0.049 with P-close < 0.47 and standardized root mean square residual = 0.063). The figure includes standardized path coefficients (on arrows), P-values (in parentheses) and explained variance in endogenous constructs (SMC, square multiple correlations, underneath the endogenous ellipses)

accounting for several controls, including physical activity. The findings suggest that video-gaming duration before bedtime is a key risk factor for abdominal adiposity as it is related to lower sleep quality of children and youth which in turn is associated with greater abdominal adiposity. This adds to prior research that has examined daily video-game play duration (14) but not timing of gaming. This suggests that future research should examine the efficacy of interventions targeting pre-bedtime video gaming as a means to reduce childhood obesity. These may include healthcare provider education of parents and children, development and enforcement of healthy family video-gaming use policies and the use of technical measures to block video-gaming use before bedtime (24).

The findings further suggest that longer video-gaming sessions can be problematic as they are linked to a higher

Table 3 Differences between good and poor sleepers (cutoff of Pittsburgh Sleep Quality Index = 5; n = 125)

	Video-gaming duration before bedtime (minutes)		Typical video-gaming session duration (minutes)		Sweet drinks while playing video-game score		Abdominal adiposity (waist-to-height ratio)	
	Good sleepers	Poor sleepers	Good sleepers	Poor sleepers	Good sleepers	Poor sleepers	Good sleepers	Poor sleepers
Mean	43.80	91.80	80.16	132.63	0.73	1.91	0.55	0.60
Standard deviation	67.20	84.00	58.15	118.79	1.31	2.39	0.08	0.11
Standard error	7.20	13.80	6.23	19.27	0.14	0.39	0.01	0.02
P-value	0.001		0.001		0.001		0.007	

intake of sugar-sweetened drinks while playing video games. This increased intake, in turn, further contributes to reduced sleep and ultimately to elevated abdominal adiposity. Previous research in adults suggests that the consumption of energy drinks can interfere with sleep and recent population-based studies suggest that consumption of energy drinks is increasing, especially in adolescents (25). This is particularly significant given recent media attention highlighting the marketing of energy drinks to improve 'gaming success', reflected in the naming of some beverages as fuel for gaming and the development of gaming websites by energy drink producers (26). We do not unfortunately have information on the specific sugar-sweetened beverages consumed in our study, but this will be an important area for future research.

The findings also point to two mediational mechanisms that are interdependent. Studies have discussed the link between reduced sleep duration and childhood obesity and how video gaming may adversely influence sleep duration (6). Sleep quality, though, a broader concept that taps into many dimensions of sleep (duration, latency, efficiency and disturbances) received less attention. The findings of this study show that an index score based on these sleep dimensions is an important possible mediational mechanism between video-game use before bedtime and obesity. Furthermore, poor sleepers have greater abdominal adiposity compared with good sleepers (27). They are also more likely than good sleepers to engage in lengthier video-gaming sessions, including before bedtime and consume more sweet drinks while playing video games. Hence, future intervention studies should focus on ways to increase sleep quality and not just duration. Behavioural approaches to improving sleep hygiene and sleep quality in adults have been shown to improve self-reported sleep quality (28). While fewer studies are available in children and adolescents, several studies do suggest that educational/behavioural approaches to improving sleep hygiene are efficacious (29). Pharmacotherapeutic approaches (e.g. melatonin) also appear to improve delayed-onset insomnia in children over the short term, but long-term efficacy and safety have been less well studied. Current recommendations suggest an initial focus on improving sleep hygiene (30), including strict avoidance of computers and video games prior to bedtime (31). Thus, the growing evidence base suggests that behavioural trials can be efficacious in improving sleep quality in children and adolescents and should be considered. Their influence in reducing obesity or improving physical health has not been fully studied.

We also note that older youth consume more sweet drinks while playing video games than younger children. This implies that interventions should be age specific (focused on prevention in younger children and reduction/substitution in older youth). The efficacy of this approach should be examined in future research. Moreover, in our sample, females had longer video-gaming sessions before bedtime compared with males (see correlation in Table 2). National statistics typically examine general video-gaming use and not specific attributes; they suggest that male teens are more active than females in video gaming (1). Our findings indicate that perhaps a closer examination of sex-based differences in video-gaming patterns is needed as females, although in general play less than males, can engage in more problematic behaviours than males (e.g. playing in general for shorter periods of time, but doing so before bedtime). This line of inquiry merits future research.

Several limitations should be noted. First, our sample was comprised of children who were outpatients of specific paediatric clinics. Hence, caution with generalization should be exercised. Second, our design did not allow for examination of changes in abdominal adiposity. Hence, causality cannot be fully supported with the existing data. Future longitudinal designs would address this limitation. While it is of interest that sweet drink consumption during video-gaming sessions was associated with poor sleep quality, the reasons why this is so are not fully known. We did not unfortunately have detailed information regarding the nature of the sweet drink (e.g. caffeinated or not) or the timing of consumption that may have contributed to our understanding of the reasons for this linkage. Lastly, this study detects potential targets to intervene upon, but does not test the efficacy of such interventions on reducing abdominal adiposity. Future studies may focus on testing such interventions.

Conclusions

This study demonstrates that the associations between video-gaming facets and abdominal adiposity are complex and indirect; different video-game use patterns can be linked to different possible mediational process including play duration before bedtime and sweet drink consumption during video-gaming sessions, which can be intertwined and ultimately be associated with childhood obesity. The design and testing of interventions to address these potentially modifiable correlates of abdominal obesity should be considered. Furthermore, paediatricians, family practitioners and other healthcare professionals, educators and parents should be aware of the inter-relationships between behaviours associated with adverse health outcomes.

Conflict of Interest Statement

No conflict of interest was declared.

Author contributions

OT conceptualized and designed the study, ran analyses, drafted the initial manuscript and approved the final manuscript as submitted. AR conceptualized and designed the study, obtained funding, acquired the data, ran analyses, provided critical revisions and approved the final manuscript as submitted. KMM conceptualized and designed the study, obtained funding, acquired the data, provided critical revisions, oversaw the project and approved the final manuscript as submitted. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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