Time spent watching television impacts on BMI in youth with obesity, but only in those with shortest sleep duration.

Keywords: overweight, obesity, childhood, screen time, sleep, physical activity, exercise, diet

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Running Title: TV and sleep in youth with obesity.

Abstract

Aim: To determine the interplay between sleep and sedentary behaviours on body mass index (BMI) in children with obesity.

Methods: Cross-sectional study of 343 children with obesity aged 4-17 years, from a Tertiary care weight management clinic in Melbourne, Victoria, Australia. Multifaceted data relating to activity and sleep from child and parent questionnaires analysed with anthropometric data collected during routine clinical care. Associations between sleep duration and activity measures were examined via regression models with adjustment for potential confounders.

Results: Higher BMI was associated with more hours spent watching television (p=0.04), as well as less reported enjoyment of physical activity (p=0.005) and less time spent in organised sport activity (p=0.005). Higher BMI was also associated with higher levels of obstructive sleep apnoea (p=0.002). Less time in bed was associated with higher levels of BMI (p=0.03) but analysis by sex revealed this association to only hold for males. In the whole group, a significant television and sleep interaction was seen, such that increasing TV watching was associated with higher BMI, but only in those with shortest sleep duration.

Conclusions: Both poor sleep and increasing screen time (including television viewing, smart-phone use, internet use or video-gaming) appear to impact BMI in children with obesity, with a particular detrimental effect of TV viewing in those who sleep less. Efforts to improve sleep time and quality in children may minimise negative effects of ST on increasing BMI and should be included in public health strategies to combat obesity in childhood.

Learning Points

What is already known on this topic: Inadequate sleep, high caloric intake, reduced physical activity and screen time are associated with higher BMI in a general paediatric population.

What this paper adds: This paper focuses on children with overweight and obesity as a cohort and differentiates between types of screen time (ST) used, finding no difference in impact on BMI. These data also reveal a sex-dependent difference in that high ST and low physical activity (PA) are associated with a higher BMI in females, but only adequate sleep is statistically significant for males. Across sexes, high ST levels related to BMI only in those subjects who reported less sleep.

Introduction

Obesity is a worldwide pandemic and its prevalence in Australia is one of the highest in the developed world[1]. Paediatric obesity is a significant concern with current data suggesting that one in four children is obese[2], with early obesity tracking strongly across the life-course, predisposing to metabolic disease later in life[3 4 5].

With an estimated annual cost of $21billion in Australia, identifying the biological and environmental cues for obesity is a national health and economic priority[6]. Current literature describes a predisposing genetic susceptibility, interacting with general environmental exposures[7 8]. This mechanism provides health promotion targets at a population level, prompting public health strategies that often target diet, sedentary activity and screen time (ST, which includes television viewing, computer gaming and smart-phone and computer usage)[9].

Despite strong data supporting theoretical measures to target these factors, current strategies for the prevention and treatment of childhood obesity have arguably failed and other factors are now being examined in more detail[10]. There is a growing body of evidence linking poor sleep quality and duration to obesity[11 12]. Sufficient sleep is essential to overall health, with sleep inadequacy triggering hormonal, metabolic and behavioural cascades that increase dietary energy intake and decrease energy expenditure[13 14 15]. Meta-analyses confirm that poor sleep quality and duration is associated with higher positive energy balance, culminating in higher body mass indices along with several other cardio-metabolic risk factors[16 17 18].

There are also strong associations between ST and reduced sleep, with some studies finding the actual time of going to bed more relevant to BMI than overall sleep duration[19]. Beyond displacing normal sleep, ST also affects arousal and upsets circadian rhythms due to light exposure[20]. Prolonged video game use has also been shown to decrease objective sleep efficiency, total sleep time and subjective sleep quality[21 22]. Conversely, regular physical activity (PA) has been linked with decreased insomnia symptoms and two studies have demonstrated altered food preferences following sleep disruption[23 24 25].

It is not currently known how sleep and ST interact with the degree of obesity in a paediatric population with obesity. It is possible that public health measures to reduce ST in children have targeted too diverse a population. However, interventions aimed at reducing ST have shown the greatest BMI changes in the upper tail of BMI distribution only, without a similar effect in the lower tail[26]. Therefore, our aim was to study a clinical cohort of obese children (n=343, 4-17 years) to determine the effect of sleep and ST on BMI.

Methods

Sample
Overweight (above 85th centile cut-off of US-derived data produced by the Center for Disease Control and Prevention) and obese (above 95th centile) children and adolescents (aged up to 17.99 years) referred to our hospital weight management service were approached for enrolment, through the Childhood Overweight BioRepository of Australia (COBRA)[27].

Questionnaires
Results from validated and standardised questionnaires from parents and patients (aged 11 years and above) relating to environment and anthropometry were pooled with data from clinical examination and medical records. For children aged under 11 years, questionnaires are from parents only. Participants were asked how many hours per week they play outdoors, watch TV, play on computers or play video games. Participants also estimated the total amount of sedentary hours. They were asked on how many days per week their family: eat in front of a TV, watch TV in their own room, participate in organised sports and walk to school. By asking the time they usually go to bed and wake up both on weekdays and weekends, the mean amount of time in bed per night was evaluated. Participants also answered questions regarding technology in the bedroom (TV, computer, etc) and how much they enjoyed physical activity (scale 0-3). These are described in Table 1.

Anthropometry and clinical data
The anthropometric and clinical data collection included height, weight and blood pressure. Medical records were reviewed for information relating to the presence of weight-related co-morbidities, including obstructive sleep apnoea.

Sleep Assessment
Self-reporting of sleep duration agrees closely with quantitative actigraphy[28 29]. Parent and child reporting of sleep habits was used, including bedtimes and sleep duration. Although sleep requirements differ across the lifespan, short sleep duration was classified as less than 6 hours, to capture all age-groups, in accordance with existing literature[30].

Statistical analyses
To examine the associations between study variables and BMI, we first performed age- and sex-adjusted regression analyses separately for each variable. Then, to examine which variables independently associated with BMI, we performed manual backward stepwise multivariable regression analyses. The final model included those variables with $P<0.05$. In addition, age and sex were forced to final models. There was a strong correlation between some of the explanatory variables (e.g. $r=0.57$ between total sedentary hours and hours watching TV). Therefore, to avoid any possible bias due to collinearity, stepwise multivariable modelling was used to evaluate the independent correlates of BMI. As the cohort comprised both boys and girls aged 4-17 years, we performed interaction analyses with logistic regression to test whether the effects of risk factors differ by age or activity, sex*enjoy physical activity and sex*hours watching TV per week interaction terms. Additionally, the multivariable analyses were performed separately for both sexes and 2 different age groups (4-12 years and 13-17 years). Finally, we analysed the association of our primary interest variable, TV watching time on BMI according to tertiles of total time in bed/week (0-33rd percentile, 34-67th percentile and 67-100th percentile) with linear regression modelling.

Results

A total of 343 subjects with obesity (aged 4-17 years) were included in this study. Subject characteristics are shown in Table 2. 20.6% of subjects had documented obstructive sleep apnoea and there was a mean 10 hours (SD 2.3h) spent in bed each night. Approximately one third of subjects reported no technology in the bedroom.

Table 3 demonstrates age- and sex-adjusted linear associations between study variables and BMI. Those with high levels of PA enjoyment had lower BMIs (p=0.004) and those with more organised sporting activities also had lower BMIs (p<0.0001). Those with higher BMI watched more TV (p=0.02), had more sedentary hours (p=0.02) and spent less time in bed (p=0.02). Obstructive sleep apnoea was associated with a higher BMI (p<0.001).

Table 4 shows the multivariate analyses, demonstrating that in total, enjoying PA (p=0.005) and having organised sports activities (p=0.005) were associated with a lower BMI, whilst more sedentary activities were associated with a higher BMI (p=0.01). Females who walked to school (p<0.001) and enjoyed PA (p<0.001) had a lower BMI, whilst females who were older (p<0.001), watched more TV (p<0.001) and seldom walked to school (p<0.001) had a higher BMI. There was a significant sex difference, in that only sleep (p=0.007) and older age (p<0.001) appeared significant for higher BMI in males.

In the stepwise multivariate model among subjects aged up to 12 years, obstructive sleep apnoea was directly associated with higher BMI and organized sports activity inversely associated with higher BMI. In a similar approach among those aged 13 years or more, obstructive sleep apnoea and TV watching in own room were directly associated with higher BMI and enjoyment of physical activity and walking to school inversely associated with a higher BMI.

Figure 1 illustrates the combined effects of bedtime and TV viewing time on BMI. There was a significant interaction in a logistic regression model (p<0.001). In subsequent analyses stratified by bedtime tertiles, increased TV viewing was associated with a higher BMI in those with the shortest time spent in bed. Contrary to this, if there was adequate sleep (those in the third tertile), TV viewing did not impact on BMI.

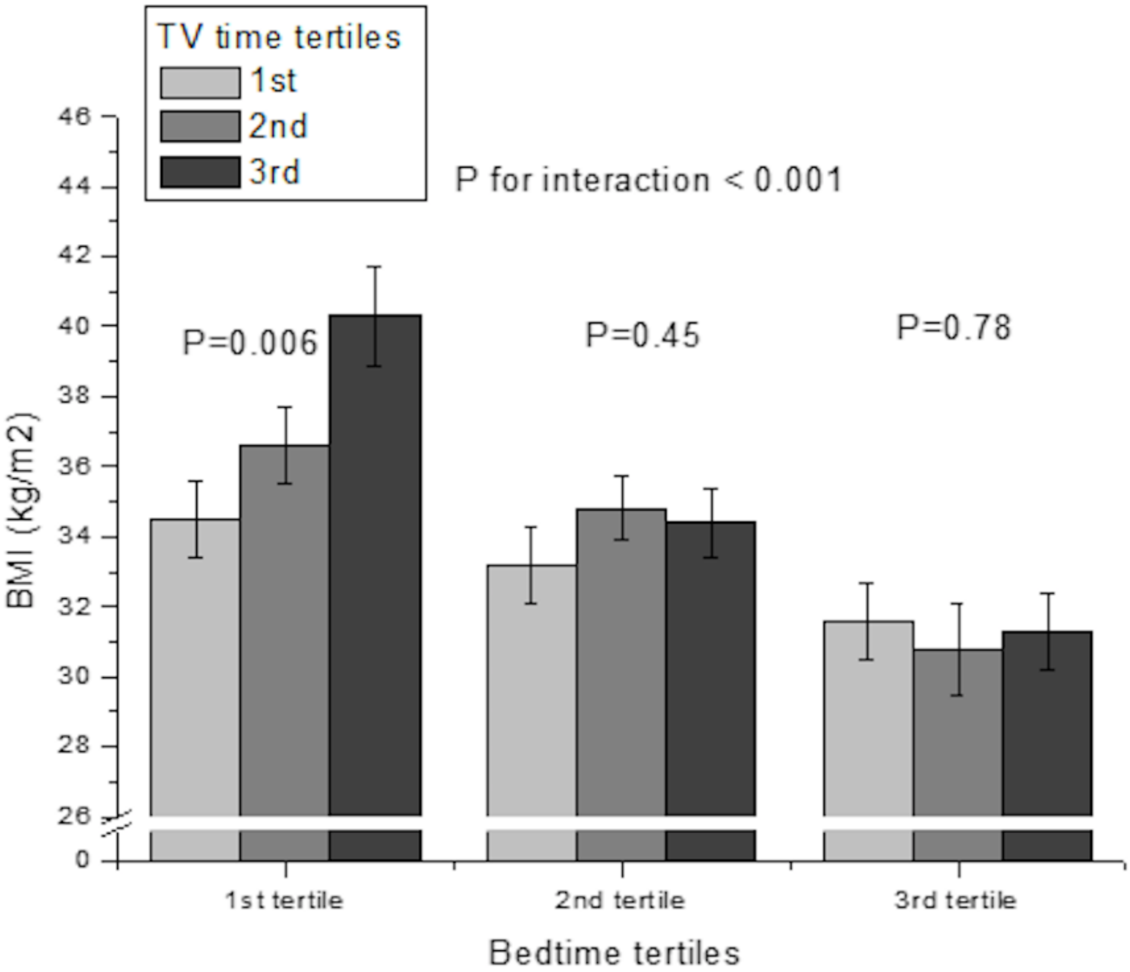
TV time tertiles
1st
2nd
3rd
P for interaction < 0.001
P=0.006
P=0.45
P=0.78
BMI (kg/m2)
46
44
42
40
38
36
34
32
30
28
26
0
1st tertile
2nd tertile
3rd tertile
Bedtime tertiles

Figure 1.

Discussion

This study demonstrates that in a cohort of overweight and obese children and adolescents, those enjoying PA and engaging in organised sports were less likely to be severely obese. Females who were older, watched more TV and seldom walked to school were generally more severely obese, whereas more obese males tended to be older and sleep less. An interesting and unexpected finding was that although both sleep and TV viewing impact on BMI in children with obesity, there appeared to be a particular detrimental effect of excess ST in those with inadequate sleep.

This study differs from existing literature with a specific focus on the upper tail of the BMI distribution as well as differentiating between types of ST used. These data also reveal a sex-dependent difference in that high ST and low PA are associated with a higher BMI in females, but only inadequate sleep is associated with a higher BMI in males. Across sexes, high ST levels are only related to higher BMI in those subjects who reported less sleep. Several mechanisms have been postulated, linking sleep duration with obesity[31]. Conceptualised as a chronic, low-grade, inflammatory state, obesity is characterised by increased circulating inflammatory markers[32]. Animal models confirm that poor sleep increases nicotinamide adenine dinucleotide phosphate (NADPH) activity in visceral white adipose tissue (VWAT)[33], producing adipose progenitors that lead to obesity and insulin resistance in sleep-deprived mice[34 35].

There is a mounting body of evidence to support the importance of sleep in obesity prevention and treatment but as yet not enough to provide consensus statements[36]. Sleep may affect several obesogenic risk factors, including diet and activity. Inadequate sleep alters food preferences towards a greater proportion of energy from fat and lower proportion from carbohydrates, as well as greater energy intake in the early morning (5-7:00am)[37]. Delayed sleep onset also provides more time for eating, is associated with increased consumption of low nutritional foods[38] and exposes children to more advertising[39]. Low PA levels is also associated with poorer quality sleep[40]. In addition to directly affecting obesity risk, inadequate sleep also negatively influences other obesity risk factors and is associated with poor cognition, reduced co-ordination, increased aggression, hyperactivity and metabolic dysfunction[41 42].

Obesity also predicted shorter sleep duration in those with somnipathies (including obstructive sleep apnoea, insomnia and asthma)[43 44]. Inadequate sleep further exacerbates body mass indices via less PA and more ST, possibly as somnolence reduces PA motivation and vigour[45]. ST affects sleep in 3 demonstrated ways, through time displacement, melatonin depression and cognitive arousal[46]. This study proves a causal relationship, suggesting that efforts to improve sleep in obese children may minimise the negative effects of ST on BMI. This study's strengths include large numbers, objective BMI measurement and a rigorous analytic approach in a relatively large sample of overweight and obese youth. There were some limitations; however, such as those associated with self-reported data and lack of data relating time to sleep onset.

In summary, our analyses support the notion that efforts to improve sleep in children with obesity may minimise the deleterious effects of ST. These findings have important public health implications at a time when paediatric obesity prevalence remains high.

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Table1: Parameters collected in COBRA, * relevant to current study

Self-completed participant information Domain: Instrument/Source (respondent[1])	**Clinical exam**
Health: Self-rated health (P, C)	Clinical history
Concern with weight: HopSCOTCH (P)	Specific details relating to weight
Help seeking: HopSCOTCH (P)	Other health issues
Pregnancy & birth: HopSCOTCH, LSAC, NHS (P)	Peri natal and Past Medical History
Early nutrition: LSAC (P)	Medications (past and present)
Family health history: HopSCOTCH (P)	Allergies
Mental health**: SDQ** (P, C); **Kessler 10** (P, C)	Immunisations
Enjoyment of physical activity (PA): LEAP(P, C)	Developmental history and schooling
Active/Sedentary time: HopSCOTCH, LSAC (P, C)	Family history
Targeted nutrition/PA: HopSCOTCH (P, C)	Sleep issues*
Transport, biking, walking**: IPAQ** (P, C)	
Childcare: HopSCOTCH (P)	Clinical examination
Sleep habits: LSAC (P, C)*	General appearance (dysmorphism, affect, body proportions)
Neighbourhood: LSAC, ALSPAC, **NEWSA** (P, C)	Cardiovascular examination including blood pressure
Socio-demographic: Census (P)	Respiratory examination
Household composition: FLAME (P)	Abdominal examination
Nutrition: 3-day prospective food diary (P, C); **ACAES** (P, C)	Skin (acne, hirsutism, acanthosis nigricans, intertrigo, striae)
Quality of life (QoL): **PedsQL Core module** (P, C); **Sizing Them Up** (P); **Sizing Me U**p (C)	Pubertal assessment (method of Tanner and Whitehouse)
MARCA: 24-hour PA recall	Anthropometry
	Height (measured to nearest 0.1cm using a stadiometer)
	Weight
	Waist circumference

HopSCOTCH: The Shared-Care Obesity Trial in Children; LSAC: Longitudinal Study of Australian Children; NHS: National Health Survey; SDQ: Strengths and Difficulties Questionnaire; LEAP: Live Eat and Play Study; IPAQ: International Physical Activity Questionnaire; ALSPAC: Avon Longitudinal Study of Parents and Children; NEWSA: Neighbourhood Environment Walkability Scale Abbreviated; FLAME: Family Lifestyle Activity Movement and Eating; ACAES: Australian Child and Adolescent Eating Survey; PedsQL: Pediatric Quality of Life survey; MARCA: Mulitmedia Activity Recall for Children and Adolescents.

Table 2. Characteristics of study subjects. Values are mean and Std Dev unless stated otherwise.

Variable	N	Mean	Std Dev
Males (%)	343	47.3	
Age (years)	343	12.1	3.2
BMI (kg/m2)	305	34.4	6.9
Obstructive sleep apnoea (%)	340	20.6	
Enjoy physical activity (scale 0-3)	333	1.4	0.8
No technology in bedroom (%)	341	33.5	
Total sedentary hours / week	315	28.6	30.8
Hours outdoor for play / week	216	11.3	21.1
Hours watching TV / week	293	20.0	20.6
Hours on computer / week	255	13.5	14.9
Hours on video-games / week	240	14.4	24.4
Days per week, family eat at TV	328	3.8	2.5
Days per week, watch TV in own room	331	1.8	2.6
Days per week, organised sport activity	330	1.7	1.9
Days per week, walk to school	329	1.6	2.1
Hours in bed / night	300	10.0	2.3

Table 3. Age – and sex-adjusted associations with BMI

Variable	beta±SE	P-value
Obstructive sleep apnoea	3.26±0.75	<0.001
Enjoy physical activity (scale 0-3)	-1.45±0.40	0.004
No technology in bedroom (%)	-0.42±0.72	0.56
Total sedentary hours / week	0.04±0.02	0.02
Hours outdoor for play / week	-0.02±0.02	0.26
Hours watching TV / week	0.04±0.02	0.02
Hours on computer / week	0.03±0.02	0.28
Hours on video-games / week	0.01±0.02	0.60
Days per week, family eat at TV	0.01±0.02	0.53
Days per week, watch TV in own room	0.29±0.13	0.02
Days per week, 7rganized sport activity	-0.60±0.17	<0.001
Days per week, walk to school	-0.46±0.15	0.002
Bedtime (time in bed / week)	-0.83±0.37	0.02

Beta±SE values are from linear regression analyses

Table 4. Stepwise multivariable models for BMI.

(a) total subjects (N= 265 in final model)

Variable	Beta	SE	P-value
Male gender	-1.18	0.62	0.059
Age (years)	1.08	0.11	<.0001
Obstructive sleep apnea (no/yes)	2.32	0.75	0.002
Enjoy physical activity (scale 0-3)	-1.10	0.39	0.005
Total sedentary hours per week	0.029	0.012	0.01
Hours watching TV per week	0.037	0.017	0.04
Days per week, organized sports activity	-0.41	0.14	0.005
Bedtime (time in bed per week)	-0.80	0.37	0.03

(b) females (N= 156 in final model)

Variable	Beta	SE	P-value
Age (years)	1.05	0.13	<0.001
Obstructive sleep apnoea (no/yes)	3.00	1.07	0.006
Enjoy physical activity (scale 0-3)	-2.06	0.53	<0.001
Total sedentary hours per week	0.037	0.015	0.02
Hours watching TV per week	0.079	0.023	<0.001
Days per week, walk to school	-0.60	0.18	<0.001

(c) males (N= 123 in final model)

Variable	Beta	SE	P-value
Age (years)	1.14	0.19	<.0001
Obstructive sleep apnoea (no/yes)	2.40	0.94	0.01
Time in bed per week	-0.11	0.04	0.007

(d) Children aged 4-12 years (N= 150 in final model)

Variable	Beta	SE	P-value
Male gender	-0.41	0.65	0.53
Age (years)	1.35	0.14	<0.001
Obstructive sleep apnoea (no/yes)	2.30	0.89	0.01
Days per week, organized sports activity	-0.43	0.17	0.02

(e) children aged 13-17 years (N= 141 in final model)

Variable	Beta	SE	P-value
Male gender (no/yes)	-2.12	1.05	0.04
Age (years)	1.31	0.38	0.001
Obstructive sleep apnoea (no/yes)	3.81	1.16	0.001
Enjoy physical activity (scale 0-3)	-1.79	0.67	0.009
Days per week, watch TV in own room	0.59	0.19	0.002
Days per week, walk to school	-0.50	0.22	0.03

SEE SEPARATE UPLOAD FOR FIGURE 1

Figure1: BMI levels according to bedtime and TV viewing tertiles.