

Published in final edited form as:

Int J Obes (Lond). 2009 April ; 33(Suppl 1): S82–S86. doi:10.1038/ijo.2009.23.

Sedentary behavior and sleep: paradoxical effects in association with childhood obesity

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Abstract

Sedentary behavior and sleep may be working in concert to increase the likelihood of a child becoming overweight, but in paradoxical ways. Reduction of sedentary behavior (that is, media screen time) has been extensively researched and touted as an intervention target. Inadequate sleep as a putative risk factor for obesity is only beginning to be explored. In this paper, we review the current state of research regarding these factors, and describe the existing evidence and mechanisms proposed to explain these relationships. Whereas the association between weight and sedentary behavior has been consistently shown in observational studies, effect sizes are small, and multiple mechanisms appear to be operating. Recent cross-sectional and longitudinal evidence suggests a link between short sleep duration and weight. Possible mechanisms here include direct metabolic effects as well as indirect behavioral pathways, including the presence of electronic media in children's bedrooms. Measurement issues present a challenge to both areas of research. Prospective studies that include more accurate measures of both sedentary behavior and of sleep will be needed to clarify causal pathways.

Keywords

sedentary behavior; screen time; sleep; overweight; youth

Introduction

The daily lives of children and their families have changed dramatically over the last several decades, impacting childhood development in many ways and contributing to the rising rates of obesity in the pediatric population. In general, as today's children are more likely to be raised by a single parent or in households where both parents work, children are less supervised than in previous generations.¹ Left to their own pursuits, children now spend more time engaged in sedentary activities, including various forms of electronic media.² Additionally, children of all ages appear to be getting less sleep than needed to function optimally during the day.^{3,4} Sedentary behavior and sleep have each received recent attention as obesity risk factors, but for different reasons. Although both are 'low energy-expending' activities, research suggests that, paradoxically, increased time in sedentary behaviors and increased time spent sleeping have opposite effects on a child's weight status. In comparison to the robust research base regarding sedentary behavior in children, however, our understanding of the relationship between sleep patterns and childhood obesity

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Conflict of interest The authors have declared no financial interests.

is in the early stages. This review describes the current state of research regarding both sedentary behavior and sleep's connections with obesity, and highlights possible pathways by which sedentary behavior and sleep deprivation may work together to increase obesity risk.

Sedentary behavior and obesity

Curtailed sedentary behavior has appropriately received substantial attention in the past decade as a way to prevent or reduce childhood obesity.^{5,6} Children today spend more time than ever before engaged in inactive pursuits. A recent review of media use in youth reported that 28% of youth watch more than 4 h of TV per day.⁷ This is consistent with nationally representative NHANES data, which suggest that approximately a quarter of children aged 4–11 years old watch more than 3 h of TV per day.⁸ These amounts represent twice the levels recommended by the Canadian Paediatric Society and the American Academy of Pediatrics; both bodies suggest limiting total media time to no more than 1–2 h per day.^{9,10} These high amounts of viewing are likely the result of the fact that an estimated 68% of youth aged 8–18 years now have a TV in their bedroom.² Having a TV in the bedroom is associated with increased hours of watching television, video/DVD viewing, and video games use.^{2,11} Furthermore, although TV viewing still dominates total screen time, the media landscape is changing, even for children of younger ages. Computer time among youth doubled between 1999 and 2004,² and an estimated 27% of 5–6 year olds now use the computer for an average of 50 min each day.¹²

Time spent participating in sedentary behavior and other low energy-expenditure activities has been associated with higher relative weights in cross-sectional^{13–15} and prospective^{16–18} studies of children. Early research in this area focused specifically on TV's connection with obesity, and because it was found to be a potent predictor of overweight, television was subsequently used as a proxy for all sedentary behavior in many studies. Three main mechanisms behind this relationship have been proposed. Early speculation that television viewing actually lowered resting metabolic rates below that of other sedentary activities has not been empirically shown.^{19,20} Likewise, a second theory that TV viewing displaces physical activity has not been well supported by research evidence either.²¹ The relationship between TV viewing and weight status is maintained in explanatory models when physical activity is accounted for statistically.^{13,14,22,23} The third major theory that garners most support is that TV viewing may operate predominantly through its impact on energy intake rather than by displacement of high-energy-expenditure activities. Associations between TV viewing and excess energy intake have been observed^{24–26} and may reflect both direct and indirect pathways. A recent laboratory-based study by Bellissimo *et al.*²⁵ which included a glucose preload or 'non-caloric' sweetener, suggested that television viewing during a meal delays normal mealtime satiation and reduces satiety signals from recently consumed food, thereby contributing to increased energy intake while watching. Another simulation study by Francis and Birch²⁷ found conflicting results, but these discrepancies likely reflect differences in study design: the children in the Bellissimo study were 9–14-year-old boys, much older than the 3–5 year-olds in the Francis and Birch study. Also, the Francis and Birch study did find that the subgroup of 3–5 year-old children who habitually watched a lot of television and typically ate more meals in front of the TV at home *did* have higher intakes when exposed to TV compared with those children who habitually viewed less television at home. TV watching may also increase average energy intake indirectly, by exposing children to commercials advertising energy-dense food products. In one study, children's screen media exposure was significantly related to subsequent requests for foods and beverages advertised, after adjusting for confounders.²⁸ Additionally, both normal weight and overweight children have been shown to increase food intake after exposure to food advertisements as compared with non-food advertisements.²⁶

Although a few intervention studies have found that reducing sedentary behavior has a beneficial effect on weight status,^{23,29,30} effect sizes from larger, observational, population-based prospective studies have been small in magnitude, and some have even identified inverse relationships.¹⁶ These weak effects are probably due in large part to measurement issues. As noted earlier, TV viewing is often used as a proxy for sedentary behaviors, but more recent studies have addressed the changing trends in media usage by expanding the TV time measure to include all ‘screen time’ (the sum of all television, video games, DVD’s, computers and other electronic media). Typically, TV time, screen time, and other sedentary behaviors are collected via parental report or child self-report, both of which are fraught with error. One issue that arises is that one cannot readily distinguish between a child actively watching TV and the TV just being ‘on’ based on parental or self-report of TV viewing hours.³¹ Given that parents increasingly spend less time at home with their child, they are less likely to have an accurate idea of what types of activities their children are engaging in, and even less so the time spent in these activities. Parental estimation of child sedentary behavior is especially difficult as children reach adolescence and spend even more time in their rooms or at friends’ houses. An additional complexity arises because children, especially adolescents, ‘multi-task,’ engaging in various forms of electronic media and other forms of sedentary behavior, such as telephone time, simultaneously.² The blurring of types of electronic media (that is, cellular phones that access the Internet, videos of TV programs) adds definitional uncertainty. Finally, non-media-related sedentary behaviors may be a large contributor of ‘down-time’ for certain sub-groups. Traveling in a car or bus, particularly in rural areas where children live far from school, may contribute to large amounts of sedentary time,³² which would be missed on a survey that only queries screen time.

Research in this area is complicated by the fact that the behaviors that contribute to the development and maintenance of obesity are intricately related. Parental weight status, which is consistently shown to be the strongest predictor of childhood weight status,^{18,33–35} appears to exert a moderating effect on the sedentary behavior–weight relationship.^{22,36} This could be due to genetics and/or behavioral modeling of TV viewing habits³⁷ and other sedentary behaviors. Additionally, reverse causation may operate to the extent that children who are already over-weight are more likely to engage in sedentary behavior. Complicating the picture further is the role of sleep. Lack of sleep at night may lead to more sedentary behavior during the day (due to tiredness), as well as exert its own independent effects on weight, as described in the following section.

Sleep and obesity

Although nationally representative sleep data for youth are scarce, several forces have conspired to threaten ‘a good night’s sleep.’ Survey data from the National Sleep Foundation indicate that 76% of parents are unhappy with their child’s sleep habits,³ and that more than half of adolescents reported feeling tired or sleepy during the day.⁴ Only one in five adolescents reported getting the ‘optimal’ 9 h of sleep on school nights, and adolescents reported sleeping on average 1 h more on the weekends than during the week.⁴ These changes are likely due to several factors, including over-loaded parent and child schedules and generational shifts in parenting that have resulted in later bed times. Coincidentally, the presence of televisions and other electronic media in children’s bedrooms also appears to have influenced bedtimes and amount of nighttime sleep. Children who have a TV in their bedroom have been shown to get less sleep and to go to bed later compared with those who have no bedroom TV.^{2,3}

Sleep is an inherently sedentary behavior. The energy requirement of sleep is lower than for any other activity,^{38,39} and at first consideration, one might expect that shorter sleep duration, or ‘sleep debt,’ would be associated with *greater* daily total energy expenditures

and thus lower weight. Evidence from both clinical and population-based studies is accumulating, however, to show that short sleep duration is associated with overweight in adults⁴⁰ and children. Cross-sectional studies conducted in children in the past decade have shown inverse relationships between short sleep duration and overweight, with odds ratios ranging from 1.5 to 3.0.^{34,35,41–43} A few recent studies have shown a prospective relationship between the amount of sleep early in life and the weight status at end points ranging from 7 to 21 years.^{18,33,44} A similar study by Lumeng *et al.*⁴⁵ observed this relationship over a shorter time period, finding that duration of sleep in third grade was independently associated with overweight in sixth grade. These latter studies have considered a wide array of potential confounders including age, sex, race, parental education, parental weight status, single parenthood, TV/videogame time, amount of physical activity, snacking while watching TV, and behavioral problems, among others. Interestingly, differences in risk have been shown between boys and girls, with the relationship between sleep and overweight apparently more powerful for boys.^{34,43} Future studies that formally assess the presence of effect modification are needed to conclude if sex differences are in fact present.

The effect of sleep debt on body weight may operate through both direct metabolic effects and indirect pathways. During normal sleep, some hypothalamic factors are activated, growth hormone-releasing hormone for example, and others are inhibited, such as corticotrophin-releasing hormone. The balance of these signaling factors mediates the release of pituitary-derived and dependent hormones such as human growth hormone and cortisol.⁴⁶ Short sleep duration appears to directly disrupt these hormonal signaling pathways, affecting the amount and timing of the release of these hormones. For instance, cortisol levels normally plummet in the early evening, but in periods of sleep deprivation, the levels remained high. Similarly, the normal growth hormone pulse that occurs shortly after sleep is broken into two or more smaller pulses with sleep deprivation, exposing tissues to the hormone for an extended period of time, albeit in smaller amounts. Growth hormone is known to decrease insulin sensitivity, and changes in duration of exposure could have an adverse affect on glucose tolerance.⁴⁶ The autonomic nervous system is also affected by sleep deprivation. Parasympathetic nervous system activity, which is typically more active during sleep, is lowered during periods of sleep deprivation, affecting the balance of many hormones.⁴⁶ In two independent studies with different designs, sleep deprivation was found to be associated with an increased appetite, most likely mediated by the decreased levels of leptin, an appetite suppressing hormone, and increased levels of ghrelin, an appetite stimulating hormone assessed in the studies.^{47,48} The subject population of one of these studies was restricted to only normal weight individuals,⁴⁷ whereas the other included overweight individuals and also observed the relationship, independent of BMI.⁴⁸ The direct mechanism by which sleep affects the endocrine system has yet to be elucidated, however, and these preliminary studies have not accounted for energy expenditure or the many other factors that could also affect sleep, hunger, and hormone levels. To our knowledge, no similar studies investigating sleep deprivation and hormone levels have been conducted in children, and the relationship between endocrine function and sleep in children who are still developing may differ greatly from adults.

The sleep deprivation–overweight relationship may also operate through indirect pathways. Children who are short on sleep or suffer from fitful sleep might be expected to be more tired during the day and, thus, less likely to engage in active play, spending their time watching television or engaging in other sedentary behaviors. Thus, sleep debt may increase obesity risk in youth by displacing physical activity that would otherwise take place naturally in a well-rested child. This has been shown in at least one study,⁴⁹ but others have found that the relationship between short sleep and obesity remained significant after adjustment for day-time physical activity.³⁴ Alternatively, time spent asleep may simply

reduce the amount of time that children are exposed to obesogenic environments, meaning less time to view commercial advertising of high-energy snacks and beverages, and less time to engage in the high-energy snack consumption that often accompanies TV viewing.^{24,26} From this perspective, the mere act of being awake at night may translate into unhealthy activities.

Most of the extant studies that have examined this relationship in children have focused on sleep duration to characterize sleep. As with sedentary behavior, measurement issues are noteworthy. The gold standard in sleep measurement and monitoring, polysomnography, is a laboratory method inappropriate for observational studies of free-living children. Therefore, parental report of sleep duration by questionnaire or sleep diary is common in observational studies but may not accurately capture time spent in bed when the child is still awake. This is particularly problematic in studies of adolescents, who spend more time alone in their rooms. As noted earlier, most children now have a television in their bedroom and may fall asleep while watching, which undermines accurate measurement of either sleep or TV viewing. Other studies have attempted to avoid these measurement issues entirely by using subjective measures of daytime sleepiness⁴² or measures of sleep problems, including restless sleep, sleep apnea, and problems falling asleep.^{45,50} Normal values for sleep disturbances in the pediatric sleep literature are few, however.⁵⁰ Reverse causation may also be operating: overweight children, who are prone to sleep-disordered breathing have been shown to have less restful sleeps and shorter sleep durations.⁵⁰ This may set up a vicious cycle whereby poor sleep in overweight children predisposes them to future excess weight gain.

Conclusion

Short sleep duration and sedentary behaviors in the form of screen time may be working in concert to increase the odds of a child becoming overweight. Further research on the role of sleep and its relation to daytime behaviors and hormonal levels is needed to confirm the existence of these possible associations, including improved methodology for assessing time spent in sedentary behaviors that reflect the way that youth interact with electronic media. Valid measurement tools are needed to accurately capture both duration and quality of sleep to understand how the two dimensions may act together to affect obesity. Additionally, studies including both measures of sedentary behavior and sleep duration will help clarify the individual pathways and detect effect modification, if in fact it exists. Reduction of sedentary behaviors, such as screen time, remains an option for obesity prevention and treatment, but as a single target, it is likely to produce only marginal results. Further delineation of the complex interrelation of sleep, time use, mood, and familial factors in racially and economically diverse samples are needed before sleep interventions can be designed or preventive guidance offered.

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