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The Relationship between Sleep, Obesity, and Metabolic Health in Adolescents – a Review

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Abstract

In this literature review, we discuss the importance of adequate sleep and the various effects of suboptimal sleep on weight maintenance and metabolic health specifically for adolescents. Two major contributors to adolescents experiencing decreased sleep duration and quality, and thus increasing the risk for developing metabolic syndrome in adolescence as well as later in adulthood, are increased electronic screen time particularly at night and early school start times. The less time adolescents spend sleeping, the less quality sleep they obtain, and the greater the disruption of endocrine hormone function. As another consequence, adolescents are more prone to making poor food choices, from choosing relatively nutrient-poor foods to consuming excess calories without necessarily increasing their energy expenditure. These choices put adolescents at greater risk for becoming obese throughout their lifespan.

Keywords

adolescents; obesity; sleep; sleep deficiency; body mass index (BMI)

INTRODUCTION

Adolescence is a critical stage in an individual's biological and cognitive development. Adolescents can be more vulnerable to rash decision-making, emotional fragility, and risky behavior, among other factors [1]. Most notably, in modern times, adolescents have been found to struggle with both sleep and obesity, more so in the 21st century in comparison to the late 20th century [2], and interestingly there is an association between the two. Studies in adolescents have shown that sleep deprivation can lead to an increase in energy consumption

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Declaration of interests

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in the absence of an increase in energy expenditure [3–5]. These increases in energy consumption lead to an increase in overall body mass index (BMI) due to changes in body composition from increased fat, leading to a vicious cycle of adolescents battling with obesity as they continue to struggle with sleep. There are multiple contributing factors facilitating sleep deficiency in adolescents, and these include the rapid societal developments in technology and increasing demands in education and productivity [6]. As such, adolescents face multiple stimuli vying for their time and attention on a daily basis. Two particular sources of sleep disruption and obesity risk in adolescents today are excessive usage of electronics and early school start times [7–9]. As society modernizes, particularly through the venue of social media, adolescents as well as adults have increased their screen time dramatically, particularly at night, which can affect sleep [10, 11]. In addition, as educational demands increase, adolescents suffer from stress and lack of sleep, both of which can be exacerbated by early school start times. This is particularly detrimental to adolescents, who are going through a critical stage of their physical development. Additionally, adolescents naturally tend to sleep later due to normal sleep phase delay [12]. Therefore, the combination of this phase shift and early school start times results in suboptimal sleep and stress. These consequences can carry well into adulthood, from cardiovascular health to weight and metabolic complications, which will be discussed later in this review.

IMPORTANCE OF ADOLESCENT SLEEP QUALITY

For adolescents, the sleep requirement is eight to ten hours every night [13]. Adequate sleep has the same benefits throughout the lifespan, including improved emotional health, productivity, brain function, and overall physical and metabolic health [14]. Conversely, though the lack of adequate sleep has similar consequences for every age group, they are more pronounced for those who are still growing. While overall sleep is critical, maintaining appropriate sleep architecture is just as important. Sleep architecture refers to the cyclical nature of the different sleep stages within a given period of sleep [15]. Sleep is characterized by two main stages: non-rapid eye movement (NREM) sleep, which is further divided into three stages (NREM-1, NREM-2, NREM-3), and rapid eye moment (REM) sleep. While NREM sleep predominates the early sleep period, REM sleep is most abundant later in a sleep period. Studies in adolescents have shown that there is a relationship between obesity and sleep duration and sleep quality [16]. Specifically, some studies have found that obesity due to shorter sleep duration may be related to shorter REM sleep duration [17], while other studies have found that shorter deep sleep (NREM-3) and REM sleep duration may be related to elevated blood pressure levels in obese individuals regardless of BMI [18]. These studies demonstrate that the quality of one’s sleep, which can be affected by going to sleep late and potentially affecting NREM sleep or waking early and possibly truncating REM sleep, is just as important as the quantity of one’s sleep.

THE VARIOUS EFFECTS OF SUBOPTIMAL SLEEP ON WEIGHT MAINTENANCE AND ADIPOSITY

Many epidemiological studies have examined the effects of suboptimal sleep on adolescent food choice and obesity risk. As reviewed by Hanlon et al. [6], sleep deprivation has been repeatedly cited as a contributing factor to increases in energy consumption or unhealthy food intake in children and in adolescents. Studies employing methods of subjective reporting of sleep [19, 20], such as the usage of self-reported questionnaires, have indicated that there is a negative correlation between sleep duration and BMI. Other studies employ objective methods of reporting sleep duration including wrist actigraphy and accelerometry [21, 22], which involve the usage of wristwatch-like sensors and mobile electromechanical devices, respectively, that monitor periods of rest and activity.

One study in adolescents with an average age of 17.7 years by Weiss [3] investigated the relationship between sleep duration and energy intake and found that shorter overall sleep duration could potentially increase one's risk for obesity due to a number of changes in eating behavior. Two studies in adolescents with an average age of 16.7 years by Fan [4, 5] found slightly different results than Weiss, concluding that as opposed to chronic sleep deprivation or shorter overall sleep, chronic sleep variability or irregular sleep patterns is associated with increased energy consumption and risk for obesity, which could be counteracted by establishing a consistent sleep pattern. One study in adolescents between the ages of 12 and 16 years by Valrie [23] investigated the association between sleep and BMI in adolescents and the impact of sleep on obesity intervention treatment. Similar to Fan's studies, Valrie's study found that disrupted sleep was a contributing factor to elevated pre-intervention BMI and waist circumference measurements. This study also found that there was a negative relationship between participant sleep deprivation and participant responsiveness to intervention treatment, indicating the role of sleep in adolescent metabolic health.

There are a few reasons for these results. According to adult studies by Mota [24] and Spaeth [25], suboptimal sleep plays a role in the disruption of sleep cycles and regulation of food intake and food choice, all of which can lead to excess weight gain and obesity. Mitchell's longitudinal study [19] found that in high school students in the United States between the ages of 14 and 18, with every self-reported hour of increase in sleep, there is a nonuniform decrease in BMI measures, indicating that sleep for adolescents can be more important at particular ages compared to others. Similar results were found in Lee and Park's study following adolescents in South Korea between the ages of 12 and 18, where sleep deprivation is found to be related to increased blood pressure and overweight [20]. Other studies in adolescents also find a negative correlation between hours of sleep and measures of adiposity, an indicator of cardio-metabolic risk [26, 27].

In their review of existing studies, Zerón-Rugerio, Trinitat, and Izquierdo-Pulido [15] detail the role of sleep and its effects on the endocannabinoid system, which regulates not just how much individuals choose to eat but also what particular foods they choose to eat. According to some other studies in adults, an increase in calorie consumption due to suboptimal sleep may be related to changes in levels of certain endocrine hormones [28] and activation of

biological systems involved in regulating hunger and appetite [29]. Depending on how much suboptimal sleep affects an individual's energy consumption and food choices, such metabolic disruptions can predispose one to weight gain.

Disruptions in sleep quality and duration have been documented as a contributing factor to weight gain both in children and in adolescents [6]. Obstructive sleep apnea (OSA) is a comorbidity frequently associated with obesity in adolescents [16]. OSA occurs when breathing involuntarily stops for short periods of time during sleep, resulting in microarousals and disruption of sleep architecture. Studies have suggested that OSA may be a contributing factor to further weight gain in children, distinct from sleep deprivation [30–32]. Proposed mechanisms for this phenomenon range over possible behavioral and endocrine hormonal changes that culminate in an increase in appetite and consumption of unhealthy foods [33, 34]. Given the cyclical nature of the consequences of sleep disorders like OSA and sleep-disordered breathing (SDB) for adolescent metabolic health, the consequences can extend well into adulthood.

ADOLESCENT SLEEP, OBESITY, ADIPOSITY – Electronics, Light at Night, Melatonin, Cortisol (going to bed late)

Excessive usage of electronics and exposure to artificial light at late-night hours by adolescents is increasingly becoming a cause for concern [35, 36]. Lissak et al. [35] found that excessive media usage by both children and adolescents could potentially be a risk factor for improper psychophysiological development. Studies also find that increased screen time could take away from sleep time, as reviewed by Cain and Gradisar [37]. Furthermore, according to a pioneering study by Figueiro and Overington [38], overexposure to artificial light from electronic devices at night can disrupt the secretion schedule of melatonin, a hormone that is an important inducer of sleep onset. The excessive screen time often leads to a decrease in physical activity, which, when unbalanced with energy consumption, can lead to weight gain and obesity later in life, as found in studies on children and adolescents between the ages of 3 years and 18 years [39–41]. Some studies have found disruption in cortisol regulation in children by extended usage of information and communication technology, specifically a reduction in the normal elevation of morning cortisol levels, which is indicative of a down-regulated awakening response via induced stress [42]. Overall, these studies show the negative impact of excessive screen time on adolescent physiological health, which can have particularly dire consequences during the formative years of adolescence.

ADOLESCENT SLEEP, OBESITY, ADIPOSITY – School Start Times (waking up too early)

For adolescents, another one of the contributors to sleep deprivation is one over which they have less control: school start times [43, 44]. For most students, weekdays translate to variable bedtimes and early waketimes due to school start times. Adolescents naturally undergo changes in their sleep cycles that increase the amount of time before sleep onset [45]. However, early school start times interrupt adolescent sleep periods, resulting in

metabolic disruptions that can lead to weight gain and obesity [46, 47]. As specifically demonstrated by Gariépy [43, 44], the effects of school start times and sleep disruption on adolescent sleep patterns are far-reaching, impacting adolescent stress, academic performance, mental health, and behavioral patterns. As indicated earlier, adolescents are naturally going through stages of development when they are more prone to making potentially dangerous choices, experiencing physical stress from hormonal changes, and navigating emotional stress from various internal and external stimuli. Therefore, additional stresses such as early school sleep times and sleep deprivation can further predispose adolescents to poor metabolic and psychological health. An increasing amount of attention is now being given to how to accommodate students and improve school start times for the sake of their metabolic health [47]. One American study in Seattle high school students found that delaying school start times by nearly an hour was associated with an increase in nightly sleep, academic performance, and attendance [48]. Similar results were found in a study of similar design in Singapore [49]. However, there have been some challenges to these studies, such as with achieving randomization in trials in participating schools, as one study in the United Kingdom found [50]. With further developments based on feedback from schools, the future of implementing delayed school start times is promising intervention.

ADOLESCENT OBESITY – Consequences into Adulthood

Given the detrimental effects of obesity on adolescent development, the implications of these effects can spread well into adulthood as well. Studies have found that adolescent obesity decreases the likelihood of one obtaining academic and long-term educational success. Ryabov conducted a longitudinal study analyzing the implications of adolescent obesity in adult educational attainment [51]. Researchers found that obesity, in tandem with socio-demographic variables such as family socioeconomic status, social networks, and immigrant status, significantly decreased the odds of one advancing in higher education. In terms of health, obesity has also been found to increase one’s likelihood of developing diseases outside of the cardiovascular profile. Chao et al. found that elevated BMI at a specific age in adolescence was correlated with an earlier onset of pancreatic adenocarcinoma [52]. In addition, the results of the study suggest that adult obesity may not increase the onset of pancreatic adenocarcinoma the same way adolescent obesity does, suggesting that adolescent obesity can simultaneously increase one’s risk for developing pancreatic adenocarcinoma and decrease the age at which one could be diagnosed. Thus, not only can adolescent obesity put one at higher risk for other metabolic diseases, but it could also predispose one to failure in other aspects of life, such as education attainment, social networking, and overall quality of life.

CONCLUSION

For adolescents, proper growth and development are essential for proper biological transition into adulthood. Sleep is a critical part of adolescent development, but in today’s society, its importance is often underestimated or entirely neglected. Adolescent metabolic dysfunction is an increasing problem and will continue to be so unless the relationship between adolescent behavior, suboptimal sleep, and risk for negative metabolic and psycho-social outcomes is given more attention and further understood. There are some measures

adolescents themselves can take to improve their sleep and overall metabolic health, but not everything is within their control. Measures to decrease sleep deprivation and disruption can be put in place to improve adolescent health, starting with delayed school start times to reduced screen time. Adolescence is a critical formative period and if optimization of sleep is addressed for teenagers, improvements in metabolic health could be achieved throughout the individual's lifespan.

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