Sleep duration and childhood obesity. An association with lifestyle habits

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ABSTRACT

Aims: Over the last decades, childhood obesity has been a crucial public health threat worldwide. In the meantime, insufficient sleep has become commonplace among children. A large body of research indicates that sleep duration is linked to children's weight status. Thus, the aim of the present work was to review the current evidence regarding the potential underlying mechanisms (i.e. biological and behavioural) involved in the association between sleep duration and childhood obesity. **Methods:** A literature search of studies published between January 2010 and January 2020 was conducted. PubMed data base was searched, using combinations of keywords. Only studies concerning school-aged children (6-18 years of age) were considered. **Results:** Twenty three studies were included. All evidence demonstrated an association between short sleep duration and less beneficial diet quality, like consuming snacks and soda regularly. Sleep restriction was found to be raising the odds of being overweight/ obese by 21% to 58%. Plus, excess screen time is associated with a lower sleep duration. With respect to physical activity, both short and long sleep were found to be associated with less active lifestyle among children. **Conclusions:** This review showed an association between sleep and childhood obesity. Sleep also seems to be related to many aspects of children's lifestyle which probably contribute to weight regulation. Public health efforts that encourage children to have enough sleep may be effective in managing obesity. ***Hellenic J Nutr Diet 2023, 14(1):56-66***

Key words: *Obesity, Childhood, Sleep, Lifestyle, Diet*

ΠΕΡΙΛΗΨΗ

Διάρκεια ύπνου και παιδική παχυσαρκία. Η συσχέτιση με τις συνήθειες του τρόπου ζωής

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Σκοπός: Τις τελευταίες δεκαετίες το ζήτημα της παιδικής παχυσαρκίας έχει λάβει τεράστιες διαστάσεις. Παράλληλα, η ανεπάρκεια του ύπνου στα παιδιά και τους εφήβους παρατηρείται ολοένα και πιο συχνά. Πληθώρα μελετών έχουν αναδείξει την ύπαρξη σχέσης μεταξύ της διάρκειας του ύπνου και του επιπέδου σωματικού βάρους. Έτσι, σκοπό της παρούσας μελέτης αποτέλεσε η ανασκόπηση των τελευταίων δεδομένων αναφορικά με τους πιθανούς μηχανισμούς (βιολογικούς και συμπεριφορικούς) που εμπλέκονται στη σχέση μεταξύ ύπνου και παιδικής παχυσαρκίας. **Μεθοδολογία:** Πραγματοποιήθηκε βιβλιογραφική ανασκόπηση μελετών δημοσιευμένων μεταξύ Ιανουαρίου 2010 και Ιανουαρίου 2020. Διερευνήθηκε η βάση δεδομένων PubMed, με χρήση διαφορετικών συνδυασμών λέξεων κλειδιά. Μόνο οι μελέτες που

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αφορούσαν παιδιά σχολικής ηλικίας (6-18 ετών) συμπεριλήφθηκαν στη μελέτη. **Αποτελέσματα:** Συμπεριλήφθηκαν 23 μελέτες. Όλα τα δεδομένα έδειξαν μία θετική σχέση μεταξύ της χαμηλής διάρκειας ύπνου και της λιγότερο ποιοτικής διατροφής. Η έλλειψη ύπνου φάνηκε να συσχετίζεται με αυξημένες πιθανότητες παρουσίας υπερβαρότητας/παχυσαρκίας της τάξεως του 21% με 58%. Επιπλέον, η υπερβολική χρήση οθονών σχετίζεται με χαμηλότερη διάρκεια ύπνου. Όσον αφορά τη φυσική δραστηριότητα, τόσο η υπερβολική όσο και η περιορισμένη διάρκεια ύπνου φάνηκε να επηρεάζουν αρνητικά τον δραστήριο τρόπο ζωής. **Συμπεράσματα:** Βάσει των ευρημάτων της παρούσας μελέτης, ο ύπνος αλληλεπιδρά με πολλές παραμέτρους της ζωής ενός παιδιού και φαίνεται να συμβάλει στη ρύθμιση του σωματικού βάρους. Η επάρκεια του ύπνου θα πρέπει να αποτελεί στόχο των μελλοντικών παρεμβάσεων για τη διαχείριση του σωματικού βάρους των παιδιών. ***Hellenic J Nutr Diet 2023, 14(1):56-66***

Λέξεις κλειδιά: *Παχυσαρκία, Παιδική ηλικία, Ύπνος, Τρόπος ζωής, Δίαιτα*

Introduction

According to World Health Organization (WHO), childhood obesity is reaching astounding proportions in many countries, and poses a crucial challenge for the global community[1]. It could be noted that the world is in the mid-point of an obesity epidemic where the number of obese children worldwide has increased to 124 million in 2016, as reported by a pooled analysis of 2.416 population-based studies[2]. It is documented that increased weight status among children predicts a risk profile in adulthood, which entails well known health and economic consequences, both for the individual and society as a whole[1,3,4]. The etiology of obesity is complicated, while lifestyle, social and environmental factors and genetic susceptibility are interchangeably involved in its occurrence[4].

Eating patterns constitute a fundamental behavioral pathway that may enhance obesity risk and it can be influenced by sleep patterns[5]. During the last years, the role of sleep habits in maintaining good health and normal body mass index (BMI) is increasingly discussed. Furthermore, it appears that insufficient sleep has become commonplace even among children. As documented by the National Sleep Foundation "2014 Sleep in America poll", 31% of US children, aged 6-11 years, sleep less than enough on school day[6]. Likewise, about 33% of European adolescents sleep <8 hours per night, as stated in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study[7]. In a research conducted among Greek children in 2018, it was found that approximately 40% of school-aged children had insufficient sleep duration[5]. Norell-Clarke et al highlighted that the proportions of Swedish children who got adequate sleep decreased between the years 2005 and 2013[8]. The American Academy of Sleep Medicine has developed consensus recommendations for the optimal amount of sleep for pediatric populations. These guidelines proposed 9-12 hours/day, on a regular basis, for schoolchildren (6 to 12 years of age) and 8-10 hours for teenagers (13 to 18 years of age) to promote optimal health[9]. Sleep definitely plays an essential role in hormonal[10,11], psychological[12] and behavioral[13] profile of human beings. It has been proposed that insufficient sleep is linked to children's eating disorder and to obesity as well[5,10,14,15].

The present article sought to review the current evidence regarding the potential mechanisms involved in the association between sleep duration and childhood obesity.

Methods

Selection of studies

A comprehensive literature search in PubMed data base using combinations of keywords: [sleep duration/patterns/habits, insufficient sleep/sleep deprivation AND obesity/adiposity/overweight OR lifestyle factors/dietary patterns/dietary habits/diet/nutrition AND children/paediatrics] was conducted. Only studies published in English, between January 2010 and January 2020, were considered. Additionally, the reference lists of the retrieved articles helped us to find relevant to the present articles that did not allocate through the searching procedure. Studies were considered eligible for inclusion in this review if they were concerning school-aged children (6-18 years of age) and investigated sleep duration as a risk factor for childhood obesity through any possible pathway. The search included also studies which evaluated all the factors linked to both sleep habits and adiposity rates such as sex and hormonal profile, physical activity, screen time. Studies examining adults or a disease population

were excluded. No restrictions were made according to study design. Tables 1, 2, 3 and 4 provide an overview of the first author, publication year, basic characteristics and main findings of the selected articles.

TABLE 1. Characteristics of the selected studies regarding the relationship between sleep duration and dietary habits.

First author	Year	Region	Sample Characteristics [size (n) or number of studies included for reviews and age range]	Type of study	Main Findings
Cordova[10]	2018	USA, Europe, Asia, Oceania	n= 72,054 30 studies (for the review) 2 - 18 y	Systematic review and meta-analysis	Odds ratio for unhealthy eating habits among children who had short sleep was (OR 1.51, 95% CI: 1.24–1.85). Snack and soda consumption was associated with less sleep (OR 1.75, 95% CI 1.24–2.46), (OR 1.16, CI 95% 1.09–1.25). Adequate sleep duration was associated with intake of fruits and vegetables (OR 0.75, CI 95% 0.65–0.86)
Weiss[16]	2010	USA	n = 240 16-19 y	Cross-sectional	After adjusting for confounders, shorter sleep duration was significantly associated with an average daily increase of calories consumed from fat of 2.2 percentage points and an average daily decrease in percentage of calories from carbohydrates of 3.0 percentage points. In unadjusted analyses, shorter sleep duration was also associated with a 2.1-fold increased odds (95% CI: 1.03–4.44) of daily consuming 475 or more kcal from snacks.
Garaulet[7]	2011	Europe (11 cities)	n=3,311 12.5–17.49 y	Cross-sectional	The proportion of adolescents who eat adequate amounts of fruits, vegetables and fish was lower in shorter sleepers than in adolescents who slept >8 h per day, and so was the probability of having adequate food habits (p <0.05).
Magriplis[18]	2018	Greece	n=4,434 10-12 y	Cross-sectional	The dietary pattern was positively associated with sleep, family meals and study hours, and was inversely associated with total screen time, frequency of eating out and eating while on some screen. Overweight and obese children were more likely to have a lower cdFI score (2%), sleep less (8%) and report more study hours (6%).
Tambalis[14]	2018	Greece	n=177,091 8-17 y	Cross-sectional	After adjusting for several covariates, insufficient dietary habits, insufficient (<8–9 h/d) sleep, inadequate PA levels and increased screen time increased the odds (95% CI) of being a frequent fast-food consumer by 77% (0.218-0.234), 30% (1.270–1.338), 94% (1.887–1.995) and 32% (1.287–1.357), respectively.
Kruger[19]	2014	USA	n=13,284 13-18 y	Cross-sectional	Short sleep duration (<7 h/night) was associated with reduced odds of vegetable and fruit consumption compared with the recommended sleep duration (>8 h/night) (OR 0.66, P <0.001), even after adjusting for demographic and social/behavioural factors (OR 0.75, P <0.001). Short sleep duration was also associated with increased odds of fast food consumption (OR 1.40, P <0.001) even after adjustment (OR 1.20, P <0.05).

TABLE 1. (continued) Characteristics of the selected studies regarding the relationship between sleep duration and dietary habits.

First author	Year	Region	Sample Characteristics [size (n) or number of studies included for reviews and age range]	Type of study	Main Findings
Hoppe[15]	2013	Denmark	n=802 4-14 y	Cross-sectional	Sleep duration was not associated with energy intake (b= -0.015, p=0.20), but there was a trend towards a positive association with intake of dietary fibre (b= 0.006, p= 0.05) and vegetables (b= 0.011, p= 0.05), and a negative association with intake of poultry (b= -0.002, p= 0.02), and a trend towards a negative association with intake of liquid 'discretionary calories' (b = -0.01, p= 0.05).
Tambalis[5]	2018	Greece	n=177,091 8-17y	Cross-sectional	Insufficient sleep duration was associated with unhealthy dietary habits such as skipping breakfast (OR 1.30, 95% CI: 1.25–1.35), fast-food consumption (OR 1.35, 95% CI 1.29–1.41), and consuming sweets regularly (OR 1.32, 95% CI 1.25–1.39).

Results

Association of sleep duration and dietary habits

A recent meta-analysis found increased odds of "unhealthy" dietary habits among children who had short sleep duration (OR 1.51, 95% CI: 1.24-1.85). More specifically, it was claimed that sleep-deprived children consumed snacks and soda much more regularly compared to those who had longer sleep duration ($p<0.01$), while long sleepers seem to consume more fruits and vegetables. Interestingly, sex specific findings were observed since girls who were short sleepers had statistically significant increased frequency of consuming fast food ($p<0.05$) and sweets ($p<0.01$)[10]. Similarly, in a cross-sectional study, after adjusting for potential confounders, it was found that insufficient sleep was significantly associated with an increase in the percentage of calories consumed from fats (average adjusted difference between those with shorter and longer sleep duration (2.2% ± 1.0% [mean ± SE], p=0.02) and a decrease in the percentage of calories from carbohydrates (−3.0% ± 1.2%, p=0.01). Furthermore, an association between less than recommended sleep (<8 hours) and high caloric intake from snacks, which was statistically significant only among girls was pointed out (OR 4.18, 95% CI: 1.14-15.37, p=0.03)[16]. In the same direction, a Canadian review of experimental studies displayed increased calorie consumption under conditions of sleep deprivation[17]. A multicentric study from 10 European cities indicated that sleep restriction among adolescents was significantly correlated to a lower possibility of having healthy food habits, regarding fruits (OR 0.72, 95% CI: 0.55-0.93, p=0.012), vegetables (OR 0.74, 95% CI: 0.59-0.9, p=0.006) and fish (OR 0.74, 95% CI: 0.61-0.90, p=0.002), and increased consumption of fast food like, pizza (p=0.016) and hamburgers (p=0.015)[7]. These results were consistent with the GRECO study by Magriplis et al, who evaluated the association of behavioral factors, including sleep, with a food index score (cdFI). The healthier the children's dietary pattern, the higher the value of the score (cdFI) was. It was reported that with every extra hour children slept, the total cdFI score increased by 0.15. However, in contrast with previous findings, it was found that cdFI score was significantly correlated with sleep duration only among boys (B=0.24, 95% CI: 0.09-0.39)[18]. Regarding fast food, the EYZHN (National Action for Children's Health) program showed that sleeping less than recommended raised the odds of being a frequent fast-food consumer by 30% (95% CI: 1.270-1.338), in both genders[14]. Another longitudinal study of American adolescents found less likely daily consumption of fruits and vegetables (OR 0.75, 95 % CI: 0.64-0.88) and more likely fast food consumption (OR 1.20, 95 % CI: 1.01-1.43) among the short-duration sleepers (<7 h/night), in a fully adjusted model[19]. A cross-sectional research regarding Danish children highlighted a trend towards a positive association between sleep duration and intake of dietary fiber

TABLE 2. Characteristics of the selected studies regarding the relationship between sleep duration and obesity.

First author	Year	Region	Sample Characteristics [size (n) or number of studies included for reviews and age range]	Type of study	Main Findings
Katzmarzyk[20]	2015	Europe, Africa, USA, South-East Asia, Western Pacific	n=6,025 9-11 y	Cross-sectional	The odds ratios for obesity from multilevel, multivariable models were (OR 0.79, 95% CI: 0.71–0.90) for nocturnal sleep duration
Miller[21]	2018	UK, USA, Canada, Australia, New Zealand, China	n=75,499 42 studies (for the review) Infants, children, adolescents	Systematic review and meta-analysis	Short sleep was associated with a greater risk of developing overweight or obesity in infancy [seven studies, 14,738 participants, risk ratio (RR 1.40, 95% CI 1.19–1.65, p <0.001)], early childhood [eight studies, 31 104 participants, (RR 1.57, 1.40–1.76, p <0.001)], middle childhood [three studies, 3,005 participants, (RR 2.23, 2.18–2.27, p <0.001)], and adolescence [(three studies, 26,652 participants, (RR 1.30, 1.11–1.53, p <0.002)]
Tambalis[5]	2018	Greece	n=177,091 8-17y	Cross-sectional	Insufficient sleep duration was found to be associated with being overweight/obese (OR 1.21, 95% CI 1.17-1.25), after adjusting for several covariates
Pereira[11]	2019	Brazil	n=596 7-8 y	Cross-sectional	Obese children had greater difficulties in maintaining the biological rhythm compared to non-obese children (p = 0.007). Some of these difficulties included sleep (p = 0.008)
Lim[22]	2019	China	n=516 6-20 y	Prospective study (6 years follow-up)	The relative risk of overweight/obesity in participants with short sleep and late bedtime was 1.30 (0.48-3.47) and 1.46 (0.70-3.05), respectively. Despite rising rates of unhealthy sleep habits and general obesity, their associations were not significant at 6-year of follow-up
Garaulet[7]	2011	Europe (11 cities)	n=3,311 12.5–17.49 y	Cross-sectional	Shorter sleepers showed higher values of BMI, body fat, waist and hip circumferences and fat mass index (P<0.05), particularly in females
Katsa[23]	2018	Greece	n=480 5-12 y	Cross-sectional	Regarding sleep habits, logistic regression analysis (LRA) showed that hour of sleep -before 22:00- was associated with decreased waist circumference (WC%) (p=0.026)
Hart[24]	2013	USA	n=37 8-11 y	Cross-over	Measured weights were 0.22 kg lower during the increase sleep than the decrease sleep condition (p<0.001)

(p=0.05) and a negative association with liquid "discretionary calories" (p=0.06). When they evaluated the differences between age-dependent tertiles of sleep duration, only consumption of liquid "discretionary calories" (i.e. sugar-sweetened beverages, cider, ice tea) was significantly lower among the long-sleepers (p=0.03)[15]. However, no statistically significant association between sleep duration and energy intake was found (b = –0.015, p = 0.20)[15]. Likewise, a very recent study underlined a positive correlation between insuf-

TABLE 3. Characteristics of the selected studies regarding the relationship between sleep duration and screen time

First author	Year	Region	Sample Characteristics [size (n) or number of studies included for reviews and age range]	Type of study	Main Findings
Przybylski[26]	2018	USA	n=50, 212 0,5–17 y	Cross-sectional	Each hour devoted to digital screens was associated with 3-8 fewer minutes of nightly sleep and significantly lower levels of sleep consistency. Furthermore, those children who complied with 2010 and 2016 American Academy of Pediatrics guidance on screen time limits reported between 20 and 26 more minutes, respectively, of nightly sleep
Carter[29]	2016	North America, Europe, Australia, Asia	n=125,198 20 studies 6–19 y	Systematic review and meta-analysis	There was a strong association between bedtime media device use and inadequate sleep quantity (OR 2.17, 95% CI: 1.42–3.32, p <0.001, I2 = 90%), poor sleep quality (OR 1.46, 95% CI: 1.14–1.88, p= 0.003, I2= 76%), and excessive daytime sleepiness (OR 2.72, 95% CI: 1.32–5.61, p= 0.007, I2= 50%)
Hisler[30]	2019	UK	n=11,361 13–15 y	Longitudinal	Heavy use of screen media was associated with shorter sleep duration, longer sleep latency, and more mid-sleep awakenings. The strongest associations emerged for using screen media to engage in social media or to use the internet
Tambalis[5]	2018	Greece	n=177,091 8–17 y	Cross-sectional	Insufficient sleep duration was found to be associated with increased screen time (OR 1.26, 95% CI 1.21–1.31) after adjusting for several covariates
Hale[28]	2014	Japan, US, Europe, China, New Zealand, Israel, Australia, Brazil, South Korea, Taiwa, Saudi Arabia	67 studies 5–17 y	Systematic review	Screen time is adversely associated with sleep outcomes (primarily shortened duration and delayed timing)

ficient sleep duration and unhealthy dietary habits such as skipping breakfast (OR 1.30, 95% CI: 1.25–1.35), fast-food consumption (OR 1.35, 95% CI: 1.29–1.41), and consuming sweets frequently (OR 1.32, 95% CI: 1.25–1.39)[5].

On the whole, all evidence demonstrated an association between short sleep duration and less beneficial diet quality in childhood and adolescence.

Association of sleep duration and obesity

Several studies have examined the relationship between youth sleep habits and obesity. A multinational cross-sectional study (n=6,025) showed that nocturnal sleep was negatively associated with adiposity in both genders[20]. Commonly, sleep restriction was found to be associated with being overweight/obese, after adjusting for several covariates, as assessed by Tambalis et al.

TABLE 4. Characteristics of the selected studies regarding the relationship between sleep duration and physical activity.

First author	Year	Region	Sample Characteristics [size (n) or number of studies included for reviews and age range]	Type of study	Main Findings
Sorić[32]	2015	Croatia, Slovenia, USA	n=276 10,5–12 y	Cross-sectional	While average sleep duration and efficiency were unrelated to physical activity, within subjects associations revealed that an extra hour spent in bed during the night was followed by a 16-minute decrease in moderate-to-vigorous physical activity (p <0.001)
Kobel[33]	2019	Germany	n=308 First and second graders	Cross-sectional	In logistic regressions, long night time sleep (≥10:08 h; compared to medium and short sleep duration) was significantly associated with not reaching the PA guideline (OR 0.60, 95% CI 0.36–0.99). However, if controlling for age, gender, parental education level and migration background, reaching the PA guideline stayed no longer significantly associated with a tertiary sleep level
Harrex[35]	2018	New Zealand	n=439 9–11 y	Cross-sectional	Children in the late sleep/late wake category accumulated fewer minutes of moderate-to-vigorous physical activity per day compared with those in the early sleep/early wake category [mean difference (95% CI): -9.4 (-15.3, -3.5)]
Hart[36]	2017	USA	n=37 8–11 y	Within-subject counterbalanced design	Children reported watching more television (p <0.001) and demonstrated lower daytime actigraph-measured activity counts per epoch (p= 0.03) when sleep was decreased (compared with increased)
Martinez[37]	2019	USA	n=308 8–10 y	Longitudinal	Cross-lagged panel analyses showed that, over 3 days, for every 1-hour increase in sleep duration, there were an expected 0.66-hour (40-minute) decrease in SED, 0.37-hour (22-minute) decrease in LPA, and 0.06-hour (4-minute) decrease in MVPA. For every 1-hour increase in LPA, there was an expected 0.25-hour (15-minute) decrease in sleep duration

(OR 1.21, 95% CI: 1.17–1.25)[5] and by Miller et al as well (RR: 1.58, 95% CI: 1.35-1.85, $p < .001$)[21]. Furthermore, in another observational study, every hour of children's sleep increased the likelihood of being overweight or obese decreased by 8%[18]. Pereira et al. observed that among obese children, there was greater difficulty in maintaining the biological rhythm pattern, which includes the sleep pattern, when compared to non-obese[11]. A prospective study conducted in Hong Kong examined the impact of short sleep duration and bedtime latency on the risk of developing obesity among normal weighted adolescents on the baseline. Despite the expected rising trends, no significant increase in the risk of developing overweight or obesity was observed, during follow-up, among the sleep-deprived adolescents in comparison to those with an average sleep duration ≥7 hours per day[22]. Findings from the HELENA study, showed that short sleepers (<8h) were characterized by significantly higher values of BMI, body fat, waist and hip circumferences and fat mass index[7]. Contextualized findings from another study, showed that children who slept before 22:00 were more likely to

have normal waist circumference (WC %), an important measure of central adiposity (p=0.026)[23]. A randomized control trial conducted among school-aged children, found that increases in sleep duration were associated with decreased reported energy intake, weight loss, and lower fasting leptin levels[24].

Association of sleep duration and screen time

Nowadays, children grow up in a digital world, which can be both effective and risky for their healthy development. The lurking dangers from digital screen overuse include obesity and sedentary lifestyle development, poor dietary habits, low sleep quality and even mental disorders. To answer the remaining questions concerning the appropriate screen time for children, the American Academy of Paediatrics (AAP) established new standards, in 2016, and recommended 2 hours or less of sedentary screen time daily[25].

In the present review, the current literature related to the complex and bidirectional relationship between sleep and screen time was reviewed. It is interesting to note that among American children (n = 50,212), those exposed to screens under the limit set by AAP in 2016 slept for an average of 26 more minutes compared to children whose caregivers reported they surpassed these guidelines. It was also showed that digital screen time was negatively associated with sleep duration (B = -0.040 to -0.049) and sleep consistency (B = -0.063 to -0.130) as well[26]. Two recent systematic reviews, pointed out that more than 90% of the examined literature among children and adolescents indicated a relation between excess screen time and delayed bedtimes and shorter total sleep time[27,28]. More specifically, Hale et al demonstrated that, among all screen-related activities, computer and mobile devices use and video gaming were more commonly related to unfavorable sleep outcomes[28]. Recent meta-analysis investigated the association between portable screen-based media devices and sleep outcomes. Combined results from 20 studies showed increased odds of inadequate sleep quantity, poor sleep quality and excessive daytime sleepiness among children who used a media device near bedtime[29]. Along these lines, in a large sample (n= 11,361) of adolescents in the UK, those who were classified as 'heavy users' of screen media slept less, reported later sleep latency and experienced lower sleep quality, for instance mid-sleep awakenings. These negative outcomes appeared stronger on school-nights and among adolescents who used social media and internet (vs. TV, video gaming). In particular, heavy social media and internet users went to sleep about one hour later on average in comparison with non-users[30]. Two more observational studies among Greek and Danish children indicated that sleep duration was significantly related to increased screen time[5,31].

Association of sleep duration and physical activity

It has been proposed that lack of sleep provokes fatigue and consequently declines the motivation needed to be physically active[17,10], yet inconsistent findings have been reviewed. Participants in the HELENA study, who slept less than 8 hours per day were found to be more sedentary, whereas no associations were found between sleep time/24h and physical activity (PA), as assessed by accelometers[7]. Data from another observational study indicated that 'insufficient' sleepers showed lower aerobic performance and PA (all $p<0.05$)[5]. A multi-center, observational study assessed 276 children, over PA and sleep duration, using a multi sensor body monitor device. Results from the statistical analysis showed that neither duration nor efficiency of nocturnal sleep was correlated with the average daily amount of Moderate to Vigorous Physical Activity (MVPA). Quite the opposite, total time in bed was inversely associated with MVPA and Moderate Physical Activity (MPA), the following day. For instance, one extra hour in bed was followed by a 16 minute-decrease of MVPA[32]. Another study examining children's PA and sleep habits concluded that long nocturnal sleep (≥10:08 h) compared to medium and short sleep duration was significantly associated with not reaching the PA guideline[33] (OR 0.60 95% CI: 0.36-0.99) by WHO suggesting >60 min of MVPA per day[34]. However, after adjusting for several covariates (age, gender, parental education level etc.), the correlation was no longer significant. The PEDALS study, used four sleep patterns (late sleep/late wake, late sleep/early wake, early sleep/early wake, early sleep/late wake) to examine whether there are any associations between PA. The model generally displayed that early wake up in the morning is linked to a more physically active lifestyle, especially when it is combined with an early sleep time[35]. Hart et al aimed to examine whether experimental changes in sleep duration would affect PA, so they randomized participants to decrease sleep time group and increase sleep time group. Sleep deprived children, on average, were less active[36]. Cross-lagged findings by the National Sleep Foundation demonstrated that long sleep duration for 3 consecutive days was associated with less MVPA, even though the association was weak[37].

Discussion

The present review reveals that there exists consistent evidence supporting that maintenance of a healthy sleep pattern is beneficial for children's dietary routine and obesity as well. Additionally, it displays the behaviorally mediated pathways leading to poor sleep habits and eventually to obesity. Specifically, short sleep duration among children was associated with 51% greater likelihood of having 'unhealthy' dietary habits like snacks and soda. Similarly, among adolescents, short sleep duration was correlated with about 30% lower odds of having healthy dietary habits such as consuming fruits, vegetables and fish. In the same direction, sleep restriction was found to be raising the odds of being overweight or obese by 21% to 58%. Plus, evidence arising from the reviewed literature agrees that excess screen time is associated with lower sleep duration. In relation to the association of sleep duration and physical activity, contrasting findings exist, while both short and long sleep seemed to be associated with being less physically active. Overall, there is sufficient evidence to support that short sleep duration is a risk factor of the development of obesity in children and adolescents and as of such, sleep improvement must be a component of health interventions.

Many plausible mechanisms explaining the observed link between short sleep and obesity have been proposed. Sleep duration unequivocally contributes to metabolic procedures and hormonal responses which my lead to a dysregulation of appetite, hunger and satiety. Key hormones thought to be implicated in those pathways are leptin, ghrelin, insulin and cortisol. Leptin is primarily secreted by adipocytes and suppresses appetite by acting on receptors in the hypothalamus, while ghrelin is released by stomach cells and arouses hunger. A review of the laboratory evidence concluded that lack of sleep down-regulates leptin, up-regulates ghrelin, along with increasing the risk of overeating and consequently weight gain. Furthermore, sleep loss in healthy volunteers seems to decrease insulin sensitivity, resulting in impaired glucose tolerance and increased diabetes risk[17,24,38]. Moreover, researchers from China have come to the conclusion that a healthy lifestyle, including healthy sleep pattern, may offset the polygenic risk of obesity in children. Specifically, a healthy lifestyle, compared to an un-healthy lifestyle, was associated with an 85% lower likelihood of being obese even among children at high polygenic risk[39]. Little is known about sleep distinctively and its interaction with genetic predisposition and pathways involved in obesity pathogenesis. Nevertheless, it is indicated that sleep duration altered the polygenic obesity risk mainly via the leptin pathway at both baseline and 10-year follow-up[40].

One of the examined studies showed no significant increase in the risk of developing overweight or obesity among short sleepers[22]. The study authors assumed that no statistical significance was reached due to the small sample size and the absence of other confounders like lifestyle and behavioral factors. Regarding the relation of short sleep duration and dietary patterns, some sex-related differences were observed. Sleep-deprived girls seemed to have greater odds of having higher caloric intake from snacks[16] and consuming more fast food and sweet[10]. A possible explanation may emerge from girls' propensity to emotional eating[41-42].

Concerning the potential mechanisms that explain the above-mentioned detrimental effect of digital media use on sleep outcomes, the main findings accuse the light of screens and the resulting psychological arousal which opposes the calmness needed to fall and stay asleep, the physiological stimulation from the content and the time displacement of sleep[28,31,43]. It seems that exposure to light-emitting screens inhibits melatonin secretion, which is a hormone that regulates the sleep–wake cycle and is typically released in the evening, and delays sleep onset[44].

Regarding the association between sleep duration and physical activity, investigations were found to be disparate and this could be attributable to the differences between the assessment methods for sleep duration and PA as well as the children's chronotype. Chronotype appears to be an underlying inclination that may form timing of sleeping, eating and activity patterns relevant to obesity[45].

The results of the present review can only be representative of the studies that have been included and are unable to provide a systematic conclusion of all studies published. Methodological differences across the studies may justify part of the observed inconsistencies. There are limitations associated with the measurements of the including variables. Most studies examined sleep duration, physical activity and dietary habits using self-reported questionnaires completed by children or caregivers. In addition, the classification of children as 'long' or 'short' sleepers varied across the reviewed studies.

Conclusion

Given the dramatic increase of the prevalence of childhood obesity worldwide, it becomes an urgent need to target the underlying mechanisms. This review examined the role of sleep duration in biological and behavioral pathways potentially contributing to obesity. Sleep appears to affect children's and adolescent's dietary habits, hormonal responses, physical activity and time spent on digital screens, through uncertain mechanisms which are increasingly discussed. This paper advocates that improving sleep habits must be a component of children's weight management programs.

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