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Is There an Association Between Adolescent Sleep Restriction and Obesity

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Abstract

Objective—This is the first prospective study of the reciprocal association between sleep restriction and weight among adolescents. Evidence on sleep duration and obesity in youth is sparse and the results have been equivocal.

Methods—Data are from a community-based, two-wave cohort study. The setting was a metropolitan area with a population of over 4 million. The cohort consisted of 4,175 youths 11–17 at baseline and 3,134 of these followed up a year later. Obesity was defined as body mass index 95th percentile for children of the same age and sex. Sleep restriction was defined as 6 or fewer hours of sleep per night on weeknights or on both weekends and weeknights. Covariates examined were age, gender, family income and depression.

Results—Results clearly demonstrated there was no association between sleep restriction and obesity at baseline. In prospective analyses, sleep restriction did not increase future risk of obesity, nor did obesity increase risk of future sleep restriction.

Conclusions—These findings call into question previous research based primarily on cross-sectional data suggesting a positive correlation between sleep restriction and obesity. However, the results for adolescents in this study are supported by one study of adolescents and by studies of adults using prospective designs. At this point, there appears to be little evidence for a temporal relation between sleep duration and obesity among adults or adolescents.

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Conflicts of Interests

There are no conflicts of interest.

Keywords

Obesity; Sleep Restriction; Adolescents; Epidemiology

Introduction

Sleep deprivation, or short sleep, is sleep time less than the average basal level of about 9 hours per night for adolescents [1]. More recently, the National Sleep Foundation has revised its guidelines for 14–17 year olds to 8–10 hours [2]. Studies indicate that many adolescents do not obtain adequate nocturnal sleep in the U.S. [3–5] as well as in many countries around the world [6]. This latter review found adolescents slept 7.64 hours in Asian studies, 8.44 hours in European studies and 7.46 hours in North American samples. As many as one-fourth of adolescents report sleeping 6 hours or less per night [7]. The National Sleep Foundation's 2006 survey found that only 1 in 5 adolescents gets 9 hours of sleep on school nights and 45% sleep less than 8 hours on school nights [2]. A typical high school senior sleeps just 6.9 hours on school nights.

Available evidence suggests that disturbed sleep and restricted sleep are associated with deficits in functioning across a wide range of indicators of psychological, interpersonal and somatic well-being [7–11]. For example, adolescents with disturbed sleep report more depression, anxiety, anger, inattention and conduct problems, drug and alcohol use, impaired academic performance, and suicidal thoughts and behaviors. They also have been reported to have more fatigue, less energy, worse perceived health and symptoms such as headaches, stomachaches and backaches.

More recent studies have further extended these findings. A prospective, 3-wave study of adolescents found that youths who curtail sleep to study exhibit more cognitive problems at school [12]. In a second prospective study, Kelly and El-Sheikh (2014) found reduced sleep duration predicted greater depression, anxiety and externalizing symptoms over time [13]. Psychological symptoms also predicted changes in sleep, but less so [13]. A large national, cross-sectional study found youths who slept less than 8 hours per night were more likely to report substance use, have suicidal thoughts, feel sad or hopeless, not being physically active, and to drink more soda pop [14].

Laboratory studies in particular have documented impaired cognitive function, daytime sleepiness and fatigue as a consequence of sleep deprivation [8, 15, 16]. Experimental studies of sleep deprivation and its effects have been rare. One study found combined sleep restriction at home and in the laboratory reduced adolescents' self-ratings of positive affect, increased negative affect and increased negative mood in response to a challenge [17–19]. A more rigorous experiment with adolescents found that sleep restriction resulted in adolescents rating themselves as more tense/anxious, angry/hostile, confused and fatigued and as less rigorous [20].

There is evidence, albeit limited, that restricted sleep is associated with overweight and obesity in children. Conclusions from 7 reviews published in 2008 concluded the evidence strongly suggested a consistent relationship between restricted sleep and overweight/obesity

among children [21–27]. The association was inconsistent among adults, particularly as age increased.

The strongest evidence for a link between shorter duration of sleep and weight actually comes from studies of children, particularly very young children [28]. Results from both cross-sectional and cohort studies of children indicate that shorter sleep duration is associated with greater odds of overweight or weight gain [29–33]. This is particularly true for preschool children. In fact, for children, the evidence suggests a rather clear dose-response relationship, that is, with each unit decrease in sleep time, there is an increase in weight or weight gain [21, 34]. However, the evidence for adolescents is not clear. One reason is that fewer studies have been done focusing on adolescents. In the 7 reviews published in 2008, only a half-dozen studies were reviewed focusing just on adolescents. All were cross-sectional studies and all found at least some evidence that shorter sleep duration was associated with overweight or weight gain [35–39]. Nielsen et al. reviewed 23 studies not included in the 2008 reviews [28]. This updated review included no new studies of adolescents, either cross-sectional or cohort studies. More recently, Cuypers et al. have reported insufficient sleep was associated with obesity only in the most extreme sleep range (5 or less hours of sleep) [40].

Thus, while the available evidence suggests an inverse association between restricted sleep and overweight/obesity among both children and adolescents, the evidence is much weaker for the latter age group [21, 28]. First, there have been fewer studies of adolescents and, second, there has been only one cohort study of adolescents. Only one study has examined the prospective association between shortened sleep duration and risk of obesity among adolescents. Calamaro et al. (2010) found no association between sleep duration at baseline and obesity at follow-up in a cohort of over 13,000 adolescents 12–18 years of age at baseline [41]. Studies of young adults suggest the association between sleep duration and weight may be bi-directional [42]. That is, short sleep increased risk of obesity and obesity increased risk of short sleep in a 3-wave cohort (ages 20, 22, and 27). No such reciprocal effects have been examined in studies of children, and none for adolescents.

At this point, there is no evidence for a prospective association between duration of sleep and weight in adolescents other than the study by Calamaro et al. (2010). This is an important gap in the literature, since data from the Whitehall II Study of adults aged 35–55 indicate a cross-sectional association between sleep deprivation and overweight but data from the cohort study found no prospective association between short sleep and weight [43]. Similar results have been reported from the CARDIA study of 18–30 year olds [44].

In summary, the answer to the question of whether restricted sleep increases the risk of overweight or obesity among adolescents (or weight problems increase the risk of sleep restriction) remains unclear.

Using data from a two-wave cohort study of youth aged 11–17 at baseline, Teen Health 2000 (TH2K), this study examined the prospective association between short sleep or restricted sleep and weight in adolescence. Specifically, the study explored the reciprocal association between restricted sleep and weight, e.g., whether restricted sleep increases the

risk for obesity, whether weight increases the risk for restricted sleep, whether the association is asymmetric, or whether there is an association at all.

Method

Sample

The TH2K sample was selected from households in the Houston metropolitan area enrolled in two local health maintenance organizations. One youth, aged 11 to 17 years, was sampled from each eligible household, oversampling for ethnic minority households. Initial recruitment was by telephone contact with parents. A brief screener was administered on ethnic status of the sample youths and to confirm data on age and sex of youths. Every household with a child 11 to 17 years of age was eligible. Because there were proportionately fewer minority subscriber households, sample weights were developed and adjusted by post-stratification to reflect the age, ethnic, and sex distribution of the 5-county Houston metropolitan area in 2000. The precision of estimates are thereby improved and sample selection bias reduced to the extent that it is related to demographic composition [45]. Thus, the weighted estimates generalize to the population 11 to 17 years of age in a metropolitan area of 4.7 million people.

Data were collected on sample youths and one adult caregiver using computer-assisted personal interviews and self-administered questionnaires. The computerized interview contained the structured psychiatric interview (see below) and demographic data on the youths and the household. Height and weight measures were conducted after the completion of the interviews. The interviews and measurements were conducted by trained, lay interviewers. The interviews took on average 1 to 2 hours, depending on the number of psychiatric problems present. Interviews, questionnaires, and measurements were completed with 4175 youths at baseline, representing 66% of the eligible households. There were no significant differences among ethnic groups in completion rates. Youths and caregivers were followed up approximately 12 months later using the same assessment battery used at baseline. The cohort consisted of 3134 youths plus their caregivers in Wave 2 (75% of Wave 1 dyads). There clearly was attrition between waves which poses a potential risk of bias.

In a previous paper, Roberts et al. (2009) addressed the issue of bias in the follow-up study in two ways [46]. First, they contrasted status factors for those in the baseline survey and those in the Wave 2 cohort, and found essentially no differences. Second, they then examined the prevalence of psychiatric disorders in the baseline study and in the Wave 2 cohort. Again, there were no differences. They further explored this issue, comparing prevalences between the 3,134 at baseline who also were in Wave 2 with those 1,041 who were not in Wave 2 (data not shown). There was a slight tendency ($p < 0.05$) for those not in Wave 2 to report a higher prevalence for anxiety and for any DSM-IV disorder. There were no other differences [47]. We have done the same contrasts for weight status and sleep variables (data not shown).

All youths and parents gave written informed consent prior to participation. All study forms and procedures were approved by the University of Texas Health Science Center Committee for Protection of Human Subjects.

Measures

Body mass index (BMI) and weight status—Height and weight were measured using standard field procedures such as a Tanita digital scale [45, 48, 49]. BMI was defined as weight/height squared (kg/m^2). Weight status was categorized as healthy weight ($\text{BMI} < 85^{\text{th}}$ percentile for children of the same age and sex), overweight (85^{th} percentile $\text{BMI} < 95^{\text{th}}$ percentile) and obese ($\text{BMI} \geq 95^{\text{th}}$ percentile).[50–52] For the overall sample at baseline, 16.5% were overweight and 19.7% were obese. Thus, 36.2% were overweight or obese. Younger youths were heavier, as were males, minority youths and those from lower income families (data not shown).

Sleep Restriction—Data on psychiatric disorders were collected using the youth version of the DISC-IV, a highly structured instrument with demonstrated reliability and validity [53]. Interviews were conducted by college-educated, lay interviewers who had been extensively trained using protocols provided by Columbia University. Interviews with the DISC-IV were administered using laptop computers.

The DISC-IV does not inquire about symptoms of insomnia other than in the context of other DSM-IV disorders (such as mood or anxiety disorders). To supplement the DISC-IV, questions were included that inquired about symptoms of disturbed sleep, focusing primarily on symptoms of insomnia, their frequency and duration. Two questions inquired about hours of sleep on average the subject experienced on weeknights during the past 4 weeks and also on weekend nights. Six hours or less was defined as short sleep duration or restriction [7, 9, 39, 41, 47, 54]. The sleep items were taken from a variety of validated sleep questionnaires, including SleepEVAL [55, 56].

Covariates—Covariates identified as correlates of sleep (age, gender, family income, and depression) were included in analyses.

Family income was assessed using total household income in the past year: $<\$35,000$, $\$35,000 - \$64,999$, and $\$65,000$ or more.

Age was assessed by age at most recent birthdate: 12 or less, 13 – 15, and 16 or older.

Given earlier results on the association between sleep and depression in this sample, major depression, defined as meeting diagnostic criteria in the past year for a DSM-IV major depressive episode, was included as a covariate [57, 58].

Table 1 presents characteristics of the sample and cohort. As can be seen, the sample is diverse. In terms of hours of sleep, about 20% slept 6 hours or less on weeknights. About 9% slept 6 hours or less every night.

Analyses

First, the association between restricted sleep on weeknights or both weeknights and weekends and obesity at Wave 1 was examined, calculating crude odds ratios and then adjusted odds ratios controlling for age, gender, family income and major depression. Second, sleep restriction at Wave 1 was used to predict obesity at Wave 2, first examining

crude odds ratios and then adjusted odds ratios controlling for the same covariates and obesity at baseline. This strategy was repeated using weight at Wave 1 to predict restricted sleep at Wave 2, controlling for sleep restriction at Wave 1.

The estimated odds ratios and their 95% confidence limits were calculated using survey logistic regression (Proc Surveylogistic) procedures in SAS V9.1 and Taylor series approximation to compute the standard error of the odds ratio [59]. Lepkowski and Bowles have indicated that the difference in computing standard error between this method and other repeated replication methods such as the jackknife is very small [60].

Results

As can be seen in Table 2, there is no cross-sectional association between either measure of restricted sleep and obesity in either bivariate or multivariate analyses.

Table 3 presents the prospective association between sleep restriction at baseline and obesity at Wave 2. Again, there is no increased crude or adjusted risk for obesity associated with prior sleep duration. The adjusted odds for short sleep all week was 1.85, which is not trivial. However, the confidence interval is quite large. This may be due to low power. It also could be the result of the effects of factors such as body image [58, 61], as well as unmeasured factors.

Table 4 presents the results of analyses to explore the effects of obesity on subsequent risk of sleep restriction (Table 4). Once again, there is no association between obesity and sleep duration. Odds all cluster near 1.0.

Discussion

As noted in the introduction, there have been few studies of sleep disturbance and weight in adolescents, and only one using cohort or prospective designs. Calamaro et al. (2010) found no association in multivariate analyses between less than 6 hours of sleep per night and risk of obesity a year later [41]. Thus, two prospective studies of adolescents have found no association between restricted sleep and adolescent obesity.

Two prospective studies of preadolescents have yielded mixed results. Seegers et al. (2011) report that shorter sleep duration trajectories from age 10 to 11 increased risk of overweight and obesity at age 13 [62]. On the other hand, Bell and Zimmerman (2010) found that shorter sleep duration at baseline increased risk of overweight and obesity for children 0–4 years of age. However, baseline sleep was not associated with subsequent weight status for ages 5–13 [63].

There have been several prospective studies of adults. Lauderdale et al. found no effect of sleep duration at baseline and weight 5 years later in a cohort 18 – 30 years of age at baseline [44]. Stranges et al. found no effects of restricted sleep on either changes in body weight or incidence of obesity at follow-up in a cohort with mean age of about 55 at baseline [43]. Gangswich et al. also found no effect of sleep duration at baseline on future changes in BMI in an adult cohort with a mean follow-up of 8 – 10 years [64]. Eisenmann et al.

reported the sleep/weight association was observed for boys, but not girls [38]. Hasler et al. found short sleep at baseline increased risk of subsequent obesity in a 13-year prospective study of young adults [42].

Prospective results from the TH2K follow-up study of one year on youths 11 – 17 at baseline mirrors those from most studies of adults, suggesting that future obesity risk is not affected by sleep duration. Further, the results of this study also suggest obesity does not affect risk of future sleep duration. Thus, unlike Hasler et al. in their cohort study of young adults, the current study finds no evidence for a bi-directional association between sleep duration and obesity [42].

Since virtually all research on sleep duration and weight in adolescents has been cross-sectional, this study also examined the association between sleep duration and weight in adolescents using only data from Wave I and found no association. These results differ considerably from other cross-sectional studies of adolescents. For example, four studies have reported an association between short sleep duration and obesity in samples including only adolescents [35–37, 39]. One of those reported this effect was limited to male adolescents [36].

Three other studies did not report results separately for children and adolescents. All reported restricted sleep was associated with increased odds of overweight/obesity [38, 65]. Since no data were reported for adolescents per se in these studies, no direct comparisons can be made with the results of this study.

As noted earlier, sleep items for this study asked whether subjects had experienced symptoms almost every day for the past 4 weeks. Thus, results are limited in that it was not possible to date onset and partition the study sample into those with acute versus chronic restricted sleep. Buysse et al. found differential results related to duration of insomnia among young adults [66]. Reviews by Gangwisch and Horne conclude that the effects of sleep duration on weight probably is limited to long-term chronic sleep deprivation [64, 67]. Additionally, the current study did not examine whether risk-factor profiles differed for those with sleep disturbance of shorter and longer duration (longer than 24 months), although it might be expected that the association with somatic, psychological, and interpersonal functioning would be pronounced for chronic sleep problems of longer duration.

There is also evidence, albeit limited, that sleep duration is only one of potentially many sleep dimensions which could affect risk for obesity in children and adolescents. Jarrin et al. (2013) examined the association of 10 measures of sleep duration, sleep disturbance, sleep quality and sleep patterns with adiposity and body composition in children and adolescents. Sleep duration was not associated with obesity. However, poorer sleep quality, more sleep disturbance, and a delayed sleep phase pattern were independently associated with measures of obesity [68].

Another limitation is that objective data on disturbed sleep were not part of this study. That is, physiologic studies were not included. However, there are data suggesting that subjective

measures of sleep from children and adolescents are modestly correlated with objective measures of disturbed sleep [69, 70].

Questions might arise about sample design. To compensate for the fact that an area probability design was not employed for this study, the sample was post-stratified to approximate the age, gender and ethnic composition of the metropolitan population 11–17. The weighted sample closely approximated the age, gender and ethnic composition of the five-county metropolitan area. Follow-up rate was 75%, which raises the issue of potential bias. However, in a previous paper data demonstrated that the Wave 1 sample and the baseline data for the Wave 1 – Wave 2 cohort were highly comparable, indicating little bias was introduced by attrition [47]. There also was no bias evident in prevalence rates for restricted sleep in Wave 1 and 2.

This study did not interview parents about either sleep disturbance or weight in their adolescents. Although there is an argument that data from multiple informants are desirable, many studies have demonstrated considerable discordance in parent-child reports of youth problems [69, 71]. Therefore, only data from youth were used for this study.

This study is the second to examine the prospective association between sleep deprivation and obesity in adolescents and the first to directly investigate whether there is a reciprocal effect. The results show no association between obesity and sleep deprivation, either cross-sectionally or prospectively. Prior obesity did not increase subsequent risk of sleep deprivation and the reverse also was true.

To date, 3 studies of adults report negative prospective results [43, 44, 64]. Only 1 study reports results supporting a prospective association between sleep deprivation and subsequent obesity [42]. Two prospective studies of adolescents (including the current study) have been done, and the results are negative. And although cross-sectional studies of adolescents consistently report an association between sleep deprivation and weight, the number of studies is quite limited. Even here, 2 studies report gender differences, with the effect observed limited to boys.

Based on the evidence available, it seems premature to argue that sleep duration plays a role in the etiology of obesity. Based on his review, Horne reaches the same conclusion, for children, adolescents and adults [67]. A fundamental requisite for such an inference is evidence for a temporal association between exposure (sleep duration, in this case) and outcome (obesity, in this case). The bulk of the prospective evidence, including current study results, strongly suggests there is no such effect.

Magee et al. have discussed in detail the methodological problems that characterize much of the literature on sleep restriction and obesity [72]. Chief among these are (1) reliance on cross-sectional designs, (2) reliance on measurement of obesity using BMI, and (3) reliance on self-reports of sleep problems, and (4) lack of consideration of potential confounding variables drawn from lifestyle, behavioral, health and environmental domains. Our study was a cohort study and we addressed more confounders than most studies (e.g. depression). But results must be tempered by the fact that this study measured obesity using only measured BMI and sleep using only self-reports of sleep quantity and quality. Future

research should attempt to correct these issues, following the suggestions of Magee et al. [72].

The results of this study extend the available data on sleep and obesity and are the first prospective reciprocal evidence from adolescents on this question. The evidence at this point does not suggest an etiologic role for sleep duration in obesity. Clearly, more data are needed on the prospective, reciprocal association between these major public health problems in adolescence. What is needed as well are studies which examine developmental trajectories of sleep and weight from childhood through adolescence and into adulthood.

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References

1. Carskadon MA, Acebo C, Jenni OG. Regulation of adolescent sleep: implications for behavior. *Annals of the New York Academy of Sciences*. 2004; 1021:276–291. [PubMed: 15251897]
2. National Sleep Foundation. 2006 Sleep in America Poll. Washington, DC: National Sleep Foundation; 2006.
3. Crowley SJ, Acebo C, Carskadon MA. Sleep, circadian rhythms, and delayed phase in adolescence. *Sleep medicine*. 2007; 8:602–612. [PubMed: 17383934]
4. Johnson EO, Roth T, Breslau N. The association of insomnia with anxiety disorders and depression: exploration of the direction of risk. *Journal of psychiatric research*. 2006; 40:700–708. [PubMed: 16978649]
5. Roberts RE, Roberts CR, Chan W. Ethnic differences in symptoms of insomnia among adolescents. *Sleep*. 2006; 29:359–365. [PubMed: 16553022]
6. Gradisar M, Gardner G, Dohnt H. Recent worldwide sleep patterns and problems during adolescence: a review and meta-analysis of age, region, and sleep. *Sleep medicine*. 2011; 12:110–118. [PubMed: 21257344]
7. Roberts RE, Roberts CR, Xing Y. Restricted sleep among adolescents: prevalence, incidence, persistence, and associated factors. *Behavioral sleep medicine*. 2011; 9:18–30. [PubMed: 21218291]
8. Carskadon, MA. Factor influencing sleep patterns of adolescents. In: Carskadon, MA., editor. *Adolescent sleep patterns: biological, social, and psychological influences*. New York: Cambridge University Press; 2002. p. 4–26.
9. Fredriksen K, Rhodes J, Reddy R, Way N. Sleepless in Chicago: tracking the effects of adolescent sleep loss during the middle school years. *Child development*. 2004; 75:84–95. [PubMed: 15015676]
10. Colten, HR.; Altevogt, BM. *Sleep disorders and sleep deprivation: an unmet public health problem*. Washington, DC: The National Academic Press, Institute of Medicine; 2006.
11. Roberts RE, Roberts CR, Chen IG. Functioning of adolescents with symptoms of disturbed sleep. *Journal of Youth and Adolescence*. 2001; 30:1–18.
12. Gillen-O'Neel C, Huynh VW, Fuligni AJ. To study or to sleep? The academic costs of extra studying at the expense of sleep. *Child development*. 2013; 84:133–142. [PubMed: 22906052]
13. Kelly RJ, El-Sheikh M. Reciprocal relations between children's sleep and their adjustment over time. *Developmental psychology*. 2014; 50:1137–1147. [PubMed: 24188035]
14. McKnight-Eily LR, Eaton DK, Lowry R, Croft JB, Presley-Cantrell L, Perry GS. Relationships between hours of sleep and health-risk behaviors in US adolescent students. *Preventive medicine*. 2011; 53:271–273. [PubMed: 21843548]

15. Dahl RE, Lewin DS. Pathways to adolescent health sleep regulation and behavior. *The Journal of adolescent health : official publication of the Society for Adolescent Medicine*. 2002; 31:175–184. [PubMed: 12470913]
16. Millman RP. Excessive sleepiness in adolescents and young adults: causes, consequences, and treatment strategies. *Pediatrics*. 2005; 115:1774–1786. [PubMed: 15930245]
17. Dags N, McGlinchey EL, Talbot LS, Kaplan KA, Dahl RE, Harvey AG. Double trouble? The effects of sleep deprivation and chronotype on adolescent affect. *Journal of child psychology and psychiatry, and allied disciplines*. 2012; 53:660–667.
18. McGlinchey EL, Talbot LS, Chang KH, Kaplan KA, Dahl RE, Harvey AG. The effect of sleep deprivation on vocal expression of emotion in adolescents and adults. *Sleep*. 2011; 34:1233–1241. [PubMed: 21886361]
19. Talbot LS, McGlinchey EL, Kaplan KA, Dahl RE, Harvey AG. Sleep deprivation in adolescents and adults: changes in affect. *Emotion (Washington, DC)*. 2010; 10:831–841.
20. Baum KT, Desai A, Field J, Miller LE, Rausch J, Beebe DW. Sleep restriction worsens mood and emotion regulation in adolescents. *Journal of child psychology and psychiatry, and allied disciplines*. 2014; 55:180–190.
21. Chen X, Beydoun MA, Wang Y. Is sleep duration associated with childhood obesity? A systematic review and meta-analysis. *Obesity (Silver Spring, Md)*. 2008; 16:265–274.
22. Patel SR, Hu FB. Short sleep duration and weight gain: a systematic review. *Obesity*. 2008; 16:643–653. [PubMed: 18239586]
23. Cappuccio FP, Taggart FM, Kandala NB, Currie A, Peile E, Stranges S, et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep*. 2008; 31:619–626. [PubMed: 18517032]
24. Knutson KL, Van Cauter E. Associations between sleep loss and increased risk of obesity and diabetes. *Annals of the New York Academy of Sciences*. 2008; 1129:287–304. [PubMed: 18591489]
25. Marshall NS, Glozier N, Grunstein RR. Is sleep duration related to obesity? A critical review of the epidemiological evidence. *Sleep medicine reviews*. 2008; 12:289–298. [PubMed: 18485764]
26. Hart CN, Jelalian E. Shortened sleep duration is associated with pediatric overweight. *Behavioral sleep medicine*. 2008; 6:251–267. [PubMed: 18853308]
27. Van Cauter E, Knutson KL. Sleep and the epidemic of obesity in children and adults. *European journal of endocrinology / European Federation of Endocrine Societies*. 2008; 159(Suppl 1):S59–S66. [PubMed: 18719052]
28. Nielsen LS, Danielsen KV, Sorensen TI. Short sleep duration as a possible cause of obesity: critical analysis of the epidemiological evidence. *Obesity reviews : an official journal of the International Association for the Study of Obesity*. 2011; 12:78–92. [PubMed: 20345429]
29. Reilly JJ, Armstrong J, Dorosty AR, Emmett PM, Ness A, Rogers I, et al. Early life risk factors for obesity in childhood: cohort study. *BMJ*. 2005; 330:1357. [PubMed: 15908441]
30. Snell EK, Adam EK, Duncan GJ. Sleep and the body mass index and overweight status of children and adolescents. *Child development*. 2007; 78:309–323. [PubMed: 17328707]
31. Touchette E, Petit D, Tremblay RE, Boivin M, Falissard B, Genolini C, et al. Associations between sleep duration patterns and overweight/obesity at age 6. *Sleep*. 2008; 31:1507–1514. [PubMed: 19014070]
32. Taveras EM, Rifas-Shiman SL, Oken E, Gunderson EP, Gillman MW. Short sleep duration in infancy and risk of childhood overweight. *Archives of pediatrics & adolescent medicine*. 2008; 162:305–311. [PubMed: 18391138]
33. Gillman MW, Rifas-Shiman SL, Kleinman K, Oken E, Rich-Edwards JW, Taveras EM. Developmental origins of childhood overweight: potential public health impact. *Obesity (Silver Spring, Md)*. 2008; 16:1651–1656.
34. Sekine M, Yamagami T, Handa K, Saito T, Nanri S, Kawaminami K, et al. A dose-response relationship between short sleeping hours and childhood obesity: results of the Toyama Birth Cohort Study. *Child: care, health and development*. 2002; 28:163–170.

35. Gupta NK, Mueller WH, Chan W, Meiningner JC. Is obesity associated with poor sleep quality in adolescents? *American journal of human biology : the official journal of the Human Biology Council*. 2002; 14:762–768. [PubMed: 12400037]
36. Knutson KL. Sex differences in the association between sleep and body mass index in adolescents. *The Journal of pediatrics*. 2005; 147:830–834. [PubMed: 16356441]
37. Chen MY, Wang EK, Jeng YJ. Adequate sleep among adolescents is positively associated with health status and health-related behaviors. *BMC public health*. 2006; 6:59. [PubMed: 16524482]
38. Eisenmann JC, Ekkekakis P, Holmes M. Sleep duration and overweight among Australian children and adolescents. *Acta paediatrica (Oslo, Norway : 1992)*. 2006; 95:956–963.
39. Seicean A, Redline S, Seicean S, Kirchner HL, Gao Y, Sekine M, et al. Association between short sleeping hours and overweight in adolescents: results from a US Suburban High School survey. *Sleep & breathing = Schlaf & Atmung*. 2007; 11:285–293. [PubMed: 17440761]
40. Cuypers K, Kvaloy K, Bratberg G, Midthjell K, Holmen J, Holmen TL. Being normal weight but feeling overweight in adolescence may affect weight development into young adulthood-an 11-Year followup: the HUNT Study, Norway. *Journal of obesity*. 2012; 2012:601872. [PubMed: 22666556]
41. Calamaro CJ, Park S, Mason TB, Marcus CL, Weaver TE, Pack A, et al. Shortened sleep duration does not predict obesity in adolescents. *Journal of sleep research*. 2010; 19:559–566. [PubMed: 20545836]
42. Hasler G, Buysse DJ, Klaghofer R, Gamma A, Ajdacic V, Eich D, et al. The association between short sleep duration and obesity in young adults: a 13-year prospective study. *Sleep*. 2004; 27:661–666. [PubMed: 15283000]
43. Stranges S, Cappuccio FP, Kandala NB, Miller MA, Taggart FM, Kumari M, et al. Cross-sectional versus prospective associations of sleep duration with changes in relative weight and body fat distribution: the Whitehall II Study. *American journal of epidemiology*. 2008; 167:321–329. [PubMed: 18006903]
44. Lauderdale DS, Knutson KL, Rathouz PJ, Yan LL, Hulley SB, Liu K. Cross-sectional and longitudinal associations between objectively measured sleep duration and body mass index: the CARDIA Sleep Study. *American journal of epidemiology*. 2009; 170:805–813. [PubMed: 19651664]
45. Andrews, FF.; Morgan, JN. Multiple classification analysis. In: Andrews, FF.; Morgan, JN., editors. *Multiple classification analysis: a report on a computer program for multiple regression using categorical predictors*. 2nd ed.. Ann Arbor, MI: Institute for Social Research, University of Michigan; 1973.
46. Roberts RE, Roberts CR, Chan W. One-year incidence of psychiatric disorders and associated risk factors among adolescents in the community. *Journal of child psychology and psychiatry, and allied disciplines*. 2009; 50:405–415.
47. Roberts RE, Roberts CR, Duong HT. Sleepless in adolescence: prospective data on sleep deprivation, health and functioning. *Journal of adolescence*. 2009; 32:1045–1057. [PubMed: 19361854]
48. Lohman, TG.; Roche, AF.; Martorell, R. *Anthropometric standardization reference manual*. Champaign, Ill: Human Kinetics Books; 1991.
49. Armstrong, N.; Welsman, J. *Young People and Physical Activity*. Oxford: Oxford University Press; 1997.
50. Centers for Disease Control and Prevention. BMI — body mass index: About BMI for children and teens.
51. Ogden CL, Carroll MD, Flegal KM. High body mass index for age among US children and adolescents, 2003–2006. *Jama*. 2008; 299:2401–2405. [PubMed: 18505949]
52. National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults-teh evidence report. *Obesity Research*. 1998; 6:51S–209S. [PubMed: 9813653]
53. Shaffer D, Fisher P, Lucas CP, Dulcan MK, Schwab-Stone ME. NIMH Diagnostic Interview Schedule for Children Version IV (NIMH DISC-IV): description, differences from previous

- versions, and reliability of some common diagnoses. *Journal of the American Academy of Child and Adolescent Psychiatry*. 2000; 39:28–38. [PubMed: 10638065]
54. Noland H, Price JH, Dake J, Telljohann SK. Adolescents' sleep behaviors and perceptions of sleep. *The Journal of school health*. 2009; 79:224–230. [PubMed: 19341441]
 55. Ohayon MM, Roberts RE. Comparability of sleep disorders diagnoses using DSM-IV and ICSD classifications with adolescents. *Sleep*. 2001; 24:920–925. [PubMed: 11766162]
 56. Ohayon MM, Roberts RE, Zulley J, Smirne S, Priest RG. Prevalence and patterns of problematic sleep among older adolescents. *Journal of the American Academy of Child and Adolescent Psychiatry*. 2000; 39:1549–1556. [PubMed: 11128333]
 57. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 4th ed.. Washington, DC: American Psychiatric Association; 2000. text revision
 58. Roberts RE, Duong HT. Perceived weight, not obesity, increases risk for major depression among adolescents. *Journal of psychiatric research*. 2013; 47:1110–1117. [PubMed: 23643102]
 59. SAS Institute. *SAS/STAT 9.1: User's Guide*. Cary, NC: SAS Pub; 2004.
 60. Lepkowski, J.; Bowles, J. *Survey Statistician*. University of Michigan: International Association of Survey Statisticians (IASS); 1996. Sampling error software for personal computers; p. 10-17.
 61. Duong HT, Roberts RE. Perceived weight in youths and risk of overweight or obesity six years later. *Journal of psychosomatic research*. 2014; 76:23–27. [PubMed: 24360137]
 62. Seegers V, Petit D, Falissard B, Vitaro F, Tremblay RE, Montplaisir J, et al. Short sleep duration and body mass index: a prospective longitudinal study in preadolescence. *American journal of epidemiology*. 2011; 173:621–629. [PubMed: 21303806]
 63. Bell JF, Zimmerman FJ. Shortened nighttime sleep duration in early life and subsequent childhood obesity. *Archives of pediatrics & adolescent medicine*. 2010; 164:840–845. [PubMed: 20819966]
 64. Gangwisch JE, Malaspina D, Babiss LA, Opler MG, Posner K, Shen S, et al. Short sleep duration as a risk factor for hypercholesterolemia: analyses of the National Longitudinal Study of Adolescent Health. *Sleep*. 2010; 33:956. [PubMed: 20614855]
 65. Ozturk A, Mazicioglu M, Poyrazoglu S, Cicek B, Gunay O, Kurtoglu S. The relationship between sleep duration and obesity in Turkish children and adolescents. *Acta paediatrica (Oslo, Norway : 1992)*. 2009; 98:699–702.
 66. Buysse DJ, Angst J, Gamma A, Ajdacic V, Eich D, Rössler W. Prevalence, course, and comorbidity of insomnia and depression in young adults. *Sleep*. 2008; 31:473. [PubMed: 18457234]
 67. Horne J. Obesity and short sleep: unlikely bedfellows? *Obesity reviews : an official journal of the International Association for the Study of Obesity*. 2011; 12:e84–e94. [PubMed: 21366837]
 68. Jarrin DC, McGrath JJ, Drake CL. Beyond sleep duration: distinct sleep dimensions are associated with obesity in children and adolescents. *International journal of obesity (2005)*. 2013; 37:552–558. [PubMed: 23419602]
 69. Sadeh A, McGuire JP, Sachs H, Seifer R, Tremblay A, Civita R, et al. Sleep and psychological characteristics of children on a psychiatric inpatient unit. *Journal of the American Academy of Child and Adolescent Psychiatry*. 1995; 34:813–819. [PubMed: 7608056]
 70. Short MA, Gradisar M, Lack LC, Wright H, Carskadon MA. The discrepancy between actigraphic and sleep diary measures of sleep in adolescents. *Sleep medicine*. 2012; 13:378–384. [PubMed: 22437142]
 71. Roberts RE, Alegria M, Roberts CR, Chen IG. Concordance of reports of mental health functioning by adolescents and their caregivers: a comparison of European, African and Latino Americans. *The Journal of nervous and mental disease*. 2005; 193:528–534. [PubMed: 16082297]
 72. Magee CA, Iverson DC, Huang XF, Caputi P. A link between chronic sleep restriction and obesity: methodological considerations. *Public health*. 2008; 122:1373–1381. [PubMed: 18722633]

Highlights

- There was no cross-sectional association between sleep restriction and obesity.
- In cohort analyses, sleep restriction did not increase future risk of obesity.
- Obesity did not increase future risk of sleep restriction.
- These null results call into question previous research on this topic.

Table 1

Un-weighted sample (N=4175) characteristics, Teen Health 2000 Wave 1.

Characteristics		Wave I (%)
Gender of Youth	Male	51.14
	Female	48.86
Age of Youth	16 +	24.91
	Between 13 and 15	48.05
	12 or less	27.04
Ethnicity of Youth	European American	35.43
	African American	35.35
	Latino American	24.57
	Other	4.65
Family Income	\$65,000 +	35.29
	\$ 35,000 – \$ 64,999	40.71
	< \$35,000	24.00
Parental Marital Status	Married	75.71
	Others	24.29
Sleep Deprivation Weeknights	6 hours	19.83
	7–8 hours	52.51
	9+ hours	27.66
Past Month Weight	Healthy Weight	61.0
	Overweight (95 th >BMI 85 th)	18.2
	Obese (BMI 95 th)	20.8

Table 2

Odds Ratios for the Association between Sleep Deprivation and Obesity (Wave 1).

Sleep Deprivation at Wave 1	Weight Status at Wave 1			
	Crude OR, 95% C.I.		Adjusted* OR, 95% C.I.	
	Healthy Weight	Obese	Healthy Weight	Obese
Sleep Restriction WN/WE	1	1.19 (0.88–1.61)	1	1.16 (0.84–1.60)
Sleep Restriction WN	1	1.13 (0.91–1.39)	1	1.16 (0.91–1.47)

Sleep Restriction WN/WE = Sleep 6 hours or less on weeknights and weekends.

Sleep Restriction WN = Sleep 6 hours or less on weeknights.

* : Adjusting for age, gender, family income and major depression.

† : Odds ratios are statistically significant ($p < 0.05$).

Table 3

Odds Ratios for the Association Between Sleep Deprivation at Wave 1 and Obesity at Wave 2.

Sleep Deprivation at Wave 1	Weight Status at Wave 2			
	Crude OR, 95% C.I.		Adjusted* OR, 95% C.I.	
	Healthy Weight	Obese	Healthy Weight	Obese
Sleep Restriction WN/WE	1	1.29 (0.90–1.84)	1	1.85 (0.91–3.73)
Sleep Restriction WN	1	1.07 (0.83–1.39)	1	0.92 (0.56–1.52)

Sleep Restriction WN/WE = Sleep 6 hours or less on weeknights and weekends.

Sleep Restriction WN = Sleep 6 hours or less on weeknights.

* : Adjusting for age, gender, family income, major depression and weight status at Wave 1.

† : Odds ratios are statistically significant ($p < 0.05$).

Table 4

Odds Ratios for the Association Between Obesity at Wave 1 and Sleep Deprivation at Wave 2.

Weight Status at Wave 1	Sleep Deprivation at Wave 2			
	Crude OR, 95% C.I.		Adjusted* OR, 95% C.I.	
	Sleep Restriction WN/WE	Sleep Restriction WN	Sleep Restriction WN/WE	Sleep Restriction WN
Healthy Weight	1	1	1	1
Obese	1.04 (0.76–1.42)	1.06 (1.09–1.34)	0.97 (0.69–1.37)	1.11 (0.86–1.43)

Short Sleep WN/WE = Sleep 6 hours or less on weeknights and weekends.

Short Sleep WN = Sleep 6 hours or less on weeknights.

* : Adjusting for age, gender, family income, major depression and sleep deprivation at Wave 1.

† : Odds ratios are statistically significant ($p < 0.05$).