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Weight gain in first-semester university students: Positive sleep and diet practices associated with protective effects

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Title: Weight gain in first-semester university students: Positive sleep and diet practices associated with protective effects

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Abstract

For university students, alterations in sleep and diet quality are common, and the propensity for weight gain is well established. The role of sleep duration during periods of rapid weight gain is understudied. This study explored the relationships between sleep duration, diet patterns, and body composition in first-year university students. Data collection occurred during the beginning of the fall (August) and spring semesters (January). Anthropometric measures included weight, height, and percent body fat (%BF). Survey questions assessed sleep and diet quality. As a group, participants (N = 60) gained weight (1.8 ± 2.1 kg) over the 4.5-month period of study. Hierarchical cluster analysis (HCA) identified three groups based on weight change between baseline and follow-up visits. Group 1 ("maintainers") (N = 21) gained 0.1 ± 1.3 kg, group 2 ("modest gainers") (N = 24) gained 2.0 ± 1.7 kg, and group 3 ("major gainers") (N = 15) gained 3.8 ± 1.8 kg. No differences in weight, body mass index (BMI), %BF, or average sleep duration existed between clusters at baseline. Minimal differences in baseline dietary behaviors between groups were noted other than maintainers used more fat, e.g., butter, to season vegetables, bread, and potatoes compared to modest gainers (p = 0.010). At follow-up, sleep duration significantly decreased from baseline among major gainers (7.1 ± 0.7 vs. 6.8 ± 0.7 h; p = 0.017) while sleep duration increased from baseline among maintainers (7.3 ± 0.9 vs. 7.6 ± 1.0 h, p = 0.048). Sleep duration at follow-up was significantly shorter among major gainers compared to maintainers (p = 0.016). Total diet scores for maintainers and modest gainers improved between visits (p = 0.038 and 0.002, respectively) but did not change among major gainers. Combining sleep and diet

education may increase the effectiveness of interventions designed to mitigate weight gain in this high-risk population.

Key words: sleep; diet quality; weight gain; college students; public health

1 Introduction

Dietary behaviors play an important role in determining body weight and body composition [1]. While these relationships are well established, more recent data suggest that sleep is also associated with these factors. Recent meta-analyses suggest that shorter sleep duration is correlated with higher body mass index (BMI) [2–7], with the strongest associations observed in younger children, adolescents, and young adults. Most studies examining weight gain longitudinally have lengthy follow-up times (e.g., 3.4 years) [6], obscuring the time course of weight change. Since first-year university students are at increased risk of gaining weight over the course of the academic year [8,9], including during the first semester [10], they are an ideal population to assess associations between sleep, diet, and weight changes over a shorter time frame.

Guidelines put forth by the National Sleep Foundation in the United States (US) recommend that adults ages 18-25 should sleep 7-9 hours per night [11]. Popular thought frequently associates college life with "all nighters" and other behaviors not conducive to adequate sleep. Contrary to this perception, evidence suggests that the majority of college students, both in the US and abroad, appear to meet sleep recommendations; however, some students do not. The prevalence of failing to meet sleep recommendations ranges from 12 – 40%, depending on the definition of insufficient sleep used in these studies [12–15]. Given the associations between sleep duration and BMI [2–7], students who do not meet sleep recommendations may be at higher risk for weight gain.

Cross-sectional reports frequently identify negative correlations between self-reported sleep duration and adiposity [13,16–19], but few longitudinal studies have examined relationships between sleep duration and weight or body composition in college students.

The findings of these studies are mixed [20–22]. Several factors could contribute to these variable results. First, the duration and design of the studies differed, ranging from approximately 12 days [22] to 9 weeks [20] to 6 months retrospectively and prospectively [21]. Second, retrospective studies can suffer from recall bias. Third, weight information was self-reported in one study [20], which could be subject to misreporting. Thus, given the varying study designs, contradicting results are not surprising.

The purpose of this study was to examine relationships between self-reported sleep duration, dietary behaviors, and objectively measured body composition over the course of an academic semester (late August/early September – January). The primary hypothesis was that students reporting the least amount of sleep would gain the most weight – predominantly as body fat – over the study's time course. A secondary hypothesis was that desirable dietary behaviors would decrease in those who gained the most weight, given the associations between poorer diet quality and obesity [23].

2 Methods

2.1 Participants

As part of a larger investigation [10], newly enrolled first-year students living on the campus of a large, Midwestern university were invited to participate via flyers, social media, e-mail, and new-student orientation activities. Participants were informed that anthropometric measurements would be taken, but study advertising emphasized an interest in characterizing health patterns to avoid self-selection bias of students only concerned about weight. For inclusion in the study, participants had to: be ≥ 18 years old; live on-campus; not be pregnant or planning pregnancy; weigh ≤ 250 kg (scale capacity);

and have no implanted medical device(s) (contraindicated for bioelectrical impedance analysis (BIA) testing).

2.2 Testing Protocol

The study lasted 4.5 months. Baseline testing occurred in late August/early September (beginning of the academic year) with follow-up in mid-January (after winter holidays). Each visit consisted of body composition measurement and survey completion. Upon providing written informed consent, participants came to the laboratory twice for testing and were instructed not to exercise or eat or drink anything except water for at least two hours prior to each visit to minimize errors in body composition testing [24].

2.2.1 Measures of sleep and dietary patterns

Two survey questions assessed sleep duration. The first question, taken from the Youth Risk Behavior Survey asked: “On an average night, how many hours of sleep do you get?” [25]. When answering the question, participants were instructed to think about the last 7 days. The second question asked: “How many hours of sleep did you get last night?”, and is frequently used in sleep research, e.g., [26–29]. Diet was assessed using the validated Starting the Conversation (STC) food frequency questionnaire [30]. The STC survey consists of eight questions and was found to be sensitive to changes in dietary patterns over a four-month period [30]. Questions on the STC survey ask about consumption of fast food; fruit; vegetables; soda and sweet tea; beans, chicken, or fish; snack chips or crackers; desserts and other sweets; and butter, margarine, or meat fat used to season breads, vegetables, or potatoes. The answers to these questions were summed to provide a total diet quality score; a lower score indicates a more healthful diet (minimum = 0, maximum = 16) [30]. The university’s institutional review board approved the study, and all participants received a small item (e.g., Frisbee, t-shirt) for their participation after each visit.

2.2.2 Anthropometric measures

Anthropometric indices were assessed by measuring height to the nearest 0.1 cm using a stadiometer and weight to the nearest 0.1 kg using a calibrated electronic scale coupled with the BIA machine. BMI was calculated from these measurements (kg/m^2). Percent body fat (%BF) was assessed by BIA (InBody 230; Biospace, Seoul, Korea). Participants wore compression shorts/tops to provide consistency in apparel worn during testing.

2.3 Data analysis

Data were analyzed using IBM SPSS Statistics (version 24.0, IBM Corporation, 2015). Data are presented as mean ± standard deviation (SD). Hierarchical cluster analysis (HCA) was used to place similar participants into groups that significantly differed by the amount of weight change between baseline and follow-up. The HCA technique allows for data exploration without requiring *a priori* decisions regarding the number of clusters [31,32]. Appropriate cut-offs for cluster membership were based on numerical (agglomeration schedule) and visual (dendrogram) output. Differences between groups were evaluated using ANOVA and Tukey's HSD post hoc tests. Within each group, comparisons between baseline and follow-up were assessed using paired t-tests [33]. Given the small number of males who completed testing, and that interpretation of BMI, sleep duration, and STC scores did not vary by sex, data from males and females were combined. Statistical significance was determined by a two-tailed p-value ≤ 0.05.

3 Results

A total of 60 participants completed testing at both baseline and follow-up. The majority of the participants were female (N = 49, 82.0%) and white (N = 54, 90.0%). The average age was 18.1 ± 0.3 years at baseline. The range of weight change among participants spanned from -2.9 to +9.1 kg, with a mean weight change of 1.8 ± 2.1 kg. The majority of participants reported sleeping ≥ 7 h per night the week prior to testing (N = 42, 70.0%), and a similar number reported sleeping ≥ 7 h the night before testing (N = 41, 68.3%) ($p = 0.341$). Compared to baseline, 42 participants (70.0%) indicated that they slept ≥ 7 h per night the week prior to testing, while 46 (78.0%) reported sleeping ≥ 7 h the night before testing ($p < 0.001$) at the final visit. For the total group, sleep duration for both the night and week before testing were not significantly different compared to baseline (night before: 7.1 ± 0.9 h (baseline) vs. 7.2 ± 1.0 h (follow-up) ($p = 0.498$); weekly average: 7.1 ± 1.3 h (baseline) vs. 7.3 ± 1.2 h (follow-up) ($p = 0.633$)).

HCA identified three groups that differed in terms of weight change ($p < 0.003$ for all). Group 1 (“maintainers”) (N = 21) gained just 0.1 ± 1.3 kg. The two other groups both gained weight but differed by the amount gained. Group 2 (“modest gainers”) (N = 24) gained 2.0 ± 1.7 kg, while group 3 (“major gainers”) (N = 15) gained 3.8 ± 1.8 kg (Figure 1). No differences between weight, BMI, %BF, sleep duration the night before, or sleep duration the week before testing existed at baseline between the groups. Changes in %BF between baseline and follow-up occurred in both the modest (21.7 ± 9.6 vs. 25.9 ± 9.0, $p = 0.008$) and major gainers (24.1 ± 5.4 vs. 27.4 ± 6.3; $p < 0.001$).

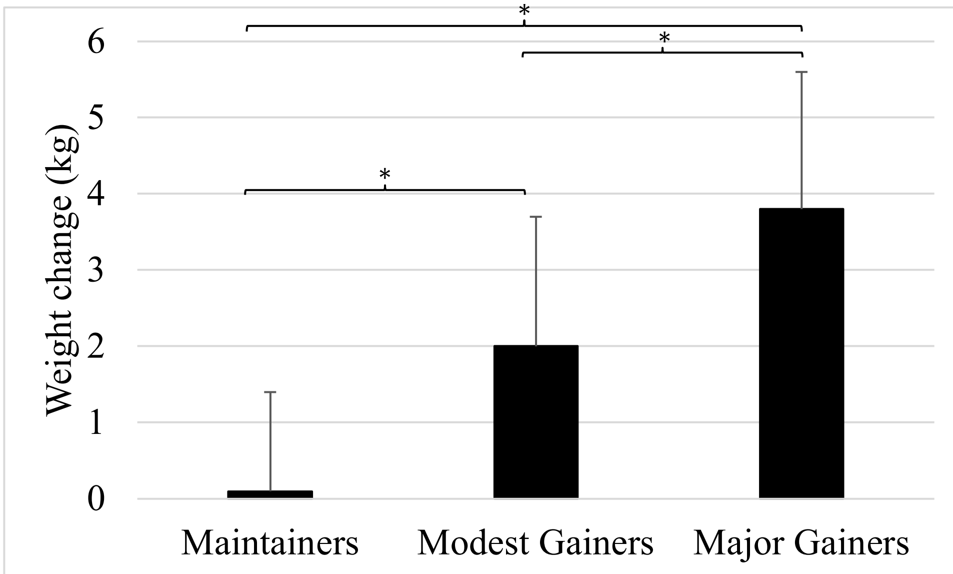

Figure 1. Weight change by the three groups identified by HCA (mean ± SD). All three groups differed in weight change. *Denotes $p<0.05$.

Changes in reported average nightly sleep duration over the past week were noted both within groups over time and between groups at follow-up. Average nightly sleep duration significantly decreased from baseline for major gainers (7.1 ± 0.7 vs. 6.7 ± 0.8 h; p = 0.017) while sleep duration increased from baseline for maintainers (7.3 ± 0.9 vs. 7.6 ± 1.0 h, p = 0.048). No differences in sleep duration were noted at baseline, but sleep duration at follow-up was nearly an hour shorter among major gainers compared to maintainers (6.7 ± 0.8 h vs. 7.6 ± 1.0 h; p = 0.016). Modest gainers did not differ from either group, nor did they alter their sleep duration between baseline and follow-up (7.0 ± 1.0 h vs. 7.1 ± 1.0 h, p = 0.641). There were no differences in the previous night's reported sleep duration between groups or within groups over time.

In terms of dietary intake patterns, no differences in total STC scores were observed between groups at either baseline or follow-up (Table 1). However, both maintainers and modest gainers experienced significant improvements in total STC scores between the two visits (p = 0.038 and p = 0.002, respectively). While major gainers also reported improvement in total STC scores, the improvement was not significant. In terms of intake of specific foods, the only difference in dietary intake at baseline was that maintainers used more fat, e.g., butter, margarine, or meat fat to season vegetables, bread, and potatoes at baseline compared to modest gainers (p = 0.010). At follow-up, modest gainers reported consuming fewer desserts and sweets compared to major gainers (p = 0.047).

Table 1. Measurements of BMI, sleep duration, and STC score at baseline and follow-up by weight gain pattern

	Maintainers (N=21)		Modest Gainers (N=24)		Major Gainers (N=15)	
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up
BMI (kg/m^2)	23.2±3.1	23.3±3.2	22.5±2.9	23.1±3.1*	21.8±2.3	23.2±2.6*
Weekly average sleep duration (h)	7.3±0.9	7.6±1.0*$^{\#}$	7.0±1.0	7.1±1.0	7.1±0.7	6.7±0.8*$^{\#}$
STC score	8.6±3.1	7.3±2.8*	7.8±2.3	6.2±2.4*	7.6±2.2	7.0±2.7

Measures taken at baseline and follow-up based on the weight gain patterns identified by HCA. STC score reflects the sum of all responses from STC survey, with possible scores ranging from 0-16; higher scores reflect poorer dietary quality. *Denotes a significant change between baseline and follow-up. $^{\#}$Denotes a significant difference between groups. No differences between groups were observed at baseline.

4 Discussion

While long-term excess energy intake – derived from dietary choices and resulting patterns of intake – has a well-established role in weight gain [34], there is limited information regarding relationships between college students' sleep duration and weight gain over time. In this study, HCA was used to identify three categories of participants based on weight change during a 4.5-month period: maintainers, modest gainers, and major gainers. Significant differences in average nightly sleep duration over the past week were observed between maintainers and major gainers, and major gainers reported sleeping significantly less, while maintainers reported sleeping significantly more at follow-up. Maintainers and modest gainers reported improvements in STC scores, suggesting that a healthier diet was consumed, but unlike maintainers, modest gainers also experienced decreased sleep duration. Percent body fat increased for both modest and major gainers, indicating that the weight gained was comprised of more fat mass than lean body mass.

Insufficient sleep promotes weight gain through a variety of mechanisms. First, sleep curtailment results in increased sedentary behavior [7] and increased energy intake [35], favoring the consumption of carbohydrates and fat [36–39]. Second, appetite hormones are also negatively affected by sleep deficit [36,40–42]. Most proposed mechanisms whereby sleep curtailment leads to increased energy intake involve hedonic (eating for pleasure) rather than homeostatic (eating for hunger) drivers, with increased sensitivity to the rewarding properties of food [41,43,44]. Given this evidence, reduced sleep duration appears to prime individuals to make unhealthy food choices with negative consequences on body weight and composition. In the present study, significantly healthier dietary patterns emerged among maintainers and modest gainers over time. These same groups increased or maintained their sleep duration, respectively. Thus, improved dietary behaviors and protected sleep time were associated with lower weight gain in this population.

In terms of average nightly sleep duration over the past week, major gainers reported sleeping nearly an entire hour less per night than maintainers at follow-up (6.7 vs. 7.6 h), and maintainers reported increased sleep (7.3 vs. 7.6 h) at follow-up. The relationship between BMI and sleep appears to be a U-shaped curve, with an ideal amount between 7-8 h/night and problems occurring with too much or too little [5]. Whether the slight increase in sleep duration by maintainers or simply maintaining sleep duration within the recommended amount helped to protect against weight gain cannot be assessed due to the observational nature of the study. While it remains to be seen if increasing sleep duration facilitates weight loss [5,45], evidence suggests that college students are willing to change sleep behaviors. For example, students who received e-mail messages about the importance of sleep maintained their self-reported sleep duration over the course of the 10-month follow-up period, unlike the control group whose sleep duration decreased [46]. Others reported that two 90-minute programs reduced the latency of sleep onset [47]. Further work exploring how increasing sleep duration affects weight change is needed.

The self-reported sleep duration in this sample is in agreement with numerous studies among college-aged populations [12–15,48]. While self-reported sleep duration is frequently used as a measure of sleep time [49–51], little work has been done to compare self-reported sleep to objective measurements. One such study reported a moderate correlation (r=0.45) between self-reported sleep duration and objective measurement using actigraphy [52], while another reported correlations of 0.34 [53]. Another study observed that correlations between self-reported sleep and FitBit data ranged from 0.56 – 0.82 [54]. In all studies, participants were found to over-estimate the amount of sleep they actually experienced. Participants in this study may also have overestimated their sleep, but this overestimation likely pertains to participants in all three groups as, previously, the correlation between self-reported and actigraphy-measured sleep was not found to differ by BMI category [53].

4.1 Strengths and Limitations

The longitudinal design of this study is a strength. Much of the work on sleep and dietary intake or weight gain/status in this population has been cross sectional or of limited duration (i.e., 1 - 2 weeks) [13,16–19,22], making it difficult to assess true changes in fat mass over time. Additionally, the study's duration of 4.5 months allowed for the inclusion of recovery sleep on the weekends. Recovery sleep has been shown to be important in preventing insufficient-sleep-related weight gain [55].

The use of hierarchical cluster analysis to identify different weight change patterns is also a strength. HCA allows the researcher to select a variable or variables that can be used to group participants into clusters of individuals with similar response patterns [32]. These clusters then differ from each other, facilitating the exploration of which factors contribute to the observed differences.

Limitations of the study include a lack of sleep quality measures. Sleep quality, like sleep duration, has been negatively associated with BMI [19,56,57]. Sleep quality is not necessarily associated with quantity, as other sleep-related factors, such as depth and time spent in various sleep stages, can contribute to the perception of quality [11]. While sleep quality lacks generally agreed upon measures [58] making it difficult to quantify, the sleep quality of college students has been shown to be poor in segments of this population [15,59]. In order to parse how sleep duration and quality affect weight gain among university students, future work should explore these factors.

A further limitation stems from the fact that information on other behaviors and environmental factors that can contribute to weight gain, such as exercise, sedentary behavior, and stress were not monitored. These factors can also contribute to reductions in sleep duration and quality [60,61].

Finally, the use of a convenience sample of students responding to advertisements to participate in a research study about health may make generalization to a wider population difficult [62]; however, it is likely that these participants would bias the results in the direction of not observing differences. That is, if they are health conscious, they are likely to be eating better and engaging in more health promoting behaviors. Still, changes and differences were observed. The fact that our study population was lean and the lack of diversity in terms of sex and race should also be noted. Exploring if and how these factors might contribute to different results in a larger sample size is worthy of future consideration.

5 Conclusions

The relationships between sleep duration and weight gain among university students are not well understood. Among the three patterns of weight change identified, students who avoided major weight gain either maintained or increased their average weekly sleep duration and engaged in improved dietary behaviors. Future work examining objective sleep duration as well as objective and subjective sleep quality will provide additional insight into these relationships.

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