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The Impact of Sleep Improvement on Food Choices in Adolescents with an Eveningness Circadian Preference

By

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requirements for the degree of

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in

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Abstract

Purpose: The aim was to investigate the relationship between sleep and desire for and intake of weight gain promoting foods at pre-treatment and following an intervention designed to improve sleep in adolescents with late bedtimes.

Methods: A sample of adolescents with late bedtimes was randomized to an intervention designed to improve sleep (TranS-C-Youth) or a control condition (Psychoeducation) and their food desire and intake in the morning was assessed at pre-treatment and post-treatment.

Results: At pre-treatment more sleep was associated with increased desire for dairy. No effects on desire for and intake of weight promoting food were observed for TranS-C-Youth compared to Psychoeducation. Adolescents with earlier bedtimes at post-treatment relative to pre-treatment ate more low Glycemic Index and dairy foods at post-treatment. This effect was not observed in those who did not improve their bedtime at pre-treatment relative to post-treatment.

Conclusions: These findings suggest that bedtime improvement can improve breakfast choices, an important meal for obesity prevention during adolescence.

Keywords: eveningness, sleep, adolescent, food

The Impact of Sleep Improvement on Food Choices in Adolescents with an Eveningness Circadian Preference

The average adolescent in the United States sleeps approximately 7 hours during the school year (Asarnow, McGlinchey, & Harvey, 2014). This falls 2.25 hours short of the recommended 9 hours (Carskadon et al., 1980; Wolfson, & Carskadon, 1998). A tendency toward an *eveningness* circadian pattern, defined as an enduring pattern of late bedtime preference (Carskadon, Acebo, Richardson, Tate, & Seifer, 1997), combined with early school start times are thought to be major contributors to this sleep deficit. There are multiple other contributors to eveningness; specifically, with the onset and progression through puberty there is a biologic shift toward both going to sleep and getting up later which can be exacerbated by reduced parental monitoring and increased social influences, academic pressure and technology use (Carskadon et al., 1997; Carskadon, Mindell, & Drake, 2006). The combined picture is of concern given that both late bedtimes and short total sleep time (TST) are independently associated with a range of adverse outcomes (Asarnow, McGlinchey, & Harvey, 2014; Goldstein et al., 2007), including higher risk of obesity (Asarnow, McGlinchey, & Harvey, 2015; Olds, Maher & Matricciani, 2011)

Rates of obesity are rising rapidly among children and adolescents (National Center for Health Statistics, 2012; Wang & Lobstein, 2006). Eating behaviors tend to persist from adolescence into adulthood (Mikkilä, et al., 2005) and thus adolescence is a particularly important period for obesity prevention. Increased intake of low glycemic index (GI) foods has been linked to obesity prevention (Ludwig, 2002; Pi-Sunyer, 2002). GI is a measure of how quickly blood glucose levels (i.e., blood sugar) rise after eating a particular type of food. Low GI foods promote satiety by supporting fat instead of carbohydrate metabolism (Brand-Miller et al., 2002). Indeed, obese children who were given high GI breakfasts ate 53% more than those with medium or low GI breakfasts (Ludwig et al., 1999).

Interestingly, the accumulating evidence points to late bedtimes, less TST and sleepiness as independent risk factors for the selection and intake of more high GI foods and fewer low GI foods. Late bedtime on non-school days has been associated with greater “fast food” consumption in adolescents (Gianotti et al., 2002). Moreover, adolescents with late bedtimes ate fewer fruits and vegetables and consumed an average of 248 more calories per day relative to adolescents with earlier bedtimes (Baron et al., 2011). An experimental study involving adult participants found that one night of short TST resulted in increased intake of carbohydrates and fat, reduced protein intake, and increased caloric intake overall (Brondel et al., 2010). Moreover, Greer, Goldstein and Walker (2013) found that desire for weight-gain promoting foods increased after sleep deprivation in adults and was predicted by subjective sleepiness.

To our knowledge, there are no published investigations as to whether sleep improvement results in healthier food choices in adolescents. There are several reasons why it is especially important to determine whether an intervention to improve sleep is effective in improving food choice; first, food intake plays a key role in the development and maintenance of obesity (Hensrud, 2004), second, obesity has severe long-term negative health consequences (Franks et al., 2010; Ludwig et al., 2001) and third, there are few effective treatments for obesity (Thompson et al., 2007; Yanovski & Yanovski, 2014).

The present study was designed to address three aims within the context of a NICHD-funded randomized controlled trial (RCT) designed to improve sleep for 10-18 year olds who exhibit an eveningness circadian preference. Aim 1 was to investigate the association between desire for and intake of weight gain promoting foods in the morning (via a food-desire task and a

snack task) and three sleep and circadian markers assessed at pre-treatment. The hypothesis tested is that later bedtime, less TST, and increased sleepiness will be associated with greater desire for and greater intake of weight gain promoting foods in the morning. Aim 2 was to investigate whether a 6 week intervention specifically derived to improve sleep in adolescents who exhibit a tendency toward eveningness (the Transdiagnostic Sleep and Circadian Intervention; TranS-C-Youth) would be associated with decreased desire for and intake of weight gain promoting foods in the morning as compared to a comparison condition (Psychoeducation; PE). The hypothesis tested is that adolescents who receive TranS-C-Youth will display decreased desire for and intake of weight gain promoting foods as compared to the PE condition. Aim 3 was to investigate the effect of sleep improvement (indexed by three sleep and circadian markers), following 6 sessions of either treatment condition, on desire for and intake of weight gain promoting foods in the morning. The hypothesis tested is that sleep improvement from pre-treatment to post-treatment, across Treatment Groups, will be associated with decreased desire for and intake of weight gain promoting foods. This aim was included given prior research showing that PE can result in a clinical improvement in sleep (Clarke et al., 2015; Harvey et al., in press).

Methods

Participants

The data for the present study were collected as part of a larger research project. Adolescents were eligible for the study if they scored within the lowest quartile on the Children's Morningness Eveninigness Preference Scale (CMEP; Carskadon, Veira, & Acebo, 1993) and if their seven day sleep diary indicated a sleep onset time of 10:40 pm or later for 10 to 13 year olds, 11 pm or later for 14 to16 year olds, and 11:20 pm or later for 17 to18 year olds at least 3 nights per week. Also, the adolescent must have had the current pattern of late bedtimes for the last 3 months. Adolescents were ineligible to participate, if (a) they could not communicate in English or Spanish, (b) they had an active, progressive physical illness (e.g., cancer, respiratory disorder) or neurological degenerative disease directly related to the onset and course of the sleep disturbance, (c) there was evidence from clinical diagnosis or report by youth or parent of sleep apnea, restless legs or periodic limb movements during sleep, (d) they had mental retardation, autism spectrum disorder, or other significantly impairing pervasive developmental disorder, (e) there was evidence from clinical diagnosis or report by youth or parent of Bipolar Disorder or Schizophrenia, or (e) they had a history of substance dependence in the past six months.

Participants were recruited for the current study via administrators and parent groups at local high schools and middle schools. Advertisements were also placed on parent list serves, daily bulletins for students, flyering, Berkeley Parent Network, Craigslist and Facebook Ads.

Design

All procedures were approved by the University of California, Berkeley, Committee for the Protection of Human Subjects. Adolescents and parent/guardian were screened (after verbal consent) through a telephone interview to determine eligibility. Adolescents who were still eligible after screening were asked to fill out a sleep diary for seven days. If youth still met criteria, they and their parent were invited for an in-person assessment. The in-person assessment included a measure of the height and weight of youth and a three-item questionnaire that asked the participants and their parents whether they have any food allergies, dietary restrictions, or whether there are foods that they do not enjoy eating. These questions ensured that we do not offer the participant food that may contain allergens or violate dietary restrictions. Any participants with relevant food allergies (i.e. gluten or dairy) or strong dislikes were

excluded. If youth meet criteria after the in-person assessment, they were enrolled in the study and scheduled for an overnight assessment. For the week prior to the overnight assessment, an additional seven days of sleep diary information was collected for each participant.

Participants spent the night prior to the food-desire and snack tasks in the laboratory. In the laboratory, each participant went to bed at their average weekday bedtime and woke at their average weekday rise time as defined by the 7 to 10 day sleep diary. In the morning, a standardized breakfast of one slice of toast and jam was provided for each participant to ensure that the participants were adequately nourished before beginning the subsequent tasks. The food-desire task followed by the snack task was then administered. An identical protocol was repeated the week following completion of 6 weeks of intervention.

Using a computer-generated random numbers list, a research assistant who was not associated with the project conducted randomization after all eligibilty assessments were completed. Adolescents were randomized to either TranS-C-Youth (n=24) or PE (n=26), stratified by age and sex.

Measures of Demographic Characteristics

Demographic characteristics assessed included parent reports of the adolescents' age, biological sex, race/ethnicity and household income.

Investigators measured height and weight, from which BMI was calculated. Because body fat percentage changes as a child develops, BMI was transformed into z-scores for age and sex.

Sleep Measures

Sleep Diary (Buysse et al., 2006; Carney, 2012). The daily sleep diary is a valid and sensitive measure in the detection of differences due to weekends, age, gender, sleep timing and sleep quality (Monk et al., 2000). In the present study, trained research assistants called the adolescents to collect their sleep diary each morning at an agreed-upon time. Calls were made as close to rise time as possible.

While the full sleep diary was administered, based on a review of the literature (Baron et al., 2011; Brondel et al., 2010), bedtime and TST were determined to be the strongest risk factors for weight gain promoting food choice and thus were selected as the sleep parameters of interest for the current investigation. Bedtime was calculated as the average time the participant reported that he/she "try to go to sleep" during the school week across 7 to 10 days of sleep diary. TST was calculated as the average total sleep time during the week. Bedtime was a continuous variable; standard clock times were converted into variables representing the number of hours and minutes from noon, such that larger numbers indicate later bedtimes. For example, individuals going to bed at 1:30 a.m. have a bedtime of 13.5 and individuals going to bed at 11:30 p.m. have a bedtime of 11.5. TST was a continuous variable, formatted in hours and minutes. TST was calculated by subtracting time spent sleeping from time spent in bed.

To test the third hypothesis, participants were categorized into groups based on whether sleep improved from pre-treatment to the post-treatment assessment or not. Bedtime and TST difference scores were calculated by subtracting pre-treatment bedtime from post-treatment bedtime and pre-treatment TST from post-treatment TST. Earlier bedtimes at post-treatment compared to pre-treatment constituted the "Bedtime Improvement Group"; the same or later bedtimes at post-treatment compared to pre-treatment constituted the "No Bedtime Improvement Group". Longer TST at post-treatment compared to pre-treatment constituted the "TST Improvement Group"; the same or shorter TST at post-treatment compared to pre-treatment constituted the "No TST Improvement Group".

Sleepiness Scale (Wolfson & Carskadon, 1998). The sleepiness scale is a well validated and widely used measure used to quantify subjective sleepiness throughout the day (Acebo & Carskadon, 1999). The sleepiness scale asks "During the last two weeks, have you struggled to stay awake (fought sleep) or fallen asleep in the following situations?" It lists 10 situations (i.e. in a class at school) scored on a 4-point likert scale ranging from "no" to "both struggled to stay awake and fallen asleep". In the present study, the sleepiness scale was administered the night before the experimental protocol.

To test the third hypothesis, participants were categorized into groups based sleepiness scores from pre-treatment to the post-treatment assessment or not. Sleepiness difference scores were calculated by subtracting pre-treatment sleepiness scores from post-treatment sleepiness scores. Lower self-reported sleepiness at post-treatment compared to pre-treatment constituted the "Sleepiness Improvement Group"; the same or increased sleepiness at post-treatment compared to pre-treatment constituted the "No Sleepiness Improvement Group".

Food Desire and Intake Measurements

Food-Desire Task (Greer, Goldstein, & Walker, 2013). Participants were seated at a computer and were instructed to rate 80 food items on a 1–4 scale according to how much they wanted that food right now. For each trial, a fixation cross was displayed for 250-ms, which was then replaced by the food image for 500 ms, then the participants were asked to rate how much they wanted the item. The task was administered on a Dell Latitude E6430 laptop. The task presented 80 pictures of food, with no packaging, collected from internet searches and cropped to standardized circles. The items were evenly distributed across five categories (salty, sweet, starchy, fruit or dairy) and varied in GI. GI per serving was defined based on International Table of Glycemic Index (Atkinson, Foster-Powell, & Brand-Miller, 2008). The same 80 food items were used in each experimental session. In order to control for lateralized motor effects, approximately half of the participants used their left hand to rate wanted items (1—strongly want; 2—somewhat want; 3—somewhat do not want; 4—strongly do not want) and the other half used their right hand (scale reversed). For all analyses, ratings were re-coded so that higher ratings indicated higher wanting. Participants were informed that they would receive snacks following the task based on whichever items they rated wanting more. They were further instructed that this meant it was in their best interest to rate each food item according to how much they actually wanted that item at the time of the session. This procedure was used to encourage participants to rate the food items according to their actual preferences (rather than according to experimental expectations or demand characteristics).

Foods shown in the food-desire task were categorized as high versus low GI based on established cutoffs for high and low GI. Low GI is defined as less than 55 and high GI is 55 or above. For each participant, the mean desire for foods categorized as high and low GI and the mean desire for foods in each food category (fruit, dairy, salt, starch, and sweet) was calculated.

Snack Task (Habhab et al., 2009; Zellner et al., 2006). The snack task has been used in the eating disorders literature as a measure of food intake and restraint (Habhab et al., 2009; Zellner et al., 2006). In the present study, food choices were modified slightly from previous protocols to match the foods displayed in the food-desire task. Participants were provided with five different snack foods to eat. The food items corresponded to items they had rated earlier in the food-desire task. The snacks available were in one of five food categories: sweet, starch, salty, fruit, or dairy. Within each food category there were two snack options, the snack offered for each category was based on which snack option the participant rated as wanting more in the food-desire task. Items within categories were matched for calories per gram, GI, texture, and

size. The 10 items offered were donuts or cinnamon rolls (sweet), tortilla chips or cheese crackers (salty), bagels or croissants (starch), grapes or strawberries (fruit), and cheddar or mozzarella cubes (dairy). Based on the International Table of Glycemic Index (Atkinson, Foster-Powell, & Brand-Miller, 2008), foods in the sweet, salty and starch categories were defined as high GI and foods in the dairy and fruit categories were defined as low GI.

All foods were unwrapped and each category of food was placed in a separate plastic bowl on the desk in front of the participant. The arrangement of the bowls on the table was counterbalanced to control for lateralization effects. All bowls appeared full and each participant was given the same amount of each food item. The research assistant said to each participant ‘‘these are the snacks you won. Feel free to eat whatever you like—they are here for you. Take a break and I'll be back in 10 minutes.’’ After 10 minutes the research assistant returned to the room to retrieve the bowls. In order to determine the amount of food eaten, the experimenter weighed each bowl before the participants arrived for the experiment and then again after the completion of the snack task. Measurements were computed in number of grams and were made using a 5-lb capacity, digital scale (with accuracy to the .10 gram). The total calories consumed were calculated based on the calorie per gram of the food and the number of grams consumed of each food. The mean number of calories of high and low GI foods, dairy, fruit, salt, starch and sweet was then calculated for each participant.

Treatment Groups

Treatment began one week after the pre-treatment overnight assessment and ended the week prior to the post-treatment overnight assessment. Treatment involved 6 individual weekly 50-60 minute sessions. The two manualized treatments were delivered during the school year to minimize the impact of summer schedule variability. The variable Time is defined as the pre-treatment and post-treatment time points.

TranS-C-Youth

A detailed description of TranS-C-Youth has been described elsewhere (Harvey, in press). TranS-C-Youth adopts a modular approach to improving sleep in youth. It is comprised of "cross-cutting" modules that are introduced in the first session (e.g., functional analysis, goal setting, motivational interviewing, education) and are typically featured in every session thereafter, "core modules" that apply to the vast majority of clients (e.g., behavioral components, daytime impairment, unhelpful beliefs, relapse prevention) and "optional modules" that are used less commonly and only if indicated by the case formulation (e.g., bedtime worry). Treatment modules were developed based on sleep and circadian principles and drawing from three evidence-based interventions: Cognitive Behavior Therapy for Insomnia (CBT-I), Interpersonal Social Rhythm Therapy (IPSRT) and treatment for Delayed Sleep Phase Type (DSPT).

Psychoeducation

The PE condition is described in detail elsewhere (Harvey et al., in press). PE is an active comparison condition that has been associated with sleep improvement (Kloss et al., 2014). Sessions focused on deriving a model in which sleep, stress, diet, health, exercise, accidents and mood are inter-related and have reciprocal effects. In addition, teens were given the choice of learning mindfulness techniques, restorative yoga techniques and/or outdoors appreciation techniques. Because of the emphasis on choice and the absence of pressure to change from a therapist, PE is thought to operate via intrinsic motivation, which is a well-documented path to sustained change (Ryan & Deci, 2000). As such, the emphasis in PE was on providing information but not on facilitating or planning for change.

Analysis Plan

All analyses were conducted in SPSS 22 (IBM Corporation, Armonk, NY, 2013). Statistical significance was evaluated using a 2-sided design with alpha set at 0.05.

Differences in pre-treatment demographic characteristics between Treatment Groups were assessed using t-tests for linear variables and chi-square tests for categorical variables.

To test the first hypothesis, linear regression analyses were used to assess the impact of bedtimes (sleep diary), TST (sleep diary) and sleepiness (sleepiness scale) on desire for and intake of high and low GI foods, calories (intake only), and fruit, dairy, salty, starchy, and sweet foods at pre-treatment. Based upon previous research, covariates for all analyses include BMI z-score, sex, race/ethnicity, household income, and age (Knutson, 2005). Separate regression models were performed for each predictor variable.

Independent sample t-tests were conducted to assess Treatment Group differences in bedtime, TST and sleepiness difference from pre-treatment to post-treatment. To test the second hypothesis, mixed design repeated measure ANOVAs were used to assess the impact of treatment condition on desire for and intake of foods at pre-treatment versus post-treatment (referred to as 'Time'). Separate ANOVAs were performed for each outcome variable with t-tests used to further explore significant main effects.

To assess sleep improvement group differences in bedtime, TST and sleepiness difference from pre-treatment to post-treatment independent sample t-tests were conducted. To test the third hypothesis, mixed design repeated measures ANOVAs were used to assess the impact of sleep improvement (separately for bedtime improvement, TST improvement, and sleepiness improvement) on desire for and intake of foods at pre-treatment versus post-treatment (referred to as 'Time'). T-tests will be conducted to further explore significant main effects.

Results

Participant characteristics

Participant characteristics and Treatment Group comparisons are presented in Table 1. The groups did not differ significantly on demographic or pre-treatment measures.

Aim 1: Association between desire for and intake of foods in the morning and three sleep and circadian markers assessed at pre-treatment

These analyses were based on the full sample of 49 participants. Mean bedtime, TST and sleepiness scores at pre-treatment are listed in Table 1 in the "Full Sample" column. Mean food desire and intake outcomes at pre-treatment are listed in Table 2 in the "Full Sample" pre-treatment column.

Three linear regression analyses were conducted, one for each of the predictor variables. Bedtime, TST and sleepiness were the predictor variables and desire for and intake of high and low GI foods, calories (intake only), and fruit, dairy, salty, starchy, and sweet foods at pre-treatment were the outcome variables. Covariates for all analyses included BMI z-score, sex, race/ethnicity, household income, and age.

Increased TST was associated with increased desire for dairy, B=.13, p=.03, 95% CI [.02-.25], R^2=.26, at pre-treatment. No other sleep and circadian markers were associated with other food desire or intake outcomes (all p's >.05) at pre-treatment.

Aim 2: Effect of TranS-C-Youth on desire for and intake of foods in the morning as compared to PE

The analyses that follow were based on participants classified by Treatment Groups. The mean bedtime, TST and sleepiness difference values from pre-treatment to post-treatment for the TranS-C-Youth and PE groups are displayed in Table 3. Results of independent samples t-tests indicate that the TranS-C-Youth group significantly advanced their bedtime and lengthened their

TST compared to the PE group from pre-treatment to post-treatment. There was no significant difference in sleepiness score from pre-treatment to post-treatment between groups. Mean food desire and intake outcomes in the TranS-C-Youth and PE group at pre-treatment and post-treatment are listed in Table 2.

Two-way repeated-measures ANOVAs were conducted, one for each of the food desire and food intake outcome variables. Treatment Group was the between-subjects factor and Time was the within-subjects factor.

No significant main effects of Treatment Group (all *p*'s>.05) were observed. There were significant main effects for Time on desire for starch, total calories eaten, high GI calories eaten and sweet calories eaten such that, regardless of Treatment Group, adolescents desired more starch, $F(1,31)=5.31$, MSE=.28, $p=.03$, $\eta^2=.15$, ate more calories total, $F(1,37)=4.08$, MSE=154917.73, $p=.05$, $\eta^2=.10$, ate more high GI calories, $F(1,37)=4.59$, MSE=106789.72, $p=.04$, $\eta^2=.11$, and ate more sweet calories, $F(1,37)=13.60$, MSE=95700.47, $p=.001$, $\eta^2=.27$, post-treatment compared to pre-treatment. No other main effects of Time were observed and there were no significant Treatment Group x Time interactions (all *p*'s>.05) for any of the food desire or intake variables.

Aim 3: Effect of bedtime, TST, and sleepiness improvement from pre-treatment to post-treatment on desire for and intake of foods in the morning

The analyses that follow were based on participants classified by Sleep Improvement Groups, as defined in the Methods section (Bedtime Improvement Group and No Bedtime Improvement Group; TST Improvement Group and No TST Improvement Group; Sleepiness Improvement Group and No Sleepiness Improvement Group). The mean bedtime, TST and sleepiness difference values for the three sets of Sleep Improvement Groups are displayed in Table 3. Both the Bedtime Improvement and No Bedtime Improvement Groups and the TST Improvement and No TST Improvement Groups significantly differed in the bedtime and TST difference scores from pre-treatment to post-treatment, but not the sleepiness difference scores. The Sleepiness Improvement and No Sleepiness Improvement Groups significantly differed in the sleepiness difference score from pre-treatment to post-treatment, but not the bedtime and TST difference scores.

Two-way repeated-measures ANOVAs were conducted, one for each of the food desire and intake outcome variables. Sleep Improvement Group was the between-subjects factor and Time was the within-subjects factor. Mean food desire and intake outcomes in the Sleep Improvement Groups at pre-treatment and post-treatment are listed in Table 4. Results are presented separately for Bedtime Improvement Groups, TST Improvement Groups, and Sleepiness Improvement Groups in the text that follows.

There were significant main effects of Bedtime Improvement Group on desire for high GI foods $F(1,30)=8.07$, MSE=1.58, $p=.008$, $\eta^2=.14$, sweets desired, $F(1,30)=4.59$, MSE=4.20, $p=.04$, $\eta^2=.21$, and salty calories eaten, $F(1,36)=6.44$, MSE=85094.57, p=.02, $\eta^2=.15$, such that, regardless of Time, adolescents in the Bedtime Improvement Group desired fewer high GI foods, fewer sweets and ate fewer calories from salty foods than adolescents in the No Bedtime Improvement Group. No other main effects of Bedtime Improvement Group were observed. Significant main effects of Time indicated that, regardless of Bedtime Improvement Group, adolescents ate more high GI calories $F(1,36)=4.01$, MSE=94848.76, $p=.05$, $\eta^2=.10$, and more sweet calories $F(1,36)=11.73$, MSE=79474.73, $p=.002$, $\eta^2=.25$, post-treatment as compared to pre-treatment.

Significant results for the Bedtime Improvement Group x Time interaction effects, following 6 sessions of either treatment condition, on desire for and intake of foods in the morning are displayed in Figure 1. This indicates that the intake of low GI $F(1,36)=7.24$, MSE=27591.89, $p=.01$, $\eta^2=.17$ (Figure 1a), fruit $F(1,36)=4.25$, MSE=1016.11, $p=.05$, $\eta^2=.15$ (Figure 1b), and dairy, $F(1,36)=4.25$, MSE=18018.11, $p=.05$, $\eta^2=.14$ (Figure 1c) calories at pre-treatment and post-treatment differed by Bedtime Improvement Group. To break down this interaction, paired samples t-tests were performed comparing pre-treatment to post-treatment intake of low GI, fruit and dairy calories in the Bedtime Improvement Group and in the No Bedtime Improvement Group. Paired samples t-tests revealed that adolescents in the Bedtime Improvement Group ate significantly more low GI $t(20)=-2.63$, $p=.02$, $r=.56$ and dairy calories $t(20)=-2.46$, $p=.02$, $r=.55$, but not fruit calories $t(20)=-1.48$, $p>.05$, $r=.10$ at pre-treatment compared to post-treatment. In the No Bedtime Improvement Group, no significant differences were observed between pre-treatment and post-treatment intake of low GI, fruit or dairy calories (all p's>.05). To further break down these interactions, independent sample t-tests were performed assessing intake of low GI, fruit and dairy calories in the Bedtime Improvement Group compared to the No Bedtime Improvement Group at pre-treatment and again at post-treatment. No significant differences were observed between the Bedtime Improvement Group and the No Bedtime Improvement Group in intake of low GI, fruit or dairy calories at pre-treatment or post-treatment (all p's>.05). No other Bedtime Improvement Group x Time interaction effects were significant.

No main effects of TST Improvement Group were observed. There were significant main effects of Time such that, regardless of TST Improvement Group, adolescents ate more high GI calories $F(1,36)=4.14$, MSE=98880.25, $p=.05$, $\eta^2=.10$, and sweet calories, $F(1,36)=10.66$, MSE=74863.12, $p=.002$, $\eta^2=.23$, at post-treatment compared to pre-treatment. No significant TST Improvement Group x Time interaction effects were observed.

No main effects of Sleepiness Improvement Group were observed. Significant main effects of Time indicated that, regardless of Sleepiness Improvement Group, adolescents more starch calories were desired, $F(1,28)=7.08$, MSE=.34, $p=.01$, $\eta^2=.20$, total calories were eaten, $F(1,34)=4.55$, MSE=172472.84, $p=.04$, $\eta^2=.12$, high GI calories were eaten , $F(1,34)=4.82$, MSE=110602.55, $p=.04$, $\eta^2=.12$ and sweet calories were eaten, $F(1,34)=11.40$, MSE=66228.47, $p=.002$, $\eta^2=.25$, at post-treatment compared to pre-treatment. No significant Sleepiness Improvement Group x Time interaction effects were observed.

Discussion

This study focused on adolescents with an eveningness circadian preference, a group known to be at increased risk for obesity (Asarnow, McGlinchey & Harvey, 2015; Goldstein et al. 2007). The present study investigated food choices in the morning; specifically desire for and intake of weight gain promoting foods. To our knowledge, this is the first study to a) investigate the relationship between sleep and breakfast choices - an important, independent risk factor for obesity in adolescents (Ludwig et al., 1999) and b) investigate sleep improvement as a potential mechanism for changes in food choice in adolescents.

The first aim was to investigate associations between self-reported bedtimes, TST, and sleepiness and two specific eating behaviors at pre-treatment: desire for and intake of weight gain promoting foods in the morning (via a food-desire task and a snack task). We hypothesized that later bedtime, less TST, and increased sleepiness would be associated with greater desire for and greater intake of weight gain promoting foods in the morning. Longer TST at pre-treatment was associated with increased desire for dairy foods. This finding is consistent with previous

research indicating that adolescents who get more sleep make better food choices (Brondel et al., 2010). While there were no other significant findings perhaps due to the limited variance at pre-treatment given that all participants had late bedtimes (mean bedtime at pre-treatment=1:02 AM) and a high level of sleep deficiency (mean TST at pre-treatment=6.64 hours, mean sleepiness score at pre-treatment=5.83), we observed a large effect size for this association between later bedtime and increased desire for dairy foods (R^2=.26). Moreover, while Greer, Goldstein and Walker (2013) found an increase in food desire for weight gain promoting foods under conditions of total sleep deprivation, our sample may have not been sufficiently sleep deprived for those same effects to emerge.

The second aim was to test the hypothesis that 6 weeks of an active intervention (TranS-C-Youth) would lead to decreased desire for and intake of weight gain promoting foods in the morning as compared to a comparison condition (PE). Contrary to our hypothesis, there were no statistically significant between group differences in desire for or intake of weight gain promoting foods. This finding was surprising given the effectiveness of TranS-C-Youth in improving sleep. Indeed the bedtime and TST difference between pre-treatment and post-treatment for the TranS-C-Youth group was significantly earlier and longer, respectively, as compared to the PE group. However, there was also variability in the sleep improvement observed within the two treatments, such that some youth in each group exhibited sleep improvements while others experienced minimal to no improvement in sleep. Notably, the PE condition included a short module that educated adolescents about healthy eating. It is possible that this dietary psychoeducation may have been sufficient to contribute to an unexpected improved food choice at post-treatment for this group.

The third aim was to examine sleep improvement as a potential mechanism for change in food choice by evaluating the effect of sleep improvement across both intervention conditions on desire for and intake of weight gain promoting foods in the morning. The results provide some support for our hypothesis that sleep improvement from pre-treatment to post-treatment across both Treatment Groups would be associated with decreased desire for and intake of weight gain promoting foods. Consistently, we found a large effect (all $\eta^2 > .14$) such that, regardless of Time, adolescents in the Bedtime Improvement Group desired less high GI and sweet foods and ate less salty foods than those in the No Bedtime Improvement group. In other words, adolescents who adopted an earlier bedtime at the end of the treatment relative to before the treatment were more likely to desire and eat fewer unhealthy foods. However, we cannot rule out the possiblity that this main effect of Bedtime Improvement Group was the result of pre-treatment differences in food desire and intake. Recall that adolescents were not randomized to Bedtime Improvement Groups, rather they were categorized into the Bedtime Improvement and No Bedtime Improvement Groups based on bedtime difference between pre- and post-treatment, a limitation that should be addressed in future research. Importantly, a large effect was observed (all $\eta^2 > .14$) such that bedtime improvement was also associated with increased intake of low GI and dairy foods at post-treatment compared to pre-treatment; meanwhile no bedtime improvement was associated with a no significant change in intake of calories from low GI foods. These findings are consistent with research by Baron et al. (2011) who reported that earlier bedtime was associated with intake of more health promoting and less weight gain promoting foods.

Interestingly, while we found that a shift towards an earlier bedtime was associated with healthier food choices, associations between food choices and our other sleep measures (i.e. self-reported sleepiness; self-reported TST) were not statistically significant. Taken together, these

findings raise the possibility that bedtime is a potential target for interventions to improve food intake in adolescents. This is consistent with literature, which identified bedtime as an important risk factor for weight gain, regardless of TST (Asarnow, McGlinchey & Harvey, 2015). Moreover, appetite regulating hormone concentrations follow a normal diurnal variation strongly linked to circadian patterns (Bodosi et al., 2004; Sanchez, Oliver, Pico & Palou, 2004). Taken together, the literature and the present findings point to the potential importance of circadian rhythm/timing when studying the link between food choice and sleep.

There were several unexpected but noteworthy findings. Regardless of Treatment or Sleepiness Improvement Group, adolescents desired more starch, consumed more total calories and more calories from high GI and sweet foods at post-treatment compared to pre-treatment. Regardless of Bedtime or TST Improvement Group, adolescents ate more high GI calories and more sweet calories at post-treatment compared to pre-treatment. Taken together, these findings suggest that following either a sleep focused or health education intervention, adolescents were eating more breakfast overall. On the one hand, eating regular breakfast is considered protective against weight gain (Cho et al., 2003; Timlin, Pereira, & Story, 2008) so this finding is positive. On the other hand, we cannot rule out the possibility that the participants felt more comfortable at post-treatment or there was a practice effect (i.e. the adolescents knew to expect a selection of breakfast items and therefore ate more during the task). However, in this study the adolescents whose sleep improvement consisted of an earlier bedtime were more likely to make healthier breakfast choices, a behavior associated with healthier weight and decreased obesity risk.

The results of the present study should be interpreted within the confines of several limitations. First, objective measures for the assessment of sleep and circadian rhythms such as actigraphy (Sadeh, Alster, Urbach & Lavie, 1989) and dim-light melatonin onset (Carskadon et al., 1997) protocols were not used. However, the daily sleep diary is a widely used and well-validated subjective measure of sleep (Buysse et al., 2006; Carney, 2012). Another limitation is the relatively small sample. The study also focused on breakfast eating patterns and results might have differed had we been able to examine eating behavior across the full day. In addition, the present study was conducted in a specific geographical region (Berkeley, California). The results should be interpreted within this environmental context. Finally, multiple comparisons were used. According to Nakagawa (2004), corrections for multiple comparisons such as the use of Bonferroni procedures further reduce power, increasing a Type II error to unacceptable levels, and they may also contribute to publication bias, hindering the advance of the field. Therefore we opted to include effect sizes as suggested by Nakagawa (2004), rather than correct for multiple comparisons. Indeed, effect sizes observed throughout the present study are considered large (η^2 or $R^2 > .14$).

In summary, earlier bedtime from pre-treatment to post-treatment, across Treatment Groups, was associated with an increased intake of healthier foods (low GI foods, fruit and dairy) as compared to adolescents whose bedtimes did not improve from pre-treatment to post-treatment. These healthier eating choices, if maintained over time, could be protective against the development of obesity. Clinically, these findings suggest that bedtime improvement can improve breakfast choices, an important meal for obesity prevention (Buyken et al., 2007) during adolescence, which is a central developmental period in terms of obesity prevention (Asarnow, McGlinchey & Harvey, 2015). Moreover, the current study demonstrates that both sleep and food choices are modifiable in a high-risk sample of adolescents. Given the high rate of sleep problems and obesity in this age group and potential impact of healthy sleep and diet on overall health and development these findings are particularly promising.

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Table 1. Demographic characteristics at pre-treatment

	Full Sample N=49	PE N=26	TranS-C N=23	Test statistic[a]	*p*
Age (years): *M (SD)*	15.15 (1.68)	15.48 (1.66)	14.77 (1.66)	$t(45)=-1.46$	.15
Sex: % male	42	44	48	$\chi^2=.01$	.92
Race: % Caucasian	50	60	43	$\chi^2=11.93$	.22
Annual Income ($): % <$30,000	6.5	4	9.5	$\chi^2=3.12$	.68
Z-score: *M (SD)*	.37 (1.0)	.47 (.98)	.28 (1.03)	$t(44)=-.71$	.48
Bedtime (hh:mm): *M (SD)*	1:02 AM (1.33)	12:48 AM (1.24)	1:19 AM (1.41)	$t(47)=1.41$	.17
TST (hours): *M (SD)*	6.64 (1.25)	6.91 (1.22)	6.34 (1.23)	$t(47)=-1.26$	.22
Sleepiness: *M (SD)*	5.97 (4.71)	5.83 (4.16)	6.2 (5.6)	$t(47)=.08$	.94

Note. [a] t values from independent t-tests for continuous variables and chi-square analyses for categorical variables assessing group differences between the PE and TranS-C Youth groups are presented.
M=mean; *SD*=standard deviation; Z-score=BMI adjusted for age and sex; hh:mm=hours:minutes.

Table 2. Means and standard deviations of food desire and intake in the full sample and Treatment Groups at pre-treatment and post-treatment.

	Full Sample		Treatment Groups			
			TranS-C-Youth		PE	
	Pre	Post	Pre	Post	Pre	Post
Desire[a]						
High GI	2.34 (0.46)	2.25 (.45)	2.41 (.40)	2.21 (.39)	2.29 (.52)	2.28 (.51)
Low GI	2.37 (0.50)	2.38 (.46)	2.38 (.45)	2.34 (.49)	2.36 (.54)	2.42 (.44)
Fruit	2.54 (0.59)	2.61 (.59)	2.52 (.61)	2.49 (.67)	2.57 (.59)	2.72 (.50)
Dairy	2.07 (0.62)	2.05 (.58)	2.09 (.61)	2.10 (.59)	2.05 (.65)	2.01 (.58)
Salt	1.96 (0.59)	1.96 (.57)	1.94 (.52)	1.96 (.57)	1.99 (.65)	1.96 (.59)
Starch	2.40 (0.49)	2.23 (.50)	2.45 (.46)	2.20 (.44)	2.35 (.53)	2.26 (.56)
Sweet	2.61 (0.63)	2.57 (.60)	2.75 (.58)	2.50 (.59)	2.48 (.66)	2.64 (.63)
Intake[b]						
Calories	441.51 (223.42)	517.33 (165.83)	445.55 (241.07)	535.25 (196.69)	437.80 (210.83)	503.49 (193.67)
High GI	334.72 (180.53)	398.72 (165.83)	339.85 (200.53)	395.72 (181.36)	330.01 (164.06)	401.04 (157.13)
Low GI	106.79 (77.81)	118.40 (88.75)	105.70 (85.91)	139.26 (96.04)	107.79 (71.33)	102.28 (81.26)
Fruit	29.03 (17.02)	30.73 (15.55)	23.81 (17.81)	28.87 (17.01)	33.85 (15.04)	32.16 (14.56)
Dairy	77.75 (71.89)	87.67 (81.04)	81.89 (77.34)	110.39 (87.19)	73.95 (67.87)	70.12 (73.15)
Salt	104.50 (109.57)	87.03 (89.80)	111.76 (126.67)	66.24 (84.67)	97.81 (93.29)	103.11 (92.24)
Starch	108.58 (87.41)	113.21 (91.50)	123.54 (91.62)	138.55 (91.24)	94.83 (82.81)	93.63 (88.80)
Sweet	121.64 (105.59)	198.48 (101.62)	104.55 (112.96)	190.93 (118.47)	137.37 (97.99)	204.31 (88.95)

Note. Data are expressed as the mean (and standard deviation). PE=Psychoeducation; Pre=pre-treatment; Post=post-treatment; GI=Glycemic Index.

[a] Desire is measured on scale from 1 to 4.

[b] Intake is measured in calories consumed.

Table 3. Means, standard deviations, and t-tests of difference in bedtimes, TST, and sleepiness from pre-treatment to post-treatment among Treatment and Sleep Improvement Groups.[a]

	Treatment Groups			Sleep Improvement Groups								
	TranS-C-Youth N=20	PE N=22	*t*	BT Imprv N=22	No BT Imprv N=20	*t*	TST Imprv N=24	No TST Imprv N=18	*t*	Sleepiness Imprv N=13	No Sleepiness Imprv N=23	*t*
BT Diff (hours)	-.81 (.89)	.29 (.75)	4.32**	-.96 (.71)	.56 (.48)	8.05**	-.79 (.86)	.50 (.58)	5.50**	-.49 (1.10)	-.07 (.98)	-1.19
TST Diff (hours)	-1.20 (1.27)	-.21 (1.76)	2.09*	-1.62 (1.64)	.35 (.68)	4.98**	-1.61 (1.53)	.55 (.46)	5.77**	-.68 (1.28)	-.64 (1.82)	-.07
Sleepiness Diff (score)	-.47 (3.31)	0.48 (6.27)	.54	-.63 (2.91)	1.12 (7.23)	.97	1.10 (6.64)	1.07 (2.60)	-1.19	-3.43 (1.99)	2.17 (5.51)	-3.64**

Note. Data are expressed as the mean (and standard deviation) or as t-values. Imprv=Improvement; Diff=Difference; *t*=t-values from independent samples t-tests; BT Diff=bedtime difference from pre-treatment to post-treatment; TST Diff=total sleep time difference from pre-treatment to post-treatment; Sleepiness Diff =sleepiness difference from pre-treatment to post-treatment.

[a] This table does not reflect the full sample because 5 TranS-C-Youth and 2 PE participants dropped out during treatment. Values displayed are means (and standard deviations).

*p <.05; **p <.001.

Table 4. Means and standard deviations of food desire and intake in Sleep Improvement Groups at pre-treatment and post-treatment.

	BT Improvement Groups				TST Improvement Groups				Sleepiness Improvement Groups			
	BT Imprv		No BT Imprv		TST Imprv		No TST Imprv		Sleepiness Impv		No Sleepiness Imprv	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Desire[a]												
High GI	2.29 (.48)	2.09 (.36)	2.42 (.44)	2.47 (.50)	2.32 (.46)	2.19 (.35)	2.40 (.47)	2.34 (.60)	2.31 (.38)	2.17 (.33)	2.40 (.45)	2.35 (.46)
Low GI	2.42 (.49)	2.39 (.45)	2.40 (.54)	2.36 (.52)	2.36 (.51)	2.38 (.43)	2.47 (.51)	2.38 (.53)	2.49 (.40)	2.39 (.21)	2.42 (.51)	2.45 (.55)
Fruit	2.63 (.59)	2.62 (.60)	2.54 (.61)	2.56 (.62)	2.54 (.61)	2.58 (.57)	2.54 (.61)	2.63 (.66)	2.62 (.52)	2.67 (.42)	2.64 (.59)	2.68 (.64)
Dairy	2.13 (.64)	2.11 (.53)	2.06 (.61)	1.95 (.67)	2.10 (.60)	2.08 (.56)	2.09 (.66)	2.00 (.66)	2.31 (.59)	2.03 (.41)	2.08 (.62)	2.11 (.67)
Salt	1.96 (.58)	1.89 (.59)	1.96 (.58)	2.07 (.57)	1.99 (.52)	1.98 (.51)	2.07 (.69)	1.93 (.70)	2.03 (.66)	1.75 (.55)	1.99 (.54)	2.12 (.55)
Starch	2.35 (.50)	2.08 (.42)	2.46 (.47)	2.44 (.57)	2.31 (.49)	2.13 (.41)	2.52 (.46)	2.40 (.62)	2.43 (.42)	2.15 (.38)	2.43 (.47)	2.33 (.53)
Sweet	2.50 (.64)	2.32 (.46)	2.73 (.64)	2.91 (.64)	2.59 (.611)	2.49 (.52)	2.63 (.69)	2.68 (.74)	2.46 (.47)	2.56 (.57)	2.71 (.66)	2.60 (.64)
Intake[b]												
Calories	374.28 (253.35)	501.17 (191.68)	513.05 (197.94)	537.81 (204.46)	435.07 (260.36)	521.44 (207.97)	447.41 (207.69)	511.62 (182.03)	386.24 (218.48)	539.75 (193.32)	471.36 (245.49)	518.42 (204.83)
High GI	282.95 (194.82)	367.28 (146.00)	376.48 (175.01)	434.60 (189.33)	333.06 (212.97)	398.90 (175.25)	320.06 (158.24)	395.09 (161.82)	283.72 (155.95)	400.93 (140.28)	36.56 (204.49)	413.97 (180.40)
Low GI	91.33 (72.86)	133.64 (97.35)	136.57 (81.19)	103.03 (78.06)	102.02 (77.11)	122.31 (94.64)	127.35 (82.19)	116.33 (83.86)	102.52 (88.23)	138.57 (90.94)	105.80 (68.75)	104.27 (87.16)
Fruit	26.27 (18.08)	33.00 (17.05)	32.75 (16.24)	27.77 (13.93)	26.48 (18.75)	30.85 (15.91)	33.19 (14.88)	30.37 (16.06)	28.12 (18.84)	31.17 (15.02)	30.77 (16.14)	29.89 (15.28)
Dairy	65.06 (66.93)	100.64 (89.89)	103.83 (77.38)	75.26 (69.83)	75.54 (72.77)	91.46 (87.19)	94.16 (76.02)	85.96 (74.72)	74.40 (76.84)	107.41 (84.14)	75.04 (65.15)	74.38 (77.76)
Salt	69.05 (81.94)	54.36 (68.39)	137.19[c] (126.16)	120.54 (99.31)	95.33 (115.46)	78.12 (87.90)	109.72 (103.84)	92.94 (92.78)	76.31 (87.32)	74.86 (86.67)	122.04 (119.29)	105.66 (89.07)
Starch	110.57 (104.91)	114.99 (98.07)	99.55 (71.01)	116.70 (85.22)	121.83 (99.49)	120.77 (95.87)	83.31 (70.83)	108.07 (86.56)	86.83 (88.99)	124.90 (80.24)	101.98 (87.64)	109.50 (96.98)
Sweet	103.33 (103.34)	197.93 (105.14)	139.74 (108.23)	197.36 (103.19)	127.03 (111.90)	200.02 (113.05)	127.03 (111.90)	194.08 (88.65)	120.58 (115.77)	201.17 (90.71)	141.01 (101.96)	198.82 (99.85)

Note. Data are expressed as the mean (and standard deviation). Pre=Pre-treatment; Post=Imprv=Improvement; BT=bedtime; TST=total sleep time.

[a] Desire is measured on scale from 1 to 4.

[b] Intake is measured in calories consumed.

Figure 1a. Low GI Caloric Intake in Bedtime Improvement and No Bedtime Improvement Groups Pre- and Post-treatment

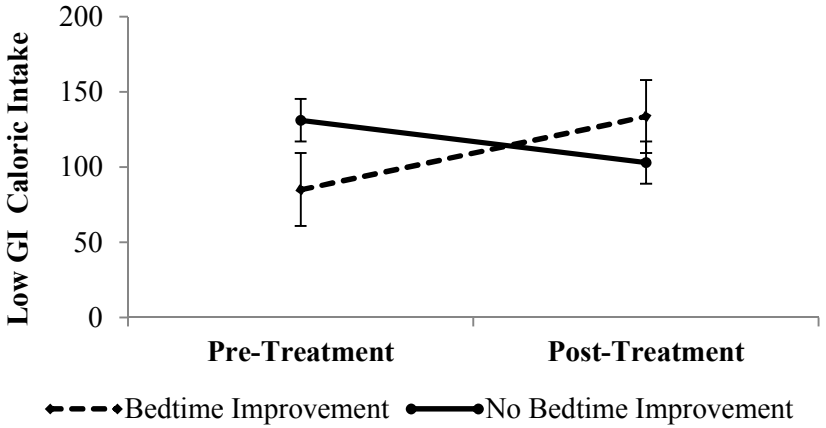


Figure 1b. Fruit Caloric Intake in Bedtime Improvement and No Bedtime Improvement Groups Pre- and Post-treatment

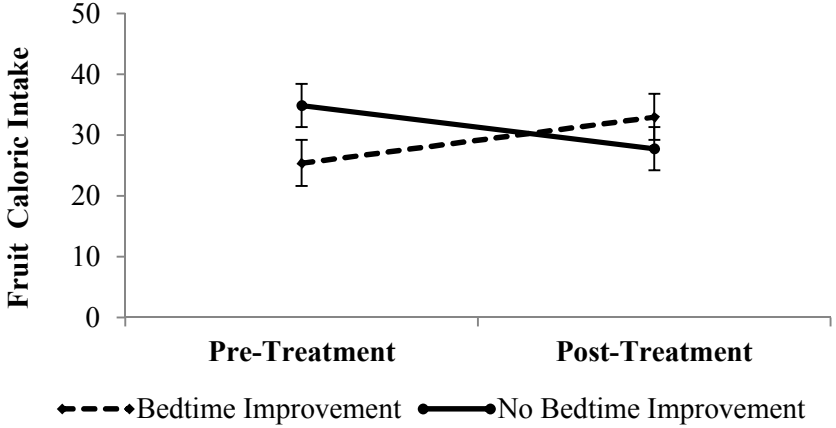


Figure 1c. Dairy Caloric Intake in Bedtime Improvement and No Bedtime Improvement Groups Pre- and Post-treatment

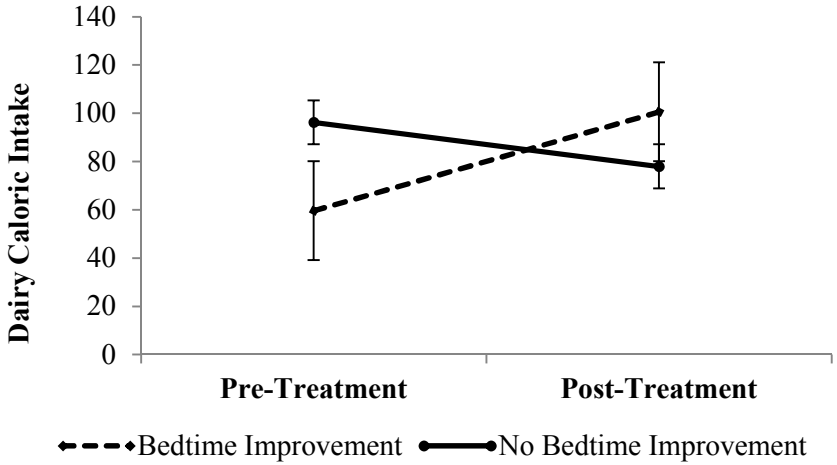


Figure 1. Bedtime Improvement Group x Time Interactions for (1a) Low GI, (1b) Fruit, and (1c) Dairy Caloric Intake: Means and Standard Error Bars. GI=Glycemic Index