GESDAV

Journal of Behavioral Health

available at www.scopemed.org

Original Research

Association between physical activity behavior and sleep-related parameters of adolescents

Paul D. Loprinzi[1], Kevin E. Finn[2], Susan A. Harrington[3], Hyo Lee[4], Michael W. Beets[5], Bradley J. Cardinal[6]

[1]*Bellarmine University, Department of Exercise Science, Louisville*
[2]*Merrimack College, Department of Health Sciences, School of Science and Engineering, North Andover*
[3]*Grand Valley University, Kirkof College of Nursing, Grand Rapids*
[4]*Sangmyung University, Department of Sport and Health Sciences, Seoul, Korea*
[5]*University of South Carolina, Arnold School of Public Health, Department of Exercise Science, Columbia*
[6]*Oregon State University, College of Public Health and Human Sciences, Corvallis*

Received: June 13, 2012

Accepted: July 25, 2012

Published Online: July 30, 2012

DOI: 10.5455/jbh.20120725113528

Corresponding Author:
Paul D. Loprinzi,
Bellarmine University
ploprinzi@bellarmine.edu

Key words: Exercise, Sleep, Epidemiology, Memory, Academic Performance

Abstract

Background**:** The purpose of this study was to examine the association between accelerometer-assessed physical activity behavior and a variety of self-reported sleeping parameters in a sample of U.S. adolescents ages 16 and 17.
Methods: Data from the 2005-2006 National Health and Nutrition Examination Survey (NHANES) was used for the study, with analyses performed in 2012. At the mobile examination center, participants were asked to wear an ActiGraph 7164 accelerometer on the right hip for 7 days following their examination. 23 questions on sleep were asked during the household interview. 293 adolescents between 16 and 17 years of age with sleeping data and sufficient accelerometry data were included in the analyses.
Results: After controlling for household income and race-ethnicity, a 1-minute increase in moderate-to-vigorous physical activity was associated with a 44 percent greater odds of having *no difficulty remembering when tired* (OR: 1.44, 95% CI: 1.06-1.96, p = 0.02). Physical activity was not associated with the other evaluated sleeping-related variables.
Discussion: In adolescents, accelerometer-assessed physical activity was, among the sleeping-related parameters, associated with difficulty remembering when tired. Future studies are needed to confirm this finding and to determine the extent to which physical activity may improve memory when tired among adolescents.

INTRODUCTION

Similar to adults [1], sleeping-related problems are frequent among the younger populations [2-4], with estimates as high as 15 million U.S. children obtaining insufficient levels of sleep [5]. As recommended by the National Sleep Foundation [6], school-age children (5-10 yrs) should obtain 10-11 hours of sleep; teens (10-17 yrs) should obtain 8.5-9 hours; and adults need 7-9 hours. Sleeping problems among adolescents may include difficulty falling asleep, early morning wakening, tired upon waking, and daytime fatigue and sleepiness. Sleep disturbances among adolescents may interfere with their quality of life, daily functioning [7], and academic performance [8].

With respect to sleep disturbances on academic performance, studies have shown that longer wake episodes at night, a proxy for sleep quality, are associated with negative school performance, along with poor sleep quality. Several studies have shown that sleep loss is associated with cognitive impairments in children [9,10]. Specifically, Harrington et al. [11] recently showed that the children with the lowest mathematics scores had significantly longer wake episodes at night. Additionally, school-aged children with fragmented sleep (as based on actigraphic estimates of night waking) showed lower performance on neurobehavioral functioning measures as well as increases in behavioral problems [12]. Similarly, in older populations, such as adolescents, Wolfson and Carskadon [13] showed that among 3,000 high school students, those with higher grades reported more total sleep, earlier bedtimes on school nights, and reduced weekend delays of sleep schedules than high school students with lower grades. Moreover, among 3,871 high school students, Shin et al. [14] showed an association between sleep quantity and quality with daytime sleepiness, which is linked with a decline in academic performance.

Consequently, strategies to improve sleep quality among adolescents are needed. Although sedative hypnotic drugs have been developed to aid in sleep quality [15], such pharmacological drugs may have considerable side effects [16]. As a result, non-pharmacological strategies, particularly among young populations, are needed. A potential strategy includes regular participation in physical activity.

In the general adult population [17,18] and among subpopulations of the adult population, such as pregnant women [19], empirical evidence indicates that physical activity is favorably associated with sleep; however, fewer studies have been conducted in younger populations. Among children and adolescents, some studies [20-26], but not all [27], have demonstrated a favorable association between physical activity and sleep. Recently, Harrington et al. [11] showed that the longer wake episodes at night were associated with fewer steps taken during the day, suggesting that wakefulness during the sleep episode is associated with increased energy expenditure, consequently allotting less energy for daytime activities. Additionally, Foti and colleagues [26] used data from the 2009 national Youth Risk Behavior Survey and showed that, after adjustments, adolescents in the 9th-12th grade who self-reported engaging in 60 minutes or more of physical activity on a daily basis had a higher odds (odds ratio: 1.24, 95% CI: 1.01-1.51) of sufficient sleep than those engaging in less physical activity. Importantly, the study by Foti and colleagues [26], along with some of the other studies in this area of inquiry, have relied on self-report measures of physical activity, which are prone to considerable measurement error including recall bias, item-interpretation and social desirability effects [28]. The recall bias, in particular, may be particularly prone to error given the inverse association observed between sleep and memory. Additionally, most studies have examined the association between physical activity and sleep latency or sleep duration, providing only a partial picture regarding the overall association between physical activity and sleep.

The present study aims to extend our knowledge base in this area and overcome some of the common limitations of previous studies by examining the association between objectively-measured physical activity (i.e., accelerometry) and 23 different sleeping-related parameters (e.g., sleep duration, sleep latency, difficulty concentrating when tired and frequency of taking sleeping pills) in a nationally representative sample of older adolescents (i.e., 16-17 years).

METHODS

Design

Data were obtained from the 2005-2006 National Health and Nutrition Examination Survey (NHANES). Briefly, NHANES employs a representative sample of non-institutionalized U.S. civilians, selected by a complex, multistage probability design. Participants were interviewed in their homes and subsequently examined in mobile examination centers (MEC) across numerous U.S. geographic locations. The survey examines a nationally representative sample of about 5,000 individuals each year. Individuals are located in counties across the country, with 15 counties visited each year. The study was approved by the National Center for Health Statistics ethics review board, with parental informed consent and adolescent assent obtained from all participants prior to data collection.

Participants

Among the 10,348 participants (ages 0 to 85 yrs) in the 2005-2006 NHANES cycle, 4,895 remained after excluding those with insufficient physical activity monitoring data; 1,643 remained after excluding those who were 18 years and older; 298 remained after excluding those with missing sleep data; 296 remained after excluding those who self-reported being pregnant; 295 remained after excluding those who were considered pregnant from a blood sample; and 293 remained after excluding those who were currently breast feeding a child. The final sample for the present study included 293 NHANES older adolescent participants between 16 and 17 years of age. The gender breakdown was 46.3% (SE [standard error] = 3.3) for males and 53.6% (SE = 3.3) for females. The mean (SE) age (years) for males and females, respectively, was 16.5 (SE = 0.05) and 16.4 (SE = 0.04).

Measurement of Physical Activity

At the MEC, participants were asked to wear an ActiGraph 7164 accelerometer on the right hip for 7 days following their examination. The ActiGraph 7164 accelerometer measures accelerations in the vertical axis using a piezoelectric plate. The accelerometer output is digitized using an analog-to-digital converter, and once digitized, the signal passes through a digital filter that detects accelerations ranging from 0.05 to 2.00 g in magnitude with frequency responses ranging from 0.25 to 2.5 Hz to filter motion outside normal human movement. The filtered signal is then rectified and summed over a pre-determined epoch period. After the activity count is sorted into an epoch, it is stored in the internal memory and then the integrator is reset to zero. Additional information on the mechanics of the ActiGraph 7164 accelerometer can be found elsewhere [29]. For the present study, activity counts were summarized in 1-min epochs. The Freedson age-specific cut-points were used to classify time spent at moderate-to-vigorous physical activity (MVPA) intensity [30,31]. For 16 and 17 year olds, respectively, the moderate-intensity cut-points were 3000 and 3239 counts/min. For vigorous-intensity, the cut-points were 6363 (16 year olds) and 6751 counts/min (17 year olds). For the analyses described here and as is recommended, only those participants with at least 4 days with 10 or more hours per day of monitoring data were included in the analyses [31]. Moderate and vigorous physical activity intensities were combined as participants spent little time in vigorous intensity activities. For example, participants engaged in 2.0 minutes (SE = 0.48) of vigorous-intensity physical activity per day. Nonwear was defined by a period of a minimum of 60 consecutive minutes of zero activity counts, with the allowance of 1-2 minutes of activity counts between 0 and 100 [31]. The ActiGraph accelerometer has demonstrated evidence of validity and reliability among youth [32,33].

Measurement of Sleeping Variables

In the 2005-2006 NHANES sample, participants 16 and older completed a variety of sleeping patterns and outcomes that were measured using the Functional Outcomes of Sleep Questionnaire [34]. The present study restricted the analyses to adolescent participants (i.e., 16 and 17 years), as their sleeping patterns are different than adults [35,36]. In the present study, 23 self-reported sleeping-related questions were evaluated, including 2 continuous variables and 21 categorical variables. The 2 continuous variables included the number of hours slept per night and time (min) it took to fall asleep (i.e., sleep latency). Details about the categorical variables can be found elsewhere [17], with these questions (along with their proportions) also found in Table 2. When insufficient observations (~ < 30) were reported for a response, response options were combined, where appropriate.

Measurement of Covariates

During a household interview, an interview-administered questionnaire assessed information on age, gender, race-ethnicity, annual household income, poverty income ratio, and student status. A trained interviewer recorded interview data electronically using computerized questionnaire forms that were programmed using Blaise software. Annual family income was self-reported in increments of $5,000 starting at $0 and up to $75,000 or more. Socioeconomic status was evaluated using the poverty to income ratio. Ranging from 0 to 5, poverty to income ratio was defined as the ratio of the family individual income to their poverty threshold. Student status was assessed by asking participants whether they were in school, on vacation from school, or neither in school or on vacation from school. Additionally, at the MEC, participants completed a questionnaire on their current health status, with possible responses including *excellent, very good, good, fair, or poor*. Lastly, to exclude participants who were breast feeding or pregnant, which may influence their sleeping patterns, participants, while being examined at the MEC, answered questions on whether they were pregnant or breast feeding. Given that some of the female participants may not have known they were pregnant, pregnancy status was also identified using a urine sample. If the urine test results were positive for pregnancy, a serum pregnancy test was also performed. For both the urine and serum pregnancy tests, an Icon 25 hCG (human chorionic gonadotropin) test kit was used for the qualitative detection of hCG in urine or serum. During examination at the MEC, body mass index (BMI) was calculated from measured weight and height (weight in kilograms divided by the square of height in meters). Weight was directly measured using the Toledo electronic weight scale with height measurements taken using the Seca electronic stadiometer. Standard procedures (e.g., no shoes) were used to measure height and weight, with detailed information provided elsewhere [37].

Data Analysis

Analyses were performed in 2012 using procedures from sample survey data (svy: commands) in STATA (version 10.0, College Station, TX) to account for the complex survey design used in NHANES. To account for oversampling and non-response, all analyses included the use of the sample weights, clustering variables, and primary sampling units. The two-year MEC sample weights were used in the present study [17]. Means and standard errors were calculated for continuous variables and proportions were calculated for categorical variables.

To determine which variables to assess in multivariate models, we first computed univariate linear regression to examine the association between MVPA (independent variable) and both continuous sleeping variables (dependent variable). Univariate multinomial logistic regression and logistic regression was used to examine the association between MVPA (independent variable) and each of the categorical sleeping-related variables (dependent variable). Prior to the regression analysis, MVPA was normalized using a log transformation. Among the significant univariate models, additional analyses were computed. Specifically, 3 models were computed. First, an unadjusted regression analyses was used to examine the association between MVPA (independent variable) and the sleeping variable (dependent variable). Second, a fully adjusted multivariate regression model was computed while controlling for potential confounding variables, including age, BMI, gender, health status, household income, poverty status, student status, and race-ethnicity. Third, to prevent over-adjustment from occurring, a minimally adjusted model was computed that only controlled for the covariates that contributed (p-value < 0.25) to the fully adjusted model. Statistical significance was established as a nominal alpha level of 0.05.

RESULTS

Demographic characteristics of the sample are displayed in Table 1. The proportion for each of the sleeping variables is displayed in Table 2. On average, the mean (SE) hours slept per night and duration (min) to fall asleep, respectively, was 7.39 (0.1) and 21.13 (1.6). Non-transformed weighted means (SE) for the average daily minutes spent at moderate, vigorous and MVPA, respectively, were 13.3 (0.8), 2.0 (0.4), and 15.3 (1.2).

Table 1. Weighted means and proportions (standard error) for selected characteristics of the 2005-2006 NHANES sample.

Variable	Mean/Proportion [standard error]
N	293
Age (yrs) (range = 16-17)	16.4 (0.02)
% Female	53.6 (3.3)
Height (cm)	168.3 (0.6)
Weight (kg)	66.9 (1.2)
BMI (kg/m^2)	23.4 (0.4)
% Overweight or Obese [a]	28.9 (3.7)
Ethnicity	
% Mexican American	11.6 (1.6)
% Other Hispanic	7.4 (3.0)
% Non-Hispanic White	59.5 (4.1)
% Non-Hispanic Black	14.7 (2.6)
% Other Race	6.6 (2.0)
Poverty Income Ratio (range = 0-5)	2.96 (0.1)
Current Health Status	
% Excellent	13.6 (2.3)
% Very Good	44.8 (3.6)
% Good	35.9 (2.4)
% Fair	5.2 (1.5)
% Poor	0.3 (0.2)
Student Status	
% In school	71.3 (6.7)
% On vacation from school	23.4 (6.1)
% Neither in school or on vacation from school	5.2 (1.8)

[a] Using CDC growth curves, overweight was defined as ≥ 85th BMI percentile for age and gender, respectively [43].

Of the univariate regression models examining the association between MVPA and the sleeping-related variables, only the variables "*ever told by doctor that you have a sleeping disorder*" and "*difficulty remembering when tired*" were significant; the results occurred in the expected direction for these two variables. Those who had no difficulty remembering when tired (16.2 min/day [SE = 1.6]; n = 232) engaged in significantly more MVPA than those who had a little or more difficulty (11.8 min/day [SE = 2.2]; n = 58) (p = 0.03). Results for the variable "*ever told by doctor that you have a sleeping disorder*" are not shown, as only 3 participants answered yes to this question; thus, providing unstable estimates.

For the variable *difficulty remembering when tired*, the unadjusted model was significant (OR = 1.47, 95% CI: 1.03-2.08). However, after controlling for BMI, gender, health status, household income, poverty status, student status, race-ethnicity and age, the association was slightly attenuated (OR: 1.38, 95% CI: 0.90-2.11; p = 0.12). After removing covariates that did not contribute (i.e., $p < 0.25$) to the model, which included controlling for household income and race-ethnicity, a 1-minute increase in MVPA was associated with a 44 percent greater odds of having *no difficulty remembering when tired* (OR: 1.44, 95% CI: 1.06-1.96, p = 0.02).

DISCUSSION

The results of the present study do not provide strong evidence regarding the association between physical activity behavior and sleep among older adolescents. This may be attributable, in part, to the minimal time spent at MVPA among the adolescent sample as well as using a sleeping questionnaire originally developed for adults. However, the present findings do suggest that physical activity among older adolescents is associated with their ability to remember things when they are sleepy or tired.

This finding that physical activity behavior is associated with the ability to remember things when sleepy or tired among adolescents is an important finding. Although confirmation from prospective and experimental studies in adolescents is needed, and although speculative, the data in the present study suggest that regular participation in physical activity may influence academic achievement given that the ability to remember things when tired may be associated with memory. This assertion is partially supported by other studies reporting a positive association between physical activity behavior and academic achievement and memory [38]. For example, Harrington et al. [11] showed that steps taken during the day negatively correlated with length of wake episodes at night, and children with longer wake episodes at night had lower mathematical scores. However, given that this study was among children, it is uncertain as to whether similar results would hold true for adolescents.

Studies among children and adolescents, as well as adults, demonstrate support that sleep facilitates memory encoding, working memory and long-term memory consolidation [39]. This ability for adequate sleep to foster memory may be through neuronal changes in the prefontal cortex area of the brain [39]. For example, sleep deprivation may negatively influence memory through deficits in prefontal cortex activity. Although speculative, even when tired, regular engagement in physical activity behavior may enhance memory by attenuating this reduction in neuronal activity within the prefontal cortex area of the brain. Additionally, physical activity behavior may enhance memory by increasing cerebral blood flow [40] and neurogenesis [41].

In summary, the findings of the present study indicate that physical activity behavior is weakly associated with sleep among adolescents; however, an important finding emerged in that physical activity behavior was associated with the participants' ability to remember things when sleepy or tired. Although physical activity behavior was objectively-measured, a limitation of this study was using a subjective measure of sleep, which was only available in the NHANES cycle. Additionally, although the Functional Outcomes of Sleep questionnaire has been validated in adults [34], its validity in younger populations, specifically adolescents, is uncertain. The mostly null findings may be attributable, in part, to the use of a non-validated questionnaire for this target population. Furthermore, the mostly null findings may also be attributable to a floor effect, as the participants, on average, engaged in little MVPA. For example, only 1.5% of the participants met the adolescent current physical activity guidelines (i.e., 420 min/week of at least moderate-intensity physical activity [60 min/day x 7 days/week]) [42]. Major strengths to this study include using an objective measure of physical activity over a 7-day period and examining the association between physical activity behavior and numerous sleep-related parameters in older adolescents. This contributes to the literature as, to the best of our knowledge, this has not previously been done. Given the cross-sectional nature of the present study, which precludes any ability to make causal inferences, future studies among adolescents are encouraged to use a prospective study design and an objective measure of sleep when further examining the association between physical activity and the ability to remember things when tired, as well as delineate the mechanisms that may explain this potential association.

Table 2. Weighted proportions of the categorical sleeping-related variables.

Sleeping Variable	Proportion (95% CI)
How often do you snore	
Never (n = 168)	59.7 (49.0-70.5)
Rarely or more (n = 97)	40.2 (29.4-50.9)
How often do you snort/stop breathing	
Never (n = 268)	95.7 (93.0-98.3)
Rarely or more (n = 18)	4.2 (1.6-6.9)
Ever told doctor you had trouble sleeping	
Yes (n = 13)	6.6 (0.3-12.8)
No (n = 280)	93.3 (87.1-99.6)
Doctor ever tell you that you have a sleep disorder	
Yes (n = 3)	0.7 (0.00-2.4)
No (n = 290)	99.2 (97.5-100)
How often do you have trouble falling asleep	
Never (n = 126)	31.1 (19.1-43.0)
Rarely (n = 80)	31.8 (23.2-40.3)
Sometimes or more (n = 87)	37.0 (25.6-48.4)
How often do you wake up at night	
Never (n = 136)	43.6 (35.6-51.6)
Rarely (n = 73)	24.7 (17.7-31.7)
Sometimes or more (n = 84)	31.5 (21.9-41.2)
How often do you wake up too early in the morning	
Never (n = 158)	53.9 (43.7-64.1)
Rarely (n = 45)	12.5 (7.0-18.0)
Sometimes (n = 55)	20.1 (13.5-26.8)
Often or more (n = 35)	13.3 (7.0-19.6)
How often do you feel unrested during the day	
Never (n = 79)	20.8 (12.6-28.9)
Rarely (n = 64)	22.6 (17.2-28.0)
Sometimes (n = 79)	26.8 (17.4-36.2)
Often or more (n = 71)	29.7 (24.3-35.1)
How often do you feel overly sleeping during the day	
Never (n = 104)	26.3 (17.7-34.8)
Rarely (n = 70)	26.2 (17.8-34.5)
Sometimes (n = 76)	25.7 (17.2-34.3)
Often or more (n = 43)	21.6 (15.7-27.5)
How often do you not get enough sleep	
Never (n = 83)	22.0 (12.9-31.1)
Rarely (n = 54)	18.7 (12.4-25.0)
Sometimes (n = 88)	27.8 (19.1-36.4)
Often or more (n = 68)	31.3 (23.2-39.5)
How often do you take pills to help you sleep	
Never (n = 274)	90.4 (86.9-93.9)
Rarely or more (n = 19)	9.5 (6.0-13.0)
How often do you have leg jerks while sleeping	
Never (n = 243)	78.0 (69.7-86.2)
Rarely or more (n = 49)	21.9 (13.7-30.2)
How often do you have leg cramps while sleeping	
Never (n = 219)	74.2 (66.1-82.3)
Rarely or more (n = 74)	25.7 (17.6-33.8)
Difficulty concentrating when tired	
No difficulty (n = 199)	69.2 (60.9-77.4)
Yes, a little difficulty or more (n = 91)	30.7 (22.5-39.0)
Difficulty remembering when tired	
No difficulty (n = 232)	78.3 (67.6-88.9)
Yes, a little difficulty or more (n = 58)	21.6 (11.0-32.3)
Difficulty eating when tired	
No difficulty (n = 280)	96.0 (92.6-99.4)
Yes, a little difficulty or more (n = 11)	3.9 (0.5-7.3)
Difficulty with a hobby when tired	
No difficulty (n = 239)	81.6 (73.1-90.2)
Yes, a little difficulty or more (n = 42)	18.3 (9.7-26.8)
Difficulty getting things done	
No difficulty (n = 245)	90.4 (84.7-96.1)
Yes, a little difficulty or more (n = 31)	9.5 (3.8-15.2)
Difficulty with finances when tired	
No difficulty (n = 182)	63.0 (51.1-74.9)
Yes, a little difficulty or more (n = 102)	36.9 (25.0-48.8)
Difficulty at work because tired	
No difficulty (n = 217)	77.8 (68.9-86.7)
Yes, a little difficulty or more (n = 66)	22.1 (13.2-31.0)
Difficulty on phone when tired	
No difficulty (n = 226)	78.9 (71.1-86.7)
Yes, a little difficulty or more (n = 65)	21.0 (13.2-28.8)

PA, physical activity

REFERENCES

1. Sigurdson K, Ayas NT. The public health and safety consequences of sleep disorders. Can J Physiol Pharmacol. 2007;85:179-183.
2. Spruyt K, O'Brien LM, Cluydts R, Verleye GB, Ferri R. Odds, prevalence and predictors of sleep problems in school-age normal children. J Sleep Res. 2005;14:163-176.
3. Liu X, Liu L, Owens JA, Kaplan DL. Sleep patterns and sleep problems among schoolchildren in the United States and China. Pediatrics. 2005;115:241-249.
4. Johnson EO, Roth T, Schultz L, Breslau N. Epidemiology of DSM-IV insomnia in adolescence: lifetime prevalence, chronicity, and an emergent gender difference. Pediatrics. 2006;117:e247-256.
5. National Sleep Foundation (2006). Sleep in Americal poll. Washington, D.C.
6. National Sleep Foundation (2011). How much sleep do we really need? Retrieved from: http://www.sleepfoundation.org/article/how-sleep-works/how-much-sleep-do-we-really-need.
7. Banks S, Dinges DF. Behavioral and physiological consequences of sleep restriction. J Clin Sleep Med. 2007;3:519-528.
8. Curcio G, Ferrara M, De Gennaro L. Sleep loss, learning capacity and academic performance. Sleep Med Rev. 2006;10:323-337.
9. Nixon GM, Thompson JM, Han DY, et al. Short sleep duration in middle childhood: risk factors and consequences. Sleep. 2008;31:71-78.
10. Touchette E, Petit D, Seguin JR, et al. Associations between sleep duration patterns and behavioral/cognitive functioning at school entry. Sleep. 2007;30:1213-1219.
11. Harrington S. Objective measurements of physical activity and sleep in eight-year-olds. Applied Nursing Research. In Press.
12. Sadeh A, Gruber R, Raviv A. Sleep, neurobehavioral functioning, and behavior problems in school-age children. Child Dev. 2002;73:405-417.
13. Wolfson AR, Carskadon MA. Sleep schedules and daytime functioning in adolescents. Child development. 1998;69:875-887.
14. Shin C, Kim J, Lee S, Ahn Y, Joo S. Sleep habits, excessive daytime sleepiness and school performance in high school students. Psychiatry and clinical neurosciences. 2003;57:451-453.
15. Richey SM, Krystal AD. Pharmacological Advances in the Treatment of Insomnia. Curr Pharm Des. 2011.
16. Watson CJ, Baghdoyan HA, Lydic R. Neuropharmacology of Sleep and Wakefulness. Sleep Med Clin. 2010;5:513-528.
17. Loprinzi PD, Cardinal BJ. Association between objectively-measured physical activity and sleep, NHANES 2005-2006. Mental Health and Physical Activity. 2011;4:65-69.
18. Youngstedt SD, Kline CE. Epidemiology of exercise and sleep. Sleep and Biological Rhythms. 2006;4:215-221.
19. Loprinzi PD, Loprinzi KL, Cardinal BJ. The relationship between physical activity and sleep among pregnant women. Mental Health and Physical Activity. In Press.
20. Nixon GM, Thompson JM, Han DY, et al. Falling asleep: the determinants of sleep latency. Arch Dis Child. 2009;doi:10.1136/adc.2009.157453
21. Liu X, Uchiyama M, Okawa M, Kurita H. Prevalence and correlates of self-reported sleep problems among Chinese adolescents. Sleep. 2000;23:27-34.
22. Gupta NJ, Mueller WH, Chan W, Meininger JC. Is obesity associated with poor sleep quality in adolescents. American Journal of Human Biology. 2002;14:762-768.
23. 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.
24. Gaina A, Sekine M, Hamanishi S, et al. Daytime sleepiness and associated factors in Japanese school children. J Pediatr. 2007;151:518-522, 522 e511-514.
25. Dworak M, Wiater A, Alfer D, et al. Increased slow wave sleep and reduced stage 2 sleep in children depending on exercise intensity. Sleep Med. 2008;9:266-272.
26. Foti KE, Eaton DK, Lowry R, McKnight-Ely LR. Sufficient sleep, physical activity, and sedentary behaviors. Am J Prev Med.41:596-602.
27. Ortega FB, Ruiz JR, Labayen I, et al. Sleep duration and activity levels in Estonian and Swedish children and adolescents. Eur J Appl Physiol.111:2615-2623.
28. Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. British journal of sports medicine. 2003;37:197-206; discussion 206.
29. Chen KY, Bassett DR, Jr. The technology of accelerometry-based activity monitors: current and future. Medicine and science in sports and exercise. 2005;37:S490-500.
30. Freedson P, Pober D, Janz KF. Calibration of accelerometer output for children. Med Sci Sports Exerc. 2005;37:S523-S530.
31. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. Medicine and science in sports and exercise. 2008;40:181-188.
32. Trost SG, Loprinzi PD, Moore R, Pfeiffer KA. Comparison of accelerometer cut points for predicting activity intensity in youth. Medicine and science in sports and exercise. 2011;43:1360-1368.
33. Loprinzi PD, Cardinal B. Measuring children's physical activity and sedentary behaviors. Journal of Exercise Science and Fitness. 2011;9:15-23.
34. Weaver TE, Laizner AM, Evans LK, et al. An instrument

to measure functional status outcomes for disorders of excessive sleepiness. Sleep. 1997;20:835-843.

35. Cappuccio FP, Taggart FM, Kandala NB, et al. Meta-analysis of short sleep duration and obesity in children and adults. Sleep. 2008;31:619-626.

36. Iglowstein I, Jenni OG, Molinari L, Largo RH. Sleep duration from infancy to adolescence: reference values and generational trends. Pediatrics. 2003;111:302-307.

37. National Health and Nutrition Examination Survey. Anthropometry Procedures Manual. 2000. Available at: http://www.cdc.gov/nchs/data/nhanes/bm.pdf.

38. Strong WB, Malina RM, Blimkie CJ, et al. Evidence based physical activity for school-age youth. J Pediatr. 2005;146:732-737.

39. Kopasz M, Loessl B, Hornyak M, et al. Sleep and memory in healthy children and adolescents - a critical review. Sleep Med Rev.14:167-177.

40. Ide K, Secher NH. Cerebral blood flow and metabolism during exercise. Prog Neurobiol. 2000;61:397-414.

41. van der Borght K, Ferrari F, Klauke K, et al. Hippocampal cell proliferation across the day: increase by running wheel activity, but no effect of sleep and wakefulness. Behav Brain Res. 2006;167:36-41.

42. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans. October 2008. [online] http://www.health.gov/paguidelines/.

43. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000;320:1240-1243.