Short Communication

An Association Between Physical Activity and Sleepiness

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ABSTRACT

Background: Physical activity (PA) has many beneficial effects on health; however, high PA level-related problems have been identified.

Aims: The current study aimed to assess associations between PA and several lifestyle habits including sleep variables in pupils in Japan.

Methods: Questionnaires of 2,722 pupils in grades 5 to 12 were included, and a multiple regression analysis was conducted using the number of days engaged in PA (PA score) as an objective variable. Several lifestyle habits including sleep-related factors were used as the explanatory variables.

Results: The factors significantly associated with an increased PA score included male gender, earlier awake time on both school days and non-school days, less screen time on non-school days, less breakfast skipping, increased sleepiness, and longer after-school activities. According to a multiple comparison test of the Bonferroni post-hoc method, pupils in both physical inactivity (PA score of 0) and excessive PA (PA score of 7) categories showed higher sleepiness scores than pupils who engaged in PA one or two days a week.

Limitations: This study used a cross-sectional design and was unable to identify a causal relationship.

Conclusion: Attention should be paid on the possibility that not only low but also high levels of PA induce sleepiness.

Keywords: negative social jet lag, pupils, self-regulation

INTRODUCTION

There is a strong general belief that physical activity (PA) has many beneficial effects on health-related quality of life[1]. Moderate-to-vigorous PA has been known to improve weight status, cardiovascular health, mental health and the cognitive performance of children and adolescents[2, 3].

Contrarily, excessive PA was suggested to affect myocardial morphology and to increase the prevalence of cardiovascular problems. Möhlenkamp et al.[4] demonstrated a high prevalence of advanced coronary atherosclerosis and myocardial scar formation in healthy marathon runners aged 50 years or more. According to the review by O'Keefe et al. [5], chronic training for and competing in extreme endurance events such as marathons, ultra marathons, ironman distance triathlons, and very long distance bicycle races, can cause transient acute volume overload of the atria and right ventricle, with transient reductions in right ventricular ejection fraction and elevations of cardiac biomarkers. Zhu et al. [6] reported the higher prevalence rates of prehypertension and hypertension in subjects performing not only vigorous-intensity PA but also moderate-intensity PA aged 15 to 45 years. The rates were 47.8% (prehypertension in vigorous-intensity PA group), 8.2%

(hypertension in vigorous-intensity PA group), 44.2% (prehypertension in moderate-intensity PA group) and 6.2% (hypertension in moderate-intensity PA group), respectively. They concluded that long-term and sustained PA may increase the risk for hypertension in young and middle-aged subjects. Moreover, according to the review attempting to highlight the recent literature regarding sleep issues in athletes, athletes are more likely to be sleep-deprived[7]. However, a few reports have assessed this association in the general adolescence population. In a sample of Brazilian senior high school (SHS) pupils, lower rather than higher PA level was reported to be associated with daytime sleepiness[8]. For junior high school (JHS) pupils, in comparison with PA levels of "almost always" group, those who reported "often," "seldom," and "almost never" PA levels demonstrated gradual higher odds ratios of sleepiness, and thus high PA levels have been concluded as an issue that should be promoted[9]. In 1882 elementary school (ES) pupils, aged 6–13 years, physical inactivity was found to be significantly associated with daytime sleepiness[10]. Thus, few studies have sounded the alarm on the excessive PA-induced sleepiness among pupils in general population. Recently, sleepiness rather than sleep duration has paid attention among adolescents in terms of academic performance[11] and self-regulation[12] In the present study, associations between PA and several lifestyle habits including sleep variables are assessed in pupils in Japan.

METHODS

The current study was a part of a survey conducted between October 2016 and November 2018. Details of the survey have been described elsewhere[13].

An original questionnaire (Table 1) was used that was constructed by referring to queries from the Japan Society of School Health[14]. The questionnaire was administered to students in grades 5-12 by their school teachers between October 2016 and November 2018. A letter was provided to the students assuring them that their responses would be treated anonymously and confidentially and that participation in the study was voluntary. Written consents (signed by a guardian) and completed questionnaires were collected by school teachers on a different day and were subsequently sent to the author. Of the 4,208 students whose questionnaires were collected from 28 public schools (15 ESs, 8 JHSs, and 5 SHSs), 2,722 agreed to participate in the study and provided responses to the required questions.

PA score was defined by the number of days per week engaged in PA. Bedtime before school days, bedtime before non-school days, wake time on school days, and wake time on non-school days were indicated by numbers corresponding to each choice in the questionnaire, and were termed as bedtime before school days score, bedtime before non-school days score, wake time on school days score, and wake time on non-school days score, respectively. The numbers selected corresponding to the questions on sleepiness, skipping breakfast, defecation, school-day screen time, non-school-day screen time, and self-reported academic performance were termed the sleepiness score, skipping breakfast score, defecation score, school-day screen time score, non-school-day screen time score, and self-reported academic performance score, respectively. Hours of after-school activity per week obtained by the product of the two numbers of the two queries (one on the frequency and the other on the duration) was termed the after-school activity score. A dinner regularity score of 1 was assigned to

the choice of 1 to 7 of the questionnaire designated regular dinner, and a dinner regularity score of 2 denoted irregular dinner (the last choice of 8 in the questionnaire). Body mass indices (BMIs) were calculated from the body weight and height reported by the subjects themselves, and the gender- and grade- standardised ones were used for the analysis.

To determine the factors associated with PA score, multiple regression analysis was conducted, using PA score as an objective variable. Grade, gender, bedtime before school days score, bedtime before non-school days score, wake time on school days score, wake time on non-school days score, sleepiness score, breakfast intake score, defecation score, screen time score of both school days and non-school days, self-reported academic performance score, after-school activity score, dinner regularity score, and standardized BMI were used as the variables. If needed, a multiple comparison test of the Bonferroni post-hoc method (MCTBM) was conducted. These analyses were conducted using a software program called "BellCurve for Excel".

This study was approved by the Committee for Medical Research Ethics of an institute where the author belonged (no. 199).

RESULTS

The numbers of participating subjects were 441 for ES male, 515 for ES female, 541 for JHS male, 508 for JHS female, 385 for SHS male and 332 for SHS female, respectively. Figure 1 showed the distribution of pupils among PA categories in each school type. Females occupied the highest rate in the 'zero' category, while males in the '7' category, except for ES. For both genders, the rate of 'zero' category increased gradually from ES to SHS via JHS. By adding the numbers of both genders together, the rate of pupils belonging to the 'zero' category was found to be 26.8% in ES, 28.9% in JHS, and 42.4% in HS, respectively.

A significant regression formula for PA score was obtained (adjusted $R2=0.16$, $p<0.001$). The factors significantly associated with an increase in PA score included male gender, earlier awake time on both school days and non-school days, less screen time on non-school days, less breakfast skipping, more sleepiness, and longer after-school activity (Table 2).

Since this result on sleepiness was not consistent to former studies[8-10], MCTBM was conducted on sleepiness score among five PA categories. The highest mean sleepiness score was 2.09 in the PA score of 'zero' category following by the PA score of 7 category (the mean sleepiness score; 2.03). The lowest value of 1.82 in the category of PA scores of 1 and 2 was significantly lower than both categories of PA score of 'zero' and 7 ($p<0.01$, Cohen's d value>0.20).

Table 1: Questionnaires

Queries	Choices for answer
Please mark your grade.	Elementary school (grade 5, 6), Junior high school (grade 1, 2, 3), High school (grade 1, 2, 3)
Please mark your gender.	Gender (male, female)
Please describe your height and weight.	Height (cm), Weight (kg)
Please mark your bed time before school days.	1. < 8 PM, 2. 8 PM – 9 PM, 3. 9 PM – 10 PM, 4. 10 PM – 11 PM, 5. 11 PM – 12 AM, 6. 12 AM – 1 AM, 7. 1 AM – 2 AM or 8. 2 AM – 3 AM or 9. > 3 AM
Please mark your bed time before non-school days.	1. < 8 PM, 2. 8 PM – 9 PM, 3. 9 PM – 10 PM, 4. 10 PM – 11 PM, 5. 11 PM – 12 AM, 6. 12 AM – 1 AM, 7. 1 AM – 2 AM, 8. 2 AM – 3 AM or 9. > 3 AM
Please mark your wake time on school days.	1. < 5 AM, 2. 5 AM – 6 AM, 3. 6 AM – 7 AM, 4. 7 AM – 8 AM, 5. 8 AM – 9 AM, 6. 9 AM – 10 AM, 7. 10 AM – 11 AM, 8. 11 AM – 12 PM or 9. > 12 PM
Please mark you wake time on non-school days.	1. < 5 AM, 2. 5 AM – 6 AM, 3. 6 AM – 7 AM, 4. 7 AM – 8 AM, 5. 8 AM – 9 AM, 6. 9 AM – 10 AM, 7. 10 AM – 11 AM, 8. 11 AM – 12 PM or 9. > 12 PM
Please mark the frequency you feel sleepy during class.	1. never, 2. sometimes, 3. often or 4. always
Please mark your frequency of eating breakfast.	1. always, 2. often, 3. sometimes or 4. never
Please mark your frequency of defecation.	1. every day, 2. every other day, 3. once every two to three days or 4. twice a week or less
Please mark the time you usually eat dinner.	1. around 6 PM, 2. around 7 PM, 3. around 8 PM, 4. around 9 PM, 5. around 10 PM, 6. around 11 PM, 7, later than 11 PM or 8. not determined
Do you participate in any kinds of after-school activity?	1. Yes, 2. No
If yes, please mark your frequency of participating in after-school activity.	1. once a week, 2. twice a week, 3. three times a week, 4. four times a week, 5. five times a week, 6. six times a week or 7. every day.
If yes, please mark the average duration of a single after-school activity.	1. 1 hour, 2. 2 hours, 3. 3 hours, 4. 4 hours or 5. 5 hours or more.
How many days a week do you perform habitual exercise except for school lessons?	0. none, 1. one day per week, 2. two days per week, 3. three days per week, 4. four days per week, 5. five days per week, 6. six days per week or 7. seven days per week
How long do you use various media devices (television, video, video game, digital versatile disc, computer, tablet, mobile [cell] phone, smart phone) in a day? Please answer separately on school days and non-school days.	On a school day. 1. < 2 hours, 2. 2–4 hours, 3. 4–6 hours, 4. 6–8 hours or 5. 8 hours or more.
	On a non-school day. 1. < 2 hours, 2. 2–4 hours, 3. 4–6 hours, 4. 6–8 hours or 5. 8 hours or more.
Please mark the best choice for your overall academic performance.	1. very good, 2. good, 3. not good or 4. poor.

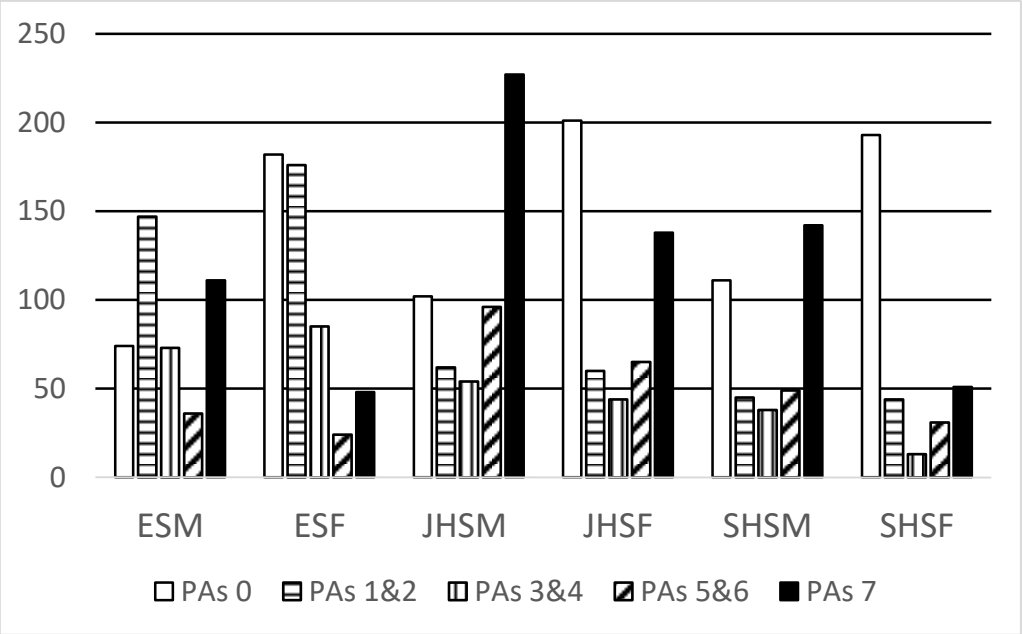
DISCUSSION

Consistent with previous reports[15, 16], the rate of pupils belonging to 'zero' category was gradually increasing from ES to HS via JHS. Some of the features of higher PA pupils (male dominancy, earlier awake time and less screen time on non-school day, and longer after-school activity) were similar to those with negative social jetlag[17], whose health consequences have been warned of[18].

Table 2: Significant factors associated with physical activity score on multilinear regression analysis

Significant Factors (score)	Regression Coefficient (95% Confidence Interval)	β	p
Constant	8.34 (7.54-9.13)	8.34	<0.001
Gender (male 1; female 2)	-1.44 (-1.64 - -1.23)	-0.25	<0.001
Screen time on non-school-day score	-0.24 (-0.38 - -0.09)	-0.09	<0.01
Sleepiness score	0.18 (0.04-0.32)	0.05	<0.05
Skipping breakfast score	-0.22 (-0.41– -0.03)	-0.04	<0.05
Wake time on school-day score	-0.41 (-0.59 – -0.23)	-0.09	<0.001
Wake time on non-school-day score	-0.40 (-0.49 – -0.31)	-0.20	<0.001
After-school activity score	0.02 (0.002–0.03)	0.04	<0.05

Figure 1: Distribution of pupils in each five physical activity score category of each school type with each gender.



With regard to the association with sleepiness, pupils with PA score categories of 'zero' and 7 showed significantly higher sleepiness scores than pupils with PA scores of 1 and 2. Sleepiness is a better predictor of not only academic performance[11] but also self-regulation[12] than sleep duration. Also, self-regulation in adolescents is known to contribute to a range of positive health and functioning outcomes that have potential long-term implications. Taken together with the importance of self-regulation, further studies are needed to investigate associations between PA and sleepiness, and to propose an optimal PA level.

There were some limitations to the current study. First, the study used a cross-sectional design and was unable to identify a causal relationship. Second, the questionnaire was not validated. However, it was made with reference to a questionnaire used in a national survey, the results of which have been used as the fundamental data for policymaking as well as for developing manuals on the proper lifestyle of children in Japan[14]. Third, the responses to the questionnaire depended on self-reports without objective measurements. It should be noted,

however, that the mean BMI values obtained were similar to those of Japanese schoolchildren.[9] Fourth, the present study did not include demographic factors such as family composition, socioeconomic status, and parents' educational background. Fifth, this study lacked age-related information as the queries we referred to lacked information about age[14]. Finally, this study did not use a standardised sleepiness scale but use a simple single question; however, test–retest reliability of the famous Epworth Sleepiness Scale has recently been reported to be poor[19]. Despite these limitations, this study for the first time showed an association between high PA level and sleepiness among pupils in the general population.

CONCLUSION

Not only low but also high levels of PA among pupils may produce sleepiness resulting in reducing self-regulation.

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