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Annual longitudinal survey at up to five time points reveals reciprocal effects of bedtime delay and depression/anxiety in adolescents



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ABSTRACT

Objective: To investigate the longitudinal relationship between sleep habits and mental health in adolescents. **Methods:** Multipoint observation data of up to five years were employed from a prospective cohort study of sleep habits and mental health status conducted from 2009 to 2013 in a unified junior and senior high school (grades 7–12) in Tokyo, Japan. A total of 1078 students answered a self-report questionnaire, including items on usual bed and wake-up times on school days, and the Japanese version of the 12-item General Health Questionnaire (GHQ-12).

Results: Latent growth model (LGM) analysis, which requires three or more time point data, showed that longitudinal changes in bedtime and GHQ-12 score (or score for depression/anxiety) were significantly and moderately correlated (correlation coefficient = 0.510, $p < 0.05$). Another result of interest was that, using an autoregressive cross-lagged (ARCL) model, bedtime and the depression/anxiety score had reciprocal effects the following year: ie, bedtime significantly affects the following year's depression/anxiety, and vice versa. In addition, the analysis provided estimates of mutually predicted changes: one-hour bedtime delay may worsen the GHQ-12 score by 0.2 points, and one-point worsening of the score may delay bedtime by 2.2 minutes.

Conclusions: By using up to five multiple time point data, the present study confirms the correlational and reciprocally longitudinal relationship between bedtime delay and mental health status in Japanese adolescents. The results indicate that preventing late bedtime may have a significant effect on improving mental health in adolescents.

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1. Introduction

An adequate amount of sleep is of great importance for the growth and maturation of adolescents, while consistent rapid declines in sleep duration have been described in adolescents over the past 100 years [1]. Not only a lack of sleep, but also a delay in sleep pattern with increasing age has been pointed out in adolescents, especially in Asian countries [2]. Mounting evidence has shown that inappropriate sleep habits, including sleep deprivation and sleep/wake timing shifts, have negative effects on cognitive and behavioral

processes, such as concentration, learning, memory, attention, and emotional regulation, which are related to academic success [1,3,4]. The effects of sleep habits are also significant for mental and physical health and its disturbances, including depression, anxiety, suicide ideation, and drug or alcohol abuse [1,3,4]. Among them, mental health status, especially depression and anxiety, is considered to be a major issue associated with sleep habits in adolescents.

A number of cross-sectional studies have observed that short sleep duration or late sleep phase (or eveningness) have been significantly associated with poor mental health, such as depression, anxiety, or loss of positive emotion in adolescents [5–14]. Late bedtime, which implies both short sleep duration and late sleep phase, has also been shown in several studies to be associated with mental health status [15,16]. However, only a limited number of longitudinal studies have been conducted to date. With regard to sleep duration, short sleep has been shown to have effects on psychological health, as well as academic function and physical health in

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young adults aged 17–25 years [17,18]. Similar results have been obtained in children aged 6–12 years [19]. But the only longitudinal study of adolescents (or teenagers), in whom sleep duration sharply decreases and mental disorders start to increase, is that by Roberts and Duong [20]. Their two time point study observed a reciprocal relationship between sleep duration and major depression, where adolescents with shorter sleep had an increased risk of major depression, which in turn decreased the duration of sleep a year later. With respect to late sleep phase (or bedtime), to our knowledge no longitudinal study has investigated the association with mental health in adolescents.

It may also be noted that the previous longitudinal studies were based on two time point observations. In a related field, the longitudinal relationship between difficulty initiating sleep and depression has been investigated among adolescents based on seven time point observations [21]. However, to the best of our knowledge, no studies have investigated the relationship between short sleep duration or late sleep phase (or eveningness) and mental health among adolescents using data from the same individuals at three or more time points. Compared with the two time point investigations, studying data at more time points has several advantages. First, more accurate estimates from sample statistics of sleep habits and mental health (ie, mean, standard deviation and their longitudinal changes and correlations) may be obtained, because the influence of selection bias can be alleviated due to increased homogeneity of sample across ages (or school grades). Second, more detailed information about intra-individual changes is available, which enables statistical modeling of the patterns of change and prediction of future changes over a longer time span. For these reasons, a more accurate and informative evaluation of the longitudinal relationship (eg, correlational and reciprocal relationships) between sleep habits and mental health may be realized.

The primary aim of the present study is to confirm whether a reciprocal relationship is observed between sleep habits and mental health (specifically, depression/anxiety) in adolescents, using data from yearly prospective observations at multiple time points (maximum = five). Bedtime is focused on as the variable for sleep habit, because bedtime may be the most useful factor in practical intervention for adolescents to improve sleep habit. “Go to bed earlier” may be a simpler instruction compared with “Sleep more” or other such instructions. The longitudinal relationship between bedtime and depression/anxiety was studied using two different statistical models. A latent growth model (LGM) [22,23] and an autoregressive cross-lagged (ARCL) model (also known as multivariate autoregression model or vector autoregression model) [24,25] were employed to evaluate correlational and reciprocal relationships of sleep habits and depression/anxiety, respectively. LGM and ARCL models are among the most popular models in longitudinal analyses for behavioral, psychological, and medical sciences. The LGM generally requires data from three or more time points [23]. An ARCL model was employed in a previous longitudinal study of depression and difficulty initiating sleep [21], although mathematical details of the model, including the inequality of autoregressive and cross-lagged coefficients, were different from the present one.

2. Subjects and methods

2.1. Subjects

We used data from a longitudinal survey of sleep habits and mental health status conducted from 2009 to 2013 in a unified junior and senior high school (grades 7–12) in Tokyo, Japan. The survey was conducted every year, and we aimed to recruit approximately 700 students each year to participate in the study. During the five-year period, a total of 1092 students attended the school, of whom 1078 (98.7%) participated in the study (539 males and 533 females,

six unknown). The subjects comprised: 120 grade 7, 118 grade 9, and 112 grade 11 students, who started to participate in survey from 2009 (data with five, four, and two time points, respectively); 119 grade 7, 118 grade 9, and 116 grade 11 students, starting from 2010 (data with four, four, and two time points, respectively); 120 grade 7 students, starting from 2011 (data with three time points); 120 grade 7 students, starting from 2012 (data with two time points); 118 grade 7 students, starting from 2013 (data with one time point); and 17 other students, who were not able to start in the year originally scheduled but were in later years. No students enter the school after grade 7 in this junior and senior high school.

With regard to the procedure of the survey, teachers handed a self-report questionnaire and an envelope to their students. The students were requested to seal the completed questionnaires in the envelopes provided after filling them out in the classroom. Research staff collected the sealed questionnaires at the school. The students and their parents were informed about the aim and content of the survey by letter, three or four weeks before the survey every year. In the letter and on the first page of the questionnaire, we clearly explained the voluntary nature of participation and that the students did not have to attend the survey sessions or complete the questionnaire if the students or their parents did not agree to participate in the survey. Attending the survey sessions and completing the questionnaire were therefore regarded as giving consent.

We complied with Japan’s Ethical Guidelines for Epidemiological Research, and the study was approved by the ethics committees of the Life Science Committee of the University of Tokyo and of the Research Department of the high school.

2.2. Measures

The questionnaire included items on usual bedtimes and wake-up times on school days, asking “What time (hours and minutes) do you usually go to bed on school nights?” and “What time (hours and minutes) do you usually wake up on school days?”, respectively, and demographic characteristics including sex and age. It also included the Japanese version of the 12-item General Health Questionnaire (GHQ-12). The GHQ-12 is one of the most widely used self-report screening tools for non-psychotic psychiatric symptoms, particularly symptoms of anxiety and depression [26]. The validity and reliability of the Japanese version of the GHQ-12 have been confirmed [27]. A four-point scale with binary scoring (0011) was used for each of the questions. Responses of ‘1’ were then added together to form the total score, with a range from 0 (best possible) to 12 (worst possible). The measures were the same every year.

2.3. Statistical analysis

We investigated the pattern of longitudinal changes in bedtime and the GHQ-12 score, and their correlational relationship by using the multivariate LGM [22,23]. In the standard LGM, bedtime (x_{jt}) and the GHQ score (y_{jt}) for the j -th subject at ($t+6$)th grade are linearly modeled by the following equations:

$$\begin{aligned} x_{jt} &= f_{lxj} + (t-1)f_{sxj} + \varepsilon_{xjt} \\ y_{jt} &= f_{lyj} + (t-1)f_{syj} + \varepsilon_{yjt}. \end{aligned} \quad (1)$$

Here, f_{lxj} and f_{lyj} are intercept factor scores of the j -th subject for each variable, which represent the true scores for each variable at the first time point (7th grade). f_{sxj} and f_{syj} are slope factor scores of the j -th subject for each variable, which represent the constant annual changes of true scores. ε_{xjt} and ε_{yjt} are measurement error terms assumed to be uncorrelated with factor scores and distributed as $\varepsilon_{xjt} \sim N(0, \varphi^2_{xt})$ and $\varepsilon_{yjt} \sim N(0, \varphi^2_{yt})$, respectively (φ^2 : error variances, N : normal distribution).

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