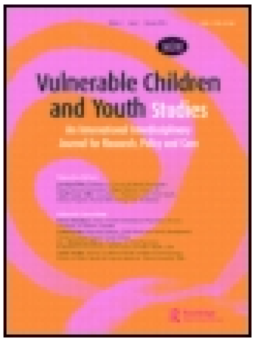
Title	Impaired Executive Function in Junior High School Students with Excess Sleep Time
Author(s)	桃田, 茉子
Citation	大阪大学, 2019, 博士論文
Version Type	VoR
URL	https://doi.org/10.18910/73471
rights	
Note	

Impaired Executive Function in Junior High School Students with Excess Sleep Time
（日本人中学生を対象にした睡眠習慣と実行機能の関連の検討）

大阪大学大学院
大阪大学・金沢大学・浜松医科大学・千葉大学・福井大学
連合小児発達学研究科
小児発達学専攻

桃　田　茉　子

２０１９年５月　博士学位論文



Vulnerable Children and Youth Studies
An International Interdisciplinary Journal for Research, Policy and Care

ISSN: 1745-0128 (Print) 1745-0136 (Online) Journal homepage: https://www.tandfonline.com/loi/rvch20

Impaired executive function in junior high school students with excess sleep time

Mako Momoda, Arika Yoshizaki, Fumiyo Nagatani, Tomoko Nishimura, Masako Taniike & Ikuko Mohri

VULNERABLE CHILDREN AND YOUTH STUDIES
https://doi.org/10.1080/17450128.2019.1580404

ARTICLE

Impaired executive function in junior high school students with excess sleep time

Mako Momoda[a], Arika Yoshizaki[b], Fumiyo Nagatani[b], Tomoko Nishimura[c], Masako Taniike[a] and Ikuko Mohri[a]

[a]Department of Child Development, United Graduate School of Child Development, Osaka University, Osaka, Japan; [b]Research Center for Children's Mental Development, United Graduate School of Child Development, Osaka University, Osaka, Japan; [c]Research Centre for Child Mental Development, Hamamatsu University School of Medicine, Shizuoka, Japan

ABSTRACT

We examined the relationship between sleep habits and executive function (EF) in Japanese junior high school students.This study was conducted using an online survey involving 1,919 boys and girls (aged 12–15 years) and their caregivers.Sleep habits were measured with the Japanese Sleep Questionnaire for junior high school students (JSQ-JH). EF was measured with the parental form of the Japanese version of Behavior Rating Inventory of Executive Function (J-BRIEF). A U-shaped relationship was found between total sleep time (ST) and behavior regulation index, metacognition index, and Global Executive Composite Score of the J-BRIEF (i.e., both short ST and long ST students showed wrong EF). Adjusted logistic regression analyses revealed that short ST group showed significantly higher scores on the J-BRIEF Shift, Emotional Control, and Initiate subscales, and the long ST group showed significantly higher scores on almost all the J-BRIEF subscales compared to the mean ST group. Regarding lifestyle, the short ST group seemed to be active until midnight leading to the shortage of ST; however, the long ST group seemed to be inactive during the day, not enjoying their school life, and difficult getting a deep sleep. Executive dysfunction was significantly associated with not only the short ST, but also excessively long ST. Education regarding the importance of sleep is required for short ST students. For long ST students, further investigation is needed to evaluate their EF and the presence of maladjustment.

ARTICLE HISTORY
Received 11 May 2018
Accepted 4 February 2019

KEYWORDS
Executive function; BRIEF; metacognition; sleep habits; adolescent

Sleep health is essential for children's physical and mental development. During adolescence, various biological factors lead to profound changes in sleep patterns. Specifically, dim-light melatonin onset delays (Carskadon, Acebo, Richardson, Tate, & Seifer, 1997) may increase emotional and sexual arousal (Sadeh, Gruber, & Raviv, 2002) may lead to a delayed sleep–wake rhythm. Furthermore, psychosocial factors including academic demands, social activities, sports and use of electronic media

CONTACT Ikuko Mohri ikuko@kokoro.med.osaka-u.ac.jp

have been found to be associated with sleep problems (Carskadon, 1990; Van den Bulck, 2007).

Executive function (EF) is an umbrella term that encompasses the set of higher-order processes that govern goal-directed actions and adaptive responses in novel, complex or ambiguous situations (Hughes & Ensor, 2009). To evaluate EF, several rating scales, such as the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000), have been developed. Epidemiological surveys have suggested that sleep deprivation leads to problems in several of the EF BRIEF subscales including Working Memory (WM; Jiang et al., 2011), Inhibit (Telzer, Fuligni, Lieberman, & Galván, 2013), and Shift (Wimmer, Hoffmann, Bonato, & Moffitt, 1992). Anderson, Storfer-Isser, Taylor, Rosen, and Redline (2009) reported that sleepy adolescents performed poorly in multiple areas of executive functioning, and that BRIEF scores were associated with the degree of sleepiness.

The fact that short sleep time (ST) increases the risk of health, behavioral, and cognitive problems is now widely accepted; however, the relationship between long ST and EF in adolescence remains unknown. Therefore, we examined the relationship between ST and EF in Japanese junior high school students.

Methods

Participants and procedures

Parents and junior high school students aged 12–15 years were recruited to participate through an Internet survey firm (INTAGE HOLDINGS Inc. Tokyo, Japan). The survey was conducted in 43 sites across Japan, and data were collected from March to April 2013. This cross-sectional study recruited eligible participants from approximately 150 million Japanese enrollments in the research firm. An e-mail containing a web address link to an online questionnaire was randomly sent by the research company to individuals who were stratified by district, gender, and age. Among the e-mail participants, parents having a child aged from 12 to 15 answer the questionnaire with smartphone, or PC. In total, 2,236 responses were obtained (response rate: 25.5%). In this study, 100% of the study's first contact with the family occurred with the mother. After she answers the questionnaire, the mother then asked her child to complete the questionnaire on the website, and we cross the answers of the mother and the adolescent. Three-hundred seventeen responses were excluded because in those the sum of ST, use of media time, and TV viewing time exceeded 24 h/day, and thus, the accuracy of the responses was doubted. Therefore, in total 1,919 responses were analyzed in this study. In the online survey, participants could not proceed without completing answers to all of the items; therefore, no missing data were observed.

Assessment of sleep status and daytime behavior

The Japanese Sleep Questionnaire for junior high school students (JSQ-JH) is designed to screen for sleep problems in Japanese junior high school students (the standardization of this questionnaire is in preparation).

The JSQ-JH consists of: (1) demographic data, (2) parent-observed sleep status of his/her child, and (3) children's self-reported lifestyle and sleep status on weeknights. Demographic data obtained from parents included the child's sex, age. Parents' observations included wake-up time, bedtime, and bedroom condition of the child (sleeping alone or co-sleeping), as well as 18 items measuring sleep-related problems using a 6-point Likert scale ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). In this study, we used all the parent-observed sleep status data and two out of the 18 items on sleep-related problems. Sample items included, 'my child wakes up at any little sound' and 'my child is often irritable during the day.' In Japan, elementary school-aged children often sleep in the same room with their parents; however, junior high students typically sleep alone. Therefore, we employed both parental observation and children's self-report to determine whether parents aware of their children's sleep.

Children's self-report consisted of items related to sleep-associated lifestyle such as bedtime, wake-up time, media/Internet use, TV viewing, electronic game playing, frequently going out at night, consumption of caffeinated drinks at night, and media/Internet use in the bedroom, in addition to sleep onset latency. In Japan, adolescents often watch TV with their family, while they use smartphone or game devices in their bedrooms. Therefore, we asked about TV viewing and other electric device use separately.

From the 21 items on the JSQ-JH, we used seven items, including: 'I cannot wake up, and I miss school'; 'I do not enjoy school very much'; 'I am always tired'; 'I go to sleep and wake up at irregular times'; 'I sometimes go out at night'; 'I have caffeinated drinks after 8 p.m.'; 'Sometimes I get home after 9 p.m.'; and 'I play games, send texts, and use the Internet in bed'. These items were greatly related to daily life and sleep quality. Regarding sleep onset latency, children who answered either, '60 minutes' or 'more than 1 hour', were categorized as having 'long sleep onset latency.' Since the JSQ-JH was not yet validated, we conducted correlation analyses to confirm the consistency of responses between parent and child. The parent-child correlations were significant on all items, total ST ($r = .42$, $p < .001$), wake-up time ($r = .89$, $p < .001$), bedtime ($r = .73$, $p < .001$), and sleep onset latency ($r = .76$, $p < .001$).

Assessment of executive function

The BRIEF parent form (Gioia et al., 2000) was used to evaluate EF and is categorized into eight subscales: Inhibit, Shift, Emotional Control (EC), Initiate, Plan/Organize, WM, Organization of Materials, and Monitor. Three EF subscales (Inhibit, Shift, EC) belong to the Behavior Regulation Index (BRI), whereas the other five (Initiate, Plan/Organize, WM, Organization of Materials, and Monitor) comprise the Metacognition Index (MCI). BRI and MCI scores are summed to create the Global Executive Composite (GEC) score. Parents rated their children's behavior on a 3-point Likert scale (*never, sometimes*, and *often*) with higher ratings indicate greater impairment. Permission to use the Japanese version of the Behavior Rating Inventory of Executive Function (J-BRIEF) was provided by the publisher (Psychological Assessment Resources, Luts, FL). We recently determined that the J-BRIEF had good reliability and validity (for complete details, see Momoda et al., 2017).

This study was approved by the Institutional Review Board of Osaka University Hospital on 31 March 2011.

Statistical analysis

We first examined the relationship between ST from the JSQ-JH and BRIEF scores in the multiple linear regression analyses. The BRIEF scores were continuous variables as the exposure measure. As it is difficult to judge suitable ST, we divided our samples by ±2SD, and the mean ST group was used as the reference for the comparisons of the long and short ST groups. We defined ST ≤ −2 SD (3.0–5.7 h), as the 'short ST' group (n = 54); −2 SD < ST < 2 SD (5.8–9.6 h), as the 'mean ST' group (n = 1,829); and ST ≥ 2 SD (9.7–12.0 h), as the 'long ST' group (n = 36).

We validated the cut-off point of the indices and subscales of J-BRIEF for Japanese junior high school students as follows: GEC, 118.5; BRI, 39.5; MCI, 77.5; Inhibit, 12.5; Shift, 12.5; EC, 14.5; Initiate, 14.5; WM, 16.5; Plan/Organize, 21.5; Organization of Materials, 12.5; and Monitor, 14.5. Receiver operating characteristic analysis revealed an optimal cut-off of 118.5 (sensitivity = 0.811, specificity = 0.828; Momoda et al., 2017). Logistic regression analyses were used to examine whether differences between ST groups led to the subsequent differences in J-BRIEF subscales. Adjusted models were examined with age and sex as a moderator to analysis possible interactions.

The Kruskal–Wallis test and chi-square test were conducted to explore the relationship between ST and participant characteristics, J-BRIEF scores, and parent- or self-reported items. All analyses were performed with SPSS Statistics 23 IBM SPSS Advanced (IBM Japan, Tokyo, Japan).

Results

Demographic and participant characteristics

A histogram of the participants' ratio and ST revealed a mound-shaped distribution with a peak at 7 h (Figure 1).

Figure 2 shows the J-BRIEF composite scores for each ST group. The histogram of the J-BRIEF composite scores revealed a U-shaped distribution against ST; the scores were high in the children with short and long ST compared with those with mean ST. The participants with the shortest ST (3 h) had the highest of all J-BRIEF composite scores.

Table 1 shows the demographic characteristics of the ST groups. School grade was not significantly different among the three groups. In the short ST group, the number of girls is significantly larger than that of boys. The short ST group woke up earlier than did the mean ST group, and the mean ST group woke up earlier than did the long ST group.

A Kruskal–Wallis test was performed to compare the J-BRIEF scores among the three groups. As shown in Table 1, all J-BRIEF composite scores of the long ST group were significantly higher than those of the mean ST group. Regarding subscales, all scores except for organization of materials were significantly higher in the

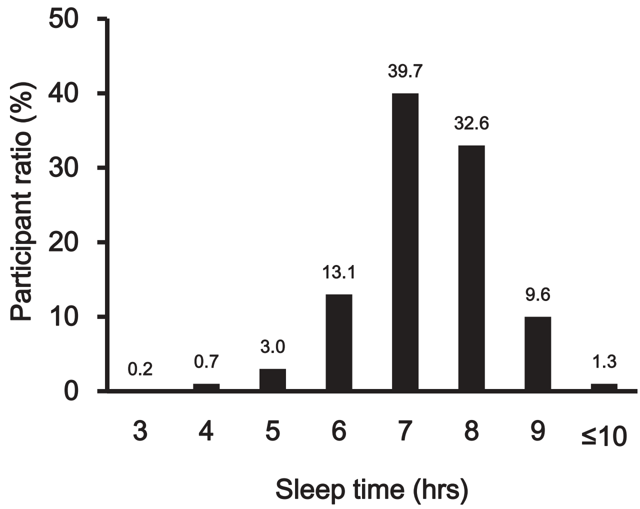


Figure 1. Histogram showing the ratio of the participants by sleep time.

long ST group than those of the mean ST group. In the long ST group, the score for inhibit was significantly higher than that of the short ST group. No significant differences in any other subscales were found between the mean ST group and the short ST group.

Relationship between J-BRIEF scores and ST

Table 2 shows the results of the logistic regression analyses using the categorized data. In the short ST group, the adjusted odds ratios (AORs) of Shift, EC, and Initiate were significantly higher compared to the mean ST group. The long ST group had significantly higher AORs in all scales and except for the organization of materials.

Association of EF with sleep-related lifestyle

We investigate the factors that affect ST and compared the sleep-related lifestyle among the three groups (Figure 3). Total TV viewing time did not differ significantly among the groups. However, TV viewing time after 10 p.m. was the longest in the short ST group compared to the other groups. Total game playing time and total Internet use time were the longest in the long ST group compared to the other groups; however, that time after 10 p.m. was the longest in the short ST group.

Association between ST and sleep-related factors

To determine sleep-related habits, we performed chi-square tests on some of the JSQ-JH questions (Table 3). The ratios that have 'long sleep-onset latency' (46.7%; $p < .001$), were significantly higher, and 'I have breakfast every day' (61.1%; $p < .001$)', were significantly lowest in the long ST group. In the short ST group was significantly associated with 'Sometimes I get home after 9 p.m. (37.0%; $p < .01$)', 'I am always

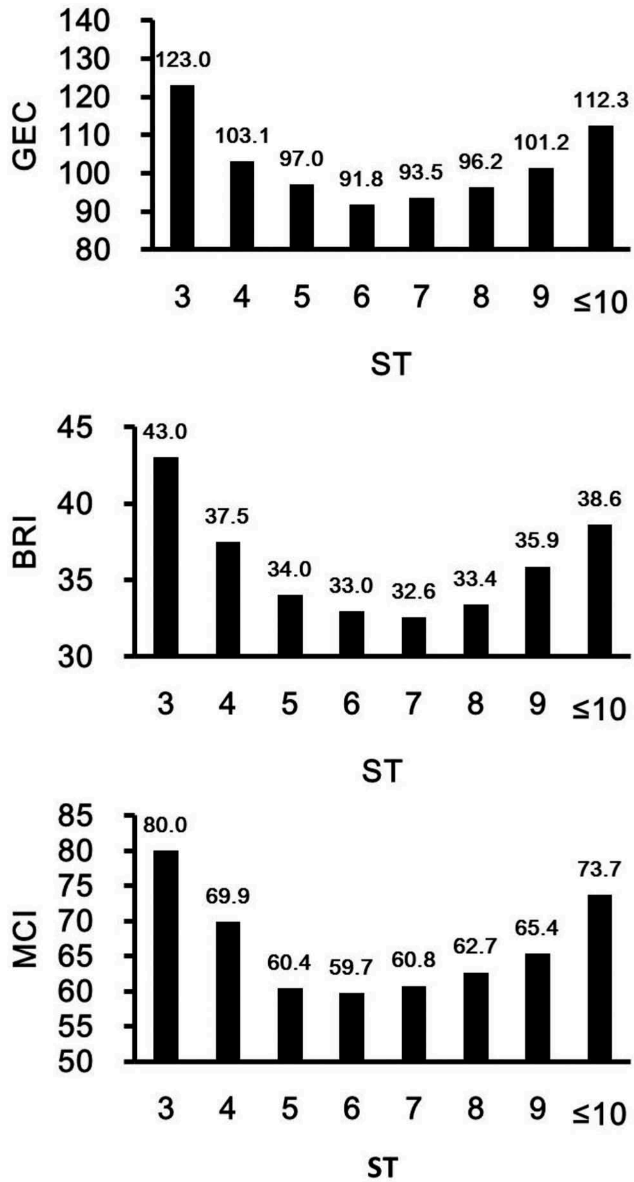


Figure 2. The mean BRIEF scores in the groups with different ST.

ST = sleep time, GEC = global executive composite, BRI = behavioral regulation index,MCI = metacognition index, BRIEF: Behavior Rating Inventory of Executive Function.

tired (20.4%; p < .001)', and 'I go to sleep and wake up at irregular times (27.1%; p < .001)'. In the long ST group was significantly associated with 'I play games, send texts, and use the Internet in bed (44.4%; p < .01)', 'I cannot wake up and miss school (22.2%; p < .001)', and 'I do not enjoy school very much (19.4%; p < .001)'. For parent-reported items, 'my child wakes up at any little sound (3.0%; p < .01)', and 'my child is often irritable during the day (12.1%; p < .001)' were significantly highest in the long ST.

Table 1. Participants' characteristics stratified by sleep time.

	Total 1,919	Short ST 54 (2.5%)	Mean ST 1,829 (95.6%)	Long ST 36 (1.9%)	Kruskal Wallis except for d
Male	910 (47.4%)	17 (31.5%)	871 (47.6%)	22 (61.1%)	*p*< .05[d]
Female	1,009 (52.6%)	37 (68.5%)	958 (52.4%)	14 (38.9%)	
Sleep time	459.4 ± 59.2	303.9 ± 36.0	461.1 ± 59.2	609.9 ± 34.3	abc***
Wake-up time	7:04 ± 1:05	6:19 ± 1:24	7:03 ± 1:02	7:53 ± 1:06	abc***
Bed time	23:00 ± 1:00	25:12 ± 1:18	23:00 ± 1:30	21:36 ± 1:23	abc***
7th grade	662 (34.5)	13 (24.1%)	635 (34.7%)	14 (38.9%)	
8th grade	658 (34.3)	17 (31.5%)	632 (34.6%)	9 (25.0%)	*n.s.*
9th grade	599 (31.2)	24 (44.4%)	562 (30.7%)	13 (36.1%)	
BRIEF subscale					
GEC	95.3 ± 24.0	100.1 ± 25.5	94.8 ± 23.6	114.1 ± 31.6	c**
BRI	33.4 ± 7.7	34.7 ± 8.3	33.2 ± 7.7	38.4 ± 9.1	c***
MCI	61.9 ± 17.5	65.4 ± 18.2	61.5 ± 17.2	75.7 ± 24.1	c**
Inhibit	11.3 ± 2.7	11.1 ± 2.3	11.2 ± 2.7	12.9 ± 3.6	b* c**
Shift	10.0 ± 2.7	10.7 ± 3.1	10.0 ± 2.6	11.7 ± 3.2	c***
Emotional control	12.1 ± 3.2	12.9 ± 3.2	12.1 ± 3.2	13.9 ± 4.0	c**
Initiate	11.4 ± 3.3	12.2 ± 3.4	11.3 ± 3.2	13.5 ± 4.3	c**
Working memory	13.2 ± 3.9	13.8 ± 4.0	13.2 ± 3.8	16.3 ± 5.2	c**
Plan/organize	16.7 ± 5.4	17.6 ± 5.5	16.6 ± 5.4	21.4 ± 7.5	c***
Organization of materials	9.3 ± 3.1	10.0 ± 3.4	9.3 ± 3.1	10.4 ± 3.6	
Monitor	11.3 ± 3.5	11.8 ± 3.8	11.3 ± 3.5	14.1 ± 5.0	c**

ST = sleep time, GEC = global executive composite, BRI = behavioral regulation index, MCI = metacognition index. a = short – mean, b = short – long, c = mean – long. *$p < .05$, **$p < .01$, ***$p < .001$. d = Chi-square test.

Discussion

In this study, Japanese adolescents' mean ST was 7–8 h, which was much the same as previously reported studies (Hyakutake et al., 2016; Ohida et al., 2004), and the total ST of Japanese students is still shorter than any other country (Gradisar, Gardner, & Dohnt, 2011; Kim, Uchiyama, Okawa, Liu, & Ogihara, 2000). In this study, students who slept 7 h showed the best EF; however, we should be careful to judge that 7-h ST is sufficient for adolescents.

As expected, the students who had a shorter ST showed higher J-BRIEF scores, indicating executive dysfunction. However, unexpectedly, the students who had a longer ST also showed higher J-BRIEF scores. As we described above, compared with mean ST group, the short ST group was impaired in Shift, EC and Initiate subscales, and the long ST group was impaired in all scales except for the Organization of materials subscale. Furthermore, in the long ST groups, EF was more broadly impaired than in the short sleep groups not only the number of items but in also the degree of dysfunction reported on each scale, as judged by the mean score of the BRIEF (Table 1.2). Shift, EC and initiate-associated brain area were pre-supplementary motor areas, dorsal and medial prefrontal cortex. Moreover, the effect of insufficient sleep in these areas related to poor performance (Crone, Wendelken, Donohue, van Leijenhorst, & Bunge, 2006; Killgore et al., 2008; Nilsson et al., 2005). The executive dysfunction of short ST group is compatible with these data.

In the short ST group, there were significantly more girls than boys. Previous studies have found that girls tend to sleep less than boys, because girls wake up earlier to prepare for school than boys do (Gau & Soong, 1995). As shown in Figure 3, TV

Table 2. Odds ratio (95% confidence interval) of the adjusted logistic regression model.

Adjusted	BRIEF scales										
ST group	GEC	BRI	MCI	Inhibit	Shift	Emotional control	Initiate	Working memory	Plan/organize	Organization of materials	Monitor
Short ST	1.40 (0.70–2.84)	1.88 (0.97–3.63)	1.65 (0.87–3.13)	0.94 (0.42–2.11)	2.18* (0.18–4.02)	1.93* (1.04–3.61)	2.22** (1.22–4.05)	1.57 (0.81–3.04)	1.59 (0.82–3.08)	1.77 (0.95–3.32)	1.80 (0.95–3.43)
Mean ST						Reference					
Long ST	4.88*** (2.49–9.54)	4.39*** (2.23–8.65)	5.09*** (2.61–9.96)	3.83*** (1.94–7.57)	3.12** (1.56–6.25)	3.13** (1.57–6.26)	4.31*** (2.21–8.40)	4.72*** (2.41–9.24)	3.65*** (1.86–7.18)	1.82 (0.87–3.83)	3.36** (1.70–6.63)

ST = sleep time, BRIEF = Behavior Rating Inventory of Executive Function, GEC = global executive composite, BRI = behavioral regulation index, MCI = metacognition index. *$p < .05$, **$p < .01$, ***$p < .001$.

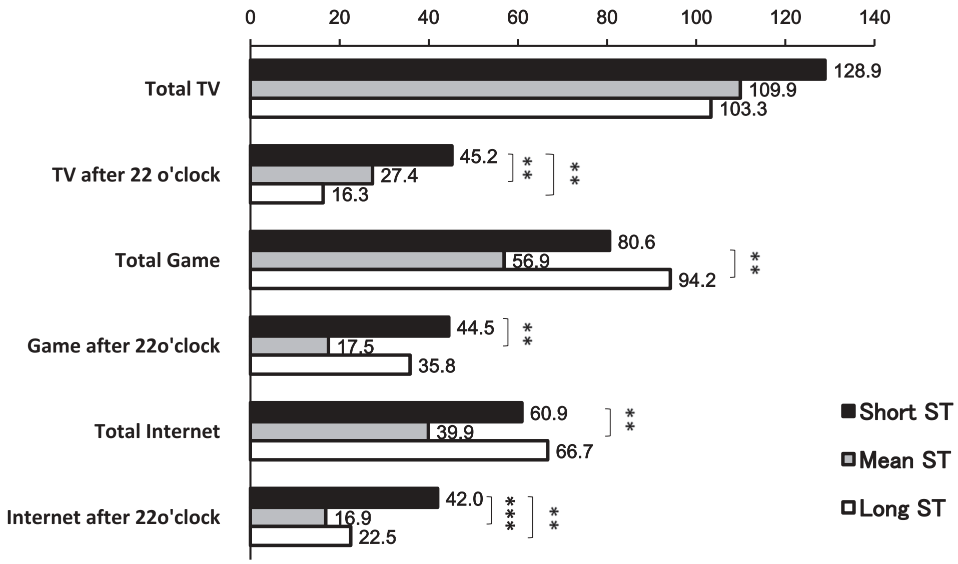


Figure 3. Comparison of sleep-related lifestyle per the three sleep time groups.
**$p< .01$, ***$p< .001$.

Table 3. Comparison of sleep-related behaviors in the three ST groups.

Sleep habits	Short ST	Mean ST	Long ST	χ2
Long sleep-onset latency	9.5%	10.3%	46.7%	***
I have breakfast every day	74.1%	88.6%	61.1%	***
I Sometimes go out at night	9.3%	7.4%	5.6%	*n.s.*
I have caffeinated drinks after 8 p.m.	5.6%	10.2%	5.6%	*n.s.*
Sometimes I get home after 9 p.m.	37.0%	36.1%	11.1%	**
I play games, send texts, and use the Internet in bed	20.4%	22.6%	44.4%	**
Self-report				
I cannot wake up, and I miss school	5.6%	1.6%	22.2%	***
I do not enjoy school very much	11.1%	3.7%	19.4%	***
I am always tired	20.4%	5.9%	13.9%	***
I go to sleep and wake up at irregular times	27.1%	6.0%	16.7%	***
Parents' report				
My child wakes up at any little sound	0.0%	0.8%	3.0%	**
My child is often irritable during the day	6.7%	2.3%	12.1%	***

The ratio of participants of each group is rated a 4 (60 min), 5 (more than 1 h) for 'long sleep onset latency' and 5 (agree) or 6 (strongly agree) for other items. ST = sleep time. **$p< .01$, ***$p< .001$.

viewing, game playing and Internet use after 10 p.m. were significantly longer in the short ST group than in the mean ST group. These habits may lead to a late bedtime and short ST. Furthermore, as shown in Table 3, these students often replied that they were 'I am always tired,' and they 'I go to sleep and wake up at irregular times.' However, their sleep latency was not long, and they were supposed to have a deep sleep, because none of the participants in this group reporting waking up with little sounds. They ate breakfast and made it to school on time and they seemed to be active in their social lives.

On the other hand, it has been reported that children with attention-deficit hyperactivity disorder (ADHD) and executive dysfunction often tend to be short sleepers (Konofal, Lecendreux, & Cortese, 2010). In addition, students with ADHD and executive dysfunction may take longer to complete their daily routine, such as homework, stopping TV viewing or Internet using, and going to bed later (Becker & Langberg, 2014). In this study, we did not assess for ADHD, and further investigation needs to clarify the relation between ADHD and short ST.

Children in the long ST group were less likely to use electric devices after 10 p.m. than children in the mean ST group. Additionally, they did not go out at night, or report missing school because of difficulty getting up, and were often irritable during the day. From these data, it appears that children in the long ST group prefer being solitary, are not actively participating in society, and do not enjoy school life. It may be possible that the long ST group may be more active during the weekend that is free from school, or they may be withdrawn as like weekdays. In this questionnaire, there were items asking about day–night reversal or later bedtimes on the weekends; however, these items aimed to identify sleep-related disorders, so we did not analyze these items. Thus, additional information is needed to clarify the details of their sleep status and life.

The association between long ST and poor EF in this study needs to be clarified. One plausible explanation is that there may be children with underlying conditions that accompany both long ST and poor EF. First, disorders with hypersomnolence, including narcolepsy and idiopathic hypersomnia, show their peak of onset in adolescence, and are often accompanied with a variety of cognitive dysfunctions (Bayard, Langenier, De Cock, Scholz, & Dauvilliers, 2012). Adolescents with these disorders often have long ST (Sateia, 2014). Therefore, there may be some children with these disorders in this study. Second, neurodevelopmental and neurocognitive disorders may be associated with executive dysfunction. These include autism spectrum disorder (ASD) and ADHD. Previous studies have found that children diagnosed with ASD have EF problems and mature later than typical-developing children (Happé, Booth, Charlton, & Hughes, 2006; Luna, Doll, Hegedus, Minshew, & Sweeney, 2007). Regarding sleep, previous studies have indicated that children with ASD had more frequent sleep problems (Hirata et al., 2016; Krakowiak, Goodlin-Jones, Hertz-Picciotto, Croen, & Hansen, 2008), including insomnia, difficulties falling asleep and maintaining sleep, and shorter ST (Elrod & Hood, 2015). In this study, long ST group reported having problems falling asleep, waking up at any little sound. Furthermore, their parents reported that their children ‘wakes up at any little sound’ significantly more often in the long ST group than in the other groups (Table 3). These are suggesting that their children’s overall sleep quality was poorer. Considering that the prevalence of ASD and ADHD are estimated to be 1–2% and 4–5%, respectively (Kessler et al., 2006; Kim et al., 2011), some of these children may have been included in the long ST group.

From the period in which we were collecting data, the usage of smartphones and other devices to access the Internet in children has increased year by year. Japanese government statistics have estimated that the penetration rate of the electronic device among junior high students was approximately 91.5% in 2014 and 92.4% in 2017. Further, the usage time by the students has increased from 130.2 min in 2014 to 148.7 min in 2017 (Cabinet Office of Japan, 2018). It has been estimated that one-fifth of adolescents have Internet access in their bedroom (National Sleep Foundation, 2006). Thus, we must pay attention to shortening ST in adolescents. However, there is no evidence that children with short ST would benefit from education about 'good sleeping habits,' and so further investigations are needed, about whether education on sleep hygiene is effective for prolonging the ST, and normalization of ST improves EF of children with excessively short ST. On the other hand, as shown in Figure 3, the long ST group reported longer Internet use time than did other groups, but they did not have much usage after 10 p.m. This group tend to use the Internet when other groups were concerned with social activities, and their ST was not affected. So, in this group, the maladaptation due to executive dysfunction might be the primary issue with regard to excessively long sleep, but this remains to be clarified.

In conclusion, this study indicates that adolescents who sleep too little or too much displayed executive dysfunction. In caring for adolescents with excessively short or long ST, we should examine the EF.

Limitations

Our study had several limitations. First, the study was designed as an online investigation; therefore, sampling biases may have existed in these results due to self-selection bias. That is, participants may have more interest in these topics. Second, several studies have shown a link between socioeconomic status (SES), sleep, and EF (e.g. Spielberg et al., 2015). However, we did not collect SES data; therefore, the social structure is unknown in our community sample. Third, our survey collected using only subjective data; therefore, its results should be complemented in studies with more objective methods using actigraphs. Finally, the Beebe (2016) editorial in *Sleep* raises possible artefactual contributors to the curvilinear relationships between sleep and outcomes. We have to consider that the required amount of sleep shows some inter-individual (short- and long-duration sleepers), and cultural valuations.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This study was partially supported in part by research grants from the Takeda Science Foundation (to M.T.), in part by research grant of the Ministry of Education, Culture, Sports, Science, and Technology of Japan (15K12721 and 16H03273 to M.T.), Osaka University Program for the Support of Networking among Present and Future Women Researchers (to M.I.), and the Center of Innovation Program from the Japan Science and Technology Agency, JST, Japan (to M.T).

References

Anderson, B., Storfer-Isser, A., Taylor, H. G., Rosen, C. L., & Redline, S. (2009). Associations of executive function with sleepiness and sleep duration in adolescents. *Pediatrics*, *123*(4), e701–e707.

Bayard, S., Langenier, M. C., De cock, V. C., Scholz, S., & Dauvilliers, Y. (2012). Executive control of attention in narcolepsy. *PloS one*, *7*(4), e33525.

Becker, S. P., & Langberg, J. M. (2014). Attention-deficit/hyperactivity disorder and sluggish cognitive tempo dimensions in relation to executive functioning in adolescents with ADHD. *Child Psychiatry & Human Development*, *45*(1), 1–11.

Beebe, D. W. (2016). WEIRD considerations when studying adolescent sleep need. *Sleep*, *39*(8), 1491–1492.

Cabinet Office of Japan. (2018). The result of the "Survey on internet use environment among adolescents in 2017". Retrived from http://www8.cao.go.jp/youth/youth-harm/chousa/h29/net-jittai/pdf/sokuhou.pdf

Carskadon, M. A. (1990). Patterns of sleep and sleepiness in adolescents. *Pediatrician*, *17*(1), 5–12.

Carskadon, M. A., Acebo, C., Richardson, G. S., Tate, B. A., & Seifer, R. (1997). An approach to studying circadian rhythms of adolescent humans. *Journal of Biological Rhythms*, *12*(3), 278–289.

Crone, E. A., Wendelken, C., Donohue, S., van Leijenhorst, L., & Bunge, S. A. (2006). Neurocognitive development of the ability to manipulate information in working memory. *Proceedings of the National Academy of Sciences*, *103*(24), 9315–9320.

Elrod, M. G., & Hood, B. S. (2015). Sleep differences among children with autism spectrum disorders and typically developing peers: A meta-analysis. *Journal of Developmental & Behavioral Pediatrics*, *36*(3), 166–177.

Gau, S. F., & Soong, W. T. (1995). Sleep problems of junior high school students in Taipei. *Sleep*, *18*(8), 667–673.

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). Test review behavior rating inventory of executive function. *Child Neuropsychology*, *6*(3), 235–238.

Gradisar, M., Gardner, G., & Dohnt, H. (2011). Recent worldwide sleep patterns and problems during adolescence: A review and meta-analysis of age, region, and sleep. *Sleep Medicine*, *12*(2), 110–118.

Happé, F., Booth, R., Charlton, R., & Hughes, C. (2006). Executive function deficits in autism spectrum disorders and attention-deficit/hyperactivity disorder: Examining profiles across domains and ages. *Brain and Cognition*, *61*(1), 25–39.

Hirata, I., Mohri, I., Kato-Nishimura, K., Tachibana, M., Kuwada, A., Kagitani-Shimono, K., … Taniike, M. (2016). Sleep problems are more frequent and associated with problematic behaviors in preschoolers with autism spectrum disorder. *Research in Developmental Disabilities*, *49*, 86–99.

Hughes, C. H., & Ensor, R. A. (2009). How do families help or hinder the emergence of early executive function? *New Directions for Child and Adolescent Development*, (123), 35–50. doi:10.1002/cd.234

Hyakutake, A., Kamijo, T., Misawa, Y., Washizuka, S., Inaba, Y., Tsukahara, T., & Nomiyama, T. (2016). Cross-sectional observation of the relationship of depressive symptoms with lifestyles and parents' status among Japanese junior high school students. *Environmental Health and Preventive Medicine*, *21*(4), 265–273.

Jiang, F., VanDyke, R. D., Zhang, J., Li, F., Gozal, D., & Shen, X. (2011). Effect of chronic sleep restriction on sleepiness and working memory in adolescents and young adults. *Journal of Clinical and Experimental Neuropsychology*, *33*(8), 892–900.

Kessler, R. C., Adler, L., Barkley, R., Biederman, J., Conners, C. K., Demler, O., … Spencer, T. (2006). The prevalence and correlates of adult ADHD in the United States: Results from the National Comorbidity Survey Replication. *American Journal of Psychiatry*, *163*(4), 716–723.

Killgore, W. D., Kahn-Greene, E. T., Lipizzi, E. L., Newman, R. A., Kamimori, G. H., & Balkin, T. J. (2008). Sleep deprivation reduces perceived emotional intelligence and constructive thinking skills. *Sleep Medicine*, *9*(5), 517–526.

Kim, K., Uchiyama, M., Okawa, M., Liu, X., & Ogihara, R. (2000). An epidemiological study of insomnia among the Japanese general population. *Sleep*, *23*(1), 41–47.

Kim, Y. S., Leventhal, B. L., Koh, Y. J., Fombonne, E., Laska, E., Lim, E. C., … Song, D. H. (2011). Prevalence of autism spectrum disorders in a total population sample. *American Journal of Psychiatry*, *168*(9), 904–912.

Konofal, E., Lecendreux, M., & Cortese, S. (2010). Sleep and ADHD. *Sleep Medicine*, *11*(7), 652–658.

Krakowiak, P., Goodlin-Jones, B., Hertz-Picciotto, I., Croen, L. A., & Hansen, R. L. (2008). Sleep problems in children with autism spectrum disorders, developmental delays, and typical development: A population-based study. *Journal of Sleep Research*, *17*(2), 197–206.

Luna, B., Doll, S. K., Hegedus, S. J., Minshew, N. J., & Sweeney, J. A. (2007). Maturation of executive function in autism. *Biological Psychiatry*, *61*(4), 474–481.

Momoda, M., Asano, R., Nagatani, F., Miyagawa, H., Nakanishi, M., Yasuda, Y., … Taniike, M. (2017). *The Japanese Journal of Psychology*, *88*(4), 348–357. doi:10.4992/jjpsy.88.16215

National Sleep Foundation. (2006). *Sleep in America poll*. Washington, DC: Author. https://www.sleepfoundation.org/sleep-polls-data/sleep-in-america-poll/2006-teens-and-sleep

Nilsson, J. P., Söderström, M., Karlsson, A. U., Lekander, M., Åkerstedt, T., Lindroth, N. E., & Axelsson, J. (2005). Less effective executive functioning after one night's sleep deprivation. *Journal of Sleep Research*, *14*(1), 1–6.

Ohida, T., Osaki, Y., Doi, Y., Tanihata, T., Minowa, M., Suzuki, K., … Kaneita, Y. (2004). An epidemiologic study of self-reported sleep problems among Japanese adolescents. *Sleep*, *27*(5), 978–985.

Sadeh, A., Gruber, R., & Raviv, A. (2002). Sleep, neurobehavioral functioning, and behavior problems in school-age children. *Child Development*, *73*(2), 405–417.

Sateia, M. J. (2014). International classification of sleep disorders. *Chest*, *146*(5), 1387–1394.

Spielberg, J. M., Galarce, E. M., Ladouceur, C. D., McMakin, D. L., Olino, T. M., Forbes, E. E., … Dahl, R. E. (2015). Adolescent development of inhibition as a function of SES and gender: Converging evidence from behavior and fMRI. *Human Brain Mapping*, *36*(8), 3194–3203.

Telzer, E. H., Fuligni, A. J., Lieberman, M. D., & Galván, A. (2013). The effects of poor quality sleep on brain function and risk taking in adolescence. *Neuroimage*, *71*, 275–283.

Van den Bulck, J. (2007). Adolescent use of mobile phones for calling and for sending text messages after lights out: Results from a prospective cohort study with a one-year follow-up. *Sleep*, *30*(9), 1220–1223.

Wimmer, F., Hoffmann, R. F., Bonato, R. A., & Moffitt, A. R. (1992). The effects of sleep deprivation on divergent thinking and attention processes. *Journal of Sleep Research*, *1*(4), 223–230.