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ORIGINAL ARTICLE

Comparison of Sleep Onset Time According to Grade, Outdoor Time, and Screen-Based Media Device Use Time in Children and Adolescents in One District of Daegu, Korea

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Objective: The purpose of this study is to identify the sleep onset time (SOT), outing activities, and screen-based media device (SBMD) use by grade and to evaluate the differences in SOT according to outing activities and SBMD use. **Methods:** A total of 10,080 students from one district in Daegu Metropolitan City completed Survey for Outing and Time Usage for Children, Adolescents, and Parents, among which SOT, outing activities, and mobile phone usage time and behavior were analyzed. **Results:** There was a significant difference in SOT on weekdays and weekends according to grade level. The SOT of high school seniors was 2 hours and 20 minutes later than that of elementary school seniors regardless of weekdays and weekends. There was a significant difference in SOT according to outing activity time, mobile game usage time, and video-watching time. **Conclusion:** The SOT is significantly delayed by grade, and the SOT of students who use a lot of SBMD is significantly delayed. It is possible that students' sleep health deteriorates depending on the grade due to various factors. It is considered that personal, educational, and socio-environmental efforts are needed to improve students' sleep health.

Keywords: Sleep; School; Social networking; Mobile game

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INTRODUCTION

Sleep is an important physiological process, and the sufficient amount and quality of sleep are very important for the physical, cognitive, and emotional development of growing children and adolescents [1]. Sleep deficiency can increases anxiety and depression as well as it is associated with obesity, worse cellular immune responses, and low academic performance in children and adolescents [2,3]. Although sleep is a very important physiological process for the physical health and emotional well-being of the youth, sleep deprivation in modern children and adolescents is becoming more common [4]. Over the past century, sleep duration per night in young people has steadily decreased, which is related to later bedtime and fixed school/workday wake-up time [5]. It is well known that Korean students sleep less than those from any other country in the world because of their competition in academic performance [6,7].

Recent technological improvement in mobile devices has led to an increase in the use of screen-based media devices (SBMD). The pattern of growth worldwide in mobile phone use among children and adolescents is similar. More than 90% of British teenagers and half of American children use a mobile phone [8,9]. In Korea, 37.8% of 1st to 3rd graders, 81.2% of 4th to 6th graders, 95.9% of middle school students, and 95.2% of high school students are using mobile phones [10]. Furthermore, 31% of toddlers under 24 months are known to use mobile phones [11].

Increased access and use of SBMD may cause a negative sleep environment for children and adolescents. A systematic review and meta-analysis of 20 studies reported that bedtime SBMD use was strongly and consistently associated with inadequate sleep

quantity, poor sleep quality, and excessive daytime sleepiness [12]. Nighttime use of SBMD also increases the possibility of headache, tinnitus, and abdominal pain in adolescents and has negative effects on physical health leading to worse health-related quality of life [13,14]. Excessive use of SBMD increases the possibility of social isolation and peer victimization, and it increases the risk of suicidal ideation, self-harm, and poor mental health in adolescents [15]. It is necessary to refrain from using a mobile phone or other electronic screen near bedtime to reduce sleep problems in the youth [16].

Although there are concerns that SBMD use has a negative impact on sleep and mental health in children and adolescents, there is a lack of research on the relationship between SBMD use and sleep, as well as basic research on sleep in Korea. During the recent COVID-19 pandemic, Korean children and adolescents spent less time going out than before the pandemic, while spending more time using mobile phones and playing mobile games, which may negatively affect sleep health [17].

This study aimed to investigate the patterns of sleep onset time (SOT) and outdoor time patterns according to grade levels of students in one district of Daegu Metropolitan City, and to compare the differences in SOT according to outing activities and SBMD use.

METHODS

Study design and participants

This study was conducted on students from the 4th grade to the 12th grade in one district of Daegu Metropolitan City. First, the Daegu Metropolitan City Office of Education explained the purpose and method of the test to management teachers at elementary, middle, and high schools in the jurisdiction. Next, a uniform resource locator (URL) was sent to allow the students who wished to participate to access the survey. The test and its purpose were explained first to students accessing the URL, and consent was obtained from the students for the use of personal data. Students who complete the consent form can begin the online test.

Subjects were instructed to complete the Survey for Outing and Time Usage for Child, Adolescent, and Parents (SOTCAP). SOTCAP is an online survey tool for students to self-report on questions about their grade, sex, number of family members, type of family, relationship with family, time of outdoor time, and time and types of mobile phone use. It has previously been used in studies assessing changes in life behavior, emotional state, and family and interpersonal relationships in pediatric patients during the COVID-19 pandemic [17]. Students who agreed to participate in this study were instructed to access the URL and fill out questionnaires sent by the Office of Education. Among the data of students who completed SOTCAP, the SOT, outdoor activities, and time and types of mobile phone use were used. A total of 10,080 students from 64 schools participated. This study was approved by the Institutional Review Board of the Yeungnam University Hospital (IRB no. YUMC 2022-08-002-005).

Data analysis

Descriptive statistics and frequency analysis were conducted to verify the demographic data of the participants. Repeat measures ANOVA was conducted to compare the SOT, outdoor time, and mobile phone usage time by grade and sex. One way-ANOVA was conducted to compare SOT according to time of mobile phone game use, social networking service (SNS) usage, and video viewing and outdoor time. Statistical significance was set at $p<0.05$, and SPSS Statistics ver. 25.0 (IBM Corp., Armonk, NY, USA) for statistical analysis was used.

RESULTS

Demographic data

In this study, 10,080 students from 4th to 12th grade participated after consenting to the use of their data. Of these, data on 9,720 students were used, excluding data with problems in the completeness and reliability of the questionnaire. Among the total participants, there were 4,673 (48.1%) male students and 5,047 (51.9%) female students. The school system in Korea is divided into six years of elementary school (grades 1−6), three years of middle school (grades 7−9), and three years of high school (grades 10−12). According to school level, 1,975 (20.3%) student were in elementary school, 5,021 (51.7%) in middle school, and 2,724 (28.0%) in high school. The distribution of students by grade ranged from 5.9% to 18.7%. Table 1 shows the demography of students from the 4th grade of elementary school to the 3rd grade of high school by grade.

Sleep onset time by grade

SOT on weekdays was 22:10 (0:53) for 4th graders, but 23:15 (1:05) for 7th graders, which was approximately 65 min late, and

Table 1. Demographic data of the participants (n=9,720)

Variable	n (%)
Sex	
Male	4,673 (48.1)
Female	5,047 (51.9)
School levels and grades	
Elementary school	1,975 (20.3)
4th	578 (5.9)
5th	654 (6.7)
6th	743 (7.6)
Middle school	5,021 (51.7)
7th	1,601 (16.5)
8th	1,818 (18.7)
9th	1,602 (16.5)
High school	2,724 (28.0)
10th	823 (8.5)
11th	899 (9.2)
12th	1,002 (10.3)

00:29 (1:11) for 12th graders, which was approximately 2 h and 20 min later than that of the 4th graders. There was a significant difference in SOT on weekdays by grade ($p<0.001$). In 7th grade, SOT on weekdays exceeded 23:00, and in 9th grade, it exceeded 0:00 of the next day. The weekend's SOT was 22:49 (0:57) for 4th graders, 00:07 (1:28) for 1st graders, and 01:13 (1:23) of the next day for 12th graders. The SOT of the 12th graders was approximately 2 h and 20 min later than that of the 4th graders. From the 5th grade, they go to bed after 23:00 on weekends, and from the 7th grade, they go to bed after 00:00 of the next day. There was a significant difference in SOT on weekend by grade ($p<0.001$). Comparing SOT on weekdays and weekends, all grades were 39–57 min late on weekends, which was statistically significant ($p<0.001$). The pattern of SOT delay according to grade was the same for both males and females (Table 2).

Comparison of outdoor time and mobile phone usage time by grade

Weekday outdoor time was 1:25 h (1:11) for 4th graders, 1:54 h (2:25) for 8th graders, and 1:46 h (2:34) for 12th graders. Outdoor time on weekdays gradually increased from 4th grade to 8th grade, but there was no difference from that of the next grade. Weekend outdoor time for 4th graders was 3:32 h (2:55). Weekend outdoor time was the longest at 4:14 h (4:31) in the 7th grade and the shortest at 3:18 h (3:41) in the 12th grade. The difference in outdoor time by grade was significant ($p<0.001$). Weekend outdoor time was 1:32 h to 2:28 h longer than weekday outdoor time, and this difference was also significant ($p<0.001$) (Table 3).

Mobile phone use on weekdays was 4:48 h (7:19) in the 4th grade and 6:31 h (5:16) in the 7th grade. The 5th graders spent the shortest time using mobile phones on weekdays at 3:54 h (3:41), and 9th graders spent the longest at 7:16 h (6:37). The 4th graders' weekend mobile phone usage time was 6:25 h (7:20). The 5th graders used it the shortest at 5:20 h (4:29), and 10th graders used it the longest at 10:03 h (7:25). The difference in mobile phone use between weekdays and weekends was 1:26 h–1:43 h for elementary school students, 2:16 h–2:30 h for middle school students, and 2:09 h–3:14 h for high school students. Differences in time of mobile phone use by grade were significant, and differences in use time of weekday and weekend were also significant ($p<0.001$) (Table 3).

Comparison of SOT according to time of outdoor, mobile games, SNS, and mobile video usage

SOT on weekdays and weekends were compared by dividing time of outdoor activities, mobile games, SNS, and mobile video use into three groups: <60 min, 60 to <120 min, and ≥120 min.

First, when outdoor time was divided into three groups, the weekday SOT was 23:25 (01:13) for the group of <60 min on weekdays, 23:29 (01:17) for the group of 60 to <120 min, and 23:44 (01:23) for the group of ≥120 min. The difference between groups was significant ($p<0.001$). In the post hoc test, there was no significant difference in SOT between the group of <60 min and group of

Table 2. Comparison of sleep onset time by grade and sex (n=9,720)

	Grade 4 (n=578)	Grade 5 (n=654)	Grade 6 (n=743)	Grade 7 (n=1,601)	Grade 8 (n=1,818)	Grade 9 (n=1,602)	Grade 10 (n=823)	Grade 11 (n=899)	Grade 12 (n=1,002)	p*	p**	p***
Total										<0.001	<0.001	<0.001
WD	22:10 (0:53)	22:26 (0:53)	22:43 (1:07)	23:15 (1:05)	23:42 (1:07)	00:04 (1:08)	00:05 (1:08)	00:22 (1:14)	00:29 (1:11)			
WE	22:49 (0:57)	23:07 (1:00)	23:26 (1:14)	00:07 (1:28)	00:34 (1:28)	00:55 (1:32)	01:02 (1:32)	01:14 (1:30)	01:13 (1:23)			
Male										<0.01	<0.001	<0.001
WD	22:14 (1:02)	22:24 (0:54)	22:40 (1:14)	23:05 (1:04)	23:34 (1:08)	23:55 (1:10)	00:07 (1:04)	00:26 (1:09)	00:35 (1:09)			
WE	22:52 (1:02)	23:03 (0:57)	23:22 (1:20)	23:55 (1:25)	00:26 (1:30)	00:45 (1:36)	01:04 (1:32)	01:16 (1:30)	01:15 (1:20)			
Female										<0.01	<0.001	<0.001
WD	22:05 (0:41)	22:29 (0:51)	22:46 (1:00)	23:23 (1:05)	23:49 (1:05)	00:12 (1:07)	00:04 (1:12)	00:16 (1:21)	00:23 (1:13)			
WE	22:46 (0:52)	23:11 (1:02)	23:30 (1:08)	00:17 (1:29)	00:39 (1:26)	01:03 (1:27)	01:02 (1:32)	01:14 (1:30)	01:11 (1:25)			

Data are presented as mean (SD). *p value by total; **p value by weekday and weekend; ***p value by grades. WD, weekday; WE, weekend

Table 3. Comparison of outdoor time and mobile phone use by grade

	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11	Grade 12	P*	p**	p***
Outdoor time (n=6,820)										<0.001	<0.001	<0.001
WD	1:25 (1:11)	1:31 (1:16)	1:48 (1:45)	1:51 (2:41)	1:54 (2:25)	1:49 (2:09)	1:50 (2:28)	1:42 (2:09)	1:46 (2:34)			
WE	3:32 (2:55)	3:59 (5:05)	3:41 (3:29)	4:14 (4:31)	4:06 (3:29)	4:04 (3:07)	3:56 (4:50)	3:33 (3:53)	3:18 (3:41)			
Mobile phone use (n=5,448)										<0.001	<0.001	<0.001
WD	4:48 (7:19)	3:54 (3:41)	5:34 (8:47)	6:31 (5:16)	6:45 (5:38)	7:16 (6:37)	6:49 (5:14)	6:50 (7:18)	6:05 (5:05)			
WE	6:25 (7:20)	5:20 (4:29)	7:17 (7:31)	9:01(6:55)	9:07 (6:31)	9:32 (6:20)	10:03 (7:25)	8:59 (6:49)	8:52 (7:01)			

Data are presented as mean (SD). *p value by total; **p value by weekday and weekend; ***p value by grades. WD, weekday; WE, weekend

Table 4. Comparison of sleep onset time according to time of outdoor, mobile game, SNS usage, and mobile video viewing

	<60 min (A)	60 to <120 min (B)	≥120 min (C)	F	p	Post hoc
Outdoor activity						
WD (n=5,013)	23:25 (01:13)	23:29 (01:17)	23:44 (01:23)	28.104	<0.001	A, B<C
WE (n=7,147)	00:11 (01:28)	00:07 (01:31)	00:26 (01:35)	27.051	<0.001	A, B<C
Gaming						
WD (n=4,819)	23:23 (01:14)	23:23 (01:14)	23:40 (01:25)	23.938	<0.001	A, B<C
WE (n=5,554)	00:07 (01:32)	00:05 (01:32)	00:32 (01:40)	51.768	<0.001	A, B<C
SNS						
WD (n=4,782)	23:52 (01:15)	23:59 (01:14)	00:08 (01:15)	20.183	<0.001	A<B<C
WE (n=5,331)	00:34 (01:28)	00:49 (01:28)	01:08 (01:35)	68.133	<0.001	A<B<C
Mobile media use						
WD (n=6,720)	23:37 (01:16)	23:48 (01:14)	23:56 (01:20)	37.556	<0.001	A<B<C
WE (n=7,753)	00:07 (01:28)	00:28 (01:29)	00:55 (01:35)	19.0939	<0.001	A<B<C

Data are presented as mean (SD). WD, weekday; WE, weekend; SNS, social networking service

60 to <120 min, but the SOT in the group of ≥120 min was significantly later than the two groups. Comparing the SOT according to the outdoor time on the weekend, the SOT was 00:11 (01:28) for the group of <60 min, 00:07 (01:31) for the group of 60 to <120 min, and 00:26 (01:35) for the group of ≥120 min. The difference between groups was significant (p<0.001). In the post-hoc test, the difference was not significant between the group of <60 min and the group of 60 to <120 min, but the SOT of the group of ≥120 min was significantly later than the two groups.

Mobile game usage time was also divided into three groups. Weekday SOTs for the <60 min group, the 60 to <120 min group, and the ≥120 min group were 23:23 (01:14), 23:23 (01:14), and 23:40 (01:25), respectively. The difference was significant (p< 0.001). In the post-hoc test, although there was a difference between the <60 min group and the 60 to <120 min group, the difference was not significant, and the ≥120 min group had a significantly later SOT than the other two groups. The weekend SOT of the three groups was 00:07 (01:32), 00:05 (01:32), and 00:32 (01:40), respectively, and the difference between the three groups was significant. In the post-hoc test, the difference in SOT between the group of <60 min and the group of 60 to <120 min was not significant, but the group of ≥120 min was significant (Table 4).

Finally, the difference in SOT between the three groups according to the time spent watching SNS and mobile videos on weekdays and weekends was significant (p<0.001). SOT according to mobile video viewing time on weekends was 00:07 (01:28), 00:28 (01:29), and 00:55 (01:35). In the post-hoc test, the difference in SOT in each of the three groups was significant (Table 4).

DISCUSSION

This study investigated SOT, outdoor time, and SBMD use by grades among 9,720 students in a district in Daegu, and compared the difference in SOT according to outdoor time and SBMD use time. Excessive use of screen-based media can lead to irregular sleep habits and negatively affect sleep duration. These negative effects on sleep can also be seen in toddlers as young as 2 years old [18,19]. It has been reported that excessive use of mobile devices is associated with difficulties in impulse control, executive function, and emotional control, and long-time use of SNS is also associated with depression or low self-esteem [20,21].

In this study, the students' SOT was gradually delayed according to the grade, and the 12th grade was delayed by 2 h and 20 min compared to the 4th grade. SOT is a variable that affects more total sleep time than wake-up time. In a study of elementary school students, the difference in SOT between 7-year-olds and 12-year-olds was 49 min, while there was a difference of 8 min in wake-up time and 47 min in sleep duration [6]. The results of this study, which showed the delayed SOT by grade level and a difference of >2 h, suggest that the total sleep time and sleep health of students may deteriorate as the grade goes up.

There are various reasons for delay in SOT, but the use of SBMD

could be considered as one of them. In this study, the use of SBDM was divided into mobile game, SNS, and mobile media use, and differences in SOT were compared according to their usage time. There was a significant difference in SOT between the group that used ≥120 min and the group that used less than that in time of mobile game use, while SNS and mobile media use showed significant differences by group for usage of <60 min, 60 to <120 min, and ≥120 min.

The contents of mobile phones of children and adolescents have a lot of interesting contents, and real-time interaction is possible. They maintain constant tension and stimulation while using their mobile phones because they are invited by many people to join the online space and engage in real-time conversations [22]. The wavelength of the light emitted by the SBMD may also be related to the delay of the SOT. The light emitted from SBMD is rich in blue light below 450 nm. This light causes alertness and has a stronger melatonin suppression effect, as well as a more phase-shifting effect on the circadian clock [23,24]. Children and adolescents are more affected by the light emitted from the SBMD because the pupil size is large and the transmittance of light through the crystal lens is high [23,25]. Using SBMD in a dark room at night may have a more negative effect on sleep [12,14,26].

Recently, interest in the relationship between outdoor time, physical activity, and sleep has increased, and research on this issue has been conducted. Unfortunately, the results of studies on the relationship between physical activity and sleep have been diverse and lack consistency. This study showed that the SOT of the group with ≥120 min of outdoor time per day was significantly later than the other groups. A study of 433 Canadian children reported that outdoor activity was not significantly associated with sleep duration, sleep chronology, and sleep efficiency [27]. In a study conducted on 275 children aged 8 years for 7 consecutive days, a high level of physical activity was rather related to poorer sleep, and there was also a report that the level of physical activity was higher the day after a bad night's sleep [28]. On the other hand, in a cohort study of 1,231 children aged 6–10 years, it was reported that the average physical activity had no effect on sleep duration and sleep efficiency, but physical activities of moderate or higher intensity increased sleep efficiency the next day [29]. A study of 591 children aged 7 years reported that a high level of daytime activity was associated with shorter sleep onset latency, whereas sedentary activity was associated with increased sleep latency [30]. Meanwhile, the effect of physical activity on sleep may differ by sex. In 10,028 middle and high school students, if the physical activity of moderate to vigorous intensity of 60 min or more per day is performed, male students are more likely to comply with the sleep duration recommendation, but female students are not [31]. The reason for the different effects of sleep by physical activity is that the concept of physical activity or outdoor activity is ambiguous; thus, it is possible that it is applied differently in each study, other factors such as obesity are involved, and further research on this issue is needed.

This study has several limitations. First, the distribution of respondents by grade was not even. This study was conducted among 4th grade students who were able to answer the questionnaire on their own; however, lower-grade students had some difficulty in understanding the survey, and high school students likely had fewer voluntary respondents due to their academic burden. Second, this study did not investigate sleep parameters other than SOT. According to previous studies, wake-up time tends to be fixed by school arrival time rather than individual characteristics, but it is necessary to investigate other sleep parameters together in future studies. Finally, this study does not use an objective tool such as actigraph; thus, it is necessary to be careful in interpreting the results.

Despite these limitations, this study investigated the change in SOT by grade for a large number of students, and compared SOT according to the time of outdoor activity, mobile game, SNS, and watching mobile videos, which were closely related to students' daily lives. In this study, SOT was significantly delayed as the grade level went up, and it was shown that students who spend more outdoor time as well as students who spend more time in mobile games, SNS, and mobile video watching have a late SOT. It is hoped that objective studies on the relationship between activity time or SBMD usage time and sleep variables for more children and adolescents be conducted in the future.

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None

Conflicts of Interest
The authors have no potential conflicts of interest to disclose.

Availability of Data and Material
The datasets generated or analyzed during the study are not publicly available due to the strictness of personal data management but are available from the corresponding author on reasonable request.

Author Contributions
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