ORIGINAL RESEARCH

Gender and Age Differences in the Relationship Between Smartphone Addiction and Sleep Duration in Korean Children: A Panel Quantile Regression Study

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Purpose: This study analyzed the longitudinal relationship between smartphone addiction and sleep duration to investigate the factors contributing to sleep deprivation in Korean children.

Methods: To overcome the limitations of previous studies, panel quantile regression analysis was used to evaluate the relationship between smartphone addiction and sleep duration. Key variables were smartphone addiction, sleep duration, gender, and age.

Results: According to the study results, the level of smartphone addiction among children significantly increased from 2018 to 2022, while sleep duration continuously decreased. A particularly strong negative relationship between smartphone addiction and sleep duration was found.

Conclusion: These results suggest that smartphone addiction is strongly associated with sleep deprivation in children, emphasizing the need for policies and intervention measures to create a healthy sleep environment for children.

Keywords: children, sleep duration, smartphone addiction, panel quantile regression analysis, problematic smartphone use, quality of life

Introduction

Sleep is a vital aspect of human physical, cognitive, and emotional well-being.[1] It is paramount for children as it directly influences growth, development, and overall quality of life through growth hormone release, muscle recovery, and memory consolidation.[2] The optimal sleep duration for children is 9–11 hours, which exceeds the 8–10 hours recommended for adolescents.[3] Childhood is a period during which sufficient sleep is crucial, but the average sleep duration for Korean children (elementary school students) has been reported to be 8.6 hours, which does not meet the recommended sleep duration.[4]

Insufficient sleep in children can lead to various adverse outcomes.[5] Physically, sleep deprivation has been reported to cause obesity due to impaired immune function, increased disease susceptibility, and hormonal imbalances that leads to overreacting and reduced physical activity.[6,7] In terms of cognition, sleep deprivation is reported to impair attention, memory, and problem-solving skills, all of which are crucial for academic performance, thereby potentially lowering academic achievement.[8,9] Moreover, sleep deprivation is reported to increase the incidence of emotional disorders such as depression and anxiety in children, and raise the risk of irritability and problem behaviors.[10] These findings indicate that insufficient sleep in children is a factor that hinders their quality of life, highlighting the need for ongoing

discussions on factors that impede adequate sleep in children. Accordingly, recent research trends emphasize the importance of addressing modifiable problem behaviors while focusing on the determinants of sleep issues.[11–13]

Smartphone addiction has emerged as a serious global issue. In Switzerland, 16.9% of students are reported to be addicted to smartphones, while in China, the figure is 21.3%, and in India, it is estimated that 39–44% of adolescents are addicted to smartphones.[14–16] In South Korea, 23.1% of smartphone users were found to be at risk of smartphone overdependence in 2023, with 65.1% of them being children, highlighting the severity of smartphone addiction among Korean children.[17] Smartphone addiction has been found to cause sleep deprivation, sleep disorders, and decreased sleep quality in children.[18,19] These findings suggest a possible link between low average sleep duration and the high prevalence of smartphone addiction among Korean children. These findings reveal a significant relationship between smartphone addiction and children's sleep patterns, underscoring the necessity to address this issue.

Reviewing previous studies on smartphone addiction and sleep, Almuaigel et al[20] reported that excessive smartphone use negatively affects sleep duration and quality in children. Yoon et al[21] found that smartphone addiction, particularly the tolerance subfactor, significantly effected sleep duration and that this relationship was moderated by age and gender. The study by Kim et al[22] also supported these findings, showing that excessive smartphone use is associated with reduced sleep duration and decreased sleep quality in children. However, previous studies have limitations as they examine the effect of smartphone addiction on sleep duration cross-sectionally, failing to verify causal relationships over time. Furthermore, they emphasize the average sleep duration of the sample, highlighting the need for a detailed consideration of optimal sleep durations for children.

Smartphone addiction is not an issue that develops over a short period; rather, it can accumulate and worsen over time, exerting negative long-term effects on children's physical and mental health.[23,24] Additionally, sleep patterns during childhood have a prolonged impact on both physical and psychological health.[25] These findings from previous research emphasize the need for a longitudinal analysis of smartphone addiction and children's sleep duration. Moreover, considering that children's sleep directly influences their development and growth,[26] a cross-sectional analysis may fail to adequately capture the dynamic changes involved in child development. Therefore, this study aims to overcome these limitations of previous research by examining the relationship between smartphone addiction and sleep duration in children through panel quantile regression analysis. Quantile regression estimates coefficients to explain specific quantiles of the dependent variable rather than the mean,[27] allowing for the consideration of various sleep durations in children and their relationship with smartphone addiction. When analyzing only the average sleep duration, the effect of smartphone addiction on children with insufficient sleep may be underestimated. Therefore, by using quantile regression analysis, this study aims to more precisely account for individual differences in sleep duration and examine how the effects of smartphone addiction differ between children with insufficient sleep and those without. This approach allows for a deeper understanding of the relationship between smartphone addiction and sleep duration in children, providing a basis for more targeted intervention strategies. In summary, this study seeks to more precisely examine the relationship between smartphone addiction and sleep duration in children using panel quantile regression analysis and based on the findings, proposes practical policy recommendations for ensuring healthy sleep in children.

Methods
Data

This study analyzed data from the Korean Children and Youth Panel Survey (KCYPS) conducted by the National Youth Policy Institute of Korea. The KCYPS is a representative survey of Korean children and adolescents that aims to provide basic data for policy formulation by comprehensively understanding their growth and developmental changes. Specifically, the KCYPS conducted detailed surveys on individual development (eg time use, cognitive development, career, social/emotional/competency development, delinquency, health, and physical development) and developmental environments (eg, home, school, friends, media, and activity/cultural environments). Additionally, the surveys were conducted through individual interviews using tablet PCs, with the sampling method being multi-stage stratified cluster sampling. The surveys are conducted annually from August to December. The panel retention rates in 2022 were 88.6% for elementary school students and 85.9% for middle school students. As of 2018, the KCYPS surveyed a total of 5197

individuals (2607 fourth-grade elementary school students and 2590 seventh-grade middle school students). The KCYPS is accessible via the Korean Children and Youth Data Archive website (https://www.nypi.re.kr/archive/mps). The research team downloaded and used the KCYPS data after submitting a data request consent form to the Korean Children and Youth Data Archive.This study utilized data from the first wave (2018) to the fifth wave (2022), spanning a total of five years. The final sample for analysis included 5187 children (2600 elementary school students and 2587 middle school students) with no missing values for key variables.

Variables

Independent Variable: Smartphone Addiction

The independent variable of this study is smartphone addiction. The Korean Children and Youth Panel Survey (KCYPS) utilized the Smartphone Addiction Proneness Scale (SAPS), developed by Kim, D. et al.[28] To develop this scale, Kim, D. et al[28] selected 29 preliminary items (1.5 times the final number of items) based on previous research on internet/ phone addiction and clinical experiences of relevant experts. A survey using the preliminary scale was conducted on 795 students from elementary, middle, and high schools across the country. Based on the reliability test results, 15 final items were selected. The final scale developed by Kim, D. et al[28] demonstrated high reliability, with a Cronbach's α of 0.880. The criterion validity of this scale was verified through its correlation with the Internet Addiction Scale, KS-II (r = 0.49). Additionally, the analysis of construct validity using structural equation modelling confirmed the validity of the four-factor structure (NFI = 0.943, TLI = 0.902, CFI = 0.902, RMSEA = 0.034). The SAPS is a rigorous self-diagnosis scale consisting of 15 items, scored on a 4-point scale (1=Strongly Disagree, 2=Disagree, 3=Agree, 4=Strongly Agree). Among the 15 items, the items "Smartphone use does not interfere with what I am doing (studying)", "I do not feel anxious without a smartphone", and "I do not spend a lot of time using a smartphone" are reverse-coded. The average score of the 15 items was calculated, with higher scores indicating a higher level of smartphone addiction. The Cronbach's alpha for the scale in this study was 0.887 in 2018, 0.882 in 2019, 0.881 in 2020, 0.857 in 2021, and 0.868 in 2022, demonstrating the scale's reliability and consistency.

Dependent Variable: Sleep Duration

The dependent variable in this study is sleep duration, which was measured using weekday wake-up time and bedtime. Sleep duration was calculated as '(Weekday Wake-up Time + 24) - Weekday Bedtime. The wake-up time and bedtime were recorded by the respondents themselves in the questionnaire. Duration was categorized into low, medium, and high levels by dividing it into 0.1 quantile (10%), 0.5 quantile (50%), and 0.9 quantile (90%). The boundary values for each quantile were 6.3 hours for the 0.1 quantile, 7.5 hours for the 0.5 quantile, and 9.5 hours for the 0.9 quantile.

Control Variables: Gender, Age

To ensure a comprehensive analysis, this study includes control variables for gender (male=0, female=1) and age (elementary school student=0, middle school student=1), both of which are dummy-coded. By incorporating these control variables, we aim to account for potential confounding factors and provide a more accurate understanding of the relationship between smartphone addiction and sleep duration.

Statistical Analysis

The data analysis for this study was conducted using Stata 15.0 software, and the analysis methods and procedures are as follows. First, descriptive statistical analysis was performed to understand the characteristics of the main variables of the study subjects. Second, before conducting panel quantile regression analysis, panel regression Analysis was conducted to determine which factors influence the sleep duration of children in relation to smartphone addiction. The Hausman Test was used to decide whether to use the Fixed Effect Model (FE) or the Random Effect Model (RE) for the panel regression analysis. Based on the Hausman Test, the Random Effect Model was selected. Third, to examine how smartphone addiction affects sleep duration at different levels (high and low), panel quantile regression analysis was used. Quantile regression is a suitable method when there is heterogeneity among sample groups or when estimating influencing factors by quantile, as it estimates coefficients to better explain specific quantiles rather than the mean of the

dependent variable distribution.[27] Traditional regression analysis focuses on average effects, which can lead to underestimating or overestimating the relationship between independent variables and the dependent variable or potentially overlooking significant relationships among the variables.[29] Therefore, by using panel quantile regression analysis, this study examines the factors influencing sleep duration, considering the distribution of its high and low values. However, traditional panel quantile regression models have the limitation of not accounting for unobserved heterogeneity.[30] To address this, this study employs the Method of Moments Quantile Regression (MM-QR) by Machado and Silva,[31] which reflects unobserved distributional heterogeneous effects.

Results
Descriptive Statistics
The demographic characteristics of the study subjects are shown in Table 1. The sample consisted of 2712 males (52.3%) and 2475 females (47.7%). In terms of age, there were 2600 elementary school students (50.1%) and 2587 middle school students (49.9%), indicating a nearly equal distribution between elementary and middle school students.

Examining the characteristics of the main variables (Table 2 and Figure 1), the average smartphone addiction score increased from 1.93 points (SD=0.51) in 2018 to 2.19 points (SD=0.44) in 2022. The average sleep duration decreased from 8.57 hours (SD=1.08) in 2018 to 7.27 hours (SD=1.14) in 2022.

The analysis results of the relationship between children's smartphone addiction and sleep duration indicated that the control variables (Table 3), gender (B=−.217, $p <0.001$) and age (B=−1.052, $p <0.001$), as well as the independent variable, smartphone addiction (B=−.271, $p <0.001$), had significant effects on sleep duration (Table 3 and Figure 2).

Table 1 Gender and Age of the Study Participants (N=5187)

Variable	Categories	N	%
Gender	Male	2712	52.3
	Female	2475	47.7
Age	Elementary school students	2600	50.1
	Middle school students	2587	49.9

Table 2 Characteristics of Smartphone Addiction and Sleep Duration

Classification	Year	Min	Max	Mean	SD
Smartphone Addiction	2018	1.00	4.00	1.93	0.51
	2019	1.00	3.87	2.06	0.49
	2020	1.00	3.87	2.15	0.52
	2021	1.00	4.00	2.13	0.46
	2022	1.00	4.00	2.19	0.44
Sleep Duration	2018	2.50	14.00	8.57	1.08
	2019	3.00	12.67	8.41	1.08
	2020	3.50	12.00	8.07	1.19
	2021	1.17	11.50	7.36	1.16
	2022	3.00	12.00	7.27	1.14
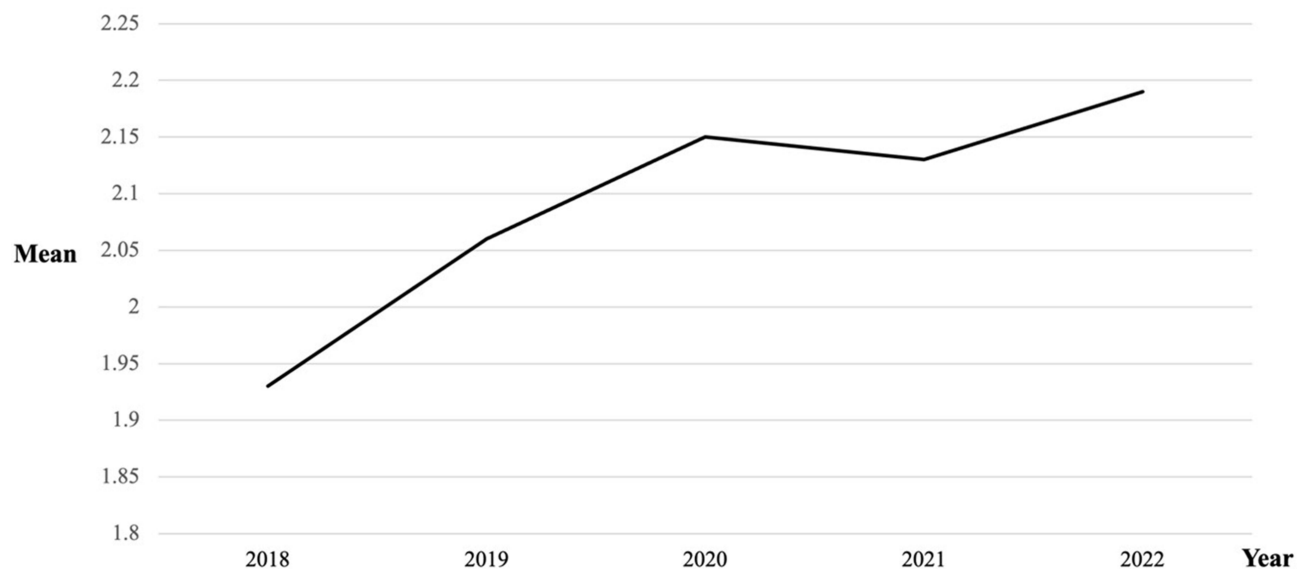
Figure 1 Changes in Smartphone Addiction Over Time.

Specifically, male children compared to female children, elementary school students compared to middle school students, and lower levels of smartphone addiction were associated with longer sleep durations.

To further examine the effect of smartphone addiction on sleep duration, panel quantile regression analysis was conducted considering different levels of sleep duration (Table 4). Gender and age significantly influenced sleep duration across all quantiles (p <0.001). This means that regardless of sleep duration, male children had longer sleep durations than female children and elementary school students had longer sleep durations than middle school students.

For the independent variable, smartphone addiction significantly affected sleep duration at the p <0.001 level in the 0.1 and 0.5 quantiles (Table 4). However, in the 0.9 quantile, smartphone addiction did not significantly affect sleep duration. This suggests that lower levels of smartphone addiction are associated with longer sleep durations when sleep duration is low or medium. However, there is no significant relationship between smartphone addiction and sleep duration when sleep duration is high.

As confirmed in Figure 3, in the case of smartphone addiction, the relative effect on sleep duration increases as the quantile rises from the 0.1 quantile to the 0.9 quantile. However, since the effect was not significant at the 0.9 quantile, it can be observed that the relative effect grows as sleep duration shifts from lower to moderate levels.

Discussion

Addiction is not limited to substances such as drugs and alcohol; it can arise from various causes. Among these, smartphone addiction is particularly prominent among children, who have easy access to smartphones in their daily lives.

Table 3 Relationship Between Smartphone Addiction and Sleep Duration in Children (Panel Regression Analysis)

Variables	B	S.E.
Gender (ref. male)	−0.217***	0.018
Age (ref. Elementary school student)	−1.052***	0.018
Smartphone addiction	−0.271***	0.015
constant	9.150	0.035

Note: B (Coefficient), S.E. (Standard Error)), ***p<0.001.
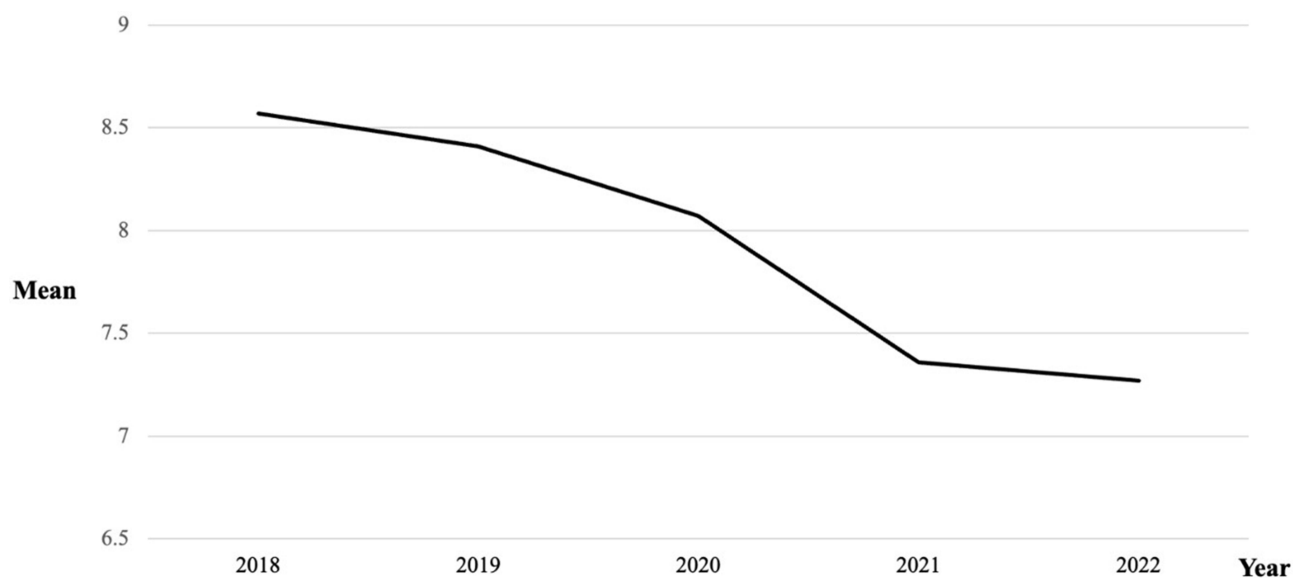
Figure 2 Changes in Sleep Duration Over Time.

The relationship between smartphone addiction and sleep deprivation is a significant concern, which adversely affects children's health and overall quality of life.[32] Therefore, this study employed panel quantile regression analysis using longitudinal data to examine the relationship between children's smartphone addiction and optimal sleep duration during childhood. The main findings of this study are as follows:

First, the level of smartphone addiction among children has continuously increased from 2018 to 2022. The average score for smartphone addiction significantly increased from 1.93 points in 2018 to 2.19 points in 2022. Regarding sleep duration, it has consistently decreased over the same period. The average sleep duration decreased from 8.57 hours in 2018 to 7.27 hours in 2022, failing to meet the optimal sleep duration for children. These results are consistent with previous studies reporting an increase in children's smartphone addiction and a decrease in sleep duration.[33,34]

Second, the panel regression analysis results indicated that the independent variable, smartphone addiction, had a significant effect on sleep duration, with higher levels of smartphone addiction being associated with shorter sleep durations. Additionally, this study confirmed significant relationships between gender, age, and the interaction between smartphone addiction and sleep duration. Male children reported longer average sleep durations than female children, a difference potentially attributable to variations in smartphone usage patterns between genders.[21] Similarly, elementary school students tended to have longer sleep durations than middle school students, likely due to differences in academic pressure and physical activity levels associated with age.[22] These age-related changes in sleep patterns are closely linked to developmental rhythms specific to children's growth stages.

Table 4 Relationship Between Smartphone Addiction and Sleep Duration in Children (Panel Quantile Regression Analysis)

Variables	$\tau = 0.1$		$\tau = 0.5$		$\tau = 0.9$	
Variables	B	S.E.	B	S.E.	B	S.E.
Gender (ref. male)	−0.293***	0.024	−0.213***	0.014	−0.148***	0.018
Age (ref. Elementary school student)	−1.227***	0.024	−1.047***	0.015	−0.900***	0.018
Smartphone addiction	−0.301***	0.024	−0.235***	0.015	−0.071	0.008
Constant	7.876	0.052	9.136	0.032	10.160	0.040

Note: B (Coefficient), S.E. (Standard Error), τ (Quantile level), ***p<0.001.
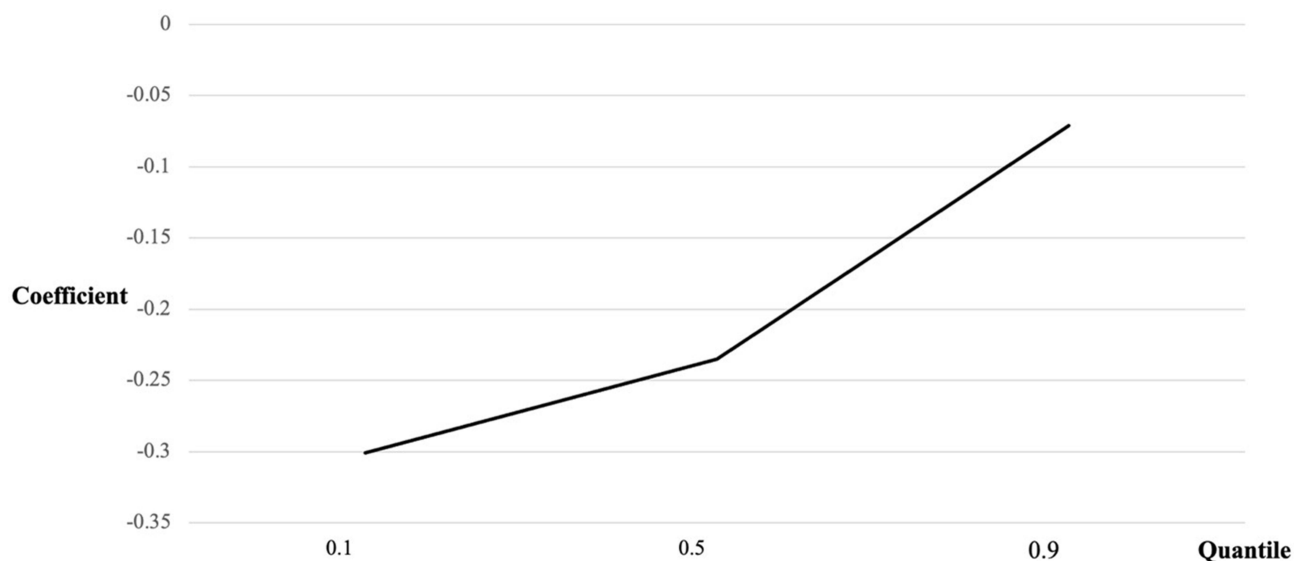
Figure 3 Panel Quantile Regression Coefficients for Smartphone Addiction.

Third, the panel quantile regression analysis results suggested an association between smartphone addiction and optimal sleep duration in children. When examined by quantile, smartphone addiction significantly related to sleep duration at the low (0.1 quantile, 6.3 hours) and medium (0.5 quantile, 7.5 hours) levels. This indicates that children with low or medium sleep durations experienced significantly shorter sleep duration with higher levels of smartphone addiction. This finding aligns with the studies by Kim et al[34] and Neamat et al,[35] which reported a negative relationship between smartphone addiction and sleep duration. However, at the high level of sleep duration (0.9 quantile, 9.5 hours), the relationship between smartphone addiction and sleep duration was not significant. According to the National Sleep Foundation's guidelines based on the latest scientific evidence, school-aged children should get 9 to 11 hours of sleep.[36] Thus, for children with low or medium levels of sleep duration, reporting significantly less sleep than is recommended, there is a need for more proactive intervention regarding smartphone addiction.

These key findings demonstrate the current status of increasing smartphone addiction and decreasing sleep duration among children while showing a significant negative relationship between smartphone addiction and sleep duration over time. Therefore, the following recommendations are made to address the issues of children's smartphone addiction and sleep duration.

Firstly, attention must be paid to the increasing proportion of children at risk of addiction over time. Schools and families should provide education on reducing smartphone use gradually and setting daily usage goals to mitigate smartphone addiction. Evidence-based strategies, such as monitoring apps (Kim et al, 2020)[22] and school-based educational programs, have been shown to be effective in addressing smartphone addiction. Even children at low risk of addiction may become vulnerable over time, so proactive support should be provided through these monitoring apps and programs to help children manage their smartphone use independently.

Secondly, broader surveys and assessments of children's sleep duration are essential to ensure optimal sleep duration during childhood. The National Sleep Foundation's guidelines, based on the latest scientific evidence, recommend 9 to 11 hours of sleep for school-aged children. Numerous studies report that insufficient sleep during childhood can have detrimental effects on physical and mental health.[32,33,35,36] However, as this study confirms, the current sleep duration of children in Korea falls far below the recommended amount. In the United States, the National Survey of Children's Health (NSCH) collects data on children's sleep, analyzing sleep deprivation rates by age, state, race, and ethnic group, and provides recommendations based on these analyses.[34,37] Ensuring optimal sleep duration during childhood is crucial for children's quality of life; thus, systematic surveys on children's sleep duration and tailored intervention plans based on these surveys are necessary.

Thirdly, it is crucial to detect smartphone addiction in children as early as possible and provide immediate counseling and treatment by addiction experts. Particularly, if the risk of smartphone addiction arises before children enter middle school, it is necessary to establish counseling and treatment programs, such as psychological counseling and family therapy, for both students and parents. Research shows that interventions targeting the microsystem, such as family counselling, are effective in managing addiction.[38] Since addiction is a complex issue that is difficult to resolve in the short term, systematic and long-term plans under expert intervention are necessary to minimize the negative effects of smartphone addiction and its impact on sleep duration. This approach should not only focus on the individual but also involve parents, teachers, and the broader environment.

Finally, government and community-level programs and campaigns should be conducted to recognize smartphone addiction as a serious issue, akin to other addictions. Currently, various governmental departments have response systems in place for game addiction, cyberbullying prevention education, and support for the prevention and treatment of cyber gambling addiction.[17] However, preventive programs targeting the fundamental cause of smartphone addiction are insufficient. Considering that serious social issues such as game addiction, cyberbullying, and cyber gambling can ultimately stem from smartphone addiction, it is necessary to strengthen public campaigns to recognize smartphone addiction as a significant problem, similar to substance and alcohol abuse. In particular, it is crucial to understand the seriousness of smartphone addiction during adolescence and to operate shelters that address addiction issues considering the characteristics of childhood. Furthermore, there should be systematic training to effectively respond to smartphone addiction.

Limitations and Future Directions

This study has several limitations. Firstly, it did not fully consider the various aspects of smartphone use, specifically the potential association between the purpose and content of smartphone use and children's sleep, highlighting a limitation in addressing qualitative differences in smartphone use. Secondly, the scope of the study subjects was limited to elementary and middle school students, excluding other age groups in childhood, such as high school students. Thirdly, despite being a longitudinal study, it has limitations in sufficiently explaining the variability of panel data. Additional analyses would be beneficial to consider factors such as individual children's characteristic changes and changes in their living environments that could affect smartphone addiction. Fourth, while the dependent variable in this study is sleep duration, it was not measured using precise electronic devices but rather based on the respondents' subjective judgments, recorded through self-reported wake-up and bedtime in the questionnaire. This introduces a limitation in the accuracy of measuring sleep duration. Fifth, although the MM-QR method used in the panel quantile regression analysis has the advantage of reflecting unobserved heterogeneous effects across different distributions, it has the limitation of not providing model specification details. Future research should address these limitations by first analyzing the purpose and content of smartphone use in detail. A qualitative research approach might also be effective in reflecting the diversity of the effect of smartphone uses on sleep. Moreover, expanding the age range to include high school students, in addition to elementary and middle school students, is necessary to encompass various age groups in childhood. This will allow for comparisons of the relationship between smartphone addiction and sleep duration across different age groups and help derive tailored policy support measures for children. Lastly, it is important to include variables reflecting individual children's characteristics and changes in their living environments that could affect smartphone addiction to understand the individual differences better and derive effective strategies to promote healthy lifestyle habits over time. Additionally, when measuring sleep duration, it is necessary to create an environment that allows for more accurate measurement, possibly by utilizing electronic devices. Furthermore, as panel quantile regression analysis is an area of ongoing research and development, if a more suitable analysis method than the MM-QR method is developed in the future, it would be desirable to apply that method to this study.

Conclusion

This study highlights the significant negative relationship between smartphone addiction and children's sleep duration, showing a marked increase in smartphone addiction from 2018 to 2022 and a concurrent decrease in sleep duration. The findings particularly reveal this relationship in children with low to medium sleep levels. Additionally,

significant gender and age differences were found, with male children and elementary school students reporting longer sleep durations than female children and middle school students. These results underscore the need for targeted interventions, addressing both smartphone addiction and demographic factors such as gender and age. Policies should focus on reducing smartphone use, especially in female children and older students, who appear more vulnerable to the negative impact of smartphone addiction on sleep. Ultimately, effective strategies are essential to mitigate smartphone addiction and promote healthy sleep habits, considering both individual behaviors and demographic differences.

Disclosure

The authors report no conflicts of interest in this work.

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