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Cilt:12, Sayı:1, 2025
Doi: 10.21020/husbfd.1529110

Original Research

Investigation of the Relationship Between Working Memory, Smartphone Addiction and Mental Fatigue in University Students

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Submission Date: August 6th, 2024 **Acceptance Date:** December 5th, 2024 **Pub. Date:** April 30th, 2025

Abstract

Objectives: This study aims to investigate the relationship between working memory (WM), smartphone addiction and mental fatigue in physiotherapy and rehabilitation students.
Materials and Methods: Smartphone addiction was assessed using the Smartphone Addiction Scale-Short Version (SAS-SV) and mental fatigue was assessed using the Mental Fatigue Scale (MFS). WM was assessed using the Working Memory Questionnaire (WMQ).
Results: The study included 120 students with a mean age of 21.49±1.40 years. A statistically significant moderately positive relationship was found between the students' WMQ and SAS-SV scores ($p<0.001$, $r=0.423$). There was a statistically significant moderately positive relationship between their WMQ and MFS scores ($p<0.001$, $r=0.559$). There was no significant difference in the students' WMQ, SAS-SV, and MFS scores according to their grades ($p>0.05$).
Conclusion: Smartphone addiction and mental fatigue negatively affect WM in Physiotherapy and Rehabilitation students. To improve WM, which is important for learning information, further studies are needed to reduce smartphone addiction.

Keywords: *mental fatigue, smartphone addiction, working memory*

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Introduction

In today's world, smart devices have become an indispensable part of our lives thanks to technological advancements. While technological progress and the widespread use of smart devices bring various advantages, they can also lead to negative impacts, such as smartphone addiction (Cheever et al., 2014; Clayton et al., 2015). The integration of smart devices into both academic and social activities among students has led to a high prevalence of smartphone addiction among university students. Various studies have reported rates of smartphone addiction among university students ranging from 22% to 60% (Alhassan et al., 2018; Alhazmi et al., 2018; Alsalameh et al., 2019; Sujadi & Ahmad, 2023). Smartphone addiction can result in anxiety, depression, cognitive issues, sleep disturbances, and musculoskeletal disorders. Studies have reported that middle school children with smartphone addiction have longer response times in working memory (WM) tasks and lower levels of physical activity (Al-Amri et al., 2023; Jang et al., 2021; Ratan et al., 2021).

Excessive internet gaming has also been associated with negative effects on cognitive functions, such as WM and verbal activity (Jang et al., 2021). Similar results have been found in studies conducted on adults in different countries (Ratan et al., 2021).

Mental fatigue is a biopsychological condition characterized by fatigue and energy depletion during or after prolonged cognitive activity (Boksem & Tops, 2008). Mental fatigue leads to decreased physical performance and negatively affects WM (Van Cutsem et al., 2017; Pergher et al., 2021).

WM is defined as the ability to momentarily retain and manipulate information. WM plays a crucial role in human behavior (Baddeley, 1992), particularly influencing academic success in reading and mathematics (Allen et al., 2020). Additionally, studies have shown that athletes with higher WM capacity and control tend to perform better (Wood et al., 2016; Vaughan & Laborde, 2021).

Previous studies have demonstrated the negative effects of smartphone addiction on physical and mental health. The relevant literature includes studies examining the impact of smartphone addiction and mental fatigue on WM in primary school students; however, studies conducted with university students are limited (Omary & Persky, 2019). As with other university students, it is hypothesised that those studying physiotherapy and rehabilitation have a high level of smartphone addiction. Graduates of the Department of Physiotherapy and Rehabilitation are expected to possess not only problem-solving skills but also the capacity to plan and implement treatment. Consequently, it is deemed important to ascertain the impact of

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smartphone addiction on working memory in these students. The present study aims to investigate the impact of smartphone use and mental fatigue on WM in Physiotherapy and Rehabilitation students. The initial year of the four-year physiotherapy and rehabilitation curriculum comprises fundamental medical sciences, while the second year encompasses introductory professional competence-oriented courses. The third year is dedicated to integrating the entirety of the acquired knowledge base and problem-solving competencies, and the final year is devoted to the consolidation of learned practices. Throughout this comprehensive process, the varying workloads among students necessitate the development of diverse levels of executive function. Furthermore, the study explores whether there are differences between different classes for different subjects at university in terms of smartphone use, mental fatigue, and WM. It was hypothesised that 1) the relationship between smartphone addiction and mental fatigue is moderately to strong, 2) the relationship between smartphone addiction and WM is moderately to strong, and 3) there are differences between classes in terms of smartphone addiction, mental fatigue and WM.

Material and Methods

Design and Participants

The study design was cross-sectional. A total of 120 students enrolled in the Department of Physiotherapy and Rehabilitation, Kutahya Health Sciences University were included in the study. Inclusion criteria were as follows: being between the ages of 18–25 years and using a smartphone for at least 1 hour a day. Exclusion criteria were as follows: having musculoskeletal problems and having undergone a surgical operation in the last 6 months. Approval for the study was obtained from the Kutahya Health Sciences University Non-Interventional Ethics Committee with decision number 2023/07-08 and Clinical Trial number NCT05952362. Written informed consent was obtained from all participants.

Procedure

The sociodemographic details (age, height, body weight, etc.) and habits (smoking) of the participating students were recorded. The students' duration of smartphone use and use during the day, duration of social media use, and duration of phone use after waking up and before going to sleep were also recorded. The scales were administered to the participants one time and face to face. Study data was collected in June 2023.

Smartphone addiction was assessed using the Smartphone Addiction Scale-Short Version (SAS-SV). The SAS-SV, developed by Kwon et al. to measure the risk of smartphone

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addiction, consists of 10 items whose responses are evaluated on a six-point Likert-type scale. The scale items are scored from 1 to 6, and the scale scores range from 10 to 60. As the scores obtained from the test increase, the risk for addiction increases (Kwon et al., 2013). Noyan et al. conducted the Turkish validity and reliability study of the scale (Noyan et al., 2015).

Mental fatigue was assessed using the Mental Fatigue Scale (MFS). The MFS was developed by Johansson et al., specifically to assess mental fatigue (Johansson et al., 2010). The scale includes items on fatigue, difficulty in starting to do tasks, mental fatigue, mental recovery, difficulty in concentrating, memory problems, slowing of thoughts, sensitivity to stress, increased emotional sensitivity, discomfort or instant action, sensitivity to light, sensitivity to noise, decreased night sleep, increased night sleep, and 24-hour changes. It is a seven-item Likert-type scale on which the responses range from 0 to 3, and there are also items such as 0.5, 1.5, and 2.5. Item scores are summed for calculation, and the threshold value is 10.5 points. Individuals scoring above 10.5 points are considered mentally fatigued. Kılınç et al. conducted the Turkish validity and reliability study of the scale (Kilinc et al., 2021).

WM was assessed using the Working Memory Questionnaire (WMQ). The WMQ, developed by Vallat-Azouvi et al., includes questions addressing problems related to WM in daily life (Vallat-Azouvi et al., 2012). The WMQ covers not only short-term memory but also attention and executive functions, including aspects of WM such as dual-tasking, mental effort, and distractibility. The WMQ consists of 30 items scored on a five-point Likert-type scale (0–4). The total score ranges from 0 to 120. Higher scores correspond to more difficulties/complaints related to WM. The internal consistency (Cronbach's alpha) of the scale is 0.93. Aksoy et al. performed the Turkish validity and reliability study of the scale (Aksoy et al., 2022).

Statistical Analysis

The statistical analysis was performed using SPSS Version 16. Numbers and percentages were used for descriptive statistics. Quantitative data were presented using mean and standard deviation. The relationship between the data was assessed through correlation analysis. Depending on the normal distribution of the data, either the Pearson or Spearman correlation coefficient was used. The correlation coefficient was interpreted as follows: negligible (r = 0.00–0.10), weak (r = 0.10–0.39), moderate (r = 0.40–0.69), strong (r = 0.70–0.89), or very strong (r = 0.90–1.00). The criterion for statistical significance was set at a p-value of ≤ 0.05 (Schober et al., 2018).

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Differences between the groups were evaluated using the Kruskal-Wallis test. As a result of the *post-hoc* power analysis performed with the data obtained from the study using the G*Power 3.0.10 program, the power of the study was determined as 99.8% with a 5% margin of error, and the effect size was determined for a sample size of 120. The sample size was calculated using G-Power software (version 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). A sample size of at least 112 participants was deemed necessary for the study, based on the parameters of power = 0.90, alpha = 0.05, two-sided. A total of 120 participants were deemed necessary to include in the study, allowing for potential dropouts.

Results

The study was completed with 120 participants. The descriptive characteristics of the individuals are shown in Table 1. The durations of smartphone use and social media were 5.32 and 3.23 hours/day, respectively.

Table 1. Descriptive Characteristics of Students

Descriptive characteristics		**Mean ± SD**
Age	Year	21.49 ± 1.40
Height	Cm	165.74 ± 7.51
Body Weight	Kilogram	60.35 ± 11.20
Body Mass Index (BMI)	Kg/m^2	21.86 ± 0.31
Duration of smartphone use	Hour	5.32 ± 2.13
Duration of social media use	Hour	3.23 ± 2.12
Duration of smartphone use immediately after waking up	Minute	15.34 ± 15.43
Duration of smartphone use before going to sleep	Minute	19.10 ± 22.17
		***N* (%)**
Gender	Female	99 (82.5)
	Male	21 (17.5)
Dominant hand	Right	110 (91.7)
	Left	10 (8.3)
Smoking	Yes	17 (14.2)
	No	103 (85.8)
Hand use while texting	Unilateral	18 (15)
	Bilateral	102 (85)

SD: Standard Deviation, Cm: Centimeter, N: Number

The results regarding the students' WM exposure, smartphone addiction, and mental fatigue are shown in Table 2.

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Table 2. WMQ, SAS-SV, and MFS Assessments of Students

Variable	Min–Max	Mean ± SD
WMQ	9–80	37.03 ± 15.13
SAS-SV	11–52	30.56 ± 8.78
MFS	6.5–35	17.93 ± 6.21

WMQ: Working Memory Questionnaire, SAS-SV: Smartphone Addiction Scale-Short Version, MFS: Mental Fatigue Scale, SD: Standart Deviation

The relationship between WMQ and smartphone addiction and mental fatigue is shown in Table 3. A statistically significant moderately positive relationship was found between the students' WMQ and SAS-SV scores. There was also a statistically significant moderately positive relationship between their WMQ and MFS scores.

Table 3. The Relationship Between WMQ, SAS-SV, and MFS

Variable		SAS-SV	MFS	WMQ
SAS-SV	***r***	1		
	p	-		
MFS	***r***	**0.463[a]**	1	
	p	**< 0.001**	-	
WMQ	***r***	**0.423[a]**	**0.559[a]**	1
	p	**< 0.001**	**< 0.001**	-

SAS-SV: Smartphone Addiction Scale-Short Version, MFS: Mental Fatigue Scale, WMQ: Working Memory Questionnaire, r: correlation coefficient, p: statistical significance level, [a]: Spearman correlation coefficient

The comparison of WMQ, SAS-SV, and MFS scores by grade is shown in Table 4. There were no statistically significant differences between the students' WM, smartphone addiction, and mental fatigue according to grade.

Table 4. Comparison of WMQ, SAS-SV, and MFS Scores by Grade

Variable	Grade 1 Mean ± SD (n=30)	Grade 2 Mean ± SD (n=30)	Grade 3 Mean ± SD (n=30)	Grade 4 Mean ± SD (n=30)	χ^2	*p*
SAS-SV	31.77 ± 8.84	30.37 ± 7.46	29.17 ± 8.23	30.93 ± 10.53	1.45	0.69[a]
MFS	17.70 ± 5.95	19 ± 5.32	17.05 ± 7.36	18 ± 6.17	2.82	0.41[a]
WMQ	37.93 ± 12.48	37.60 ± 14.78	35.23 ± 17.21	37.37 ± 16.26	1.65	0.64[a]

SAS-SV: Smartphone Addiction Scale-Short Version, MFS: Mental Fatigue Scale, WMQ: Working Memory Questionnaire, p: statistical significance level, χ^2: Chi-Square value, SD: Standard Deviation, [a]: Kruskal-Wallis test

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Discussion and Conclusion

This study found that smartphone addiction and mental fatigue negatively affected WM, and concluded that increased smartphone addiction and mental fatigue reduced WM. Additionally, no significant difference was found between WM, mental fatigue, and smartphone addiction according to grade. The a priori first and second hypotheses were accepted. The third hypothesis was rejected.

The process of acquiring new information is called learning, and, as a result, memory is formed (Baars & Gage, 2013). WM is one of our fundamental cognitive functions, allowing us to keep information in mind for short periods and work with this information later. WM is the gateway through which information must pass for conscious processing. Therefore, a well-functioning WM is crucial for a variety of daily activities, including learning and academic performance (Gathercole et al., 2004; Bull et al., 2008).

Studies on university students found that smartphone addiction led to low academic performance (Rathakrishnan et al., 2021), anxiety, and depression (Ge et al.,2023). The presence of a smartphone and constantly thinking about the phone have been shown to negatively affect learning and memory (Tanil & Yong, 2020). The present study found that university students with high smartphone addiction had a worse WM. Tu et al. investigated the impact of smartphone usage at different times for 6 days on WM in high school students and showed that restricting smartphone use in bed improved WM the next day (Tu et al., 2023). A study conducted by Liebherr et al. found that even when the smartphone was completely turned off, it still negatively affected WM performance (Liebherr et al., 2020). Another study on adolescents aged 12–17 years found a difference in WM between children with and without smartphone addiction (Mohta & Halder, 2021). However, there was no difference in WM between middle school children with and without smartphone addiction (Al-Amri et al., 2023). Generally, studies have determined that smartphone addiction negatively affects WM. While studies on university students show a more negative impact on WM, studies on adolescents show a more uncertain effect. We consider that the impact of smartphone addiction on WM may vary depending on age.

Mental fatigue is a subjective feeling and a psychobiological state that occurs after performing a demanding cognitive task for a prolonged period of time (Van der Linden et al., 2003). When a person is mentally fatigued, continuous attention and performance levels on WM tasks are reduced (Helton & Russell, 2015; Helton & Russell, 2017). In the present study, all of the students were mentally fatigued. This fatigue was also higher in students with high

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smartphone addiction. Students with higher mental fatigue had a worse WM. Not only mental fatigue but also physical fatigue negatively affects WM. A study conducted with musicians found that participants with physical fatigue had a worse WM (Jain & Nataraja, 2019).

When giving a series of instructions to students in a class, they use their short-term memories to repeat it to themselves. However, when they return to their desks and have to perform the first task in the instructions if their WM is weak, they are likely to have forgotten what to do. The process of recalling the information and then carrying out individual steps relies on WM (Alloway & Copello, 2013). As physiotherapy and rehabilitation department courses are predominantly practical, students need to use WM to transfer information to their long-term memories. In other words, students with high WM are expected to have high academic achievement. In this study, no significant difference was found in WM according to grades. One possible reason for the lack of difference could be that the students were evaluated at the end of the period when their classes and exams were finished.

As far as we know, no other study in the literature has investigated the impact of smartphone addiction on WM in Department of Physiotherapy and Rehabilitation students. According to the results of this study, smartphone addiction negatively affects WM. Therefore, we consider that conducting studies into ways of reducing smartphone addiction can improve academic performance in students. A study examined changes in WM performance in pharmacy faculty students over a semester and found that although WM could fluctuate over time, it is unclear how stress and fatigue contribute to these fluctuations. More importantly, further research is needed on whether these changes in WM affect the academic decision-making process, such as a student's decisions on studying. It has been found that students still have high WM even during times of high stress and fatigue (Omary & Persky, 2019). In future studies, it is considered important to reevaluate the WMs of physiotherapy and rehabilitation department students during exam periods, when they may experience higher stress levels.

This study determined that smartphone addiction and mental fatigue negatively affected WM in physiotherapy and rehabilitation department students. Considering the impact of WM on daily life activities and academic performance, it is crucial for students to have a good WM. Owing to the relationship between WM, smartphone addiction, and mental fatigue, preventive measures are recommended to improve academic performance.

Limitations

This study assessed students at the end of the semester. It would have been beneficial to evaluate cognitive functioning levels at different periods, especially before and after exam

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periods when stress levels are high. Additionally, objective tests assessing cognitive functioning could have been used as an evaluation tool, rather than just using surveys alone.

Funding

No financial support was received in this study.

Declaration of Competing Interest

There is no conflict of interest between the authors.

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