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Molecular & Cellular Biomechanics 2025, 22(2), 650.
https://doi.org/10.62617/mcb650

Article

Understanding the biomechanics of smartphone addiction: The physical and cognitive impacts of prolonged device use on college students

Qiufang Sheng

Marxist Academy, Henan Technical College of Construction, Zhengzhou 450064, China; QiufangSheng2002@outlook.com

CITATION

Sheng Q. Understanding the biomechanics of smartphone addiction: The physical and cognitive impacts of prolonged device use on college students. Molecular & Cellular Biomechanics. 2025; 22(2): 650. https://doi.org/10.62617/mcb650

ARTICLE INFO

Received: 28 October 2024
Accepted: 4 November 2024
Available online: 22 January 2025

Abstract: The widespread use of smartphones, particularly among college students, has raised concerns about the negative impacts of prolonged device use on physical and cognitive health. While smartphones offer many conveniences, excessive usage can lead to a range of biomechanical and psychological issues, including posture-related strain, repetitive strain injuries (RSIs), eye strain, impaired cognitive function, and elevated levels of anxiety and stress. This study aims to examine the physical and cognitive impacts of prolonged smartphone use among college students, focusing on biomechanical strain, cognitive impairments, and psychological effects. It explores the relationship between smartphone addiction and its effects on posture, musculoskeletal health, eye fatigue, focus, memory retention, and mental health. The study was conducted with a sample of 37 college students in China. Data collection involved physical assessments, including posture analysis, musculoskeletal screening, and cognitive assessments, such as focus and memory tests. Mental health was evaluated using standardized surveys for anxiety, stress, and depression. Statistical analyses were used to interpret the data, including descriptive statistics, paired t-tests, correlation analysis, and multiple regression. The results indicated a significant increase in neck tilt angle, posture discomfort, and wrist strain over the study period, with higher smartphone usage correlating with worse physical outcomes. Cognitive performance, mainly focuses and memory retention, significantly declined with increased smartphone usage. In addition, elevated levels of anxiety and stress were observed among heavy smartphone users, with a strong correlation between high smartphone usage and negative psychological effects.

Keywords: smartphone addiction; biomechanics; cognitive impairment; posture strain; anxiety; college students

1. Introduction

The pervasive use of smartphones in modern society has raised significant concerns about their impact on physical health, cognitive function, and psychological well-being [1,2]. College students, in particular, are a key demographic with high smartphone dependency, using these devices for academic purposes, social interaction, and entertainment [3,4]. While smartphones provide undeniable benefits, the long hours spent on these devices have led to a growing phenomenon known as “smartphone addiction,” associated with various negative outcomes [5–7]. Existing research has primarily focused on the psychological aspects of smartphone addiction, including its link to anxiety, stress, and depression [8,9]. However, less attention has been paid to the biomechanical consequences, such as musculoskeletal strain and visual fatigue, which arise from the physical use of smartphones. Prolonged smartphone use often results in poor posture, leading to conditions such as “text neck”, repetitive strain injuries (RSIs) in the hands and wrists, and digital eye strain.

Furthermore, cognitive impairments, including reduced attention span and memory disruptions, have also been observed in individuals who frequently use smartphones.

Despite the increasing awareness of these issues, there remains a lack of comprehensive research that simultaneously addresses both the physical and cognitive impacts of smartphone use, particularly among college students. This study seeks to fill this gap by examining the biomechanics of smartphone addiction and its associated cognitive effects. Specifically, this research aims to investigate the relationship between prolonged smartphone use and physical strain (neck tilt, posture discomfort, and wrist strain) and cognitive outcomes such as focus, memory retention, and Mental Health (MH) indicators like anxiety and stress. This study aims to provide a holistic understanding of how prolonged smartphone use affects both the body and the mind, with a particular focus on college students who are increasingly vulnerable to these impacts. By addressing both the biomechanical and cognitive aspects of smartphone addiction, this study aims to contribute to the growing body of literature on digital health and inform strategies for mitigating the negative effects of excessive smartphone use [10–13].

The remainder of this paper is structured as follows: Section 2 discusses the biomechanical impacts of prolonged smartphone use, focusing on physical strain, posture issues, repetitive strain injuries, and eye strain. Section 3 addresses the cognitive and psychological impacts, examining impairments in attention, memory, and learning, as well as MH effects such as anxiety, stress, and depression. The methodology used in this study is detailed in Section 4, which outlines the study population, data collection methods, and monitoring processes. Section 5 presents the results, including descriptive statistics and the outcomes of paired t-tests, correlation analyses, multiple regression, and ANOVA. Finally, Section 6 concludes the paper, providing recommendations for future research and interventions to mitigate the negative impacts of smartphone addiction.

2. Biomechanical impacts of prolonged smartphone use

2.1. Physical strain and posture

One of the most immediate and noticeable biomechanical effects of prolonged smartphone use is the physical strain caused by poor posture. The widespread phenomenon known as “text neck” has become prevalent, characterized by a forward head posture where the neck tilts downward while the individual looks at their smartphone. This position increases the weight exerted on the cervical spine, often leading to neck pain and stiffness. In a neutral position, the head weighs about 10 to 12 pounds, but when tilted forward, the strain increases exponentially—reaching up to 60 pounds depending on the angle. Over time, this posture can lead to long-term musculoskeletal disorders, particularly affecting the neck, upper back, and shoulders.

Additionally, the slouched back position that often accompanies prolonged smartphone use can lead to chronic upper back pain and misalignment of the spine. Constant use of the hands to hold and manipulate the device also places stress on the wrist and fingers, leading to discomfort or pain. The continuous, repetitive motions associated with scrolling and typing contribute to wear and tear on the muscles and tendons in these areas, heightening the risk of injury. As a result, college students, who

often spend hours on their devices for academic and social purposes, are particularly vulnerable to musculoskeletal problems affecting the neck, shoulders, hands, and wrists [14–18].

2.2. Repetitive strain injuries (RSIs)

Another primary concern stemming from excessive smartphone use is the development of Repetitive Strain Injuries (RSIs), especially in the hands and wrists. A typical example is carpal tunnel syndrome, a condition caused by compression of the median nerve as it passes through the wrist. The condition can result in symptoms such as tingling, numbness, and pain in the hand and fingers. The repetitive nature of smartphone use, particularly texting, typing, and swiping, contributes to this overuse injury. These continuous movements can inflame the tendons and ligaments in the wrist, leading to pain and discomfort that can hinder daily activities and academic tasks [19,20].

Moreover, the small size of smartphones forces users into unnatural hand positions, exacerbating the risk of RSIs. The frequent need to grip the phone tightly and rapid finger movements across a small screen place significant strain on the tendons in the fingers and hands. Over time, this repetitive stress leads to a cumulative impact that can result in chronic pain or reduced functionality, especially if left untreated.

2.3. Eye strain and visual fatigue

In addition to physical strain on muscles and joints, prolonged smartphone use contributes significantly to eye strain and visual fatigue. The condition, often called digital eye strain, arises from the excessive focus required to view small text and images on a screen for extended periods. The muscles around the eyes must work harder to maintain focus, and this sustained effort leads to discomfort, blurred vision, and headaches. For college students who rely heavily on smartphones for reading, studying, and communication, this strain is often exacerbated by long hours of screen exposure without breaks.

One of the primary culprits of eye strain is the brightness of the smartphone screen, especially when viewed in dimly lit environments. This can cause the eyes to work harder to adjust to varying light conditions, resulting in irritation and fatigue. Furthermore, prolonged exposure to the blue light emitted by smartphone screens is particularly harmful. Blue light penetrates deep into the eye and has been linked to disruptions in circadian rhythms, as it suppresses melatonin production, the hormone responsible for regulating sleep. Over time, irregular sleep patterns and insufficient rest can significantly affect cognitive and physical health. For college students, disrupted sleep due to excessive smartphone use can impact academic performance, mood, and overall well-being.

3. Cognitive and psychological impacts

3.1. Impaired attention and focus

The cognitive consequences of prolonged smartphone use are increasingly evident, particularly in how it impairs attention and focus. Constant device interaction, which typically involves frequent notifications, multitasking between applications, and switching between tasks, fragments attention. Each time a user responds to a notification or shifts focus to their smartphone, their brain is forced to reorient, resulting in a diminished ability to concentrate on any task. Over time, this behavior leads to a shorter attention span, which hinders the ability to engage in deep, focused work. College students, who often engage in extended study periods, are especially vulnerable to this erosion of attention, as smartphone distractions can detract from their academic focus.

The issue of multitasking is also particularly problematic. While smartphones allow users to engage in multiple activities simultaneously—such as texting while studying or browsing social media during lectures—this perceived efficiency comes at a cognitive cost. Studies have shown that humans are not truly capable of multitasking; instead, they rapidly switch between tasks, which leads to cognitive overload. This constant task-switching reduces productivity and increases the likelihood of errors as the brain struggles to manage competing demands. This overload can impede students' ability to absorb and retain information during study sessions or lectures, contributing to lower academic performance over time.

3.2. Memory and learning disruptions

Smartphone addiction also negatively impacts memory and learning processes. One of the key mechanisms through which this occurs is the effect on short-term memory, which is essential for learning and information retention. The constant use of smartphones for quick information retrieval—often called "cognitive offloading"—means that individuals rely less on their memory and more on their devices to store and retrieve information. While this may seem convenient, it has long-term memory retention and learning implications. The habitual act of quickly referring to a smartphone for answers disrupts the brain's natural processes of encoding and retaining information, which is crucial for academic success.

For college students, the overuse of smartphones can translate into difficulties in recalling lecture material or performing well on exams, where memorization is often critical. Additionally, the distractions posed by smartphones during study sessions fragment the learning process, making it harder to establish meaningful connections between concepts or engage in reflective thinking, both of which are essential for higher-level learning. As a result, smartphone addiction can lead to deteriorating academic performance and a general decline in learning efficacy.

3.3. MH effects

The psychological toll of smartphone addiction is also significant, particularly when it comes to MH. Excessive smartphone use has been linked to heightened levels of anxiety, stress, and depression. The constant connectivity that smartphones provide can create an overwhelming pressure to remain available, respond to messages, and keep up with social media, all of which contribute to anxiety. This pressure is often exacerbated by academic and social demands for college students, leading to higher

stress levels. Moreover, the addictive nature of smartphones—mainly through social media platforms designed to maximize user engagement—can trap individuals in a cycle of compulsive checking, which only serves to increase feelings of stress and anxiety.

Depression is another consequence of smartphone addiction, mainly when social media is involved. The constant comparison to others, exposure to unrealistic portrayals, and the fear of missing out (FOMO) are all contributing factors. Over time, these experiences can erode self-esteem and lead to feelings of inadequacy, loneliness, and isolation despite being digitally connected. The impact can be particularly pronounced for college students who are at a stage of life marked by social development and self-identity formation.

In addition to these direct psychological effects, there is a strong link between smartphone addiction and feelings of social anxiety and loneliness. Ironically, while smartphones are designed to connect people, over-reliance on digital interactions can weaken face-to-face communication skills and increase social anxiety in real-world interactions. Many students report feeling more comfortable engaging through a screen than in person, which can contribute to isolation and loneliness, further entrenching the cycle of smartphone addiction. Furthermore, the dopamine-driven feedback loops embedded in social media platforms—where likes, comments, and shares serve as validation—can distort self-worth, making individuals overly reliant on external approval leading to fragile self-esteem.

4. Methodology

4.1. Study population

The study was conducted among a cohort of 37 college students from a university in China, carefully selected to represent a balanced mix of gender, academic disciplines, and socioeconomic backgrounds. The initial cohort was composed of 42 students, but after a screening process to eliminate individuals with pre-existing musculoskeletal or cognitive conditions that might interfere with the study results, five students were excluded, leaving a final participant count of 37. The participants were all between the ages of 18 and 24, a critical age range for studying smartphone addiction due to the high level of smartphone usage among young adults in China. Demographically, 60% of the participants were male and 40% were female. All participants reported daily smartphone usage exceeding four hours, with many reaching an average of six to eight hours daily. This high level of device interaction made them an ideal population to assess the biomechanical and cognitive impacts of prolonged smartphone use.

4.2. Data collection methods

Data collection was divided into two primary categories: physical assessments and cognitive assessments, designed to capture both the biomechanical and psychological effects of smartphone addiction.

- Physical Assessments: Physical assessments focused on identifying the biomechanical impacts of smartphone use. Each participant underwent a posture

analysis where their natural body position while using a smartphone was monitored, with specific attention to neck tilt, back slouch, and hand positioning. Musculoskeletal screening was performed to identify any strain in the neck, shoulders, wrists, and hands, with particular attention to symptoms associated with repetitive strain injuries (RSIs). Eye strain tests were conducted using standard optometric methods to measure visual fatigue and surveys to assess the subjective experience of eye discomfort and the need for corrective measures (such as breaks or adjusted screen brightness).

- Cognitive Assessments: To evaluate the cognitive impacts of smartphone addiction, participants completed a series of focus and memory tests. These tests were designed to assess their ability to concentrate on tasks without distraction, measure their short-term memory retention, and monitor their cognitive performance under multitasking conditions, which mirrors typical smartphone usage patterns. In addition, psychological surveys were administered to capture levels of anxiety, stress, and depression, as well as perceptions of social connectedness and loneliness. The surveys included standardized tools such as the Beck Anxiety Inventory (BAI) and the Perceived Stress Scale (PSS), providing quantitative data on participants' MH concerning smartphone usage.

4.3. Duration and monitoring

The study spanned eight weeks. During this time, participants were required to log their daily smartphone usage, including the number of hours spent on their devices, the types of activities they engaged in (e.g., social media, gaming, studying), and their physical posture while using their smartphones. Data was collected through smartphone apps that tracked screen time and weekly self-reported surveys that participants completed during check-in sessions.

In addition to self-reported data, physical assessments were conducted at the start, midpoint, and end of the study to monitor changes in posture, musculoskeletal health, and eye strain over time. Cognitive assessments were also conducted at these intervals to track potential shifts in focus, memory, and psychological well-being. Continuous monitoring, objective assessments, and participant feedback provided a comprehensive dataset to analyze the biomechanical and cognitive impacts of prolonged smartphone use on the college student population.

5. Results

The descriptive statistics (**Table 1** and **Figure 1**) for the study population reveal key insights into smartphone usage's physical and cognitive impacts among college students. The average daily smartphone usage was 6.7 hours, ranging from 4.3 to 9.4 hours. This high level of engagement is consistent with the widespread reliance on smartphones for academic and social activities in this demographic. The neck tilt angle, a key measure of posture, had a mean of 31.2 degrees, with substantial variation (standard deviation of 6.1), indicating that many students exhibit significant forward head posture, commonly associated with prolonged smartphone use. The mean posture discomfort rating was 5.3 on a 10-point scale, with some participants reporting discomfort as high as 9.4. Wrist strain, another biomechanical concern, had a mean

rating of 4.7, with a wider spread (standard deviation of 2.0), suggesting that some individuals experience significant strain while others report relatively mild discomfort.

Table 1. Descriptive statistics.

Measure	Mean	Median	Standard Deviation	Minimum	Maximum
Average Daily Smartphone Usage (hrs)	6.7	6.2	1.3	4.3	9.4
Neck Tilt Angle (degrees)	31.2	29.4	6.1	19.1	41.3
Posture Discomfort Rating (1–10)	5.3	5.6	1.5	2.4	9.4
Wrist Strain Rating (1–10)	4.7	4.3	2.0	1.4	8.8
Eye Strain Score (1–10)	6.3	6.1	1.7	3.1	8.9
Focus Test Score (max 100)	73.0	73.0	8.4	55.0	88.0
Memory Retention Score (%)	63.0	64.0	10.3	41.0	82.0
Anxiety Level (BAI Score)	18.2	17.1	4.3	10.4	25.9
Stress Level (PSS Score)	19.7	19.2	4.2	12.3	27.4
Depression Level (1–10)	4.8	4.4	1.7	1.6	6.9

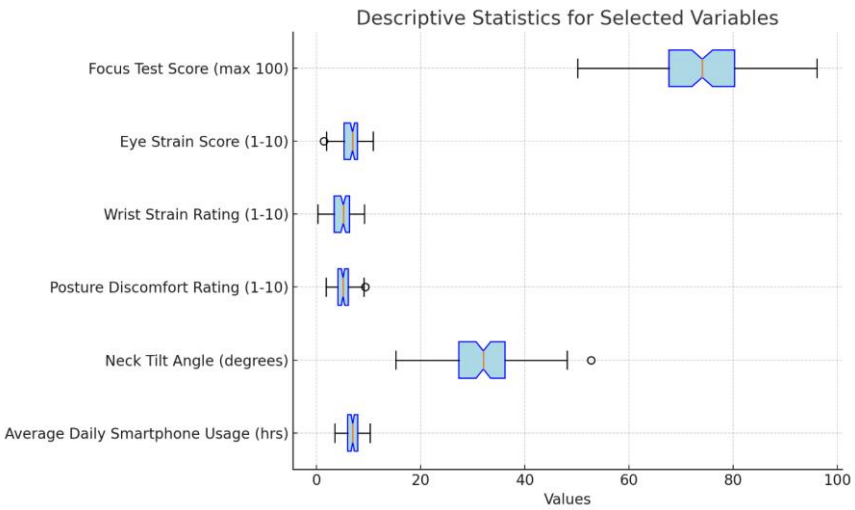

Figure 1. Descriptive statistics.

Eye strain, a common complaint linked to prolonged screen time, had a mean score of 6.3, with some students experiencing high levels of discomfort (maximum score of 8.9). This finding aligns with the expected strain from extended exposure to smartphone screens, mainly when used in poorly lit environments. Cognitively, the average focus test score was 73.0, ranging from 55 to 88, indicating varied attention spans among the participants. Memory retention, a key factor in academic performance, had a mean score of 63%, reflecting moderate retention capabilities, likely affected by frequent distractions. Anxiety and stress levels were moderately high, with mean scores of 18.2 (BAI) and 19.7 (PSS), respectively, indicating that many students are experiencing elevated psychological strain, potentially exacerbated by constant smartphone usage. Depression levels, though relatively low (mean of 4.8), still suggest a baseline level of emotional distress among the population.

The paired t-tests comparing pre- and post-study measures (**Table 2** and **Figure 2**) provide significant insights into the worsening physical and cognitive conditions

over the study period. Neck tilt angle increased from a mean of 31.2 degrees at the beginning of the study to 35.7 degrees at the end, with a highly significant t-value of 4.25 ($p < 0.001$). This result highlights the direct impact of prolonged smartphone usage on posture, leading to more significant neck strain over time. Posture discomfort also increased significantly, from a mean of 5.3 to 6.8 ($t = 3.97$, $p < 0.001$), reinforcing the finding that more extended periods of smartphone use contribute to worsening musculoskeletal strain. Wrist strain showed a similar trend, increasing from 4.7 to 5.9 ($t = 3.45$, $p < 0.005$), further supporting the connection between repetitive smartphone use and physical discomfort in the hands and wrists.

Table 2. Paired *t*-tests comparing pre- and post-study measures.

Measure	Pre-Study Mean	Post-Study Mean	*t*-value	*p*-value
Neck Tilt Angle (degrees)	31.2	35.7	4.25	< 0.001
Posture Discomfort Rating (1–10)	5.3	6.8	3.97	< 0.001
Wrist Strain Rating (1–10)	4.7	5.9	3.45	< 0.005
Eye Strain Score (1–10)	6.3	7.5	4.62	< 0.001
Focus Test Score (max 100)	73.0	65.8	−4.78	< 0.001

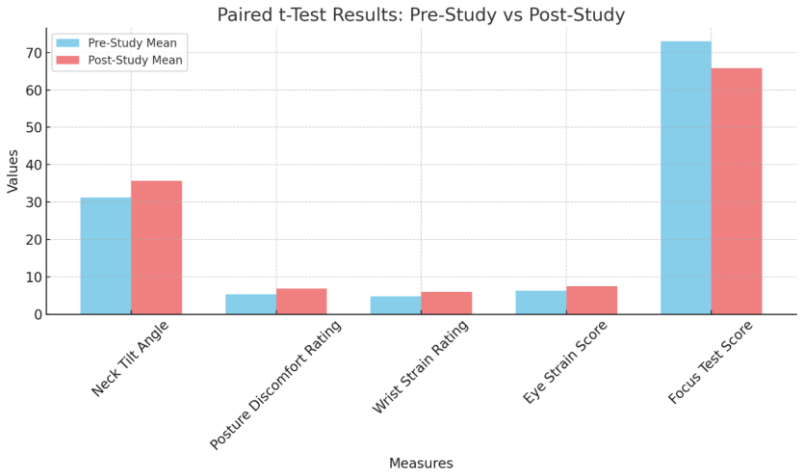

Figure 2. Paired *t*-test results.

Eye strain, as expected, worsened significantly over the study period, with mean scores rising from 6.3 to 7.5 ($t = 4.62$, $p < 0.001$). This finding is consistent with the known effects of prolonged screen time on visual fatigue and discomfort. Cognitively, focus test scores declined from 73.0 to 65.8, with a *t*-value of −4.78 ($p < 0.001$), indicating a marked reduction in students' ability to concentrate after prolonged smartphone use. This decline underscores the cognitive overload that excessive smartphone use can impose, further hampering attention and academic performance.

The correlation analysis (**Figure 3** and **Table 3**) reveals significant relationships between daily smartphone usage and physical and cognitive outcomes. The moderate positive correlation between daily smartphone usage and neck tilt angle ($r = 0.52$, $p < 0.01$) indicates that prolonged smartphone use is associated with increased forward head posture, suggesting a biomechanical strain on the neck. A strong positive correlation exists between smartphone usage and posture discomfort ($r = 0.61$, $p <$

0.001), showing that as smartphone usage increases, so does physical discomfort in the musculoskeletal system, particularly in the neck and back. Wrist strain also shows a moderate positive correlation with smartphone usage ($r = 0.47$, $p < 0.01$), supporting the idea that repetitive hand movements related to texting and scrolling contribute to strain. Eye strain is similarly correlated with smartphone usage ($r = 0.55$, $p < 0.001$), reflecting the visual fatigue that results from prolonged screen exposure.

Table 3. Correlation coefficients (*r*).

Variable	Correlation with Daily Smartphone Usage (*r*)	*p*-value
Neck Tilt Angle	0.52	< 0.01
Posture Discomfort Rating	0.61	< 0.001
Wrist Strain Rating	0.47	< 0.01
Eye Strain Score	0.55	< 0.001
Focus Test Score	−0.62	< 0.001
Memory Retention Score	−0.45	< 0.01
Anxiety Level (BAI Score)	0.58	< 0.001
Stress Level (PSS Score)	0.49	< 0.01
Depression Level	0.46	< 0.01

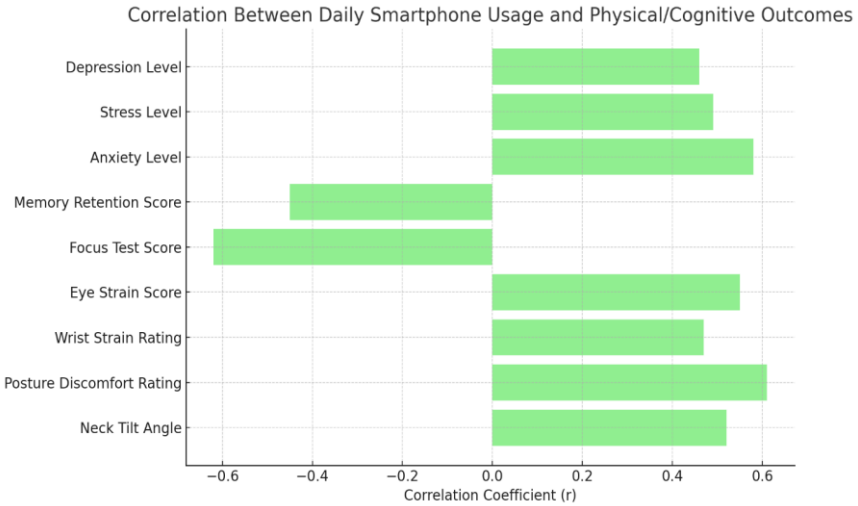

Figure 3. Correlation analysis.

On the cognitive side, a strong negative correlation exists between smartphone usage and focus test scores ($r = -0.62$, $p < 0.001$), indicating that more time spent on smartphones leads to a significant reduction in attention span and cognitive performance. Memory retention also shows a moderate negative correlation with smartphone use ($r = -0.45$, $p < 0.01$), suggesting that high smartphone usage impairs short-term memory and learning capabilities. The psychological variables show strong and moderate correlations with smartphone usage. Anxiety levels are strongly correlated with smartphone use ($r = 0.58$, $p < 0.001$), implying that increased smartphone interaction heightens feelings of anxiety, likely due to constant notifications and social media pressure. Similarly, stress levels show a moderate positive correlation ($r = 0.49$, $p < 0.01$), suggesting that heavy smartphone user's

cognitive load and social demands increase stress. Depression levels also show a moderate positive correlation (r = 0.46, p < 0.01), indicating that prolonged smartphone use, mainly when linked to social media, can lead to feelings of isolation and emotional distress.

The multiple regression analysis (**Figure 4** and **Table 4**) demonstrates the influence of several factors on physical and cognitive impacts. Daily smartphone usage significantly predicts neck tilt angle (β = 0.41, p < 0.01), confirming that more extended smartphone use contributes to more excellent forward head posture. Additionally, the type of activity (β = 0.27, p < 0.05), specifically social media use, significantly predicts worse neck posture, suggesting that certain activities exacerbate physical strain more than others. Gender also emerges as a significant predictor, with female students showing higher neck tilt angles on average (β = 0.35, p < 0.01), indicating a potential gender difference in susceptibility to posture-related issues. For cognitive outcomes, daily smartphone usage is a strong negative predictor of focus test scores (β = −0.49, p < 0.001). This result reinforces the correlation findings, suggesting prolonged smartphone use significantly reduces attention span and cognitive performance. Anxiety levels (β = −0.36, p < 0.01) and perceived stress (β = −0.33, p < 0.05) also predict reduced focus, highlighting the role of psychological strain in cognitive impairment. Elevated levels of anxiety and stress, which are common among high smartphone users, further degrade attention and hinder academic performance.

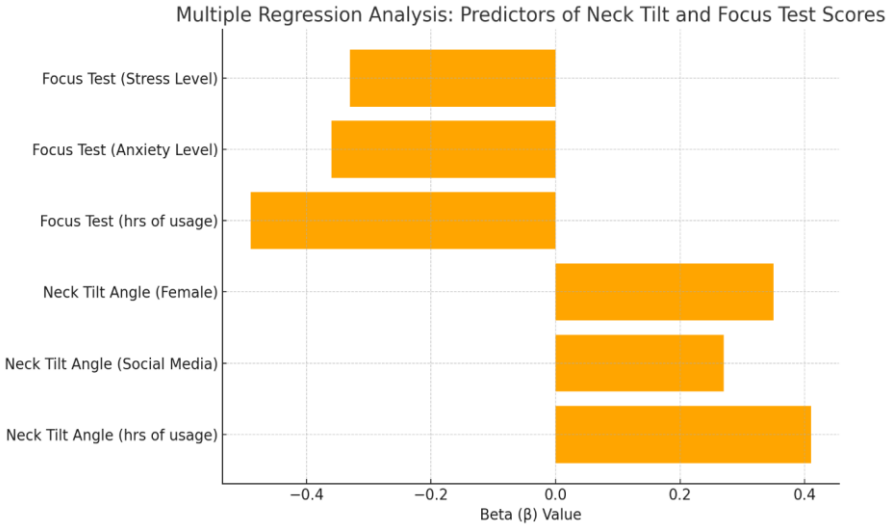

Figure 4. Multiple regression analysis.

Table 4. Multiple regression analysis.

Dependent Variable	Independent Variable	Beta (β)	p-value
Neck Tilt Angle	Daily Smartphone Usage (hrs)	0.41	< 0.01
	Type of Activity (Social Media)	0.27	< 0.05
	Gender (Female)	0.35	< 0.01
Focus Test Score	Daily Smartphone Usage (hrs)	−0.49	< 0.001
	Anxiety Level (BAI Score)	−0.36	< 0.01
	Perceived Stress (PSS Score)	−0.33	< 0.05

The ANOVA results (**Figure 5** and **Table 5**) reveal significant differences in physical and cognitive outcomes based on gender and age. For neck tilt angle, the *F*-value of 4.92 ($p < 0.05$) indicates a significant difference between males and females, with females exhibiting a more significant neck tilt than males. This suggests that female students may be more prone to postural issues related to smartphone use. On the other hand, the *F*-value of 3.08 ($p > 0.05$) for posture discomfort ratings indicates no significant difference between genders despite females reporting slightly higher discomfort. Cognitively, there is a significant difference in focus test scores between genders ($F = 5.52$, $p < 0.05$), with males performing better on average than females. This suggests that females may experience more cognitive impairment due to higher multitasking demands or more significant smartphone-related distractions.

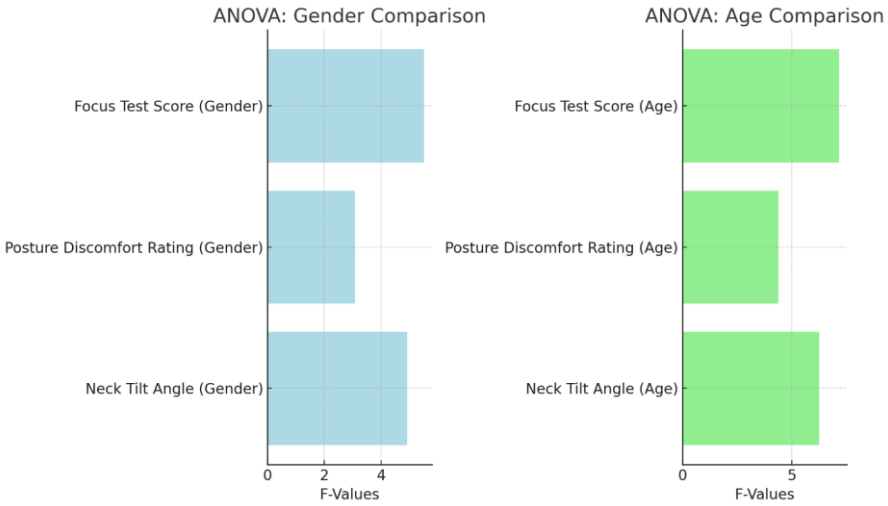

Figure 5. ANOVA result.

Table 5. ANOVA result.

Dependent Variable	Grouping Factor	*F*-value	*p*-value	Significant Difference
Neck Tilt Angle (degrees)	Gender (Male, Female)	4.92	< 0.05	Yes (Female > Male)
Posture Discomfort Rating (1–10)	Gender (Male, Female)	3.08	> 0.05	No
Focus Test Score (max 100)	Gender (Male, Female)	5.52	< 0.05	Yes (Male > Female)
Neck Tilt Angle (degrees)	Age (18–20, 21–22, 23–24)	6.24	< 0.01	Yes (23–24 > Younger)
Posture Discomfort Rating (1–10)	Age (18–20, 21–22, 23–24)	4.37	< 0.05	Yes (23–24 > Younger)
Focus Test Score (max 100)	Age (18–20, 21–22, 23–24)	7.15	< 0.01	Yes (Younger > Older)

Age also plays a significant role in physical and cognitive outcomes. For neck tilt angle, there is a significant difference based on age ($F = 6.24$, $p < 0.01$), with older students (aged 23–24) showing more significant neck tilt compared to younger students. This could be due to cumulative exposure to smartphone use over time. Similarly, posture discomfort ratings also show a significant difference based on age ($F = 4.37$, $p < 0.05$), with older students reporting more discomfort, likely due to long-term smartphone use and its impact on musculoskeletal health. For cognitive performance, focus test scores reveal a significant difference across age groups ($F = 7.15$, $p < 0.01$), with younger students (aged 18–20) performing better than older students. This suggests that younger students may have greater cognitive flexibility

and focus, while older students might experience more cognitive fatigue or distractions related to smartphone overuse.

The Chi-Square test results (**Figure 6** and **Table 6**) highlight significant associations between high smartphone usage and physical symptoms and MH outcomes. The test for wrist pain reveals a significant association (Chi-Square = 6.28, $p < 0.05$), indicating that students with high smartphone usage are likelier to report wrist pain than those with lower usage. This suggests that repetitive motions associated with smartphone use, such as texting and scrolling, contribute to physical strain. Neck pain also shows a significant association with high smartphone usage (Chi-Square = 7.85, $p < 0.01$), reinforcing the findings from the ANOVA results that prolonged smartphone use exacerbates musculoskeletal strain, particularly in the neck.

Table 6. Chi-Square test results.

Categorical Variable	Chi-Square Value	*p*-value	Significant Association
Wrist Pain vs. Smartphone Usage	6.28	< 0.05	Yes (High usage > Low usage)
Neck Pain vs. Smartphone Usage	7.85	< 0.01	Yes (High usage > Low usage)
Blurred Vision vs. Smartphone Usage	5.11	< 0.05	Yes (High usage > Low usage)
Anxiety Levels vs. Smartphone Usage	8.43	< 0.01	Yes (High usage > Low usage)
Stress Levels vs. Smartphone Usage	6.97	< 0.01	Yes (High usage > Low usage)

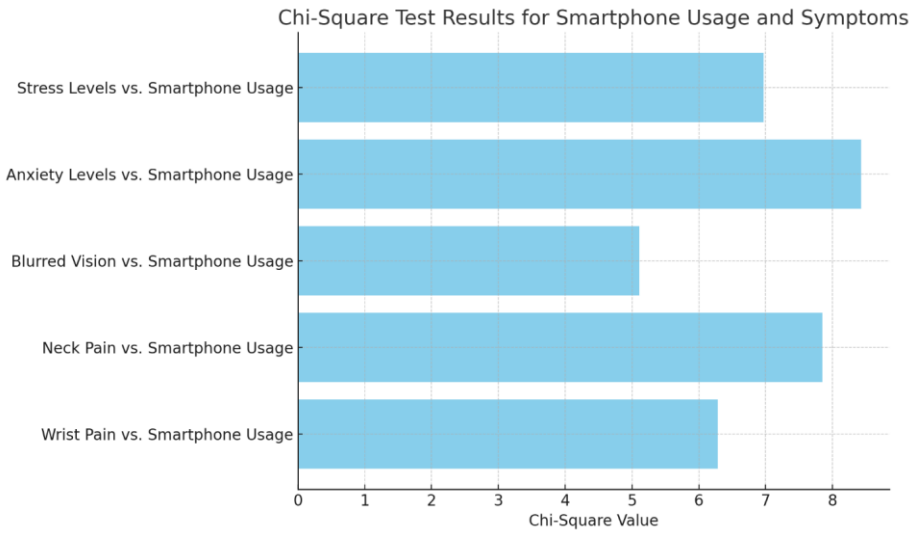

Figure 6. Chi-Square test results.

Blurred vision is another symptom significantly associated with high smartphone usage (Chi-Square = 5.11, $p < 0.05$), suggesting excessive screen time leads to visual fatigue and discomfort. This finding aligns with the known effects of prolonged exposure to smartphone screens, such as eye strain and dryness. MH outcomes, including anxiety and stress, are strongly associated with high smartphone usage. The Chi-Square test for anxiety levels reveals a significant association (Chi-Square = 8.43, $p < 0.01$), indicating that heavy smartphone users are more likely to report elevated anxiety levels. Similarly, stress levels are significantly associated with high smartphone usage (Chi-Square = 6.97, $p < 0.01$), suggesting that the pressures of

constant connectivity, multitasking, and social media engagement contribute to heightened stress among heavy smartphone users.

6. Conclusion and future work

The findings of this study reveal that prolonged smartphone use has significant physical and cognitive impacts on college students. Increased neck tilt, posture discomfort, and wrist strain were strongly associated with high smartphone usage, particularly among those who spent more time on social media. In addition, cognitive performance, mainly focus and memory retention, showed a marked decline with higher levels of smartphone use. The correlation between smartphone overuse and MH issues such as anxiety and stress further emphasizes the need to address these challenges. Gender and age were significant factors, with female and older students showing more pronounced physical strain while younger students demonstrated better cognitive performance. The Chi-Square tests highlighted the prevalence of symptoms such as wrist and neck pain, blurred vision, and elevated anxiety among high smartphone users.

In conclusion, this study underscores the urgent need for strategies to reduce the adverse effects of excessive smartphone use, especially in the college demographic. Interventions that promote healthier smartphone habits and ergonomic and cognitive strategies are essential to improving physical and mental health.

Ethical approval: Not applicable.

Conflict of Interest: The author declares no conflict of interest.

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