ORIGINAL ARTICLE

Nr 2023;13 (4):593-602

Correlation Between Smart Phone Addiction, Back Functional Disability, Core Stability Muscles Endurance and Morphology in Young Adults

Asmaa Mahmoud Hussin[1], Salwa Fadl AbdElmaged[2], Hatem Mohamed El-Azizi[3], Mona Mohamed Ibrahim[2]

[1] *Sheikh Zayed Specialized Hospital, Ministry of Health and Population, Giza, Egypt*
[2] *Department of Physical Therapy for Musculoskeletal Disorders and its Surgery, Faculty of Physical Therapy, Cairo University, Giza, Egypt*
[3] *Department of Radiodiagnosis, Faculty of Medicine, Cairo University, Cairo, Egypt*

CORRESPONDING AUTHOR:
Mona Mohamed Ibrahim
Department of Physical Therapy for Musculoskeletal Disorders and its Surgery
Faculty of Physical Therapy
Cairo University
1 Gamaa Street
12613 Giza, Egypt
E-mail: mona.ibrahiem@pt.cu.edu.eg; mona.ibrahiem@cu.edu.eg

DOI:
10.32098/mltj.04.2023.11

LEVEL OF EVIDENCE: 3

SUMMARY

Background. The effect of smartphone use on the cervical spine has been extensively examined and verified independent of time or age, although its negative effects on the lower back require additional research.

Purpose. The purpose of this study is to investigate the relationship between smartphone addiction and back functional disabilities, as well as the endurance and morphology of core stability muscles.

Methods. One hundred eight subjects (72 males and 36 females) were divided into 2 groups, Group A: 66 addicts (27 females and 39 males) and Group B: 42 non-addicts (9 females and 33 males) based on their smartphone use as measured by smartphone addiction scale short version (SAS-SV). The Oswestry disability index (Arabic version) was used to assess back functional disabilities, and diagnostic ultrasonography was used to assess lumber muscle morphology (cross-sectional area CSA and muscle thickness MT) of the lumbar erector spinae and multifidus. Finally, the endurance of core stability muscles was evaluated using supine and prone bridge tests.

Results. The results showed no association between SA and back functional disabilities. Furthermore, CSA, MT of lumber erector spinae, and multifidus were not associated with addiction. On the other hand, back muscle endurance was associated with addiction as the non-addict group recorded higher holding time in the supine bridge test ($p = 0.021$). Furthermore, smartphone addiction recorded higher dorsal pain and more duration of smartphone use especially in the form of social networking and video watching in the addict group ($p > 0.05$).

Conclusions. There is no evidence that smartphone addiction is correlated with back pain severity, back functions, and CSA or MT of multifidus and erector spinae muscles. On the other hand, smartphone addiction affects core stability and muscle endurance assessed by supine bridge tests.

Study registration. Protocol registration number at clinical trials.gov is NCT05321030.

KEY WORDS

Smartphone addiction; back muscle morphology; core stability; back pain; endurance.

INTRODUCTION

Smartphone use has been spread all over the world. The number of mobile phone users in Egypt raised in the last year 2022 by 64% according to the National Telecommunications Regulatory Authority (NTRA). The Coronavirus disease (COVID-19) pandemic was one of the causes that increased smartphone use due to isolation and social distance leading to more physiological and psychological affection (1).

Smartphone addiction (SA) is one of the psychological affection which falls under the category of behavioral addiction (2). SA was assessed using various versions of valid and reliable questionnaire as the smartphone addiction scale (SAS) (3) or using phone applications (4) or even specific questions regarding smartphone usage (5).

The physiological dysfunctions secondary to smartphone overuse were musculoskeletal (6, 7), respiratory (8), visual (9), and neural (10). Controversial findings were found in the literature concerning the impact of smartphones on body systems, particularly the musculoskeletal system. Thus, further research about the musculoskeletal impairments associated with smartphone use is required (11).

Lumbar proprioception deficit increased post smart phone usage but no changes were reported concerning lumbar curvature (12). Although, others found increased lumber lordosis and thoracic kyphosis in participants with or without low back pain (LBP) after a minimal time of smartphone use in sitting posture (13, 14). Moreover, smartphone overuse is also associated with altered trunk muscle activation and posture (14).

Smartphone overuse was also associated with increasing back pain in young adults either asymptomatic or symptomatic subjects. Mechanical LBP is highly reported in adults (15). There are many risk factors including the excessive use of electronic and hand-held devices (16, 17). Back pain is associated with morphological changes in multifidus and erector spinae as a cross-sectional area (18). Although back muscles are considered very important in maintaining core stability, no research up to the author's knowledge studied the correlation between them and smartphone overuse. The relationship between smartphone use and increasing pain severity in the lumber spine is reported (19, 20).

Back pain could prevent the normal activity of daily living (ADL). Although, the effect of smartphone usage on back functions is still under investigation. However, the correlation between pain severity and duration of phone use failed to reach significant levels (20, 21). Furthermore, smartphone usage may interfere with activities of daily living (ADL) and walking (7, 22).

Muscle endurance, morphology (cross-sectional area, thickness, side-to-side symmetry, fatty infiltration) and muscle contractility are pain-sensitive changes (23-28). Therefore, this study aims to investigate the relationship between smartphone addiction and back pain and functional disability, as well as the endurance and morphology of core stability muscles.

METHODS

This cross-sectional observational study was carried out in Kasr Al-Ainy Hospital, between December 2021 and November 2022. This study was conducted following the ethical standards established in the Declaration of Helsinki of 1946 and was approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University (P.T. REC/012/003474 – Date of approval: July 11, 2021).

Participants

Using G-power version 3.1.9.7 for Windows and regarding the t-test study, an alpha level of 0.05, confidence interval 95%, and effect size of 0.25 (to detect small effects), two groups, and nine dependent variables, the total sample size was 136 subjects. Three hundred volunteers were screened as shown in **figure 1**, one hundred fifty asymptomatic participants were enrolled in this study, and 108 completed all the steps of the study (**figure 1**). Subjects were divided based on the addiction score into two groups, Group A: 66 addicts (27 females and 39 males) and Group B: 42 non-addicts (9 females and 33 males). This is a valid and reliable 10-question scale for the detection of smartphone addiction. Each question has a possible score ranging from 1 to 6, with a total questionnaire score ranging from 10 to 60 points. A score of 34 is considered a cut-off for smartphone addiction, with greater scores indicating more addiction (29).

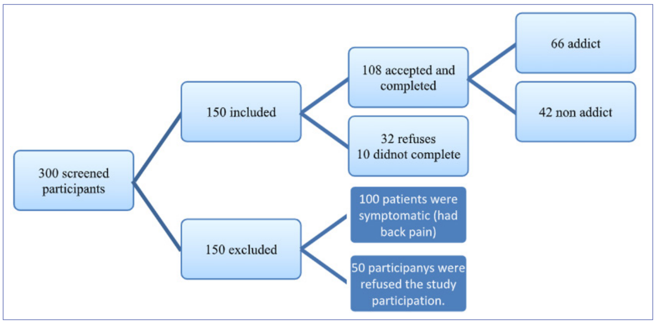

Figure 1. Flowchart of participants.

Participants were interviewed and their demographic data were obtained and recorded, SAS-SV, subjective data about smartphone usage, and Oswestry disability index (ODI) to assess the correlation between addiction and functional disabilities (30, 31). They are asymptomatic participants either male or female, their age is ranged from 17 to 35 years old, and their body mass index (BMI) ranged from 19.0 to 29.9 kg/m². Furthmore, they should be Arabic speakers smartphone users. Participants were excluded if they are athletes or had any history of spinal trauma or dysfunction, systemic disease presenting in the back (such as ankylosing spondylitis), spinal deformity, or leg length discrepancy were observed.

Procedures

Initially, the examiner screened subjects against study eligibility criteria and explained the study's purposes and procedures carefully and thoroughly. Eligible participants were invited to participate in the study and if they agreed, an informed consent was signed. Data collected by the subjects themselves were demographic data, back pain severity, and ODI. The second step is the assessment of core muscle morphology by diagnostic ultrasonography which was executed by an expert radiologist (Dr. HE). The last step was the assessment of core stability endurance by supine and prone bridge tests which were recorded by stopwatch.

Assessment

Pain secondary to prolonged smartphone use

Pain severity was assessed by the visual analog scale (VAS), as the participants were asked about the site of pain due to prolonged smartphone use, if the back is affected, he/she report its severity. VAS is a 10-cm line with two endpoints. Zero indicated no pain and 10 indicated intolerable pain, the patients were asked to put a mark on the line which indicates their pain severity, and the intensity was measured by a ruler in millimeters. VAS is a valid and reliable method for pain assessment (32).

Assessment of back functional disability

The Oswestry disability index assesses pain and functional disability by demonstrating the effect of back discomfort on the level of activity and is divided into ten components. The score for each item ranges from 0 to 5, the score was calculated by the addition of the values assigned for each of the 10 individual questions (30).
The total score was calculated and presented as a percentage, where 0% represents no disability and 100% represents the worst possible disability. Disability is categorized as follows: mild or no disability (0%-20%), moderate disability (21%-40%), severe disability (41%-60%), incapacity (61%-80%), restricted to bed (81%-100%) (31). ODI is a valid and reliable method for the assessment of pain and functional disability of low back pain. A 10% is considered minimal clinical importance difference (MCID) (33, 34) with 76%, and 63% sensitivity and specificity respectively (35). The Arabic version of ODI was used in this study and its validity and reliability were documented (36).

Assessment of core muscle morphology

Ultrasonography (US) was used for the assessment of muscle cross-sectional area (CSA) and muscle thickness (MT). US is a valid and reliable assessment tool for multifidi CSA and MT in younger asymptomatic individuals (37, 38), showing excellent within-day, interrater reliability, and good-to-excellent between-days, interrater reliability. MDCs ranged from 1.01-1.26 cm in lumber multifidus (LM) measurement of old adults with LBP (39). Lumbar erector spinae (LES) measurement showed excellent reliability (40).

Ultrasonography image conducted using General Electric E9 equipped with a 3.5 and 7.5 MHz curvilinear transducer for measurement of the multifidus CSA, MT, and CSA of lumber erector spinae. Subjects were lying on their abdomen, minimizing the lumbar lordosis using a pillow. Detection of spinous processes was performed manually by ultrasound imaging through a view of the spinous processes relative to the sacrum in the sagittal section. Then the aquatic gel is applied for CSAs measurement of the LM muscle, measurement done at L4 during rest. LM can be visible bilaterally on both sides of the spine or separately. The CSA of the multifidus was measured by tracing around the muscle border with the cursor on the screen as shown in **figure 2** (28, 38, 41).

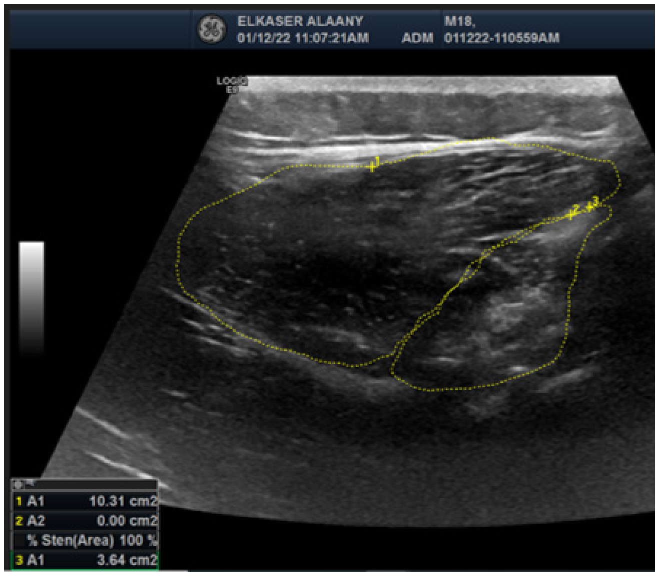

Figure 2. Cross sectional area measurement.
A1 multifidus; A2 erector spinae.

Assessment of multifidus MT was done at rest and during contraction via a contralateral arm lift 5 cm off the table measured by a ruler with the shoulder at 120 of abduction and elbow at 90 of flexion assessed by goniometer with approximately 30% of maximum voluntary contraction done through carrying a bottle of water based on the individual's body weight < 68.2 kg = 0.68 kg, 68.2-90.9 kg = 0.9 kg. Participants were asked to maintain the contraction for 3 seconds (38,41). In the same manner, the CSA of LES was measured during rest and at the level of the L3 transverse process of the L3 vertebra (42).

Assessment of core muscle endurance

Prone and supine bridge tests were used as indicators for lumbar spine stabilization endurance capability. Bridging maneuvers are practical, reliable, and valid methods for the assessment of core stability. In the prone bridge, each subject was lying on the abdomen, supported on the elbow, shoulder-width apart with a narrow base although the feet still not touching. The participant was asked to raise his/her pelvis off the floor by supporting his body weight on the shoulders and toes as shown in **figure 3**. The position was maintained until fatigue or pain.

In the supine bridge, each subject began lying on his back with 90 knee flexion, thighs parallel to each other with a narrow base. The subject was asked to raise his/her pelvis maintaining shoulder, hip, and knee in a straight line. Time of maintenance was recorded when the individuals perceived fatigue or pain. Instructions about the correct position were given. Normal individuals were capable to maintain both positions for about 1-2 minutes without disturbance (43).

Figure 3. Assessment of core muscle performance.

(A) Supine bridge; **(B)** Prone bridge.

Statistical analysis

Initially, the Kolmogorov-Smirnov test was used to determine the normality of the data. Because the primary outcomes were normally distributed, parametric tests were used for analysis. Independent t-tests were used to find the significant difference in the mean between groups. The correlation between smartphone addiction and the tested variable was done using Pearson correlation coefficient. Continuous variables as ultrasonographic measurement and core stability testing were presented as mean ± standard deviation (SD). The qualitative variable as ODI score was presented as count (%). All statistical tests were performed using the statistical package for social studies (SPSS) version 16 for Windows. The level of significance for all statistical tests was set at $p < 0.05$.

RESULTS

There was no statistically significant between groups in personal data as age or body mass index (BMI). 21.05 ± 2.24 years, 23.05 ± 2.42 kg/m^2 is the mean ± standard deviation of age and body mass index (BMI) of group A and 21.38 ± 2.13 years, 23.30 ± 3.03 kg/m^2 for group B.

Participants were questioned about their painful areas induced by using the phone and recorded them. The answers ranged from cervical, lumber, dorsal, eyes, shoulder, hand, finger, wrist, or more than one segment even there was no pain was reported, the dorsal pain addict group showed statistically significant differences from the other groups ($p = 0.03$), but both groups reported more pain in the cervical region as shown in **table I**. Furthermore, information about how posture can cause discomfort was gathered from participants without offering them any options. According to participants, the positions that caused pain were flexed postures while standing, prone, sitting, or resting on one's side, and there were no differences between the groups as in **table II**.

Questions about the duration of morning and whole-day smartphone use were asked and the choices were given

Table I. Painful area during smartphone use.

Painful area during usage	Addict n = 66		Non addict n = 42		Chi-square	P-value
	No.	%	No.	%		
Cervical	38	57.6	25	59.5	2.68	0.10
Lumber	10	15.2	8	12.1	0.22	0.64
None	3	4.5	1	1.5	1.00	0.32
Dorsal	7	10.6	1	1.5	4.50	0.03*
Eye	3	4.5	5	7.6	0.50	0.48
Shoulder	3	4.5	2	3.0	0.20	0.65
Hand	2	3.0	0	0.0	2.00	0.16
Fingers	2	3.0	3	4.5	0.20	0.65
Wrist	2	3.0	0	0.0	2.00	0.16

*Significant at P-value < 0.05.

Table II. Posture causing pain.

Posture cause pain	Addict n = 66		Non addict n = 42		Chi-square	P-value
	No.	%	No.	%		
Flexed during supine	1	1.5	1	2.4	0.00	1.00
Flexed posture	20	30.3	14	33.3	1.06	0.30
Flexed posture during sitting	14	21.2	7	16.7	2.33	0.13
Flexed posture during supine	5	7.6	5	11.9	0.00	1.00
None	2	3.0	1	2.4	0.33	0.56
Sitting	9	13.6	5	11.9	1.14	0.29
Standing	1	1.5	2	4.8	0.33	0.56
Supine	0	0.0	1	2.4	1.00	0.32
Supine with raising phone	0	0.0	2	4.8	2.00	0.16
Prone	1	1.5	0	0.0	1.00	0.32
Side lying	2	3.0	0	0.0	2.00	0.16
There was no specific posture	1	1.5	0	0.0	1.00	0.32

in standard formula 1-2 h, 3-4 h, 5-6 h, or more than 6 h. The last choice (more than 6 h) recorded a statistically significant difference between groups, as smartphone addicts used their smartphones more than 6 h (p = 0.03) as shown in **table III**, whereas morning smartphone use did not show any statistically significant differences between groups.

Furthermore, as shown in **table IV**, the functions performed using the smartphone were given in the form of social networking, video watching, gaming, texting, dialing, more than one task, or all of the above. Social networking and video watching were statistically greater in the addict group (p = 0.01).

The Pearson correlation coefficient was used to assess the association between SA and back function, back muscle morphology, and core muscle endurance. The results showed no association between SA and back dysfunction. Furthermore, CSA and MT of both muscles were not associated with addiction. On the other hand, back muscle endurance was associated with addiction as the non-addict group recorded higher holding time in the supine bridge test (p = 0.021) as shown in **table V**.

Table III. Time spent on a smartphone during the day.

Duration of smart phone use (hours)	Addict n = 66		Non addict n = 42		Chi-square	P-value
	No.	%	No.	%		
1-2 h	8	12.1	4	9.5	1.33	0.25
3-4 h	18	27.3	15	35.7	0.27	0.60
5-6 h	15	22.7	13	31.0	0.14	0.71
> 6 h	22	33.3	10	23.8	4.50	0.03*

*Significant at P-value < 0.05.

Table IV. Significant results from comparisons between groups.

Group	Addict n = 66	Non addict n = 42	Chi-square	P-value
Painful area during usage	10.6%	1.5%	4.5	0.03*
Duration of smartphone use (more than 6h)	33.3%	23.8%	4.5	0.03*
Personal usage (social network)	33.3%	19%	6.53	0.01*
Personal usage (videos)	0%	16.7%	7	0.01*

*Significant difference P-value < 0.05.

Table V. Correlation between SA and back function, core muscle performance and smartphone use.

Group	R	P-value
Supine bridge	-0.27	0.005*
Prone bridge	-0.06	0.51
Frequency of use	0.31	0.02*
ODI	-0.81	0.85

*Significant difference P-value < 0.05.

DISCUSSION

The purpose of this study was to look at the relationship between smartphone addiction and changes in back function and morphology and endurance of core stability muscles in asymptomatic people. Smartphone use did not worsen the severity of back discomfort as measured by VAS. Morphological muscle state, as evaluated by CSA and MT in ultrasonographic pictures, did not differ by addiction score. The ODI revealed no major dysfunction affecting the back. The absence of back pain in both groups may be due to the absence of immediate assessment after prolonged use of the smartphone because the static posture for a prolonged time in using a smartphone is one of the primary causes of pain even though there were no significant differences between groups in VAS score (20, 44). Furthermore, the results about the effect of smartphones on the back differ in the patient's reported level of pain intensity experienced after prolonged smartphone use (45, 46). On the other hand, upper body pain is reported in almost all studies that measured the effect of smartphone usage on musculoskeletal system dysfunctions even though our results reported that the cervical spine is the most painful area in both groups (10, 46-49). Back pain may be masked by higher-intensity cervical pain.

The absence of back dysfunction in both groups may be related to the young participant's age and the absence of pain as ODI showed higher scores in chronic low back pain patients and our participants are all asymptomatic (50, 51). To the author's knowledge, there was no study investigated the effect of smartphones on back function however, the effect of smartphones on neck function is measured and the results were contradicted. Bertozzi *et al*. reported that although 50% of the participant reported neck pain, there was no correlation between neck pain and NDI score and that may be due to low-intensity neck pain reported by the student (52).

MT and CSA differ significantly with gender as larger sizes in male gender (53, 54). However, the lack of the appropriate number of females in the current study interfered with the analysis of the gender differences in all measured variables. Because the instructions and positioning were the same for all participants, the variation between right and left measurements could be related to human error, sample diversity in lifestyle, posture, physical demand, and degree of activity (55). Body composition measures, side-to-side asymmetry, fatty infiltration, and BMI are closely connected with CSA, which may explain the lack of substantial changes in addiction levels (43, 56, 57), Willmink gave the same conclusion when he performed dynamic isolated lumbar training for lumbar multifidus and found clinically relevant improvement without any changes in CSA of lumbar multifidus muscles (58). Goubert's study showed no significant differences between groups in the size of multifidus and erector spinae CSA although fat cross-sectional area and lean muscle fat index were significantly higher in MF and ES in continuous CLBP compared to non-continuous CLBP (59). The absence of pain and its subtle changes in muscle structure may be the cause of the non-significant statistical differences found in muscle morphology. Furthermore, all assessment processes were done in static posture which put little demand on the motor and sensory system so not all dysfunction became obvious (60).

There are statistically significant differences in supine bridge score which may be attributable to higher lumber lordosis while sitting. Addictive smartphone users typically sit on their phones, putting additional strain on the lumbar spine and adjacent structures, and the back extensors become over-activated (61-63).

Postural analysis and EMG studies showed increased flexion angle for the neck and trunk with minimal (5 min) or prolonged smartphone use (up to 15 min) with concomitant hyperactivity of cervical erector spinae. Although, lower trapezius and thoracic erector spinae recorded a reduction in their activity in the same posture and time. Unfortunately, back muscle activity did not report in this study (64). Furthermore, young aged participants are cable of maintaining and reaching high degrees of flexion which stretches the extensors and stimulates the pain-sensitive mechanoreceptors if the position is maintained for a long time (6, 65).

The relationship between muscle structure and function is mutual and the pain can affect both of them. At the beginning of the pain sensation, the nociceptive stimulation affects back muscle function if the pain is not treated and became

chronic it affects muscle structure (66) hence it may be one of the causes of significant results in core stability testing.
A lot of studies failed to correlate smartphone addiction with dysfunctions as in Wahba study reported that the addiction score cannot be correlated to the differences in the magnitude of change in pain and proprioception, regardless of task duration (20). Also Marcel reported that there was no correlation between smartphone addiction and back VAS score or spinal postural changes reported (45). Furthermore, tension headache failed to be correlated with smartphone addiction (67) with the same conclusions about craniovertebral angle (68) and the absence of correlation may be related to compensatory changes in the thoracic spine.
The effect of smartphone addiction on spine core stability is tested in the cervical spine and reported no differences between groups in deep cervical flexors endurance holding time (7). Spinal stability was reported to be affected in another study that measured the response of the cervical spine to sudden activities post-phone use: Eunjee *et al.* suspected that the cause may be due to cervical muscle stretch leading to fatigue and hyperactivity (69).

Limitations

To the best of our knowledge, this is the first study to look into the relationship between smartphone use and ultrasonographic measurement. However, there are certain limits. First, the assessment was completed without the use of a phone. Second, the degree of activity among participants was not fixed. Third, the study only included a control group. Finally, because this was a preliminary study with no prior data, the sample size was not computed.
This study, on the other hand, was blinded, which is supposed to reduce research bias. Furthermore, all participants were students attempting to minimize variations in lifestyle. Future research is needed to address these limitations and examine the effect of smartphone usage duration in different age groups and patients with various LBP etiologies and severity levels.

CONCLUSIONS

There is no evidence that smartphone addiction is correlated with back pain severity, back functions, and CSA or MT of Multifidus and erector spinae muscles. On the other hand, Smartphone addiction affects core stability muscle endurance assessed by supine bridge tests.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

AH: patients physical assessment, outcomes measurement. SA: writing – original draft, writing – review & editing. HE: morphological measurement assess by ultrasonography. MI: results assessment, writing – original draft, writing – review & editing.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Serra G, Lo Scalzo L, Giuffrè M, Ferrara P, Corsello G. Smartphone use and addiction during the coronavirus disease 2019 (COVID-19) pandemic: cohort study on 184 Italian children and adolescents. Ital J Pediatr. 2021;47(1):150. doi: 10.1186/s13052-021-01102-8.
2. Griffiths M. Gambling on the internet: A brief note. J Gambl Stud. 1996;12(4):471-3. doi: 10.1007/BF01539190.
3. Kwon M, Lee JY, Won WY, et al. Development and validation of a smartphone addiction scale (SAS). PLoS One. 2013;8(2):e56936. doi: 10.1371/journal.pone.0056936.
4. Cho S, Lee E. Development of a Brief Instrument to Measure Smartphone Addiction Among Nursing Students. CIN Comput Informatics, Nursing. 2015;33(5):216-24. doi: 10.1097/CIN.0000000000000132.
5. Haug S, Paz Castro R, Kwon M, Filler A, Kowatsch T, Schaub MP. Smartphone use and smartphone addiction among young people in Switzerland. J Behav Addict. 2015;4(4):299-307. doi: 10.1556/2006.4.2015.037.
6. Lee S, Lee D, Park J. Effect of the cervical flexion angle during smart phone use on muscle fatigue of the cervical erector spinae and upper trapezius. J Phys Ther Sci. 2015;27(6):1847-9. doi: 10.1589/jpts.27.1847.
7. Lee H. Neck Pain and Functioning in Daily Activities Associated with Smartphone Usage. J Korean Phys Ther. 2016;28(3):183-8. doi: 10.18857/jkpt.2016.28.3.183.
8. Jung SI, Lee NK, Kang KW, Kim K, Lee DY. The effect of smartphone usage time on posture and respiratory function. J Phys Ther Sci. 2016;28(1):186-9. doi: 10.1589/jpts.28.186.

9. Park YH, An CM, Moon SJ. Effects of visual fatigue caused by smartphones on balance function in healthy adults. J Phys Ther Sci. 2017;29(2):221-3. doi: 10.1589/jpts.29.221.
10. AlZarea BK, Patil SR. Mobile Phone Head and Neck Pain Syndrome: Proposal of a New Entity. OHDM. 14(5):313-7. Available at: https://www.walshmedicalmedia.com/open-access/mobile-phone-head-and-neck-pain-syndrome-proposal-of-a-new-entity-2247-2452-1000833.pdf.
11. Toh SH, Coenen P, Howie EK, Straker LM. The associations of mobile touch screen device use with musculoskeletal symptoms and exposures: A systematic review. PLoS One. 2017;12(8):e0181220. doi: 10.1371/journal.pone.0181220.
12. Yoon JO, Kang MH, Kim JS, Oh JS. The effects of gait with use of smartphone on repositioning error and curvature of the lumbar spine. J Phys Ther Sci. 2015;27(8):2507-8. doi: 10.1589/jpts.27.2507.
13. In TS, Jung JH, Jung KS, Cho HY. Spinal and Pelvic Alignment of Sitting Posture Associated with Smartphone Use in Adolescents with Low Back Pain. Int J Environ Res Public Health. 2021;18(16):8369. doi: 10.3390/ijerph18168369.
14. Choi S, Kim M, Kim E, Shin G. Low back muscle activity when using a smartphone while walking. In: Human Factors and Ergonomics Society. 2019:1099-102. doi: 10.1177/1071181319631185.
15. Schmidt CO, Raspe H, Pfingsten M, et al. Back pain in the German adult population: prevalence, severity, and sociodemographic correlates in a multiregional survey. Spine (Phila Pa 1976). 2007;32(18):2005-11. doi: 10.1097/BRS.0b013e318133fad8.
16. Hakala PT, Rimpelä AH, Saarni LA, Salminen JJ. Frequent computer-related activities increase the risk of neck-shoulder and low back pain in adolescents. Eur J Public Health. 2006;16(5):536-41. doi: 10.1093/eurpub/ckl025.
17. Silva GR, Pitangui AC, Xavier MK, Correia-Júnior MA, De Araújo RC. Prevalence of musculoskeletal pain in adolescents and association with computer and videogame use. J Pediatr (Rio J). 2016;92(2):188-96. doi: 10.1016/j.jped.2015.06.006.
18. Sions JM, Teyhen DS, Hicks GE. Criterion Validity of Ultrasound Imaging: Assessment of Multifidi Cross-Sectional Area in Older Adults With and Without Chronic Low Back Pain. J Geriatr Phys Ther. 2017;40(2):74-9. doi: 10.1519/JPT.0000000000000073.
19. Kim HJ, Kim JS. The relationship between smartphone use and subjective musculoskeletal symptoms and university students. J Phys Ther Sci. 2015;27(3):575-9. doi: 10.1589/jpts.27.575.
20. Wahba M M, Othman D, Morsi S. Smartphone usage duration is not associated with increased pain or proprioception deficit in young adults with chronic mechanical low back pain : a cross- sectional study. Bull Fac Phys Ther. 2020;25(1). doi: 10.1186/s43161-020-00010-y.
21. Alsalameh AM, Harisi MJ, Alduayji MA, Almutham AA, Mahmood FM. Evaluating the relationship between smartphone addiction/overuse and musculoskeletal pain among medical students at Qassim University. J Family Med Prim Care. 2019;8(9):2953-9. doi: 10.4103/jfmpc.jfmpc_665_19.
22. Luo Y, Zheng H, Chen Y, Giang WCW, Hu B. Influences of Smartphone Operation on Gait and Posture During Outdoor Walking Task. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2020;1723-7. doi: 10.1177/1071181320641418.
23. Wang H, Zheng J, Fan Z, et al. Impaired static postural control correlates to the contraction ability of trunk muscle in young adults with chronic non-specific low back pain: A cross-sectional study. Gait Posture. 2022;92:44-50. doi: 10.1016/j.gaitpost.2021.11.021.
24. Prasetyo M, Nindita N, Murdana IN, Prihartono J, Setiawan SI. Computed tomography evaluation of fat infiltration ratio of the multifidus muscle in chronic low back pain patients. Eur J Radiol Open. 2020;7:100293. doi: 10.1016/j.ejro.2020.100293.
25. Nandlall N, Rivaz H, Rizk A, Frenette S, Boily M, Fortin M. The effect of low back pain and lower limb injury on lumbar multifidus muscle morphology and function in university soccer players. BMC Musculoskelet Disord. 2020;21(1):96. doi: 10.1186/s12891-020-3119-6.
26. Lévesque J, Rivaz H, Rizk A, Frenette S, Boily M, Fortin M. Lumbar Multifidus Muscle Characteristics, Body Composition, and Injury in University Rugby Players. J Athl Train. 2020;55(10):1116-23. doi: 10.4085/1062-6050-304-19.
27. Schryver A, Rivaz H, Rizk A, Frenette S, Boily M, Fortin M. Ultrasonography of Lumbar Multifidus Muscle in University American Football Players. Med Sci Sports Exerc. 2020;52(7):1495-501. doi: 10.1249/MSS.0000000000002292.
28. Hides JA, Stanton WR, McMahon S, Sims K, Richardson CA. Effect of stabilization training on multifidus muscle cross-sectional area among young elite cricketers with low back pain. J Orthop Sports Phys Ther. 2008;38(3):101-8. doi: 10.2519/jospt.2008.2658.
29. Kwon M, Kim DJ, Cho H, Yang S. The smartphone addiction scale: development and validation of a short version for adolescents. PLoS One. 2013;8(12):e83558. doi: 10.1371/journal.pone.0083558.
30. Fairbank JC, Pynsent PB. The Oswestry Disability Index. Spine (Phila Pa 1976). 2000;25(22):2940-52; discussion 2952. doi: 10.1097/00007632-200011150-00017.
31. Davidson M, Keating J. Oswestry Disability Questionnaire (ODQ). Aust J Physiother. 2005;51(4):270. doi: 10.1016/s0004-9514(05)70016-7.
32. Ostelo RW, de Vet HC. Clinically important outcomes in low back pain. Best Pract Res Clin Rheumatol. 2005;19(4):593-607. doi: 10.1016/j.berh.2005.03.003.
33. Chiarotto A, Maxwell LJ, Terwee CB, Wells GA, Tugwell P, Ostelo RW. Roland-Morris Disability Questionnaire and Oswestry Disability Index: Which Has Better Measurement Properties for Measuring Physical Functioning in Nonspecific Low Back Pain? Systematic Review and Meta-Analysis. Phys Ther. 2016;96(10):1620-37. doi: 10.2522/ptj.20150420.
34. Vianin M. Psychometric properties and clinical usefulness of the Oswestry Disability Index. J Chiropr Med. 2008;7(4):161-3. doi: 10.1016/j.jcm.2008.07.001.
35. Monticone M, Baiardi P, Vanti C, et al. Responsiveness of the Oswestry Disability Index and the Roland Morris Disability Questionnaire in Italian subjects with sub-acute and chronic low back pain. Eur Spine J. 2012;21(1):122-9. doi: 10.1007/s00586-011-1959-3.
36. Ramzy R. Validation of the Arabic Version of the Oswestry Disability Index Developed in Tunisia for low back pain patients in the UAE. 2008.

37. Larivière C, Gagnon D, De Oliveira E Jr, Henry SM, Mecheri H, Dumas JP. Ultrasound measures of the lumbar multifidus: effect of task and transducer position on reliability. PM R. 2013;5(8):678-87. doi: 10.1016/j.pmrj.2013.03.010.
38. Kiesel KB, Uhl TL, Underwood FB, Rodd DW, Nitz AJ. Measurement of lumbar multifidus muscle contraction with rehabilitative ultrasound imaging. Man Ther. 2007;12(2):161-6. doi: 10.1016/j.math.2006.06.011.
39. Sions JM, Velasco TO, Teyhen DS, Hicks GE. Reliability of ultrasound imaging for the assessment of lumbar multifidi thickness in older adults with chronic low back pain. J Geriatr Phys Ther. 2015;38(1):33-9. doi: 10.1519/JPT.0000000000000021.
40. Ranson CA, Burnett AF, Kerslake R, Batt ME, O'Sullivan PB. An investigation into the use of MR imaging to determine the functional cross sectional area of lumbar paraspinal muscles. Eur Spine J. 2006;15(6):764-73. doi: 10.1007/s00586-005-0909-3.
41. Wallwork TL, Hides JA, Stanton WR. Intrarater and interrater reliability of assessment of lumbar multifidus muscle thickness using rehabilitative ultrasound imaging. J Orthop Sports Phys Ther. 2007;37(10):608-12. doi: 10.2519/jospt.2007.2418.
42. Watanabe K, Miyamoto K, Masuda T. Use of Ultrasonography to Evaluate Thickness of the Erector Spinae Muscle in Maximum Flexion and Extension of the Lumbar Spine. Spine. 2004;29(13):1472-7. doi: 10.1097/01.BRS.0000128755.84693.
43. Schellenberg KL, Lang JM, Chan KM, Burnham RS. A clinical tool for office assessment of lumbar spine stabilization endurance: prone and supine bridge maneuvers. Am J Phys Med Rehabil. 2007;86(5):380-6. doi: 10.1097/PHM.0b013e318032156.
44. Cagnie B, Danneels L, Van Tiggelen D, De Loose V, Cambier D. Individual and work related risk factors for neck pain among office workers: a cross sectional study. Eur Spine J. 2007;16(5):679-86. doi: 10.1007/s00586-006-0269-7.
45. Betsch M, Kalbhen K, Michalik R, Schenker H, Gatz M, Quack V, et al. The influence of smartphone use on spinal posture–A laboratory study. Gait Posture. 2021;85(5):298-303. doi: 10.1016/j.gaitpost.2021.02.018.
46. Alsalameh AM, Harisi MJ, Alduayji MA, Almutham AA, Mahmood FM. Evaluating the relationship between smartphone addiction/overuse and musculoskeletal pain among medical students at Qassim University. J Family Med Prim Care. 2019;8(9):2953-9. doi: 10.4103/jfmpc.jfmpc_665_19.
47. Kim SY, Koo SJ. Effect of duration of smartphone use on muscle fatigue and pain caused by forward head posture in adults. J Phys Ther Sci. 2016;28(6):1669-72. doi: 10.1589/jpts.28.1669.
48. Chieh C, Siang L, Hua H. Impact of Prolonged Tablet Computer Usage with Head Forward and Neck Flexion Posture on Pain Intensity, Cervical Joint Position Sense and Balance Control in Mechanical Neck Pain Subjects. J Med Biol Eng. 2020;40(3):372-82. doi: 10.1007/s40846-020-00525-8.
49. Ojha R, Sindhu B, Sen S. Effects of smartphone addiction on sitting neck posture & hand discomfort. Int J Health Sci. 2022;6(4):13642-50. doi: 10.53730/ijhs.v6nS2.8595.
50. Hong JH, Kim HD, Shin HH, Huh B. Assessment of depression, anxiety, sleep disturbance, and quality of life in patients with chronic low back pain in Korea. Korean J Anesthesiol. 2014;66(6):444-50. doi: 10.4097/kjae.2014.66.6.444.
51. Palmer KT, Goodson N. Ageing, musculoskeletal health and work. Best Pract Res Clin Rheumatol. 2015;29(3):391-404. doi: 10.1016/j.berh.2015.03.004.
52. Bertozzi L, Negrini S, Agosto D, et al. Posture and time spent using a smartphone are not correlated with neck pain and disability in young adults: A cross-sectional study. J Bodyw Mov Ther. 2021;26:220-6. doi: 10.1016/j.jbmt.2020.09.006.
53. Lim JH. Correlations of symmetry of the trunk muscle thickness by gender with the spinal alignment in healthy adults. J Korean Phys Ther. 2013;25(6):405-10.
54. Watson T, McPherson S, Starr K. The association of nutritional status and gender with cross-sectional area of the multifidus muscle in establishing normative data. J Man Manip Ther. 2008;16(4):E93-8. doi: 10.1179/jmt.2008.16.4.93E.
55. Rankin G, Stokes M, Newham DJ. Abdominal muscle size and symmetry in normal subjects. Muscle Nerve. 2006;34(3):320-6. doi: 10.1002/mus.20589.
56. Lee HI, Song J, Lee HS, Kang JY, Kim M, Ryu JS. Association between Cross-sectional Areas of Lumbar Muscles on Magnetic Resonance Imaging and Chronicity of Low Back Pain. Ann Rehabil Med. 2011;35(6):852-9. doi: 10.5535/arm.2011.35.6.852.
57. Niemeläinen R, Briand MM, Battié MC. Substantial asymmetry in paraspinal muscle cross-sectional area in healthy adults questions its value as a marker of low back pain and pathology. Spine (Phila Pa 1976). 2011;36(25):2152-7. doi: 10.1097/BRS.0b013e318204b05a.
58. Willemink MJ, van Es HW, Helmhout PH, Diederik AL, Kelder JC, van Heesewijk JP. The effects of dynamic isolated lumbar extensor training on lumbar multifidus functional cross-sectional area and functional status of patients with chronic nonspecific low back pain. Spine (Phila Pa 1976). 2012;37(26):E1651-8. doi: 10.1097/BRS.0b013e318274fb2f.
59. Goubert D, De Pauw R, Meeus M, Willems T, Cagnie B, Schouppe S, Van Oosterwijck J, Dhondt E, Danneels L. Lumbar muscle structure and function in chronic versus recurrent low back pain: a cross-sectional study. Spine J. 2017;17(9):1285-96. doi: 10.1016/j.spinee.2017.04.025.
60. Schabrun SM, van den Hoorn W, Moorcroft A, Greenland C, Hodges PW. Texting and walking: strategies for postural control and implications for safety. PLoS One. 2014;9(1):e84312. doi: 10.1371/journal.pone.0084312.
61. Endo K, Suzuki H, Nishimura H, Tanaka H, Shishido T, Yamamoto K. Sagittal lumbar and pelvic alignment in the standing and sitting positions. J Orthop Sci. 2012;17(6):682-6. doi: 10.1007/s00776-012-0281-1.
62. Stewart DM, Gregory DE. The use of intermittent trunk flexion to alleviate low back pain during prolonged standing. J Electromyogr Kinesiol. 2016;27:46-51. doi: 10.1016/j.jelekin.2016.01.007.
63. Dejanovic A, Cambridge EDJ, McGill S. Isometric torso muscle endurance profiles in adolescents aged 15-18: Normative values for age and gender differences. Ann Hum Biol. 2014;41(2):153-8. doi: 10.3109/03014460.2013.837508.

64. Park JH Ms, Kang SY PhD, Lee SG PhD, Jeon HS PhD. The effects of smart phone gaming duration on muscle activation and spinal posture: Pilot study. Physiother Theory Pract. 2017;33(8):661-9. doi: 10.1080/09593985.2017.1328716.
65. Malmström EM, Karlberg M, Fransson PA, Melander A, Magnusson M. Primary and coupled cervical movements: the effect of age, gender, and body mass index. A 3-dimensional movement analysis of a population without symptoms of neck disorders. Spine (Phila Pa 1976). 2006;31(2):E44-50. doi: 10.1097/01.brs.0000194841.83419.0b.
66. Hodges PW, Danneels L. Changes in Structure and Function of the Back Muscles in Low Back Pain: Different Time Points, Observations, and Mechanisms. J Orthop Sports Phys Ther. 2019;49(6):464-76. doi: 10.2519/jospt.2019.8827.
67. Kim C, Lee D. Comparison of Smartphone Addiction, Anterior Head Posture, Quality of Life, and Headache Impact according to the Presence or Absence of Tension Headaches in College Students. J Korean Soc Integr Med. 2020;8(4):117-23.
68. Selvaganapathy K, Rajappan R, Dee TH. The effect of the smartphone addiction on craniovertebral angle and depression status among university students. Int J Intagr Med Sci. 2017;4(5):537-42. doi: 10.16965/ijims.2017.118.
69. Eunjee K, Donghyun S, Dasom P, Hyorim K, Gwanseob S. Reflexive Response of Neck Muscle to Sudden Perturbation after Prolonged Smartphone Use. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2021;65(1):1250-3. doi: 10.1177/1071181321651085.