

Original Research

Desk operation reduces neck and shoulder load during smartphone use

Kakeru Ito ¹⁾²⁾, Akio Kikuchi ¹⁾³⁾ and Toshiaki Sato ¹⁾³⁾

- 1) Graduate School of Health Sciences, Yamagata Prefectural University of Health Sciences, 260 Kamiyanagi, Yamagata City, Yamagata, 990-2212, Japan
- 2) Department of Rehabilitation, Yamagata Saisei Hospital, 79-1 Okimachi, Yamagata City, Yamagata, 990-8545, Japan
- 3) Department of Occupational Therapy, Faculty of Health Sciences, Yamagata Prefectural University of Health Sciences, 260 Kamiyanagi, Yamagata City, Yamagata, 990-2212, Japan

ABSTRACT

Objective: Smartphones have become indispensable tools in modern life. Based on previous studies, the duration of smartphone use and neck flexion angle affect the upper trapezius muscle activity. However, the effects of the smartphone holding position and the presence or absence of upper limb support during use have not been sufficiently investigated. Therefore, this study aimed to clarify the effects of smartphone holding positions and upper limb support during smartphone use on physical and psychological outcomes.

Methods: This study included 18 healthy young men, of whom 17 were included in the final analysis. Participants performed smartphone operations for 20 minutes in three postures: desk operation, thigh operation, and spatial operation. Upper trapezius muscle activity, neck flexion angle, and subjective fatigue were measured to assess posture-related differences over time.

Results: Upper trapezius muscle activity did not show significant changes over time in any condition. In contrast, neck flexion angle increased significantly from baseline in all postures, and subjective fatigue increased significantly over time in all conditions. Among the three conditions, upper trapezius muscle activity was highest in the spatial operation condition, whereas neck flexion angle and subjective fatigue were lowest in the desk operation condition.

Conclusions: These findings suggest that supporting the upper limbs during smartphone use may reduce upper trapezius muscle activity. Moreover, the desk operation posture may be the most effective for reducing physical load on the neck and shoulders.

Keywords: smartphone, upper trapezius muscle, average rectified value, neck flexion angle, visual analogue scale

INTRODUCTION

Many people use smartphones daily not only for communication but also for entertainment such as videos and games. More than 90% of university students use their smartphones for more than three hours daily, with the majority exceeding five hours.¹ Furthermore, the use of smartphones has increased since the COVID-19 pandemic.^{2,3} Although indispensable in daily life, prolonged use can cause visual strain, musculoskeletal problems, and addiction.⁴⁻⁷

Particularly for musculoskeletal symptoms, the duration of smartphone use is significantly associated with pain in the neck, shoulders, and hands.⁴⁻⁶ In addition, prolonged use and greater neck flexion angle (NFA) increase upper trapezius fatigue,⁸⁻¹⁰ and individuals with neck pain tend to show higher upper trapezius activity than those without symptoms.¹¹

Therefore, the use of smartphones with reduced neck flexion may help prevent musculoskeletal symptoms such as stiffness of the neck and shoulders.

In musculoskeletal research on smartphone use, surface electromyography (EMG) has been widely utilized to measure muscle activity and fatigue.⁸⁻¹¹ Most studies used a single-electrode pair on the target muscle to measure overall muscle activity. However, measurements using only a single pair of electrodes provide limited information,^{12,13} and even the attachment of multiple electrodes may not be sufficient due to their large size. Recently, multichannel surface EMG with over 60 electrodes has been developed and is widely utilized.¹²⁻¹⁵ This method provides more extensive and detailed muscle activity information than conventional single-electrode measurement. Few studies applied it to the

Received 21 June, 2026. Revised 28 July, 2026. Accepted 7 August, 2026.

Correspondence to Toshiaki Sato: tsato@yachts.ac.jp

use of smartphone, but it might be effective for obtaining detailed muscle activity information in such tasks. On the other hand, many studies on smartphone operation have focused on the effects of usage time and NFA on muscles such as the upper trapezius and cervical erector spinae.⁸⁻¹⁰ In particular, smartphone operation with a lower NFA has been suggested to be effective in reducing fatigue and muscle activity.^{9-11,16} Studies comparing differences in posture based on NFA have also been conducted.^{17,18} However, few studies have simultaneously investigated muscle activity and NFA across different postures during smartphone use. Moreover, to the best of our knowledge, no previous study has comprehensively evaluated upper trapezius muscle activity using multichannel surface EMG together with NFA and subjective fatigue while comparing different smartphone operating postures, including variations in smartphone holding position and upper limb support.

Therefore, the purpose of this study was to investigate the effects of differences in smartphone holding positions and the presence or absence of upper limb support on upper trapezius muscle activity, NFA, and subjective fatigue using multichannel surface EMG.

METHODS

Participants. This study included 18 healthy young adult men with no pain or injury in their limbs or trunk and no history of orthopedic or neurological disorders. All were right-handed and provided written informed consent. The study adhered to the ethical standards set by the Declaration of Helsinki and was approved by the Ethics Committee of Yamagata Prefectural University of Health Sciences (No. 2311-24). The sample size was calculated using G*Power 3.1 for repeated measures ANOVA. The parameters were set as follows: effect size = 0.25, α = 0.05, power = 0.8, number of groups = 3, number of measurements = 5, correlation among repeated measures = 0.5, and nonsphericity correction ϵ = 0.4. As a result, the required sample size was determined to be 16 participants.

Experimental design. Participants sat on the chair without a backrest and performed smartphone tasks for 20 minutes in three different postural conditions. The three postures for the task were “desk operation” with upper limb support on the desk, “thigh operation” with upper limb support on the thighs, and “spatial operation” without upper limb support (Fig. 1). These

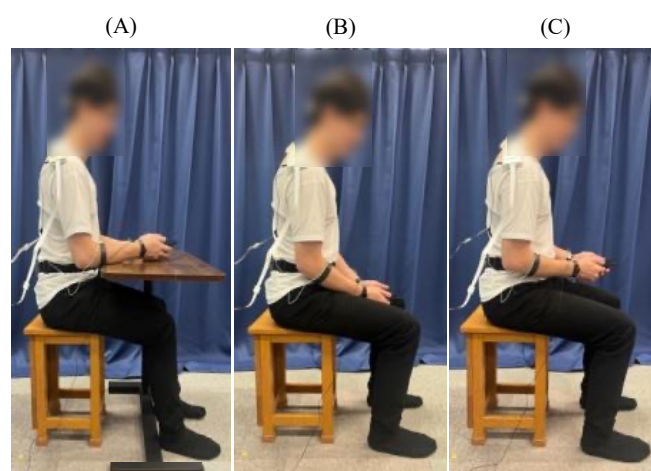


Figure 1. Task posture

(A) Desk operation with upper limb support on the desk, (B) Thigh operation with upper limbs on the thighs, (C) Spatial operation without upper limb support.

postures were selected to compare the effects of smartphone holding positions and the presence or absence of upper limb support. In the desk operation and spatial operation, the elbows were flexed at 90° and the operation time for each task posture was set to 20 minutes based on previous studies.^{8,19} The smartphone operation involved holding a smartphone (iPhone 13, Apple, USA) with both hands and repeatedly playing the game Tetris (Tetris, N3TWORK, USA) with the right thumb. Initially, to record the condition around the shoulder before the tasks, the right upper trapezius muscle activity during 2 minutes of rest and the visual analogue scale (VAS) were measured. The VAS assessed shoulder-related fatigue on a 100-mm scale, with 0 indicating no fatigue and 100 indicating maximum fatigue.^{11,12,20} Afterwards, a 5-minute rest was taken, and the VAS was recorded once again to make sure it matched the pre-task record before proceeding with the task. During the task, participants were instructed to maintain a stable posture. The participants were verbally guided to return to their initial posture if postural changes occurred, such as changes in upper limb position or rounded back. In addition, the VAS was recorded every 5 minutes to assess shoulder fatigue, the task was performed within a comfortable range while monitoring fatigue. The tasks were conducted in a random order, with a rest period of at least 20 minutes between them. Following the rest, 2 minutes of muscle activity and the VAS were recorded in a resting state, and the next task was carried out after confirming that both were comparable to the pre-task values.

Multichannel surface EMG recording. Surface EMG was recorded from the right upper trapezius

muscle using a matrix electrode (GR08MM1305, OT Bioelettronica, Italy) consisting of 64 electrodes arranged in a two-dimensional planar array (Fig. 2). Before attaching the electrodes, the skin was treated with abrasive paste and alcohol in order to ensure signal quality. The electrodes were placed such that the center of the second row was aligned with the midpoint of the line connecting the spinous process of the seventh cervical vertebra and the acromion, and they were secured with tape (C38, Nichiban, Japan).²¹ Ground straps were attached to both wrists and the right forearm. Monopolar surface EMG signals were recorded using a 16-bit AD converter (Quattrocento, OT Bioelettronica, Italy) with a sampling frequency of 2048 Hz and a band-pass filter of 10-500 Hz.¹⁵ EMG signal recording and analysis were performed using OTBioLab+ Version 1.5.5. software (OTBioLab+, OT Bioelettronica, Italy).

NFA and motion analysis. The NFA during each task was measured using a three-dimensional motion analysis system (Myomotion, Noraxon USA, USA), with motion sensors attached to the occiput, spinous process of the seventh cervical vertebra, and sacrum. The NFA was calculated from the sensors placed on the occiput and the spinous process of the seventh cervical vertebra. Calibration was performed before each task measurement, with the neutral neck position (facing straight ahead) set as 0° and the angles during the tasks were then recorded.

Motion analysis was performed using two web

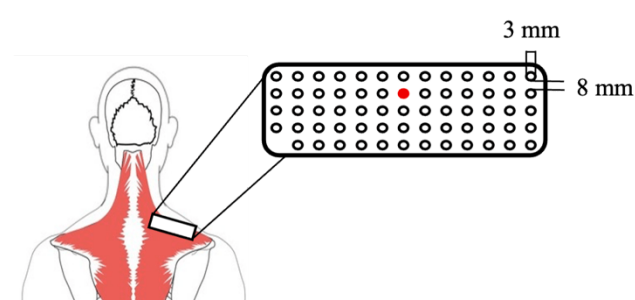


Figure 2. Electrode placement and matrix electrodes

The matrix electrode was attached to the right upper trapezius muscle so that the midpoint of the line connecting the C7 spinous process and the acromion was aligned with the center of the second row of the matrix electrode (indicated in red). The matrix electrodes were 3 mm in diameter and were arranged in 5 × 13 with an 8 mm interelectrode distance, totaling 64 electrodes due to the absence of one electrode in the bottom-left corner.

cameras (C920, Logitech International SA, Switzerland) placed at the front and right sides. A synchro light (EM-MR228, Noraxon USA, USA) was used to synchronize the cameras with the multichannel surface EMG. The recordings and analysis were performed using MR3.18 software

(MR3, Noraxon USA, USA).

Data processing. The muscle activity of the upper trapezius was quantified using the average rectified value (ARV) derived from EMG signals over five intervals, each separated by 5 minutes. The ARV was calculated for each channel during the 1-minute periods before and after each analysis interval, and the average value across all channels was used as a representative measure of overall upper trapezius muscle activity.^{12,13} For the NFA, the average value of the 1-minute periods before and after each 5-minute analysis interval was also used. The VAS was recorded at 5-minute intervals starting from the beginning of the task.

Statistical analysis. A two-way repeated measures ANOVA was first used to examine differences in across task posture over time for each parameter. For factors showing significant interactions or main effects, one-way ANOVA was carried out.¹⁸ One-way repeated measures ANOVA was applied to normally distributed data, whereas the Friedman test was utilized for non-normally distributed data. Normality was tested using the Shapiro-Wilk test. If a main effect was found in the one-way ANOVA, post-hoc multiple comparisons were performed using the Bonferroni method. The significance level for all tests was set at 5%, and statistical analyses were conducted using EZR Version 1.61, an extension of R Version 4.3.3.²²

RESULTS

Out of the 18 participants who performed the tasks, 17 were included in the analysis, excluding 1 participant who exhibited non-task-related movements such as turning the neck during the tasks. The basic characteristics of the analyzed participants were age 20.9 ± 1.5 years, height 169.9 ± 5.8 cm, and weight 66.9 ± 8.9 kg.

Temporal changes of each parameter. Table 1 shows the median values of ARV, NFA, and VAS for each task posture. ARV remained unchanged across all postures ($p > 0.05$) (Table 1). NFA increased significantly compared to the beginning in all postures ($p < 0.05$ – 0.01), with no further change after 5 minutes ($p > 0.05$) (Table 1). The VAS has shown to increase significantly over time in all postures ($p < 0.05$ – 0.01) (Table 1).

Comparison of task postures for each parameter.

Table1 ARV, NFA, and VAS for each task posture

		0 min	5 min	10 min	15 min	20 min
(A)	ARV	0.022 ^{§**}	0.026	0.025 ^{§**}	0.027 ^{§**}	0.025 ^{§**}
	[mV]	(0.018-0.026)	(0.022-0.030)	(0.022-0.031)	(0.023-0.033)	(0.021-0.030)
	NFA	18 ^{§**}	25 ^{a**§**}	24 ^{a**§**}	26 ^{a**§**}	23 ^{a**§**}
(B)	[degree]	(15-19)	(18-26)	(21-28)	(21-28)	(19-26)
	VAS	8	13 ^{a**}	15 ^{a**b*}	23 ^{a**b**}	26 ^{a**b**c**d**§*}
	[mm]	(2-18)	(7-19)	(9-24)	(12-33)	(13-39)
		0 min	5 min	10 min	15 min	20 min
(C)	ARV	0.020 ^{§**}	0.023 ^{§**§**}	0.022 ^{§**§**}	0.024 ^{§**}	0.021 ^{§**}
	[mV]	(0.017-0.023)	(0.019-0.024)	(0.020-0.026)	(0.019-0.026)	(0.019-0.024)
	NFA	30 ^{§**}	37 ^{a**§**§**}	37 ^{a**§**§**}	40 ^{a**§**§**}	40 ^{a**§**§**}
(D)	[degree]	(24-36)	(25-47)	(27-47)	(32-46)	(30-47)
	VAS	13	14 ^{a*}	18 ^{a*b*}	24 ^{a*b**c**}	36 ^{a**b**c**d**§**}
	[mm]	(3-17)	(13-16)	(14-24)	(15-39)	(20-47)
		0 min	5 min	10 min	15 min	20 min
(E)	ARV	0.034 ^{§**†**}	0.034 ^{†**}	0.036 ^{§**†**}	0.037 ^{§**†**}	0.037 ^{§**†**}
	[mV]	(0.029-0.036)	(0.031-0.037)	(0.030-0.040)	(0.033-0.039)	(0.032-0.042)
	NFA	23 ^{§**}	29 ^{a**§**†*}	30 ^{a**§**†**}	30 ^{a**§**†**}	32 ^{a**§**†**}
(F)	[degree]	(20-30)	(26-34)	(26-34)	(26-35)	(30-37)
	VAS	12	15 ^{a**}	17 ^{a**b**}	22 ^{a**b**c**}	33 ^{a**b**c**d**§**}
	[mm]	(5-16)	(13-21)	(15-26)	(17-34)	(20-53)

Median (IQR). (A) Desk operation, (B) Thigh operation, (C) Spatial operation. ARV: Average rectified value. NFA: Neck flexion angle. VAS: Visual analogue scale.

*p < 0.05, **p < 0.01. a: Comparison with 0 minutes, b: Comparison with 5 minutes, c: Comparison with 10 minutes, d: Comparison with 15 minutes. #: Comparison with desk operation, †: Comparison with thigh operation. §: Comparison with spatial operation

ARV and NFA revealed significant differences among task postures at all time points, with ARV being the highest in spatial operation and NFA being the highest in thigh operation ($p < 0.05-0.01$) (Table 1). The VAS showed significant differences only at 20 minutes, with thigh and spatial operations producing higher fatigue than desk operations ($p < 0.05-0.01$) (Table1).

DISCUSSION

This study investigated the effects of smartphone holding position and upper limb support on upper trapezius muscle activity, NFA, and VAS across three task postures. Previous musculoskeletal research on the use of a smartphone has mostly investigated temporal changes using a single pair of surface electrodes or compared differences in NFAs. To our knowledge, is the first to use multichannel surface EMG in smartphone research to comprehensively evaluate upper trapezius muscle activity together with NFA and subjective fatigue across different operating postures. As a result, temporal changes were observed in some NFA and VAS measures, while posture comparisons revealed significant differences in ARV, NFA, and some VAS (Table 1). The present study provides new insights into the physical demands associated with smartphone use by comprehensively evaluating muscle activity, NFA, and subjective fatigue across different smartphone operating postures.

Temporal changes. In the present study, ARV did not change over time in any of the three task postures. A previous study reported that although cervical erector spinae muscle activity significantly increased over time during smartphone use, no temporal changes were observed in the upper trapezius muscle.²³ The authors suggested that the upper trapezius may be activated from the beginning of smartphone use to maintain neck and shoulder posture and support the weight of the upper limbs and smartphone, but becomes passively elongated over time due to the sustained load.²³ Moreover, upper trapezius muscle activity during smartphone use has been reported to remain below 10% of maximal voluntary contraction,¹¹ indicating that smartphone operation imposes a relatively low muscular load. According to the size principle, low-intensity contractions primarily recruit fatigue-resistant type I muscle fibers.²⁴ Therefore, muscle activity during smartphone use may predominantly involve type I fibers, which are capable of sustaining prolonged contractions with minimal fatigue. Taken together, the absence of temporal changes in ARV may be explained by sustained postural activation of the upper trapezius under relatively low muscular load during smartphone use.

NFA increased significantly in all task postures compared to the initial time point, but showed no further changes after 5 minutes (Table 1). Previous studies investigating NFAs during smartphone use

have mostly reported an increase over time.^{17,18,23} In this study, verbal cues were provided to correct posture in order to clarify the effects of smartphone holding position and upper limb support. These adjustments, often made after 5 minutes, are considered to have contributed to the absence of further changes in the NFA.

VAS scores increased significantly over time in all task postures (Table 1). While previous studies have reported increases after 10 minutes in patients with neck pain,⁸ this study found fatigue in asymptomatic young adults as early as 5 minutes. The requirement to maintain a static posture with minimal movement may also have amplified the sensation of fatigue.

Comparison of task postures. Differences in ARV are likely due to upper limb support during the operation. Previous study reported lower upper trapezius muscle activity with forearm support²⁵ and higher activity with elevated arms, as the muscle supports arm weight and stabilizes the scapula.¹¹ Therefore, the highest muscle activity occurred during the unsupported spatial operation.

NFA differences are likely influenced by upper limbs and smartphone positions. A previous study found no effect of arm support on NFA,¹⁷ but arm positions were not controlled. In this study, arm positions were fixed for each task posture, and any changes were promptly adjusted, which may have made the NFA more sensitive to posture differences. Furthermore, the thigh operation showed the highest NFA because the smartphone was positioned lower than in other postures.

VAS showed differences among task postures only at 20 minutes. This may be related to NFA, as muscle fatigue and pain in the upper trapezius are greater when the NFA is high while using a smartphone.^{9,10} Therefore, VAS was likely higher in thigh and spatial operations, which showed greater NFA than desk operation. Previous studies reported that static seated work imposes a continuous load on the neck,²⁶ and higher NFA further increases neck muscle tension, potentially leading to neck pain.²⁷ Moreover, individuals with neck and upper limb pain exhibited greater NFAs and tended to adopt postures without back or forearm support.²⁵

Thus, the desk operation characterized by a low NFA and upper limb support may be effective in reducing the load on the neck and shoulders.

Limitations. This study has two limitations. First, the study participants were limited to healthy young adult

males. Previous research has indicated differences in muscle activity and NFAs depending on the presence or absence of musculoskeletal symptoms.^{11,25} Furthermore, reports suggest that the NFA during a smartphone use increases more in males than in females.¹⁷ Therefore, future studies should also explore the impact of disease status and gender differences. Second, to clearly examine the effect of upper limb support, verbal cues were provided to maintain posture during the tasks. While this may have influenced natural smartphone operation, it allowed for consistent posture across participants. Future studies should investigate smartphone use under more natural conditions.

Usefulness of this study. The findings of this study showed that changes in NFA and VAS occurred after 5 minutes, and comparisons between task postures revealed different outcomes across all parameters. Prolonged smartphone use of more than 6 hours per day increases the prevalence of musculoskeletal pain in the neck, shoulders, and hands, with long-term smartphone use contributing to the onset of musculoskeletal pain.⁶ In order to prevent these issues, it is important to take breaks within 5 minutes and operate the smartphone in a posture that supports the upper limb and a low NFA. The results of this study are useful for providing guidance on movements aimed at reducing neck and shoulder strain during smartphone use in daily life.

CONCLUSION

This study aimed to investigate the effects of posture differences during smartphone use on upper trapezius muscle activity, NFA, and subjective fatigue. The results revealed that posture differences during smartphone use influenced upper trapezius muscle activity, NFA, and VAS. Smartphone use with upper limb support reduced upper trapezius muscle activity, suggesting that desk operation with the lowest NFA may help reduce strain on the neck and shoulders.

ACKNOWLEDGMENTS

We thank Prof. Tasuku Sotokawa of Yamagata Prefectural University of Health Sciences for his assistance in the statistical analysis. We also thank students at Yamagata Prefectural University of Health Sciences for their cooperation in this research.

FUNDING

The authors did not receive support from any organization for the submitted work.

CONFLICT OF INTEREST

The authors declare no conflicts of interest. Akio Kikuchi is the Editor-in-Chief of *Clinical and Health Sciences Journal*. He was not involved in and did not have access to any information regarding the peer-review or editorial decision-making process for this article. An independent editor oversaw the entire peer-review process and made the final editorial decision.

REFERENCES

- [1] Wang Z, Zheng J. Relationship between smartphone usage time and mental health of college students. *Rev Argent Clin Psicol*. 2020;29(1):177-86.
- [2] Oka T, Hamamura T, Miyake Y, Kobayashi N, Honjo M, Kawato M, et al. Prevalence and risk factors of internet gaming disorder and problematic internet use before and during the COVID-19 pandemic: A large online survey of Japanese adults. *J Psychiatr Res*. 2021;142:218-25.
- [3] Schmidt SCE, Anedda B, Burchartz A, Eichsteller A, Kolb S, Nigg C, et al. Physical activity and screen time of children and adolescents before and during the COVID-19 lockdown in Germany: a natural experiment. *Sci Rep*. 2020;10(1):21780.
- [4] Berolo S, Wells RP, Amick III BC. Musculoskeletal symptoms among mobile hand-held device users and their relationship to device use: A preliminary study in a Canadian university population. *Appl Ergon*. 2011;42(2):371-8.
- [5] AlAbdulwahab SS, Kachanathu SJ, AlMotairi MS. Smartphone use addiction can cause neck disability. *Musculoskelet Care*. 2017;15(1):10-2.
- [6] Mustafaoglu R, Yasaci Z, Zirek E, Griffiths MD, Ozdinciler AR. The relationship between smartphone addiction and musculoskeletal pain prevalence among young population: a cross-sectional study. *Korean J Pain*. 2021;34(1):72-81.
- [7] Ashwini KV, Shankar SS, Rajbanshi D, Paudel S, Singh P, Chandana KM, et al. The consequences of gaming on mobile devices versus laptops on binocular visual functioning. *TNOA J Ophthalmic Sci Res*. 2023;61(2):207-14.
- [8] 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.
- [9] Lee S, Choi YH, Kim J. Effects of the cervical flexion angle during smartphone use on muscle fatigue and pain in the cervical erector spinae and upper trapezius in normal adults in their 20s. *J Phys Ther Sci*. 2017;29(5):921-3.
- [10] 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.
- [11] Namwongsa S, Puntumetakul R, Neubert MS, Boucaut R. Effect of neck flexion angles on neck muscle activity among smartphone users with and without neck pain. *Ergonomics*. 2019;62(12):1524-33.
- [12] Nishikawa Y, Watanabe K, Chihara T, Sakamoto J, Komatsuzaki T, Kawano K, et al. Influence of forward head posture on muscle activation pattern of the trapezius pars descendens muscle in young adults. *Sci Rep*. 2022;12(1):19484.
- [13] Watanabe K, Yoshida T. Effect of arm position on spatial distribution of upper trapezius muscle activity during simulated car driving. *Int J Occup Saf Ergon*. 2022;28(3):1766-72.
- [14] Huang C, Klein CS, Meng Z, Zhang Y, Li S, Zhou P. Innervation zone distribution of the biceps brachii muscle examined using voluntary and electrically-evoked high-density surface EMG. *J Neuroeng Rehabil*. 2019;16(1):73.
- [15] Ito K, Kikuchi A, Sato T. Comparison of muscle activity distribution in the biceps brachii using monopolar and bipolar multichannel surface electromyography. *PLoS One*. 2025;20(7):e0325464.
- [16] Choi JH, Jung MH, Yoo KT. An analysis of the activity and muscle fatigue of the muscles around the neck under the three most frequent postures while using a smartphone. *J Phys Ther Sci*. 2016;28(5):1660-4.
- [17] Alfaitouri S, Altaboli A. The Effect of posture and duration of smartphone usage on neck flexion angle. *Proc Hum Factors Ergon Soc Annu Meet*. 2019;63(1):962-6.
- [18] Lee SY, Lee DH, Han SK. The effects of posture on neck flexion angle while using a smartphone according to duration. *J Korean Soc Phys Med*. 2016;11(3):35-9.
- [19] Kato Y, Fukuda S, Suzuki Y, Ota S. Effect of posture feedback band on posture alignment and pain during a visual display terminal task. *Jpn Soc Exp Mech*. 2016;16(4):315-9. (in Japanese with English abstract).
- [20] Lee KA, Hicks G, Nino-Murcia G. Validity and reliability of a scale to assess fatigue. *Psychiatry Res*. 1991;36(3):291-8.
- [21] Kleine BU, Schumann NP, Stegeman DF, Scholle HC. Surface EMG mapping of the human trapezius muscle: the topography of monopolar and bipolar surface EMG amplitude and spectrum parameters at varied forces and in fatigue. *Clin Neurophysiol*. 2000;111(4):686-93.
- [22] Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. *Bone Marrow Transplant*. 2013;48(3):452-8.
- [23] Park JH, Kang SY, Lee SG, Jeon HS. The effects of smart phone gaming duration on muscle activation and spinal posture: Pilot study. *Physiother Theory Pract*. 2017;33(8):661-9.
- [24] Henneman E, Somjen G, Carpenter DO. Functional significance of cell size in spinal motoneurons. *J Neurophysiol*. 1965;28(3):560-80.
- [25] Gustafsson E, Johnson PW, Lindegård A, Hagberg M. Technique, muscle activity and kinematic differences in young adults texting on mobile phones. *Ergonomics*. 2011;54(5):477-87.
- [26] Ariëns GAM, Bongers PM, Douwes M, Miedema MC, Hoogendoorn WE, van der Wal G, et al. Are neck flexion, neck rotation, and sitting at work risk factors for neck pain? Results of a prospective cohort study. *Occup Environ Med*. 2001;58(3):200-7.
- [27] Hansraj KK. Assessment of stresses in the cervical spine caused by posture and position of the head. *Surg Technol Int*. 2014;25:277-9.