ORIGINAL

Differences in the activity of the shoulder girdle and lower back muscles owing to postural alteration while using a smartphone

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Abstract : The purpose of this study was to clarify the influence of different postures on the activity of the shoulder girdle and lower back muscles while using a smartphone. Sixteen healthy male participants maintained two postures while using a smartphone : a good posture in which the tragus and acromion were closer to the vertical line passing through the greater trochanter, and a poor posture in which the tragus and acromion were farther from the vertical line passing through the greater trochanter. The target muscles were the rhomboid major (Rhom), upper trapezius, middle trapezius, lower trapezius (LT), lumbar erector spinae (LES), and lumbar multifidus (LMF). The activities of the Rhom and LT were significantly lower with poor posture than those with good posture. The activities of LES and LMF were significantly higher with poor posture than those with good posture. The results of this study indicated that poor posture was associated with hypoactivity of the shoulder girdle muscles and hyperactivity of the lower back muscles when compared with good posture. Poor posture for prolonged periods while using a smartphone would lead to malfunction of the shoulder girdle muscles and musculofascial lower back pain. J. Med. Invest. 67 : 274-279, August, 2020

Keywords **:** *posture, smartphone, shoulder girdle muscles, low back pain, fine-wire EMG*

INTRODUCTION

Lower back, shoulder, and neck pain are common in daily life, and have the highest complaint rates among people with illness or injury in Japan (1). Recently, many people are using smartphones. In Japan, the personal smartphone ownership rate is 64.7% (2). In addition, more than 90% of individuals in their 20's and 30's own one (2). People who frequently use mobile devices, such as mobile phones and smartphones have a high percentage of chronic lower back, neck, and shoulder pain (3-6).

Many people often adopt a poor posture during smartphone use (7). People who use mobile devices often present with a posture with the head forward and shoulders rounded because of flexion of the neck and abduction of the scapula resulting from placing their hands forward to see the screen. These postures might lead to fatigue and pain in the neck and shoulder. Several studies have suggested that hyperactivity and increased strain on cervical muscles, such as the upper trapezius (UT) and cervical erector spinae, are cited as a cause of pain and discomfort in the neck and shoulder (8-11).

Postural correction is important in the prevention and improvement of shoulder, neck, and lower back pain. Exercise of the posterior shoulder girdle muscles, including the middle trapezius (MT), lower trapezius (LT), and rhomboid major (Rhom) is effective in postural correction (12,13). Abdelhameed *et al.* clarified that exercise training and postural correction improved disability and symptoms related to upper extremity musculoskeletal disorders among touchscreen smartphone users (14). Thus, identification of the causes of the symptoms and conscious postural correction are considered important in preventing and alleviating symptoms, such as low back pain, shoulder pain, and neck pain. Although previous studies have mainly focused on the cervical region, such as the cervical angles and changes in neck muscle activity while using a smartphone and mobile devices, there are few reports on the activities of the shoulder girdle and lower back muscles related to posture control.

The purpose of this study was to clarify the influence of different postures on the activity of the shoulder girdle and lower back muscles while using a smartphone measured using fine-wire and surface electromyography (EMG). We hypothesized that poor posture would show hypoactivity of the shoulder girdle muscles, such as the Rhom, MT, and LT, and hyperactivity of the lower back muscles, such as the lumbar erector spinae (LES) and multifidus (LMF).

MATERIALS AND METHODS

Participants

A power analysis was performed to estimate the number of participants for the paired *t*-test using G*Power 3.1.9.4 (Heinrich-Heine Universität, Germany). The number of participants was estimated as 15 with an alpha level = 0.05, power = 0.80, and effect size Cohen's d = 0.8. Sixteen healthy males (age : 21 ± 2 years, height : 170.9 ± 5.1 cm, and weight : 68.1 ± 10.2 kg) participated in this study. Participants were excluded if they had low back pain, shoulder pain, and neck pain in the prior three months. All participants provided written informed consent prior to participation. This study was approved by the ethics committee of our institution (approval number : 2016-020).

Postural analysis

We attached markers to the tragus, acromion, C7 spinous process (15), anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), and greater trochanter on the dominant side

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of the participants. A digital camera (EXLIM EX-100, CASIO, Japan) was set on a tripod 1.2 m high and 3 m away from the participants. Two postures, good and poor postures, were measured using a smartphone. Good posture was defined when the tragus and acromion markers were closer to the vertical line passing through the greater trochanter marker, while poor posture was defined when the tragus and acromion markers were farther from the vertical line passing through the greater trochanter marker (Figure 1). Participants performed each posture for 10 s while holding a smartphone. The upper arms were placed at the side of the body with the elbow flexed. Participants performed each posture in a random order. We used the ImageJ (16) for posture analysis. The forward head angle (FHA) and forward shoulder angle with respect to C7 (FSA-C7) were defined as the angles formed by the vertical line passing through the C7 marker and the line connecting the C7 and tragus markers and the C7 and acromion markers, respectively, (15). The forward shoulder angle with respect to the greater trochanter (FSA-GT) was defined as the angle formed by the vertical line passing through the greater trochanter marker and the line connecting the greater trochanter and acromion markers (Figure 2). The anterior pelvic tilt angle (APT) was defined as the angle formed by the horizontal line passing through the ASIS marker and the line connecting the ASIS and PSIS markers. The sagittal vertical axis (SVA) distance rates were calculated by dividing the distance from the vertical line from C7 to the vertical line joining the midpoint of the ASIS and the PSIS by the distance from the ASIS and PSIS and multiplying by 100 (Figure 3). All angles and SVA distance rates were measured three times. The average value of the three measurements and the intraclass correlation coefficients (ICC) were calculated.

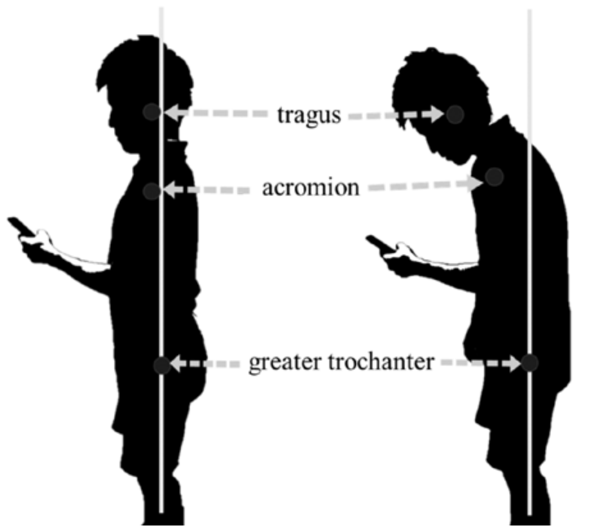

Figure 1. Definition of posture (left : good posture, right : poor posture)

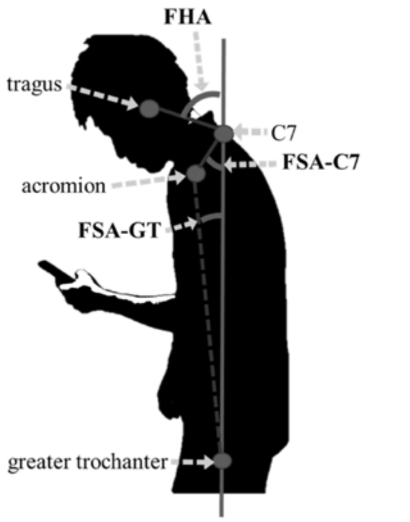

Figure 2. Definition of each postural angle

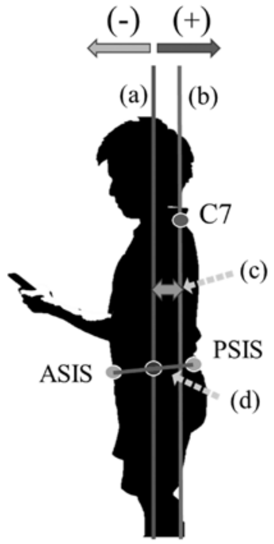

Figure 3. SVA distance rates analysis (a) : Vertical line passing through the midpoint of the ASIS and PSIS. (b) : Vertical line passing through C7 marker. (c) : Vertical distance between (a) and (b). (d) : distance between ASIS and PSIS. The SVA distance rate was calculated as follows : (c) / (d) · 100. Positive value : (b) is located behind (a). Negative value : (b) located ahead of (a).

Measurement of muscle activity

The target muscles in this study were the Rhom, UT, MT, LT, LES, and LMF, all of which were measured on the participant's dominant side. The Rhom activity was measured using bipolar intramuscular fine-wire electrodes (Unique Medical Co., Ltd., Tokyo, Japan) and other muscles were measured using surface electrodes (Blue Sensor N-00-S, METS Co., Japan). The bipolar intramuscular fine-wire electrodes were covered with a Teflon coating, except for the tips. The fine-wire electrodes were placed into 23-gauge sterilized needle (0.60 × 60 mm), and the tips were bent back to from 3- and 5-mm hooks (17). The needle with fine-wire electrodes attached was sterilized by heating at 121°C for 20 min using a small fully automatic high-pressure steam sterilizer (Taneda Medical Instruments Co., Ltd., Tokyo, Japan). The fine-wire intramuscular electrodes were inserted into the Rhom by an experienced orthopedist. The participants were placed in the prone position with the back of the dominant hand placed on their low back (Figure 4-A). After identification of the Rhom using ultrasonography (LOGIQe, GE, USA), the insertion site was disinfected with alcohol. The bipolar fine-fire electrodes were inserted into the Rhom under ultrasonography guidance (Figure 4-B). The insertion site was at the midpoint of the base of the spine of the scapula and the inferior angle of the scapula (18). The Rhom EMG amplitude was checked with

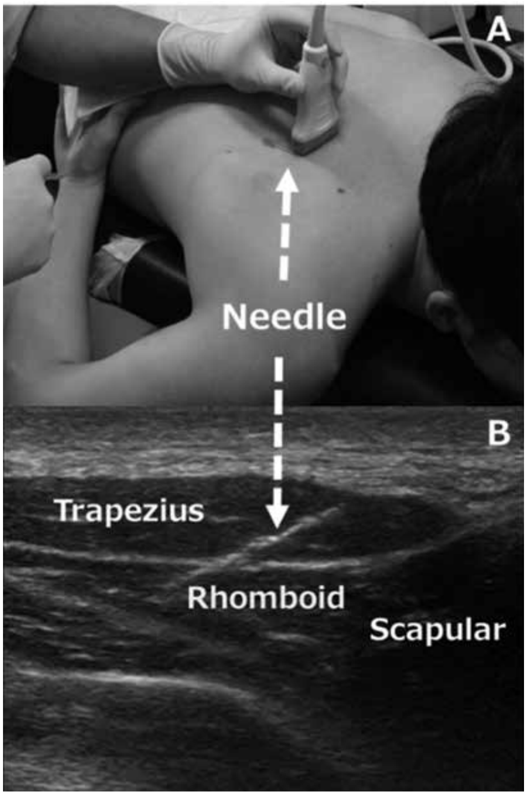

Figure 4. Fine-wire insertion into the rhomboid major (Rhom)

active scapula elevation and adduction to confirm the accurate insertion. After rubbing the skin with alcohol to reduce skin impedance, the surface electrodes were attached parallel to the muscle fibers. The surface electrodes were 8-mm in diameter, and the electrode distance was 20-mm. The placement of the surface electrodes was based on previous studies (19-21) and recommendation of SENIAM (22). The surface electrodes were placed as follows : UT, the upper back halfway between the C7 spinous process and acromion process (19) ; MT, midpoint between the medial border of the scapula and the spine at the level of Th3 (22) ; LT, 2/3 on the line from the base of scapula spine to the 8th thoracic vertebra (22) ; LES, 30 mm lateral to the L3 spinous process (20) ; and LMF, 20 mm lateral to the L5 spinous process (21). Both the fine-wire and surface EMG were measured using a wireless EMG telemeter system (BioLog DL-5000, S&ME Co., Japan) at a sampling rate of 1000 Hz.

Maximum voluntary isometric contraction

To compare the muscle activity of each posture, maximum voluntary isometric contraction (MVIC) was measured as an index of normalization after completion of all the posture trials. Participants performed against the manual resistance applied by the same examiner for all MVIC measurements. The MVIC measurement method was as follows : Rhom, the participants performed adduction and downward rotation of the scapula in the prone position with the back on the dominant hand placed on the lower back, and the examiner applied manual resistance to scapula abduction and upward rotation of the distal upper arm (23) ; UT, the participants shrugged their shoulders in the sitting position while the examiner pushed downward between the neck and acromion on both sides (23) ; MT, the participants adducted their scapula in the prone position with 90° abduction of the shoulder while the examiner pushed downward on their distal upper arm (23) ; LT, the participants elevated their upper arm in the prone position with the shoulder abducted at 145° while the examiner pushed downward on their distal upper arm (23) ; LES and LMF, the participants extended their trunk in the prone position while the examiner pushed their upper thoracic area (20). MVIC measurements of each muscle were taken for 5 s in a random order. A resting period of more than 30 s was allocated between MVIC measurements.

Data processing

The raw muscle activity data were analyzed using a biological information analysis software (BIMUTAS-Video, Kissei Comtec Co, Ltd, Japan). The bandpass filter for the EMG data was processed at 20-450 Hz to eliminate motion artifacts (17). The analysis was performed in the middle 5 s of each posture holding for 10 s. The EMG activity was represented as percent maximum voluntary isometric contraction (%MVIC), which was calculated by normalizing the root mean square value of each muscle activity by the highest root mean square value of the MVIC. The highest root mean square value of the MVIC was calculated using the root mean square during 1 s of the MVIC trials.

Statistical analysis

All data are expressed as mean ± standard deviation. A paired *t*-test was used to compare the outcome of each postural analysis and each muscle activity in good posture and poor posture. Statistical analyses for the *t* test and ICC were performed using SPSS version 23.0 software (IBM Japan Co., Ltd., Japan). The effect size (ES) was calculated to represent the magnitude of difference between muscle activity and postural alignment for each posture. ES was defined as small, moderate, and large if the value of Cohen's d ranged from 0.2 to 0.5, 0.5 to 0.8, and > 0.8, respectively (24). The significance level was set at 0.05.

RESULTS

Postural analysis

The postural variables and SVA distance rate of each posture are shown in Table 1 and Figure 5, respectively. The ICC (1,1) of postural measurement performed three times was 0.984-0.995, with high reliability in all cases. There were significant differences between good posture and poor posture for FHA (50.5 ± 7.2° vs. 67.2 ± 11.2°, respectively, $p < 0.01$, ES = 1.77), FSA-GT (0.0 ± 2.3° vs 8.2 ± 5.2°, respectively, $p < 0.01$, ES = 2.05), APT (7.0 ± 3.9° vs 4.4 ± 4.1°, $p < 0.01$, ES = 0.65), and SVA distance rates (37.0 ± 9.9% vs. -3.5 ± 24.4%, respectively, $p < 0.01$, ES = 2.17). There was no significant difference between good posture and poor posture for FSA-C7 (56.4 ± 15.0° vs. 53.9 ± 10.1°, respectively, $p = 0.51$, ES = 0.19).

Table 1. The postural variables of each posture (n = 16)

	good posture	poor posture	*p* value	Effect size
FHA	50.5 ± 7.2	67.2 ± 11.2	**0.000***	1.77
FSA-C7	56.4 ± 15.0	53.9 ± 10.1	0.51	0.2
FSA-GT	0.0 ± 2.3	8.2 ± 5.2	**0.000***	2.05
APT	7.0 ± 3.9	4.4 ± 4.1	**0.001***	0.65

Values are presented as means ± standard deviations (°). FHA, forward head angle ; FSA-C7, forward shoulder angle for C7 ; FSA-GT, forward shoulder angle for greater trochanter ; APT, anterior pelvic tilt angle. * Significant difference by paired *t*-test.

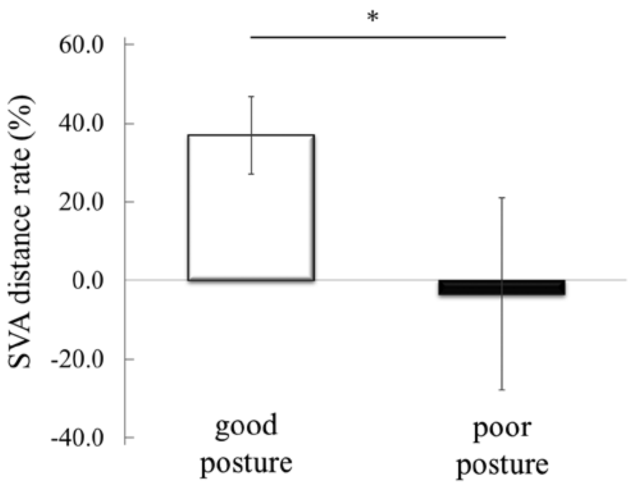

Figure 5. Differences in sagittal vertical axis (SVA) distance rate between good posture and poor posture (n = 16). Values are presented as mean ± standard deviation (%). * : $p < 0.01$ by paired *t*-test.

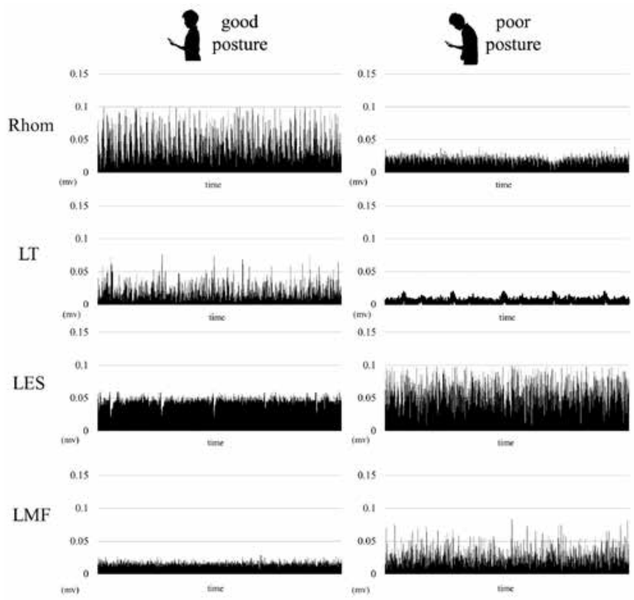

Figure 7. Representative raw electromyographic data of Rhom, LT, LES, and LMF in good posture and poor postures. Rhom, rhomboid major ; LT, lower trapezius ; LES, lumbar erector spinae ; LMF, lumbar multifidus.

Muscle activity

The activities of each muscle are shown in Figure 6. The activity of the Rhom (4.4 ± 7.5%MVIC vs 8.4 ± 7.2%MVIC, respectively, $p < 0.01$, ES = 0.55) and LT (5.0 ± 5.4%MVIC vs 10.2 ± 8.3%MVIC, respectively, $p < 0.05$, ES = 0.75) was significantly lower in poor posture than that in good posture. The activities of the LES (11.1 ± 6.1%MVIC vs 4.4 ± 3.0%MVIC, respectively, $p < 0.01$, ES = 1.39) and LMF (10.0 ± 4.0%MVIC vs 4.1 ± 2.0%MVIC, $p < 0.01$, ES = 1.85) were significantly higher with poor posture than those with good posture. Representative raw EMG data of Rhom, LT, LES, and LMF in good posture and poor posture are shown in Figure 7. There were no significant differences between postures for UT (2.8 ± 3.9%MVIC vs 1.9 ± 3.0%MVIC, respectively, $p = 0.09$, ES = 0.25) and MT (1.3 ± 1.0%MVIC vs 1.6 ± 1.3%MVIC, respectively, $p = 0.54$, ES = 0.20).

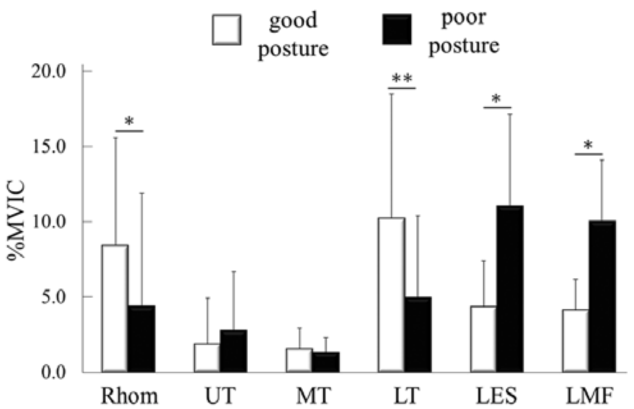

Figure 6. EMG activity of each muscle in good posture and poor posture (n = 16). Values are presented as mean ± standard deviation (%MVIC). Rhom, rhomboid major ; UT, upper trapezius ; MT, middle trapezius ; LT, lower trapezius ; LES, lumbar erector spinae ; LMF, lumbar multifidus. * : $p < 0.01$ by paired *t*-test. ** : $p < 0.05$ by paired *t*-test.

DISCUSSION

We clarified that poor posture showed lower Rhom and LT activity, and higher LES and LMF activity than those in good posture. The results of this study indicated that poor posture was associated with hypoactivity of the shoulder girdle muscles and hyperactivity of the lower back muscles when compared with good posture.

Regarding postural analysis, there were significant differences between good posture and poor posture for FHA, FSA-GT, APT, and SVA distance rates. This showed that good posture was closer to the ideal posture than poor posture, and poor posture presented a forward head and forward shoulder posture when compared to good posture in the sagittal plane. The ideal alignment on the sagittal plane is when the earlobe, acromion, greater trochanter, anterior part of the patella, and lateral malleolus are located on a vertical line (25). Conscious postural changes in this study could influence the change in muscle activity.

The activity of the Rhom and LT was significantly higher in good posture than that in poor posture in this study. These muscles are considered important for postural maintenance and are also reported to affect cervical posture (26). It is believed that the Rhom and LT activities while using a smartphone are necessary to maintain good posture. Previous studies reported improvements in forward head, rounded shoulder, and muscle strength by intervention to strengthen LT and MT (13). Weakness or underactivity of the shoulder girdle muscles, such as the Rhom, MT, and LT are associated with neck pain (27, 28). Additionally, forward head and rounded shoulder postures have been shown to be associated with neck and shoulder pain (29). Thus, we consider that using a smartphone for a prolonged period in poor posture causes a decrease in the function of the shoulder girdle muscles, such as the Rhom and LT, which can lead to neck and shoulder pain.

Previous studies indicated that poor posture, such as forward head posture and slouched posture, increased the activity of the cervical erector spinae (9, 10). However, few studies have investigated the influence of different postures on the activity of the lower back muscles while using a smartphone. The activities of the LES and LMF were higher with poor posture than those with good posture in this study. It is considered that poor posture, which displaces the head and shoulder forward caused anterior translation of the center of the mass and increased trunk flexion torque, owing to which, the LES and LMF generate the trunk extension torque and became more active to offset the trunk flexion torque. Previous studies demonstrated that the load to erecter spinae was increased by an increase in the trunk flexion angle and thoracic kyphosis (30, 31). In addition, the continuation of lumbar kyphosis caused an increase in LES activity and its spasm (32). Therefore, increasing the required muscle activity to maintain posture could lead to muscle fatigue and pain. Poor posture during smartphone use might lead to musculofascial lower back pain due to hyperactivity of the lower back muscles.

The activity of the MT, which is believed to be important for maintaining good posture, did not show a significant difference between good posture and poor posture in this study. The origin of the MT is the spinous processes of the first to fifth thoracic vertebrae, and the insertion is the medial border of the acromion and upper border of the scapular spine (23). The origin of the Rhom is the spinous processes of the second to fifth thoracic vertebrae, and the insertion is the medial border of the scapula (23). The Rhom is attached to the medial border of the scapula, so it has a function of maintaining the scapula adduction position while holding the scapula in the thorax. This difference in the origin and insertion indicates that the moment arm of the MT, which generates the scapula adduction torque is greater than that of the Rhom. If dynamic scapula adduction motion is required, we believe that high MT activity is required. However, the good posture in this study was not such a dynamic motion. Therefore, we consider that the necessity to activate the Rhom for good posture was high, while that to activate the MT for good posture was low. This finding suggests that the activity of MT may not be important in maintaining a good posture.

There are a few limitations to this study. First, the postural analysis variables of each posture are only measured in the sagittal plane. We did not evaluate the alignment of the scapula in the coronal and transverse planes. Second, we did not measure the center of mass and range of motion of the cervical spine, thoracic spine, and scapula. These outcomes might influence the muscle activity of each posture.

In conclusion, the results of this study indicated that poor posture showed hypoactivity of the shoulder girdle muscles and hyperactivity of the lower back muscles when compared with good posture. Using a smartphone in poor posture for a prolonged period might lead to malfunctioning of the shoulder girdle muscles, increase the load on the lumbar region, and cause muscle fatigue and musculofascial lower back pain. We suggest that a good posture activating the Rhom and LT while using a smartphone may be beneficial to prevent and improve musculofascial lower back pain.

CONFLICT OF INTERESTS-DISCLOSURE

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