Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/jptcp.v31i5.6179

COMPARING THE IMPACT OF MCKENZIE EXERCISES AND KINESIO TAPING ON CERVICAL MUSCLES FATIGUE IN SMARTPHONE USERS BY JOINT ANALYSIS OF SPECTRUM AND AMPLITUDE METHOD

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Abstract

Background: Using smartphones has increased dramatically; however, it causes the incidence of neck musculoskeletal disorders. Muscles fatigue is a predictive biomarker and precursor of neck musculoskeletal disorders. Accordingly, this study aims to compare the effect of McKenzie exercises and Kinesio taping on the fatigue of some cervical muscles while texting with a smartphone.

Methods: This was a randomized controlled single-blinded trial. Twenty-four smartphone users participated in this crossover study. All 24 subjects were experimented with the McKenzie, taping and control groups conditions. Root mean square and median frequency of the right and left upper trapezius, cervical erector spinae, and sternocleidomastoid muscles was measured during 30 min of texting with a smartphone. A 90-s break was considered in the middle of the task. Interrupted time series design and joint analysis of spectrum and amplitude methods was used for analyzing electromyography data.

Results: In contrast to the other two groups, cervical muscles fatigue did not occur in the last 15 min of the task in the McKenzie group. Compatibly, in the McKenzie group, the median frequency coefficient of determination of all muscles, except the left cervical erector spinae, was significantly different from the control group in the last 15 min of the task ($P < 0.001$).

Conclusion: The McKenzie exercises can prevent or even improve cervical muscles fatigue caused by texting with a smartphone. Consequently, it can help prevent neck musculoskeletal disorders related to smartphone texting like text neck syndrome.

Keywords: McKenzie exercises; Kinesio taping; muscle fatigue; musculoskeletal disorders; smartphone users.

1. Background

Currently, especially following the COVID-19 pandemic, the use of smartphones has increased significantly [1]. Meanwhile, evidence demonstrates that the use of smartphones is related to the occurrence of musculoskeletal disorders (MSDs) and related symptoms [2, 3]. The most common complication is neck-shoulder pain whose prevalence has increased significantly in young people during the last 20 years [4]. Particularly at this age, texting with a smartphone is associated with neck and upper limb pain [2]. It can also cause text neck syndrome in smartphone users who maintain an unfavorable position of their neck while using their device for a long time [5]. However, there is still no specific guideline for the management, prevention, or proper ergonomics in this field.

There have been extensive ergonomic studies and efforts over the past decade to minimize the consequences of smartphone usage. Accordingly, it is difficult to provide a set of ergonomic recommendations for smartphone users [4].

There are evidences that have examined the effects of some interventions on muscle fatigue in smartphone users [6-8]. The authors of the studies separately have analyzed normalized median frequency (MF) and root mean square (RMS) to investigate muscle activity and muscle fatigue. Therefore, they had to keep the flexion angle constant which made their results ungeneralizable to non-laboratory conditions.

The taping method was first introduced in the 1970s by Kase Kenso. It includes different methods of sticking elastic tapes that have mechanical properties similar to human skin [9]. Sticking the taping on specific areas of the skin with stretching creates more space between the muscles and the skin, along with the intermuscular compartment, which increases blood and lymph flow and reduces muscle metabolites by discharging them into the bloodstream, so it may reduce local muscle fatigue. This mechanism is known as the skin-lifting effect [9]. In addition, the tension of the band stimulates the superficial mechanoreceptors in the fascia and sub-dermis. By stimulating surface mechanoreceptors, taping can affect the central nervous system that integrates sensory afferents and finally regulates and modulates the activity of motor gamma fibers, sequentially may improve cervical proprioception, thus improving muscle activity [10]. Another intervention that may affect cervical muscles fatigue of smartphone users is McKenzie exercises.

Robin McKenzie introduced the McKenzie method in 1985. Since the 1990s, the use of this treatment method has grown and spread worldwide. McKenzie exercises often rely on the individual's strength and only require training, so they are also very affordable and can be used by everyone. They encourage people to take care of themselves and their emphasis is on extension. It is the opposite of activities with sustained neck flexion, such as using a smartphone [11, 12]. Sustained flexion posture increases the load relaxation of the posterior passive tissues of the neck and reduces the effective stiffness of the cervical spine [13]; therefore, these exercises can prevent the increase in load relaxation of the posterior passive tissues by temporarily reducing the length of the posterior passive tissues. Another characteristic of these exercises is performing movements at the end of the range of motion, which can help reduce the limitation in the range of motion. On the other hand, using a smartphone can reduce the cervical range of motion [14]; therefore, McKenzie may maintain the normal neutral zone of the cervical spine by improving the range of motion, thereby improving the position sense and sequentially it may enhance motor system activity [15]. However, based on the best of our knowledge, studies investigating the effect of McKenzie exercises on muscle fatigue were very limited.

To investigate muscle fatigue, surface electromyography (EMG) is used as a well-known method. When using EMG as an indicator of fatigue, it should be considered that EMG measures the electrical manifestations of fatigue, but it does not directly measure mechanical fatigue, which is the reduction in the muscle's ability to produce mechanical force [16]. When using EMG and its spectral parameters, such as MF, or intensity parameters, such as RMS to examine fatigue during real activity, there is a basic problem that during activity, intensity and spectrum dynamics are related to fatigue as well as the level of muscle force [16]. The relationship between fatigue and electromyographic changes is confirmed only in laboratory conditions, where the muscle production force is kept constant at a certain level. In this case, these changes are not caused by the change in muscle force; however, it is related to time-dependent phenomena, such as fatigue. In addition, when the level of contraction during the desired activity is less than 20% of the maximum voluntary contraction, which applies to working with a smartphone, the spectral indicators of EMG give contradictory answers and results about fatigue [6, 7, 16]. Hence, it is helpful to use the joint analysis of spectrum and amplitude (JASA) method introduced by Hägg, Luttmann and Jäger (2000) to check muscle condition at different times of low-level activities, such as ergonomic studies because in this method, changes of RMS and MF are considered simultaneously [16].
Accordingly, this study was conducted to compare the effects of taping of the upper trapezius (UT) and cervical erector spinae (CES) and McKenzie exercises of retraction extension and retraction rotation on the performance of UT, CES, and sternocleidomastoid (SCM) muscles during texting with a smartphone. In this way, we can realize which can effectively prevent muscle fatigue. Thus, we compare the effect of the desired interventions on muscle function under conditions similar to real conditions aiming to obtain new results in this field by using combination of interrupted time series design and JASA method to analyze EMG data [16, 17]. We hypothesised that Kinesio taping and McKenzie exercises cause less muscle fatigue during texting with a smartphone than solely taking a break.

2. Methods

2.1. Study Design

This research was a randomized and crossover clinical trial. The participants attended the study on three different days. The test conditions for each day were randomly chosen to reduce the risk of bias and avoid the order effect. This was a single-blinded study; accordingly, preparation of subjects was done by a researcher (E. N.), the assessor (F. E.), who blinded by a curtain, recorded the data. Then data was coded by another researcher (R. K.) in order to analysis.

2.2. Study Participants

Twenty-four healthy young adults of the rehabilitation school students participated in this study. They recruited by convenient sampling (Table 1). All of 24 subjects were experimented with the three conditions.

Table 1. Mean (standard deviation) of participant characteristics.

Variables	Total Samples (n = 24)	Males (n = 16)	Females (n = 8)
Age (years)	31.71 (8.30)	31.75 (8.58)	31.63 (7.71)
Weight (kg)	70.75 (7.39)	73.25 (6.52)	66.87 (9.74)
Height (m)	1.75 (0.04)	1.77 (0.03)	1.72 (0.04)

The inclusion criteria were as follows: being in the age range of 18 to 40 years; having at least 6 months of experience working with a smartphone for at least 2 h a day; being right-handed; and having a neck disability index equal or less than 8% or less than 4 points [18, 19].
The exclusion criteria were as follows: having neck or shoulder pain problem, upper limb radicular pain, or upper limb numbness; having a history of acute or chronic neck, shoulder, back, or leg

problems; hearing disorders; eye disorders, such as ocular surface disorder and computer vision syndrome; and visual impairment [20].
Informed consent was obtained from all subjects involved in the study. In addition, the study was conducted in accordance with the Declaration of Helsinki of 1975, as revised in 2000, and approved by Research Ethics Committee.

2.3. Experimental Procedure

The participants came to the laboratory on three different days with a maximum interval of two days. At the first time of the person's presence in the laboratory, the subjects were randomly assigned to three groups and the sequence of their placement in the groups was determined through the following website https://statpages.info/latinsq.html. Based on the Williams square design, 6 sequences were defined for the participants (ABC, BCA, CAB, CBA, ACB, BAC), one of which was randomly selected for each participant [21]. Every time the participants came to the laboratory, they rested in the supine position for 15 min before starting the experiment. After that, they completed the NDI-IR questionnaire [18]. Then, the electrodes were attached and fixed on the person's skin according to the mentioned instructions. Next, to match the starting position, the participants were asked to sit on a chair with support and adjustable height so that the knee and hip were bent at 90 degrees and the soles of their feet were on the floor [6]. Finally, after 1 min of rest, the person started to perform the task. In McKenzie group the subject did the McKenzie exercises and in taping group tapes was attached before starting the task. when the activity started, the EMG data was also recorded for 1 min. EMG assessor was blinded by a curtain between the subject and the assessor. After 2 min of non-recording, 1 min of EMG recording was done and the same procedure continued every 2 min until the break time. Then the subject rested for 90 seconds or did McKenzie exercises again. Following the break, the same procedure was done in the last 15 min (Figure 1).

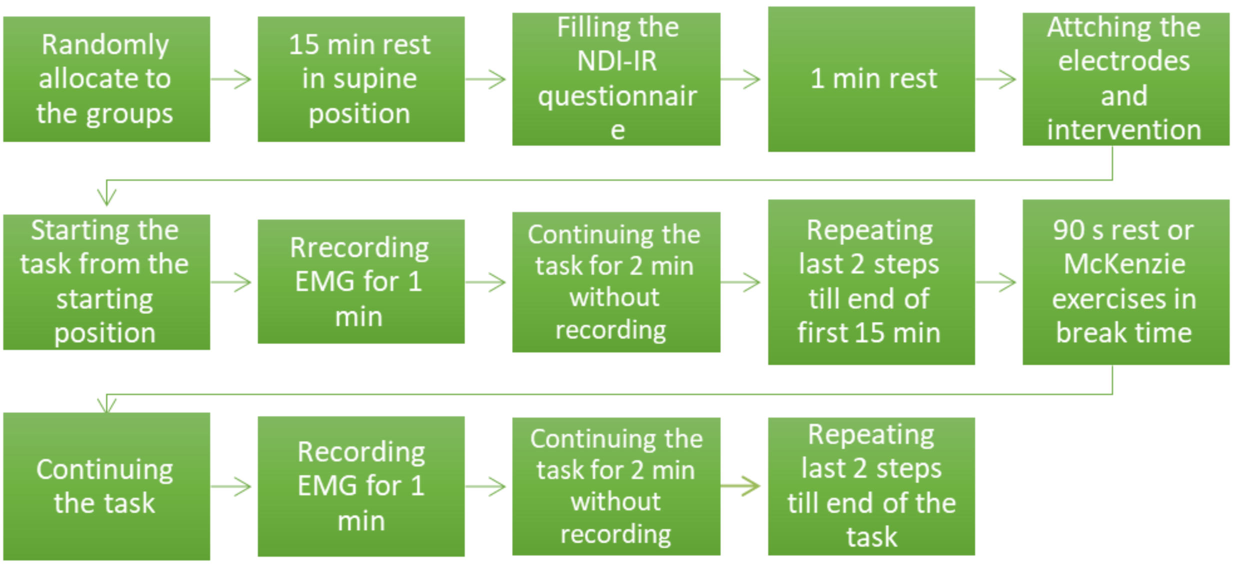

Figure 1. Experimental procedure flowchart.

2.4. Surface Electromyography

The Biometrics Datalog Wired EMG system (Biometrics Ltd., UK) was used. Three bilateral cervical muscles include two neck extensors, UT, and CES, along with one neck flexor, SCM. They were monitored while texting with a smartphone. Wired integral electrodes with input impedance greater than 100 MΩ were used. The size of the electrodes was 10 mm and the distance between the centers of the bipolar electrodes was 20 mm to reduce the crosstalk noise [22]. To minimize skin noise, the area before connecting the electrodes was shaved, abraded by sandpaper, and cleaned with alcohol to reduce skin resistance. Before sticking the electrodes, we also ensured that the surface of the skin was

completely dry and skin impedance was below 10 kΩ [22]. Then, the electrodes were placed in the direction of the desired muscle fibers with double-sided adhesive [22]. The following describes how the exact locations of the EMG electrodes were determined.
To record EMG signals of SCM, the person lies supine and turns the head to the opposite side. The muscle belly was grasped and the electrodes were stuck so that their middle point was located in the middle point of the muscle [23]. Then, the subject sat straight, his hands were hung by the side of the body, and his palms were faced inward, the place of the electrodes was specified [22]. To record the activity of the UT, the electrodes were connected in such a way that the middle point between C7 and the acromion was exactly between the recording electrodes [22]. For CES, the electrodes were stuck parallel to the muscle belly in such a way that the middle point between the electrodes was located at the level of the C4 spinous process [6]. Finally, electrolyte gel was applied on the styloid process of the radius and the reference electrode was strapped on it. The electrode wires were taped to the body to prevent movement artifacts [22]. Electromyography settings were such that a simple band-pass filter was applied to remove frequencies < 10 Hz and > 400 Hz [8]. Also, a notch filter at 50 Hz was used to reduce power-line electricity noise [8].

2.5. Task Specifications
A total of three 30-min audios were prepared from Golestan Saadi's audiobook, a well-known Iranian book. In choosing the book, we tried to pay attention to its text which has an emotionally neutral effect and is understandable for everyone. The sounds were compiled in such a way that all 3 repetitions of the text were the same and had a slow and uniform speed. By starting the audio playback, the participants texted the audiobook they heard through 2 air pods on a Galaxy Note 4 smartphone (SAMSUNG Co.) with both hands. Texting was performed in 3 different study conditions:

(1) Control group: The participant does the texting task with a smartphone for 15 min. Then the subject rests for 90 s; during the break time, flexion or extension is not allowed. Next, the subject continues to operate for another 15 min.

(2) McKenzie group: The participant does the texting task with a smartphone for 15 min. Then the subject performs the McKenzie exercises for 90 s in the following way. Left hand is placed on chin and right hand is placed on the left side of the back of head. Left hand pushes the chin straight back, then it turns head to the left side with the help of right hand, hold for 3 s and repeats this activity five times. Next, the position of hands is changed and head is moved to the right. Next, the subject pushes the chin straight back (retraction) with both hands and bends the head back completely (extension). Afterward, the participant turns the head a little to the right and a little to the left. These movements are repeated 10 times [11, 12]. After that, the task is continued for 15 min.

(3) Taping group: A standard taping with a width of 5 cm and a thickness of 0.5 mm is used. According to previous studies, two Y-shaped types and one I-shaped type are used. First, a Y type with initial tension on the acromion is attached and asked the person to bend the head and neck to the opposite side. Then with about 30%-35% tension, one sequence is directed toward C7 and another toward T3. It is pulled and attached with the initial tension at these points [7, 9]; the other Y type with the initial tension on the T1-T2 space is attached and asked the person to bend and rotate the head and neck to the opposite side, with approximately 20%-25% tension of one sequence from the right and the other sequence from the left to the hair growth line around C1-C2, and it is stuck with the initial tension at the endpoint. In the end, the person is asked to bend the head forward, and then the I-shaped tape is attached using the space-tape method in the C3-C6 range, perpendicular to the muscle fibers and the Y-type [9, 24]. The participant does the task with his smartphone for 15 min. Then, like the control group, the subject rests for 90 s and continues to operate for another 15 min.

2.6. Data Analysis
The independent variables included 3 studied groups, including control, McKenzie and taping. Dependent variables included coefficient of determination (R^2) of RMS of the muscles before and

after the break, R^2 of MF of the muscles before and after the break, as well as the condition of target muscles according to the JASA method (force increase, fatigue, force decrease, and recovery). To statistically analyze R^2 data, the distribution of the data was first checked. The data distribution was not normal. Accordingly, the Wilcoxon test was used to compare before and after the break time. The Kruskal-Wallis test was used to compare R^2 between groups. Finally, the Bonferroni post hoc test was used to determine which group was different from the others. The statistical analysis was performed using the SPSS software, version 16. The level of significance for all statistical tests was set at $P < 0.05$.

3. Results

3.1. Analysis of the Muscles Condition by Joint Analysis of Spectrum and Amplitude Method

For each muscle, five EMG recordings existed before the break and five recordings after the break. First, the average RMS and MF of each EMG recording was calculated. The set of EMG recordings before and after the break formed two graphs. The R^2 of these graphs was calculated. The R^2 line slope was determined by computing the equation of the line. It was downward or upward (Figure 2 and 3). After determining the direction and value of R^2 of RMS and MF, we could use the JASA method to determine the muscle condition in the period before or after the break time (Figure 4).

The results showed that fatigue did not occur in the left CES muscle in any of the groups. Also, in the McKenzie group, fatigue did not occur in any of the muscles after the break time (in the last 15 min of the task). While in the control group, except for the left CES, fatigue was evident in the rest of the muscles after the break time. The occurrence of recovery was not detected in any of the muscles and any of the groups (Table 2).

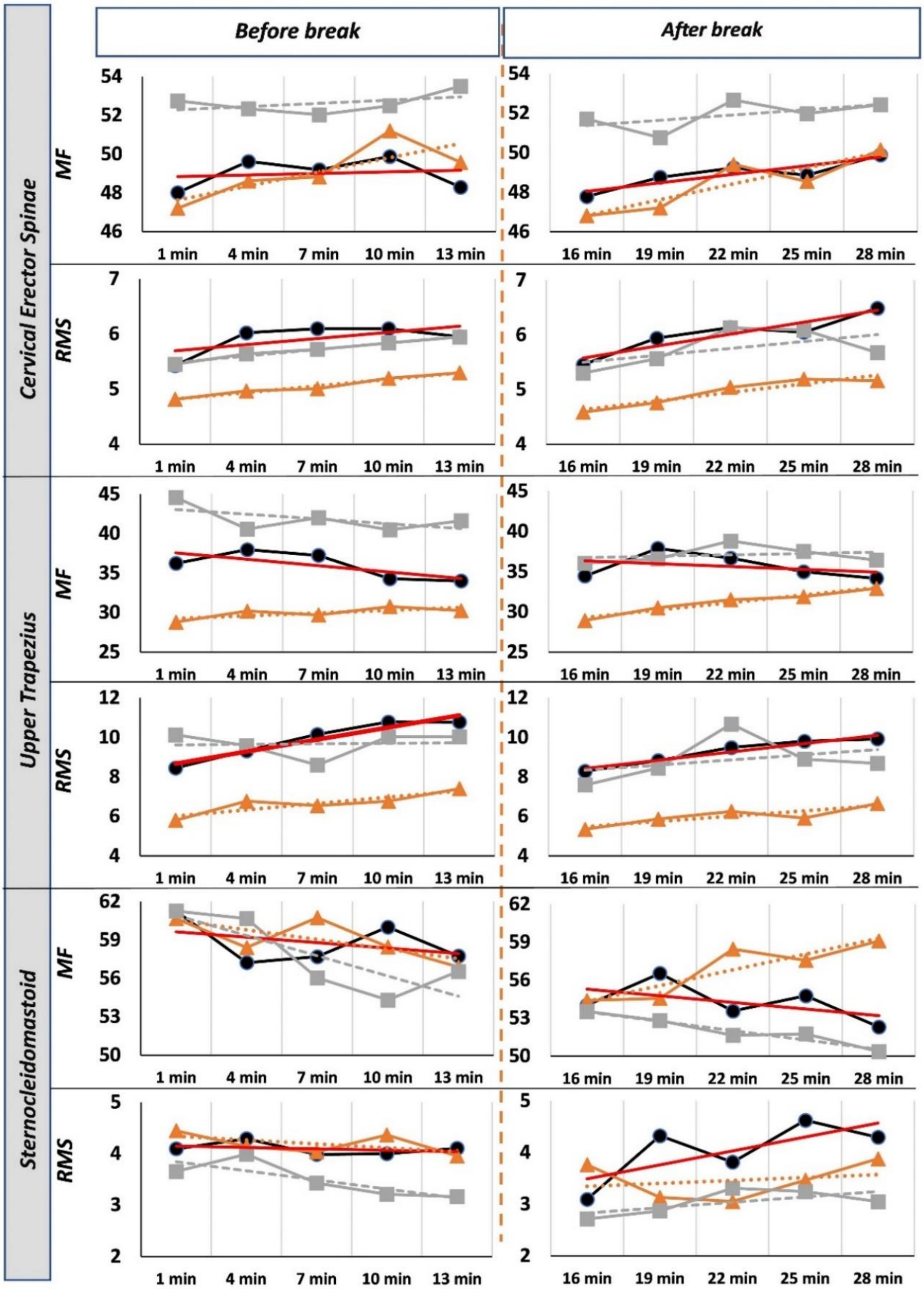

Figure 2. Joint analysis of spectrum (median frequency) and amplitude (root mean square) of left side cervical erector spinae, upper trapezius and sternocleidomastoid muscles; MF = median frequency; RMS = root mean square; solid red trend line = control; round dot orange trend line = McKenzie; dash gray trend line = taping; round marker black line graph = control; triangular marker orange graph = McKenzie; square marker gray graph = taping.

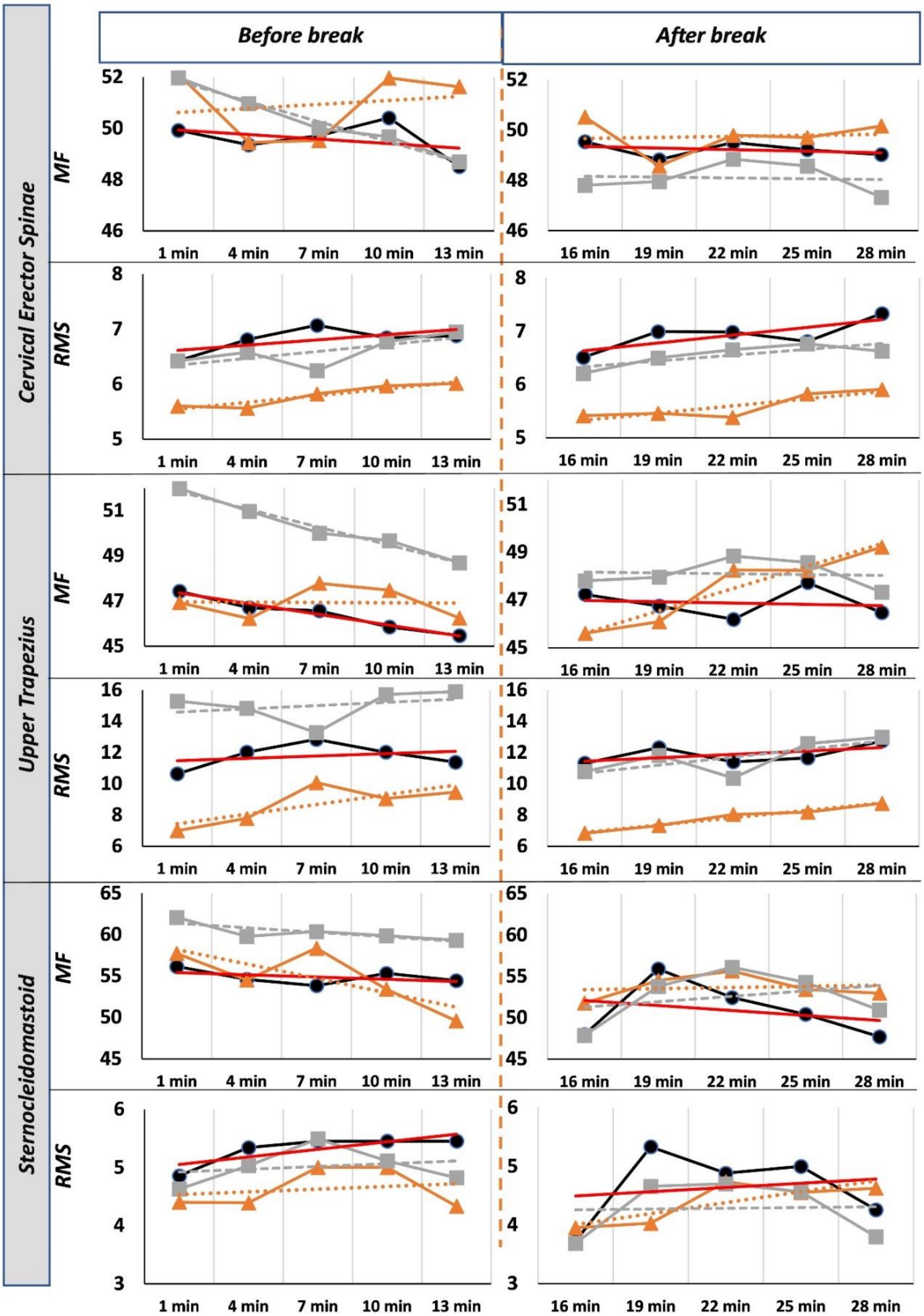

Figure 3. Joint analysis of spectrum (median frequency) and amplitude (root mean square) of right-side cervical erector spinae, upper trapezius and sternocleidomastoid muscles; MF = median frequency; RMS = root mean square; solid red trend line = control; round dot orange trend line = McKenzie; dash gray trend line = taping; round marker black graph = control; triangular marker orange graph = McKenzie; square marker gray graph = taping.

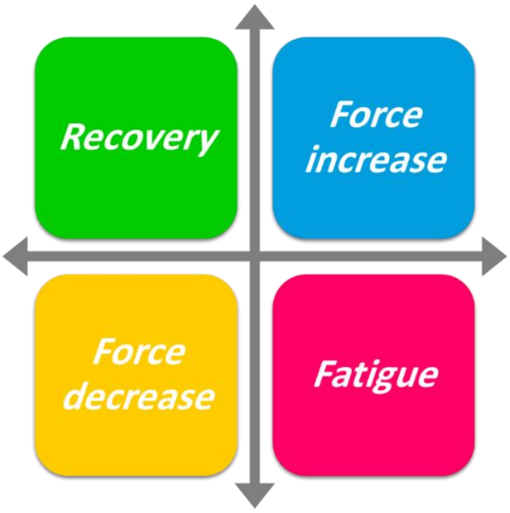

Figure 4. Detecting muscle condition by JASA plot. Horizontal axis is representative of root mean square coefficient of determination value; vertical axis is representative of median frequency coefficient of determination.

Table 2. Muscles condition based on joint analysis of spectrum and amplitude before and after the break time.

Muscle	**Time**	**Muscle Condition**		
		Control	McKenzie	Taping
Left CES*	Before break	Force increase	Force increase	Force increase
	After break	Force increase	Force increase	Force increase
Right CES	Before break	Fatigue	Force increase	Fatigue
	After break	Fatigue	Force increase	Force increase
Left UT†	Before break	Fatigue	Force increase	Fatigue
	After break	Fatigue	Force increase	Force increase
Right UT	Before break	Fatigue	Fatigue	Fatigue
	After break	Fatigue	Force increase	Fatigue
Left SCM‡	Before break	Force decrease	Force decrease	Force decrease
	After break	Fatigue	Force increase	Fatigue
Right SCM	Before break	Fatigue	Fatigue	Fatigue
	After break	Fatigue	Force increase	Force increase

*Cervical erector spinae muscle; †upper trapezius muscle; ‡sternocleidomastoid muscle.

3.2. Statistical Analysis of Coefficient of Determination of Root Mean Square and Median Frequency of the muscles

The average RMS of each recording was calculated. Then, R^2 was calculated for each subject for five recordings before the break time and five recordings after the break time. Finally, the comparison of R^2 values showed that R^2 of RMS data had a significant difference only in the left SCM muscle before and after break ($P < 0.001$). In addition, the results showed that in none of the muscles, R^2 of RMS data was not significantly different between groups (Table 3).

Table 3. Results of analysis of coefficient of determination of root mean square of right and left cervical erector spinae, upper trapezius and sternocleidomastoid muscles before and after the break time by Wilcoxon (within the three groups) and Kruskal-Wallis (between the three groups) tests.

Muscle	**Time**	**Between Groups (*P* Value)**	**Within Groups (*P* Value)**		
			Control	McKenzie	Taping
Left CES*	Before break	0.883	0.256	0.959	0.875
	After break	0.593			
Right CES	Before break	0.503	0.642	0.535	0.836
	After break	0.773			
Left UT†	Before break	0.502	0.469	0.535	0.148
	After break	0.327			
Right UT	Before break	0.262	0.134	0.535	0.877
	After break	0.103			
Left SCM‡	Before break	0.379	<0.001	<0.001	<0.001
	After break	0.252			
Right SCM	Before break	0.663	0.820	0.331	0.215
	After break	0.161			

*Cervical erector spinae muscle; †upper trapezius muscle; ‡sternocleidomastoid muscle.

The MF data were analyzed similarly to the RMS data; however, the results were different compared to RMS. The Wilcoxon test showed that the R^2 of the MF data before the break time had a significant difference from the data after the break. In addition, the results of the Kruskal-Wallis test showed that the R^2 values of the MF data of the groups were significantly different in all muscles, except for the left CES muscle, especially in the last 15 min of the task, after the break time (Table 4).

The Bonferroni test determined that the R^2 data of the MF of the right CES and left UT muscles before the break and the R^2 data of the MF of the all muscles, except for the left CES muscle, after the break time in the McKenzie group were significantly different from the control group ($P < 0.001$). In addition,

the right CES, right SCM, and left UT muscles in the taping group after the break were significantly different from the control group ($P < 0.001$). The Bonferroni test also showed that the R^2 of the MF data of the right CES and left UT muscles before the break and the right UT and left SCM muscles after the break in the McKenzie group were significantly different from the taping group ($P < 0.001$).

Table 4. Analysis of coefficient of determination of median frequency of right and left cervical erector spinae, upper trapezius and sternocleidomastoid muscles before and after the break time by Wilcoxon (within groups) and Kruskal-Wallis (between groups) tests.

Muscle	**Time**	**Between Groups (*P* Value)**	**Within Groups (*P* Value)**		
			Control	McKenzie	Taping
Left CES*	Before break	0.325	0.535	0.088	0.01
	After break	0.918			
Right CES	Before break	<0.001	0.756	0.679	<0.001
	After break	<0.001			
Left UT†	Before break	<0.001	0.215	0.301	<0.001
	After break	<0.001			
Right UT	Before break	0.335	0.408	<0.001	0.569
	After break	<0.001			
Left SCM‡	Before break	0.457	0.642	<0.001	0.056
	After break	<0.001			
Right SCM	Before break	0.123	0.039	<0.001	<0.001
	After break	<0.001			

*Cervical erector spinae muscle; †upper trapezius muscle; ‡sternocleidomastoid muscle.

4. Discussion

Investigating fatigue by the JASA method showed that, in the McKenzie group, fatigue did not occur in any of the muscles in the last 15 min of the task; however, in the control group, fatigue occurred or continued in all muscles, except for the left CES during this period. Compatibly, in the McKenzie group, the R^2 of the MF changes in the last 15 min of the task was significantly different from the control group in all muscles, except for the left CES.

The results of the muscle fatigue investigation showed that muscle fatigue occurred in the first 15 min of the task, even in the McKenzie and the taping groups. To better understand the possible reason for these findings, it is better to first refer to the definition of fatigue. Muscle fatigue is a decrease in maximum potential to produce force or power results from activity which can be accompanied by the continuation or maintenance of a task or lead to the cessation of activity [25].

More precisely, the process of activation of fatigue signals through the III and IV afferents is a functional behavior in which the central nervous system becomes aware of the muscles' status [26]. The mechanical output that a motor command creates in a normal muscle is different from the mechanical output that the same motor command creates in a fatigued muscle. Therefore, before issuing the motor commands to continue the activity, the fatigue signals must report this mismatch to the central levels. Hence, when the central nervous system transforms motor intention to elaborate the motor plan, it considers the III and IV afferents' discharges and their origin; accordingly, it reorganizes posture and movement strategies and motor apparatus redundancy more optimally [27]. Based on our observations in the present study, doing McKenzie exercises seems to help CNS to better modulate fatigue through the mentioned procedure.

According to Figures 2-3 and Tables 2 and 4, the participants in the McKenzie group were significantly more successful in improving and managing fatigue in the last 15 min of the task compared to the control group. Even in some muscles, they had significantly different MF R^2 and less fatigue compared to the taping group. To understand the reason, first, we must refer to the concept of internal models.

They are the basic neural mechanisms of predictive movement control which are divided into two categories; inverse model and forward model. By using forward internal models, according to the instant state of the body and in response to the efference copies, the system can predict the future state of motor apparatus and sensory feedback. To perform each task, the central nervous system activates several forward models. Each forward model is paired with a controller. By interacting with motor memory in the cerebellum and comparing them with real sensory feedback in the parietal lobe, the central nervous system can predict and plan motor behavior to perform the task smoothly, without delay, and accurately. For this purpose, when a sensory prediction has a low error and is close to a real feedback sensor, the corresponding controller is set as the criterion for issuing subsequent motor commands [27].

When sustained neck flexed posture during texting with a smartphone continues, the position sense changes due to an increase in the length of tissues in the direction of flexion and the change in the length of the tissues in the direction of rotation, subsequently changing in the proprioceptive signals [14, 28]. These changes, which are associated with changes in the neutral zone, cause an error in the actual sensory feedback used in selecting the forward internal model. As a result, the predicted feedback becomes incorrect and causes motor control malfunctions. This damaging process happened in the control group and, to some extent, in the taping group. It led to the continuation of fatigue in the last 15 min. Based on the Cinderella hypothesis, the continuation of fatigue following sustained low-intensity tasks, such as texting with a smartphone, causes overloading of type 1 motor units that have the lowest recruitment threshold and slow twitch, fatigue-resistant fibers [16, 29]. It is the most well-known mechanism of muscle damage and neck-shoulder MSDs following fatigue in repetitive, low-load, long-duration activities [30].

Contrariwise, in the McKenzie group, as reported by Korakakis et al., repeated end range of motions have corrected the defects of proprioception signals and improved position sense [15]. As a result, the motor system has functioned correctly and could find a solution to deal with muscle fatigue.

Hence, McKenzie exercises can prevent MSDs in the neck-shoulder area of smartphone users, because fatigue is a predictive biomarker of MSDs and has a proven initiating role in the occurrence of MSDs in the neck-shoulder area [30, 31].

Electromyographic measurement of the upper limb muscles was not investigated in this study. To determine the exact approach to compensate or correct the adoption of non-aligned posture in the neck during the task, in future studies it is better to examine the electromyography of the deltoid muscles, especially the anterior deltoid, as well as one of the extensor muscles in the forearm area, especially the extensor carpi radialis brevis. In this case, the effect of the interventions on the upper limb can also be investigated. In addition, in this study, all participants were healthy people. In future studies, it is necessary to investigate the effect of these interventions on the performance of neck muscles in smartphone users suffering from mechanical neck pain.

5. Conclusions

When texting with a smartphone for a long time, merely taking a break was not enough because it could not effectively prevent neck muscle fatigue. On the other hand, performing McKenzie exercises had a considerable effect on maintaining the proper functioning of the motor system, improving muscle fatigue and sequentially preventing neck MSDs. Moreover, McKenzie exercises were more effective in controlling fatigue during working with a smartphone compared to taping method.

Acknowledgments: We thank all subjects participated in the study for their patience and cooperation. Also, we thank doctor Forough Eftekhari for participating as blinded assessor.

Registration numbers: Iranian Registry of Clinical Trials registration number is IRCT20220226054127N1. Registration date is 2022-04-09, 1401/01/20. URL of approved registration is https://irct.behdasht.gov.ir/trial/62252.

Ethical considerations: Informed consent was obtained from all subjects involved in the study. In addition, the study was conducted in accordance with the Declaration of Helsinki of 1975, as revised in 2000, and approved by Research Ethics Committee of School of Nursing and Midwifery & Rehabilitation – Tehran University of Medical Sciences (protocol code IR.TUMS.FNM.REC.1400.212 and date of approval 2022-02-23).

Funding details: The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Authorship inclusion criteria: According to the ICMJE recommends authorship inclusion was based on meeting all the following four criteria: ‘Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND drafting the work or revising it critically for important intellectual content; AND final approval of the version to be published; AND agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved’.

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