ORIGINAL ARTICLE

Smartphone overuse: Effect of rehabilitation program on neck ROM, trapezius, and sternocleidomastoids muscle effort in collegiate asymptomatic individuals

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ABSTRACT

Study design: Two-group, pre-test–post-test randomized trial. Purpose: the study aims to investigate the adverse effects of overusing smartphones devices on neck range of motion (ROM) and neck muscle activity. In addition, investigating the benefits of performing daily exercise protocol to increase the neck ROM and neck muscle activity for the smartphone's users. Methods: Forty-eight collegiate students were recruited to participate in the study. twenty-four healthy students using the smartphone for a maximum of 2 hours daily and 15 h per week [18 Males and 6 females; 20.4 years; 1.71 m; 68.4 kg; 21.7 kg/m^2] were randomized to a healthy group. Twenty-four overusing smartphone students [14 Males and 10 females; 21.1 years; 1.70 m; 70.2 kg; 22.8 kg/m^2] were considered as an overuse group. After comparison, the overuse group was divided randomly to control group and case group. The case group was performed the daily exercise protocol for 8 weeks. EMG for neck muscle and neck range of motion (ROM) measurements were collected at baseline for healthy and overuse groups. Same measurements were collected at baseline, and 8 weeks for both case and control groups. Results: overuse group showed a decrease in neck flexion, extension and lateral flexion ROM and UT, MT, LT, and SCM MVIC levels compared to the healthy group. MVIC levels of the muscles increased in the treatment group but did not change in the control group. Conclusion; smartphone usage would negatively affect the neck posture. The stretching and strengthening exercises were beneficial to improve the neck muscle strength and range of motion.
Keywords: Sport medicine, Smartphone, Text neck pain, Neck exercises.

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INTRODUCTION

Smartphone has become a ubiquitous portable device used in texting, communication, reading, emailing, and entertainment. Over one-quarter of the world population owns at least one type of smart handheld device. Globally, the number of smart devices is approaching 6.8 billion. Additionally, it was expected that SMS frequency in the world would increase from 5.9 trillion annually in 2011 to reach to 9.4 trillion by 2018. (Kietrys et al., 2015; Lee., 2016). Nonetheless, Google market research reports that American smartphone users communicate with network services, emailing, and text SMS (short message service) more than 20 hours a week and at least two hours daily (Lee et al., 2015). Correspondingly, Canadian college students spent 4.6 hours daily on smartphone hand-held devices (Berolo et al., 2011). In comparison, 91% of the American smartphone users perform instant messaging, SMS, or e-mailing. Further, SMS is considered to be the highest communicative facility among university students in the United States (Skierkowski & Wood, 2012). In 2012, the smartphone was used by 99% of Swiss adults aged 15-24; where 79% used smartphones for text messaging (Gustafsson et al., 2017). Smartphone users frequently adopt a prolonged forward head posture while looking down at the screens of mobile devices. This posture causes fibrosis of muscular fibres and overstretching of muscles around the neck spins, which increases the possibility of neck pain (Gold et al., 2012; Xie et al., 2016; Toh et al., 2017; Cuéllar & Lanman 2017). The exaggeration on using mobile technology led to text neck pain syndrome (TNP). (Lepp, et al., 2013; Gustafsson et al., 2011). Text neck pin (TNP) has illustrated as a static muscular load on the cervical spines results from forward neck flexion without supporting of arms muscles during holding the smartphone. Moreover, handling the device with one hand and typing with only one thumb increases the frequent contraction in typed thumb and handled hand, which causes neck and shoulder pain (Gustafsson et al., 2017; Dvir et al., 2008; Gilchrist et al., 2016; Xie et al., 2018).

All in all, several studies reported the adverse effects of excessive smartphone usage, and its relation to musculoskeletal disorders of the upper limb region. Also, it was adversely affecting the physical and cardiorespiratory fitness (Lepp et al., 2013; Kim et al., 2016; Rezasoltani et al., 2012). The neck musculoskeletal complaints reported for Canadian university students were 84% for neck pain, and 52% for shoulders (Berolo et al., 2011). In comparison, 44.4% of individual Korean university students represented the prevalence of neck pain and 45.2% for shoulder pain (Kim & Kim, 2015), Likewise, demonstrated a prevalence rate of 72.5% for neck and shoulder pain (Balakrishnan et al., 2016). reported complaints of neck pain with 44.1% and 32% for upper back pain (Shan et al., 2013). On the other hand, Damasceno, et al. reported no relation between text neck and neck pain in 18-21-year-old young adults (Damasceno et al., 2018).

The research regarding detriments, neck muscles efforts, and neck range of motion (NROM) of smartphone-usage has been relatively scarce. As an attempt to ameliorate the youth health, the current study aims to investigate the risk factor of excessive smartphone usage for the collegiate student. Therefore, the first hypothesis was the smartphone usage hours would adversely affect the neck range of motion and decrease the neck muscle activity. The second hypothesis of the study was the daily neck exercise protocol would increase the neck range of motion and neck muscle activity for the smartphone's users.

METHODS

Procedure and criteria

The study design was a double-blinded, randomized, controlled trial, parallel group. The study was approved by the local Ethics Committee of Damietta University, Egypt and was performed in accordance with

Declaration of Helsinki ethics standards. The target participants consisted of collegiate smartphone users with TNP for the case group and those who are healthy athletes for the control group. The history of pain data and the daily hours of using the smartphones were collected after the study procedures were explained to the subjects. All participants were volunteers and were provided written informed consent prior to performing the study.

There were specific exception criteria for each group. Nevertheless, both group's participants should be between 18 and 25 years of age and right handed. The exception criteria for the smartphone group were: (a) using the smartphone for at least 6 h a day and a minimum of 40 h per week;(b) continuous texting on the smartphone at least 1-2 hour daily; (c) suffering from a pain in the posterior region of the neck, lasting more than 3 months; (d) have not consumed anti-inflammatory medicines within one month; and (e) have not performed any strength of flexibility exercise for neck, lasting more than 3 months. In addition, the exception criteria for the healthy group were: (a) have no neck pain, neck surgeries or trauma, diabetes, neurological surgeries or diseases, osteoporosis, vascular insufficiency, or cardiovascular; (b) using the smartphone for a maximum of 2 hours daily and 15 h per week; and (c) continuous texting on the smartphone less than an hour daily. (Caputo et al., 2017; Rudolfsson et al., 2012).

Participants

Forty-eight collegiate students were recruited to participate in the study. Thirty collegiate smartphone over users and twenty-seven healthy university students were recruited to participate in the study. The study procedures were explained to all the participants and twenty-four healthy students (18 males and 6 females) agreed to participate. For the smartphone group, the criteria and neck diagnoses excluded six smartphone users. The neck pain diagnosis was based on usage time, history and clinical examination. Four smartphone users were excluded because their neck pain was not more than 3 months, as confirmed by three experienced (i.e., more than five years) physicians through examination of the stiffness in the neck, tightness of muscles, sense of fatigue, region of pain spreading, as well as standard Magnetic resonance imaging MRI in some cases (Larsson et al., 2007). Two additional participants were excluded for anti-inflammatory consumption. Thus, twenty-four smart device users (14 males and 10 females) were arbitrarily assigned to either a treatment group or control group (Table 1). The randomization was carried out by software (Computerized Covariate Adaptive Randomization Program, version 1.0, Middle Tennessee State University, Murfreesboro, TN). The treatment group received daily home-exercise protocol in parallel with the daily texting usage while the control group performed the normal texting day without received exercises.(Kim,2013; Andersen et al., 2010).

Table 1. Baseline characteristics of the study participants (mean ± standard deviation).

Groups	N	Age (year)	Height (cm)	Mass (kg)	BMI (kg/m^2)	STU (hour)
Healthy	24	20.4 ± 2.14	171.6 ± 2.94	68.4 ± 3.22	21.7 ± 2.33	1.26 ± 0.36
Smart phone	TG (12)	20.8 ± 2.64	169.4 ± 3.72	71.5 ± 2.74	22.7 ± 1.67	6.42 ± 0.27
	CG (12)	21.3 ± 0.97	170.4 ± 1.2	70.7 ± 0.54	22.9 ± 0.2	6.31 ± 0.41

Note. N, number; BMI, body mass index; STU, smartphone time usage; TG, treatment group; CG, control group.

Exercise protocol

The duration of the home-exercise protocol was 8 weeks. The exercise protocol was performed 35-45 minutes daily. The exercise protocol included strength, flexibility, and stretching exercises for neck and shoulder. The neck stretching exercises included neck retraction, head drop, head up from supine, side bend, neck rotation, neck flexion, shoulder blade pull, cat and cow pose, child pose, palm tree, arm back and down the head, and arm opposite stretch. Whereas, the strength exercise included neck extension and flexion, neck side flexion, lateral neck extension, biceps curls, pullovers, arm hyperextension, arm abduction, arm flys, upright row, and reverse flys. Additionally, red and blue elastic bands (Thera-Band) and dumbbells 2-10 kg were used in the exercise protocol (Gaballah et al.,2017).

To learn how to perform the home-exercise protocol, the treatment participants (7 males and 5 females) were invited to three training sessions by an experienced (i.e., more than three years) rehabilitation specialist. The training sessions included: exercise performing prescription, protocol intensity, repetitions instructions, and practicing rules. In the third training session, all the subjects were asked to perform the exercise protocol. Then they received the protocol on a CD and they were encouraged to practice the daily protocol with the same frequency. (Caputo et al.,2017). Further, phone numbers, email, and other contact information were provided to follow up and support the participant at home. The home-protocol follow up and support processes were conducted once a week by an experienced physiotherapist.

Data collection

Outcomes were measured at baseline before the beginning of the home-exercise protocol. However, only the smartphone group outcomes (treatment and control) were collected in the same manner after the 8wks home-exercise rehabilitation. Study outcomes were muscle electromyographic activities (EMG) of four selected muscles and neck range of motion. The participants performed warm-up for 8-10 minutes after accomplished the measurement sessions. Furthermore, these tests occurred under equivalent temperature conditions (22-25 C) and in the same time in the morning 10.30 am.

The selected muscles during the EMG test session were upper Trapezius (UT), middle trapezius (MT), lower trapezius (LT), and sternocleidomastoid (SCM). Muscle activation evaluation data were collected according to SENIAN standards for electrodes positioning by EMG system (ME6000 telemetric hardware system, Mega Electronics Ltd., FINLAND) (Ghazwan et al., 2017). Participants were asked to perform MVC for each selected muscle on the right side only. To ensure high fidelity of the EMG signals of the selected muscles, the skin at each site was shaved, lightly abraded with sandpaper, and cleaned with rubbing alcohol before electrode placement. The EMG was measured after the subjects stood and flexed, extended and laterally bent the neck. Each test was performed twice, and each effort was held for 5 s with a 30-s rest between repetitions. The EMG signals were sampled at a frequency at 1024 Hz. Then all EMG signals were processed. A notch filter centred at 10 Hz was also used to reduce power-line interference. (Gilchrist et al., 2016).

The neck range of motion (ROM) measurements were flexion (NF), extension (NE), right lateral flexion (NRLF), and left lateral flexion (NLLF). The neck angular measurements were collected according to the goniometer criterion validity of the cervical range of motion. During the ROM measurement, the participants were asked to sit in a chair with their feet on the floor and their head in the natural position. Then the participants performed the maximum painless movement in each neck measurement. (Dvir& Prushansky,2008; Tousignant et al., 2000).

Statistical analysis

Student t test was used to compare neck ROM, and SCM and trapezius maximum voluntary isometric contraction (MVIC) between the individuals who used smart phone more than six hours and the individuals who used smart phone less than two hours. Repeated measures of ANOVA were performed to determine time by group interactions for each testing parameters. Bonferroni post hoc test was used when significant interaction was observed. Statistical significance level was set at $p < .05$.

RESULTS

Individuals who used smart phone more than 6 hours showed decrease in neck flexion, extension and lateral flexion ROM and UT, MT, LT and SCM MVIC levels compared to the individuals who used smart phone less than 2 Hours ($p < .001$) [Table 1].

Table 1. Group difference in neck ROM and maximum voluntary isometric contraction of the trapezius and SCM muscles.

	Group 1 (n = 24)	Group 2 (n = 24)	Mean difference (95% CI)	*p*-Value
Flex ROM	59.05 ± 1.77	62.85 ± 1.54	-3.80 (-4.77,-2.83)	<.001
Ext ROM	58.61 ± 1.57	68.49 ± 1.68	-9.97 (-10.82,-8.93)	<.001
R LF ROM	45.22 ± 2.64	48.05 ± 2.10	-2.83 (-4.21,-1.44)	<.001
L LF ROM	44.98 ± 2.52	47.92 ± 1.91	-2.94 (-4.24,-1.64)	<.001
SCM MVIC	18.88 ± 1.81	28.63 ± 1.38	-9.52 (-10.63, -8.41)	<.001
UT MVIC	21.73 ± 1.76	31.25 ± 2.05	-10.24 (-11.31, -9.17)	<.001
MT MVIC	18.98 ± 1.40	29.22 ± 2.19	-10.62 (-12.01, -9.23)	<.001
LT MVIC	22.82 ± 2.04	33.44 ± 2.70	-9.75 (-10.69, -8.82)	<.001

Table 2. differences in neck ROM and MVIC of the trapezius and SCM muscles between case and control groups.

	Time	Case (n = 12)	Control (n = 12)	Mean difference (95% CI)	*p*-Value
Flex ROM	Pre-test	58.70 ± 1.67	59.40 ± 1.88	-0.70 (-2.20, 0.81)	.34
	Post-Test	58.17 ± 1.67	61.12 ± 1.80	-2.96 (1.49, 4.43)	<.001
Ext ROM	Pre-test	59.17 ± 1.82	58.06 ± 1.07	1.11 (-0.16, 2.37)	.08
	Post-Test	57.03 ± 1.67	66.35 ± 1.62	-9.33 (-10.72,-7.93)	<.001
R LF ROM	Pre-test	45.10 ± 2.31	45.35 ± 3.03	-0.25 (-2.53, 2.03)	.82
	Post-Test	44.23 ± 0.95	47.35 ± 1.20	-3.12 (-4.03, -2.20)	<.001
L LF ROM	Pre-test	44.86 ± 2.16	45.11 ± 2.93	-0.25 (-2.43, 1.93)	.81
	Post-Test	44.00 ± 1.01	47.24 ± 1.31	-3.23 (-4.23, -2.24)	<.001
SCM MVIC	Pre-test	18.95 ± 2.18	18.80 ± 1.44	0.15 (-1.42, 1.71)	.85
	Post-Test	17.92 ± 0.98	26.42 ± 1.16	-8.49 (-9.40, -7.58)	<.001
UT MVIC	Pre-test	21.69 ± 1.91	21.76 ± 1.68	-0.06 (-1.59, 1.46)	.93
	Post-Test	20.43 ± 1.30	30.05 ± 1.33	-9.62 (-10.73, -8.51)	<.001
MT MVIC	Pre-test	18.83 ± 1.62	19.14 ± 1.20	-0.31 (-1.52, 0.90)	.60
	Post-Test	19.71 ± 1.45	27.98 ± 1.30	-8.26 (-9.43, -7.10)	<.001
LT MVIC	Pre-test	23.59 ± 1.78	22.05 ± 2.06	1.53 (-0.10, 3.16)	.06
	Post-Test	23.08 ± 1.49	31.56 ± 1.79	-8.47 (-9.87, -7.08)	<.001

Time by group interactions were significant for neck flexion ($F(1,22) = 4.96$, $p = .04$), extension ($F(1,22) = 130.17$, $p < .001$) and right lateral flexion ($F(1,22) = 6.66$, $p = .02$) and left lateral ROM ($F(1,22) = 6.72$, $p = .02$). Neck ROMs increased in treatment group after treatment but did not change in control group. There were also significant time by group interactions for SCM ($F(1,22) = 77.64$, $p < .001$), UT ($F(1,22) = 91.22$, $p < .001$), MT ($F(1,22) = 112.58$, $p < .001$) and LT ($F(1,22) = 69.17$, $p < .001$) MVICs. MVIC levels of the muscles increased treatment group but did not change in control group [Table 2].

DISCUSSION

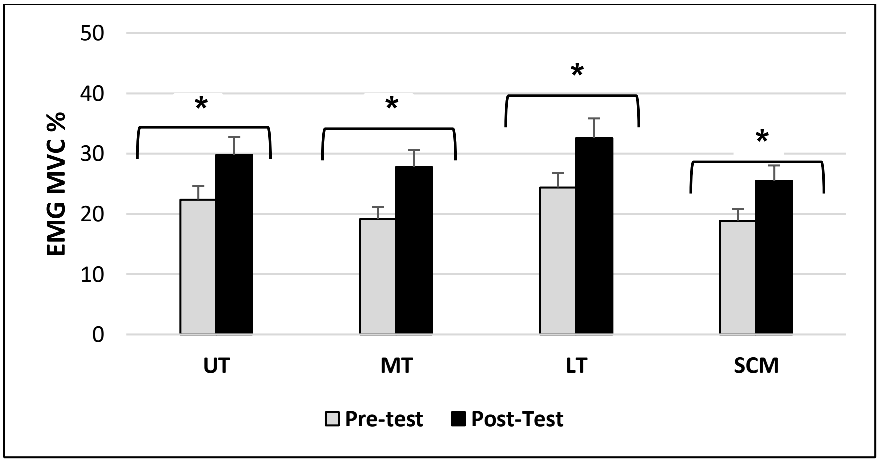
The principal finding of the present study was the smartphone usage hours adversely affect the neck ROM and neck muscles' MVIC. The increased usage hours of smartphone caused the decrease in neck flexion, extension and lateral flexion range of motion in the collegiate students. In addition, the increased usage hours of the smartphone resulted with the decreased upper trapezius, middle trapezius, lower trapezius and sternocleidomastoid muscles' MVIC levels. The present study also showed that the application of the neck exercises in the collegiate students at risk increased the neck range of motion and MVIC levels of the neck muscles.

In previous studies, the deteriorations of the neck posture were typically observed in the young persons who used smartphones. (Kietrys et al., 2015; Kim & Kim,0215; Kim,2013; Guan et al., 2016; Kim,2015; Park et al., 2017; Ning et al., 2015; Schabrun et al., 2014). It is suggested that the time of smartphone usage, device type and texting style influences cervical posture, but the common consensus is the forward head position of the necks increases as the duration of the smartphone usage increase. (Park et al., 2017), aimed to determine the amount of postural change of the neck when the participations played game with their smartphones and they indicated that forward head posture increased as the duration of smartphone usage increases. Moreover, some studies quantified the neck flexion range of motion during sitting and texting on the smartphone devices (Ning et al., 2015), observed that smartphone users maintained spectacular flexion of 46.4° during using a smartphone while sitting at the table and 45.6° while typing on hand-held mobile devices. Likewise, (Schabrun et al., 2014), observed high forward head measurements during texting and walking. Similarly, (Guan et al., 2016), observed significant increase in head and neck forward posture in mobile phone users. The study identified gender differences in the flexion posture while using the smartphones. The males represented 51.92° of neck flexion, whereas it was 47.09° in females.

The authors showed that as the participants looked at the smartphone, the neck flexion angles increased approximately 14.5° which indicating a considerable amount of head posture. Previous studies specified that a neck angle over 40° was considered as a reference for 'forward head posture'. In our study neck flexion ROM was determined between 59°-62°, indicating that the collegiate students who used smartphone frequently had a forward head posture. These results were corresponding with the previous findings that smartphone usage adversely affects the head and neck posture.

It has been showed that cervical and thoracic erector spinae, upper and lower trapezius muscle activations might change due to the position of the head and neck (Guan et al., 2016; Kim,2015; Park et al., 2017; Ning et al., 2015; Harms-Ringdahl et al.,1986), specified that there was a high correlation between posture and muscle activity. (Park et al., 2017), found that the EMG activities of cervical erector spinae muscle group increased with a 5 minutes usage of smartphone. The authors also indicated that upper trapezius EMG activity was low as time of smartphone usage progressed. One possible explanation of this decrease in UT could be that the muscle was passively stretched by the flexed posture of the head and neck. In the present study the MVIC of the SCM, UT, MT and LT were determined, and the results showed that each MVICs of the muscles decreased when the smartphone usage time increased. We believe that flexion posture of the neck might provoke the compression and share forces of the cervical spine as the usage of smartphone increased and this mechanical load of the neck muscles resulted with the muscle fatigue. This claim was also supported by the previous studies that showed more than 16 minutes of smartphone use was related with moderate neck pain. Harms-Ringdahl et al.,1986; Kim et al.,2013).

It is well known that there is a rapid increase in the frequency of smartphone usage and that causes various musculoskeletal problems. The greatest factor in neck pain are decreasing the cervical mobility. (Williamson et al.,2015), and dysfunctions of the neuromuscular (Bobos et al.,2016). In addition, the prolonged smartphone use might cause poor proprioception(Kim & Kim,2015; Kim et al.,2013 ; Park et al.,2013) reported that 20 minutes of smartphone use could induce fatigue in neck muscles. Loss of proprioception and muscle fatigue combined with the flexor head posture might result with the neck pain (Lin et al.,2009), reported that 83% of the participants experienced neck and hand pain during texting on a smartphone.



Note. (*) (Significant difference p < .05.

Figure 1. The improvement between the EMG activity in pre-tests and post-tests of neck muscles for the case group.

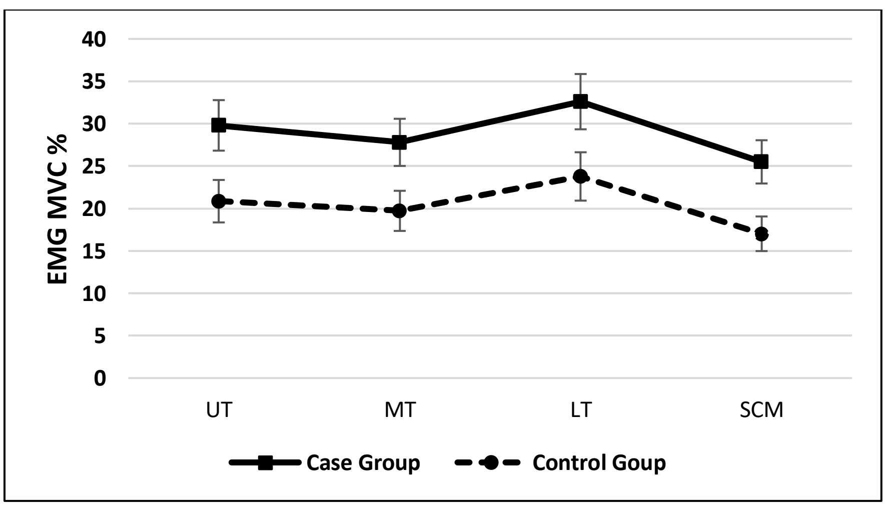


Figure 2. The post-tests deference in EMG activity for the neck muscles between the case group and control group. upper Trapezius (UT), middle trapezius (MT), lower trapezius (LT), and sternocleidomastoid (SCM).

To optimize the pain around neck, researchers are focused on the rehabilitation and exercise programs for the postural changes of the neck and also fatigue around the neck muscles. (Kim et al.,2016), investigated the acute effect of neck exercises on fatigue levels of the muscles. The participants in their study were asked to perform stretching exercises and stabilization exercises before the use of smartphone. The specific cervical exercises have been noted to increase neck function (Ayhan et al.,2016; Ris et al.,2016), enhancing the neck muscles strength (Lee et al.,2016; Jull et al.,2007), improved the sternocleidomastoid (SCM), splenius capitis (SC) muscle activity and also after 8 weeks' neck pain was decreased(Ludvigsson et al.,2015; Falla et al.,2013).

It has been indicated that both the stretching and strengthening exercises reduced the muscle fatigue in smartphone users (Kim,2013; Kim et al., 2016). Different from (Kim et al., 2016) study, we applied an 8-week exercise program for the smartphone users. The exercise protocol in the present study was included strength exercises, flexibility and stretching exercises for neck and shoulder. Smartphone users in the treatment group performed better neck muscle MVIC when compared to smartphone users in the control group [Figure 2]. Consequently, the EMG activation of UT, MT, LT, and SCM was greatest when flexibility and strength exercises were applied to the neck, for flexion and extension, compared to the control group [Figure 1]. These seems to be agreement with the theories of the exercise effect of neck and shoulder pain(Ayhan et al.,2016; Bobos et al.,2016).

It is documented that stretching exercises increase the inner pressure of the muscles through mild muscle contraction. The rhythmic contraction of the muscles increases blood circulation as well as improves the blood flow (Shin & Park,1997). Neck stabilization exercises had positive effects on the deep neck muscles and increases muscular strength and endurance. In the present study we both apply the stretching and strengthening exercises to improve the muscle performance. We also gave the smartphone users a detailed exercise program on a CD and encouraged them to practice the daily exercises. Therefore, we believe that this systematic and comprehensive exercise program prevented the adverse effects of the smartphone usage for the participants in the present study.

CONCLUSION

Increased smartphone usage hours would negatively affect the neck posture. Forward head and neck posture were associated with the usage hours of the smartphone. The more the usage hours increased, the more head and neck positioned anteriorly. This posture resulted with the decrease muscle strength and range of motion around the neck in collegiate students. The stretching and strengthening exercises were beneficial to improve the neck muscle strength and range of motion. Therefore, it is important to encourage the students to do exercises to protect the neck health, to prevent the cumulative trauma and future neck problems.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Contributions are specified according to the CRediT (Contributor Roles Taxonomy) as follows:

Conceptualisation: Ahmed Gaballah. Methodology: Ahmed Gaballah. Formal analysis: Ahmed Elshalakamy. Investigation: Ahmed Gaballah. Data curation: Ahmed Elshalakamy. Writing – original draft: Ahmed Gaballah. Writing – review & editing: Harald Tschan. Supervision: Harald Tschan. All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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