Hong Kong Physiotherapy Journal (2016) 35, 37–44

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.hkpj-online.com

RESEARCH REPORT

Exercise training and postural correction improve upper extremity symptoms among touchscreen smartphone users

Abeer Ahmed Abdelhameed [a,b], Amr Almaz Abdel-aziem [c,*]

[a] *Department of Physiotherapy, College of Health Sciences, University of Sharjah, Sharjah, United Arab Emirates*
[b] *Department of Physical Therapy for Cardiovascular/Respiratory Disorders and Geriatrics, Faculty of Physical Therapy, Cairo University, Giza, Egypt*
[c] *Biomechanics Department, Faculty of Physical Therapy, Cairo University, Giza, Egypt*

KEYWORDS
exercise training;
hand grip;
smartphone;
upper extremity symptoms

Abstract *Background:* Repetitive movements and poor posture are associated with over-use of smartphones when texting or playing games and significantly contribute to the symptoms of pain and discomfort in the upper extremities.

Objective: This study investigated the effect of exercise training and postural correction on disabilities of the arm, shoulder, and hand (DASH), hand grip and key pinch strength among smartphone users.

Methods: One hundred university students were randomly divided into two groups; the experimental group participated in a 12-week programme of exercise training and postural corrections. The control group were instructed to follow their usual routine for smartphone utilization. Measurements of DASH scores, hand grip strength, and key pinch grip strength were conducted before and after 12 weeks for both groups.

Results: There were no significant differences between the start values of both groups for DASH scores, hand grip strength, and key pinch strength ($p > 0.05$). However, there was a significant improvement in all outcomes measured in the experimental group ($p < 0.05$), with significant changes in the outcomes of the control group.

Conclusion: Postural correction combined with a selected exercise training programme improved the hand grip, key pinch grip strength, and upper extremity disability and symptoms associated with smartphone use among university students.

* Corresponding author. Biomechanics Department, Faculty of Physical Therapy, Cairo University, 7 Ahmed Elziat Street, Bean Elsariate, El Dokki, Giza, Egypt.

E-mail addresses: amralmaz@yahoo.com, amralmaz74@gmail.com (A.A. Abdel-aziem).

http://dx.doi.org/10.1016/j.hkpj.2016.06.001
1013-7025/

Introduction

In the past few years, touchscreen smartphones have replaced most of the keypad phone products due to their versatility and abundance of applications. However, as many people maintain their neck flexed when using portable devices, there is a growing debate about the effect of touchscreen smartphones on the musculoskeletal system among prolonged users of these devices. Similar to desktop and laptop computers, prolonged use of touchscreen smartphones may also contribute to increased risk for the development of musculoskeletal symptoms such as chronic neck and shoulder pain [1,2].

With each new generation of mobile phone, there are more built-in functions which lead to increased exposure and use of mobile phone functions. In younger persons, these exposures may be of great importance due to their developing musculoskeletal structure, their tendency to use their mobile phone for messaging and gaming, and the likelihood of greater exposure as a result of repetitive messaging and gaming activities [3].

The combination of repetitive movements, poor posture, and over-use of mobile phones for texting or playing games, without taking rest breaks, can cause injury to the nerves, muscles, and tendons in the fingers, hands, wrists, arms, elbows, shoulders, and neck, which if ignored, may lead to long-term damage [4]. The frequency and duration of use of cellular phones is increasing, and the design characteristics of these phones give rise to concerns regarding their impact upon body mechanics [5].

Gustafsson [6] showed differences in physical load between the group of mobile phone users with musculoskeletal symptoms and the group without symptoms. He also found differences in muscle activity and kinematics between different texting techniques. Preliminary studies on the effect of mobile hand-held device use among university students revealed a significant association between upper extremity symptoms and frequent utilization of a mobile hand-held device [7]. Moreover, Gustafsson et al [8] found prospective associations were established between exposure to text messaging on mobile phone and musculoskeletal pain in neck, shoulder, and arm, and numbness/tingling in hand/fingers for both men and women.

Recently, a few epidemiological studies reported a high prevalence of neck—shoulder symptoms among mobile device users. A study in Canada indicated rates of 46—52% in shoulder symptoms among 140 individuals and 68% in neck symptoms [1]. Another study in China reported over 40% of neck—shoulder pain among 2575 young mobile phone users [9].

Touchscreen tablet users are exposed to extreme wrist postures that are less neutral than other computing technologies and may be at greater risk of developing musculoskeletal symptoms [10]. Moreover, head and neck flexion angles during tablet use were greater, in general, than angles previously reported for desktop and notebook computing [11]. Gold et al [12] reported that over 90% of university students adopted a flexed neck posture, with protracted shoulders and nonneutral wrist postures on the typing side when they used their mobile devices.

Despite the reported association between mobile use and upper extremity symptoms there is a gap in the knowledge on how exercise and proper hand grasp can improve these symptoms. Considering the increased use of touchscreen mobile phones among young people it is important to identify how physical therapy interventions can reduce these symptoms. The aim of this study was to examine the effect of a training programme and postural corrections on hand grip strength, key pinch strength, upper extremity disability, and symptoms associated with touchscreen smartphone use among university students.

Methods

Participants

In this study, 217 students from Cairo University, Giza, Egypt were identified as potential participants. A total of 100 students (age, 18—26 years) who reported mild to moderate symptoms in disabilities of the arm, shoulder, and hand (DASH) questionnaire (DASH score $\geq$ 25) [13], were invited to the study. They were recruited by convenience sampling. In order to be recruited, individuals had to have at least 6 months' experience in using smartphones for at least 3 hours daily. They had to be right hand dominant and prefer to use the right hand in one handed text entry. Other essential requirements were texting and typing speeds to make sure that all participants had similar skills in texting on a smartphone and typing on a desktop computer. Individuals were asked to perform a texting speed test on an iPhone 4s (Apple Inc., Cupertino, CA, USA) using both hands as well as perform a typing speed test on a desktop computer before entering the study. Only those who achieved a minimum texting speed of 15 words per minute on the smartphone and typing speed of 30 words per minute on the computer keyboard were recruited. The exclusion criteria were: (1) history of traumatic injuries or surgical interventions of the neck or upper limbs; (2) medical conditions which may have a negative effect on the spine and upper limbs; (3) chronic diseases such as rheumatoid arthritis, osteoarthritis, and other connective tissue disorders that affect the musculoskeletal system; and (4) neurological and orthopaedic disorders as well as sensory deficits [14].

Before the start of the study participants were allocated to two groups, the experimental group or the control group, using SPSS computer programme (version 16.0; SPSS Inc., Chicago, IL, USA) to conceal group allocation. Participants in the control group were advised to keep their regular routine and avoid any unusual activities that may increase the load on the arm and hand. Participants in the experimental group were engaged in a 12-week exercise programme. The CONSORT diagram showing the recruitment, assignment and progression of patients through the study is presented in Figure 1.

All procedures had been thoroughly explained and consent forms were obtained from all participants. The study was approved by the human research ethics committee of the Faculty of Physical Therapy at Cairo University and each participant signed written consent. The participants were recruited from Cairo University. The study was run in

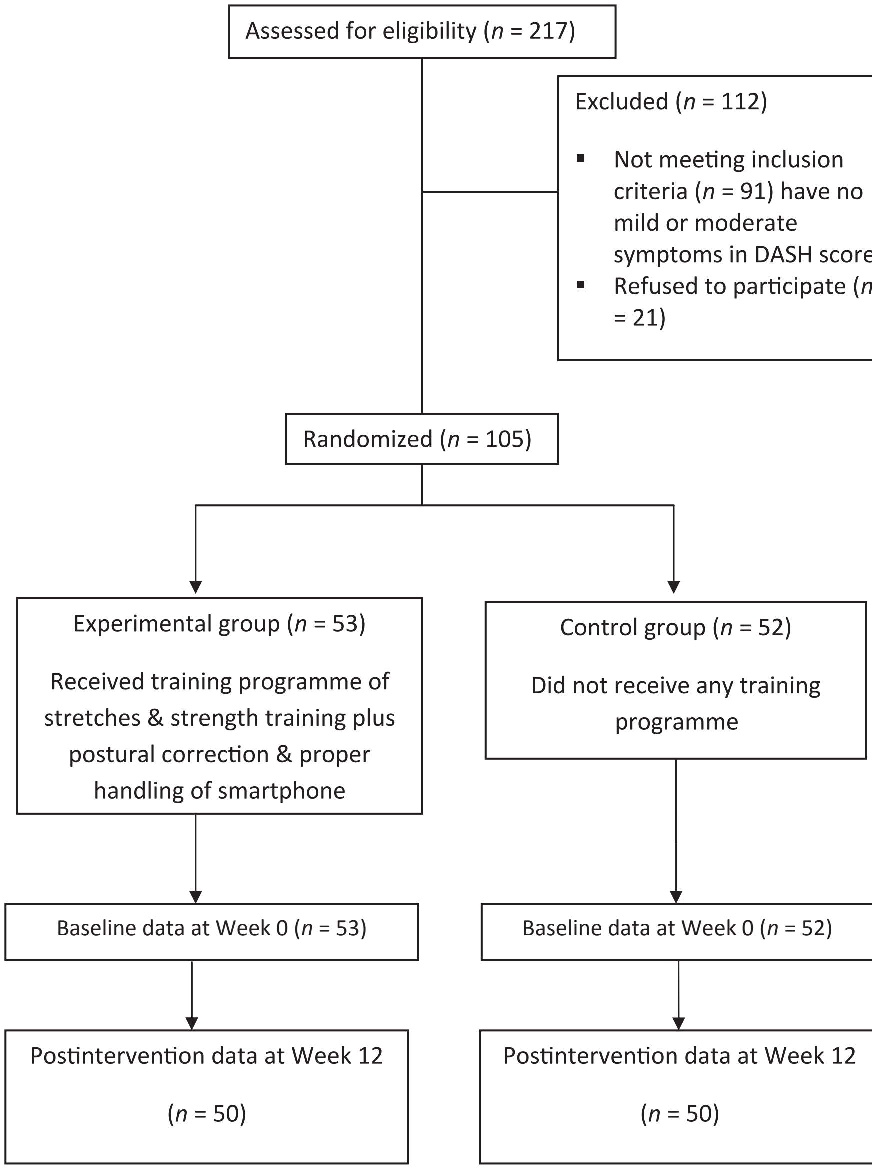

Figure 1. CONSORT diagram of the study. DASH = disabilities of the arm, shoulder, and hand.

accordance with the Helsinki Declaration of 1975, as revised in 1996 [15].

Assessment

The DASH outcome measure is a 30-item, self-reported questionnaire designed to measure physical function and symptoms in people with any of several musculoskeletal disorders of the upper limbs. This gives clinicians and researchers the advantage of having a single, reliable instrument that can be used to assess any or all joints in the upper extremity. Participants were instructed to read the questions and carefully choose the proper score from the 5 point scale. They received a clear description of the questionnaire and were asked to answer all questions as applicable. The score for each participant was calculated as:

$$[(\text{sum of } n \text{ responses}) - 1] \times 25, \quad (1)$$

where n is equal to the number of completed responses. DASH score may not be calculated if there are more than three missing items [16]. The DASH questionnaire includes questions regarding pain, functional limitations, and tingling, weakness, and stiffness on shoulder, arm, and hand. It is a reliable, valid, and responsive tool for measuring the outcome in different regions of the upper extremities [17].

Grip strength was tested first, followed by key pinch. For each of the tests of hand strength, the participants were seated with their shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in neutral position, and wrist between 0° and 30° dorsiflexion and between 0° and 15° ulnar deviation [18,19]. For each strength test the scores of three successive trials were recorded [20]. The assessment was conducted with the dominant hand, as Sharan et al [21] reported that there is a correlation between hand dominance and musculoskeletal disorders.

Equipment

We used the standard, adjustable-handle Jamar dynamometer (Asimov Engineering Co., Los Angeles, CA USA), which has been reported as the most accurate for measuring grip strength [22,23]. For standardization, it was set at the second handle position for all participants. The dynamometer was lightly held around the readout dial by the examiner to prevent inadvertent dropping.

The B&L pinch gauge (B&L Engineering, Tustin, CA, USA), used to measure key pinch, was held by the examiner at the distal end to prevent dropping. Scores were read on the needle side of the red readout marker. The calibration of both instruments was tested periodically during the study. The Jamar dynamometer and the B&L pinch gauge had the highest calibration accuracy of the instruments tested [23].

Data pertaining to upper extremity symptoms, hand grip strength, and tip pinch strength were collected from all participants on two different occasions; at the start of the study and 12 weeks later.

Training programme

Stretching exercises: sideway arm stretch; participant folded his hands together and turn palms away from body as the arms were extended forward a gentle stretch should be felt all the way from shoulders to fingers. Forward arm stretch; participant folded his hands together and turn palms away from body, but this time arms should be extended over his head. Forearm and wrist stretch with elbow completely straight each participant should extend his arms in front of their chest and with their palm down, and bend the hand on the outstretched arm down toward the floor. Then turn the palm up and stretch the hand up toward the body. This stretches the forearm and wrist muscles. All stretches were held for 10 seconds and repeated eight times for each session [24].

Strength training: the intervention group were enrolled in a 12-week programme of strengthening exercises (dumbbell exercises) for muscles of the neck, shoulder, elbow, and wrist. These were performed for 20 minutes, three times a week. (1) Front raise: from a neutral starting position the participant lifts one arm at a time to 90° shoulder flexion, and 90° internal rotation. The elbows are slightly flexed (~5°) during the entire range of motion. (2) Lateral raise: the participant is standing with arms in neutral starting position and the elbows are in a static slightly flexed position (~5°). The participant lifts both arms to 90° shoulder abduction and 30° horizontal flexion. (3) Reverse flies: the participant is sitting bent over forward with the back straight and arms hanging. The arms are raised bilaterally, while keeping the elbows in a static slightly flexed position (~5°), until the upper arms are horizontal. (4) Shrugs: the participant is standing erect with arms to the side and elevates the shoulders as high as possible in a maximal shrug. (5) Wrist extension: sitting with the forearm pronated on a support. From full palmar flexion the participant moves the wrist to full dorsal flexion.

Participants performed exercises in a rotating manner to optimally increase training load, and rested for 1–2 minutes in between sets [25]. The participants performed warm-up exercises at the beginning of each training session, with 10 repetitions of each exercise and 50% of 1 repetition maximum (RM). At the beginning and halfway through the intervention period, the participants were tested to optimize the training intensity and the loads were progressively increased according to the principle of periodization and progressive overload [26]. The intensity of the programme increased gradually from 20 RM at the beginning of the intervention period to 8 RM further along in the process.

Proper handling; clear and illustrated guidelines were given to all participants in the study groups including: adopt a neutral grip that keeps the wrist as straight as possible, as bending the wrist can add to the strain, adequate pausing and break times to avoid repetitive motion injuries due to performing the same task over and over, and switch activities between both hands frequently [13].

The participants were educated on the importance of correct postural alignment of the spine during sitting and standing activities. They were asked to adopt ideal head position, and were instructed to sit with the head in a "balanced position" considered by the participants to be ideal without any manual or verbal feedback regarding the position adopted. The posture was held for 10 seconds and repeated three times, and a 10-second rest period was allowed between repetitions [27].

Data analysis

Data were analysed using SPSS for Windows version 16.0 (SPSS Inc., Chicago, IL, USA). An independent *t* test was used to compare demographic variables of the participants, and the Chi-square test was used for gender. Analysis of variance was used to compare DASH, the hand dynamometer, and the key pinch dynamometer of both groups, with time as the within participant factor (baseline measurement vs. postintervention measurement) and group as the between participant factor (experimental vs. control). Independent *t* tests were used to compare the change score between the two groups. Least significant difference test was used to locate the source of differences. The level of significance was set at 0.05 for all tests.

Results

There were no significant differences between the two groups in age, weight, height, and body mass index ($p > 0.05$; Table 1). Descriptive statistics of the DASH, hand dynamometer, and key pinch dynamometer values of the two groups are illustrated in Table 2.

There were no significant differences between prevalues of both groups ($p > 0.05$) for DASH scores, hand grip, and key pinch grip dynamometer values. Moreover, there was no significant difference between pre- and postvalues of the DASH, hand grip, and key pinch grip of the control group ($p > 0.05$).

For DASH scores, the postvalue of the experimental group was significantly lower than that of the control group ($p = 0.048$). The postvalue of the experimental group was significantly lower than the prevalue ($p = 0.001$). For handgrip and key pinch grip dynamometer values, the

Table 1 Demographic characteristics of participants.

	Control group, $n = 50$	Experimental group, $n = 50$	p
Age (y)	20.22 ± 1.97	20.30 ± 1.88	0.836[a]
Height (m)	168.42 ± 9.77	169.04 ± 10.60	0.643[a]
Weight (kg)	76.42 ± 16.31	65.90 ± 16.41	0.762[a]
Body mass index (kg/m^2)	23.53 ± 3.89	22.79 ± 3.94	0.347[a]
Sex (male/female)	36/14	39/11	0.488[b]

Data are presented as mean ± standard deviation, unless otherwise indicated.
[a] Independent *t* test.
[b] Chi-square test.

Table 2 Values of DASH, hand dynamometer, and key pinch dynamometer.

	Control group, $n = 50$		p	Experimental group, $n = 50$		p[a]
	Prevalue	Postvalue		Prevalue	Postvalue	
DASH	35.10 ± 8.11	35.66 ± 7.84	0.085	37.88 ± 8.51	32.62 ± 6.63	0.001
Hand dynamometer (kg)	30.46 ± 3.57	30.14 ± 3.31	0.692	30.94 ± 4.53	35.02 ± 4.56	0.001
Key pinch dynamometer (kg)	12.29 ± 1.96	12.10 ± 1.82	0.625	12.88 ± 1.91	14.49 ± 2.15	0.001

Data are presented as mean ± standard deviation.
$p > 0.05$ means no significant difference.
$p < 0.05$ means a significant difference.
[a] Least significant difference's analysis of variance.

postvalue of the experimental group was significantly higher than the postvalues of the control group ($p = 0.001$). The postvalue of the experimental group was significantly higher than the prevalue ($p = 0.001$), as shown in Table 2.

Analysis of the change scores revealed that the experimental group had significantly more changes in DASH scores, hand grip, and key pinch grip dynamometer ($p = 0.001$) compared with the control group, as shown in Table 3.

Discussion

This study was conducted to examine the effect of an exercise training programme and postural correction on upper extremity disability and symptoms associated with touchscreen smartphone use among university students. The results of the current study showed a significant improvement in upper extremity disability and symptoms, hand grip strength, and key pinch strength of the experimental group, without significant changes in these outcome measures of the control group.

Previous studies [28,29] showed an association between upper limb disorders such as neck and shoulder pain and cellular phone over-use, which may explain why only 100 out of 217 eligible participants with mild to moderate symptoms of DASH score were selected. In addition, Storr et al [30] reported a female patient with de Quervain's tenosynovitis due to cell phone use. The patient sent 2500 texts per month, and stated that the specific thumb movement caused the tenosynovitis or other over-use trouble around the thumb.

Young et al [11] who reported that the head and neck flexion angles during tablet use were greater than angles previously reported for desktop and notebook computing, which could explain the neck pain symptoms of the participants. Moreover, there is a disturbance in electromyographic activities of neck and hand muscles; Xie et al [14] concluded that smartphone texting was associated with higher activity in neck extensor and thumb muscles but lower activity in upper and lower trapezius as well as wrist extensors, compared with computer typing.

The values of hand grip strength of the participants of this study were less than the normative values of a similar age group reported by Mathiowetz et al [20]. In their study, the

Table 3 Change score of DASH, hand dynamometer, and key pinch dynamometer.

	Control group, $n = 50$	Experimental group, $n = 50$	p[a]
DASH	0.55 ± 2.07	−5.26 ± 2.07	0.001
Hand dynamometer (kg)	−0.32 ± 1.22	4.08 ± 1.12	0.001
Key pinch dynamometer (kg)	−0.19 ± 1.04	1.61 ± 1.02	0.001

Data are presented as mean ± standard deviation.
[a] Independent *t* test.

average values of hand grip strength were 54.81 kg for males and 31.71 kg for females. However, the normal values of key pinch strength are 11.78 kg for males and 7.97 kg for females, which is similar to the results of our study.

The nonsignificant difference in the DASH, hand grip, and key pinch strength postvalues of the control group can be explained by the findings of Sengupta et al [31], who reported that due to the small keyboard, greater strain may be placed on the hand and arm muscles during mobile phone use compared to desktop or laptop use. This is in addition to the considerable increase in neck flexion angle during texting to look sharply downwards or to hold arms out in front to read the screen, leading to fatigue and pain in the neck and shoulders. Moreover, static loading caused by holding the hand-held device for long durations, often coupled with hazardous body postures and over-use of the hand muscles are likely contributors to the development of myofascial pain syndrome of the hand, forearm, neck, and upper back muscles [32].

The improvement of outcome measures of the experimental group is supported by the findings of Gram et al [33], who used the same exercise training programme to investigate the effect on neck/shoulder pain and headache among office workers. They found that neck/shoulder training at the workplace reduced neck pain and headache among office workers, and confirmed the positive effect of exercise training to reduce the upper extremity symptoms [25,34].

Key pinch strength was tested in the current study because the carpometacarpal joint represents the most important functional key in a human hand due to its circumduction and opposition abilities. These functions are very unique to humans and mean that its anatomy and functions are at risk of overloading due to excessive activity [35]. The saddle shape and reciprocal engagement of the carpometacarpal joint are stabilized by powerful ligamentous structures such as the intermetacarpal ligament, posterior oblique ligament, and dorsal radial ligament, which are involved in the movements described above [36]. The ability to reach keys in different areas of the mobile phone screen is regulated by changing the flexion angle of the carpometacarpal joint [37]. So, the key pinch strength was used to assess the strength of the thumb because it is the most affected part of the hand due to touchscreen phone use. The results of the current study proved its strength reduction due to touchscreen phone use and improvement due to proper handling and exercise training.

The reduction of the DASH score of the experimental group is supported by the findings of Pedersen et al [38], who reported that specific strength training at the workplace can lead to significant long-term reductions in spinal and upper extremity pain and DASH scores. It also supported by the findings of a few high quality studies showing the effectiveness of training on shoulder symptoms [39,40] and combined neck/shoulder symptoms [41,42]. Moreover, the improvement of the experimental group can be explained by the effect of postural correction training on assuming ideal head position, which is in accordance with the findings of previous studies [43—45] which reported that proper head position can minimize the stresses and strains acting on the upper body by creating a state of musculoskeletal balance. Proper and frequent postural correction to an upright neutral postural position serves two functions. Firstly, it minimizes the adverse loads on the cervical joints induced by poor spinal, cervical, and scapular postures. Secondly, it may train the deep postural-stabilizing muscles of the spine to better perform their functional postural-supporting role. Hence, assuming a proper head position is a common approach for the treatment of neck and shoulder pain syndromes.

The shoulder girdle attaches by muscles to the scapula and the back of the thoracic rib cage. These upper back muscles are prone to developing painful irritation. In clinical practice pain complaints from the neck, the shoulder girdle, and part of the shoulder are associated [46]. Neck, shoulder, and upper back muscles are all involved during repetitive movements/activity of the arms with a common effect on all three regions, which explains the importance of this study.

The significant improvement in DASH scores, hand grip, and key pinch strength of the experimental group may be due to a change in central pain perception, which is known to be altered in chronic pain conditions [47]. A change in pain level could result in beneficial changes in overall pain perception and a decreased pain sensitization. A previous study showed central adaptations of pain perception in response to neck/shoulder rehabilitation, i.e., pressure pain threshold also increased in other nontrained parts of the body [48]. The current study was unique in reporting the effect of strength training, postural correction, and proper handling on upper extremity pain among touchscreen users. To our knowledge this has not been reported in previous training intervention studies.

There are some limitations of this study. First, our participants were not selected randomly, because all were volunteers. This could cause a biased sample in favour of higher hand strength scores. There was an attempt to avoid a competitive atmosphere at the testing sites in order to decrease the chance of this happening. Second, the only outcome measure used to assess the thumb strength was key pinch. Other outcomes such as tip and palmar pinch were not considered. Third, the exercise training was semisupervised, so we were not sure if all participants performed the exercise with the same frequency, intensity, and duration. However, they were seen at least once per week to confirm that. Finally, the touchscreen phones used in this study had different screen sizes that would require different finger actions when operating the devices. Hence there is still a need to investigate the relationship between screen size and the effect of a training programme. Future research is needed to examine the effect of exercise intervention on the electromyographic activities of the thumb, forearm, shoulder, and neck extensor muscles.

Conclusion

The present study demonstrated that exercise training, postural correction, and instruction on the proper handling of touchscreen smartphones reduced the upper extremity disability and symptoms and improved the hand grip strength and key pinch strength. Therefore, exercise training and ergonomic guidelines concerning the use of touchscreen smartphones will reduce the risk of developing upper extremity musculoskeletal disorders.

Conflicts of interest

The authors have no conflict of interest to declare.

Funding/support

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgements

The authors wish to thank Dr Waleed Mohamed Aboelmeaty, Assistant Professor, Faculty of Education, Mansura University, Egypt, for helping with the statistical analysis. We would like to thank all of the students who participated in the study.

References

[1] Berolo S, Wells RP, Amick 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;42:371—8.

[2] Kim GY, Ahn CS, Jeon HW, Lee CR. Effects of the use of smartphones on pain and muscle fatigue in the upper extremity. J Phys Ther Sci 2012;24:1255—8.

[3] Gustafsson E, Johnson PW, Hagberg M. Thumb postures and physical loads during mobile phone use — a comparison of young adults with and without musculoskeletal symptoms. J Electromyogr Kinesiol 2010;20:127—35.

[4] Kleinert CM. Trapezio-metacarpal arthritis: the price of an opposable thumb. Indian J Plast Surg 2011;44:308—16.

[5] Chany M, Marras WS, Burr DL. The effect of phone design on upper extremity discomfort and muscle fatigue. Hum Factors 2007;49:602—18.

[6] Gustafsson E. Ergonomic recommendations when texting on mobile phones. Work 2012;41(Suppl. 1):5705—6.

[7] Abdelhameed AA. Upper extremities symptoms among mobile hand-held device users and their relationship to device use. In: Proceedings of the 5th Health and Environment Conference in the Middle East, 2014; March 2014. p. 71—7. Dubai, UAE, 3—4.

[8] Gustafsson E, Thomée S, Grimby-Ekman A, Hagberg M. Texting on mobile phone and musculoskeletal symptoms. A 5 years cohort study. In: Proceedings of the 19th Triennial Congress of the IEA, 9—14 August 2015, Melbourne.

[9] Shan Z, Deng G, Li J, Li Y, Zhang Y, Zhao Q. Correlation analysis of neck/shoulder pain and low back pain with the use of digital products, physical activity and psychological status among adolescents in shanghai. PLoS One 2013;8:78—109.

[10] Young JG, Trudeau MB, Odell D, Marinelli K, Dennerlein JT. Wrist and shoulder posture and muscle activity during touch-screen tablet use: effects of usage configuration, tablet type, and interacting hand. Work 2013;45:59—71.

[11] Young JG, Trudeau M, Odell D, Marinelli K, Dennerlein JT. Touch-screen tablet user configurations and case-supported tilt affect head and neck flexion angles. Work 2012;41:81—91.

[12] Gold J, Driban J, Thomas N, Chakravarty T, Channell V, Komaroff E. Postures, typing strategies, and gender differences in mobile device usage: An observational study. Appl Ergon 2012;43:408—12.

[13] Kietrys DM, Gerg MJ, Dropkin J, Gold JE. Mobile input device type, texting style and screen size influence upper extremity and trapezius muscle activity, and cervical posture while texting. Appl Ergon 2015;50:98—104.

[14] Xie Y, Szeto GP, Dai J, Madeleine P. A comparison of muscle activity in using touchscreen smartphone among young people with and without chronic neck-shoulder pain. Ergon 2015;28:1—12.

[15] World Medical Association. Declaration of Helsinki, 4th (Somerset West) amendment. 1996. www.wma.net/en/30publications/10policies/b3/17c.pdf.

[16] Beaton D, Katz JN, Fossel AH, Wright JG, Tarasuk V, Bombardier C. Measuring the whole or the parts: Validity, reliability, and responsiveness of the disabilities of the arm, shoulder and hand outcome measure in different regions of the upper extremity. J Hand Ther 2001;14:128—42.

[17] Kitis A, Celik E, Aslan UB, Zencir M. DASH questionnaire for the analysis of musculoskeletal symptoms in industry workers: a validity and reliability study. Appl Ergon 2008;40:251—5.

[18] Kraft GH, Detels PE. Position of unction of wrist. Arch Phys Med Rehabil 1972;53:272—5.

[19] Pryce JC. Wrist position between neutral and ulnar deviation that facilitates maximum power grip strength. J Biomech 1980;13:505—11.

[20] Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M, Rogers S. Grip and pinch strength: normative data for adults. Arch Phys Med Rehabil 1985;66:69—72.

[21] Sharan D, Mohandoss M, Ranganathan R, Jose J. Musculoskeletal disorders of the upper extremities due to extensive usage of hand held devices. Ann Occup Environ Med 2014;26:22—5.

[22] Kirkpatrick JE. Evaluation of grip loss. Calif Med 1956;85:314—20.

[23] Mathiowetz V, Weber K, Volland G, Kashman N. Reliability and validity of hand strength evaluation. J Hand Surg 1984;9:222—6.

[24] Tom Valeo, How to Handle High-Tech Hand Injuries. http://www.webmd.com/arthritis/features/how-to-handle-high-tech-hand-injuries, (last accessed in October 2015).

[25] Andersen L, Zebis MK, Pedersen MT, Roessler KK, Andersen CH, Pedersen MM, et al. Protocol for work place adjusted intelligent physical exercise reducing musculoskeletal pain in shoulder and neck (VIMS): a cluster randomized controlled trial. BMC Musculoskelet Disord 2010;11:1471—4.

[26] Ratamees NA, Alvar BA, Evetoch TK, Housh TJ, Kibler B, Kraemer WJ, et al. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc 2009;11:687—708.

[27] Kwon JW, Son SM, Lee NK. Changes in upper-extremity muscle activities due to head position in subjects with a forward head posture and rounded shoulders. J Phys Ther Sci 2015;27:1739—42.

[28] Yoong JK. Mobile phones can be a pain—text messaging tenosynovitis. Hosp Med 2005;66:370.

[29] Ashurst JV, Turco DA, Lieb BE. Tenosynovitis caused by texting: an emerging disease. J Am Osteopath Assoc 2010;110:294—6.

[30] Storr EF, de Vere Beavis FO, Stringer MD. Texting tenosynovitis. N Z Med J 2007;14:1267.

[31] Sengupta A, Grabiner S, Kothari P, Martinez G. Ergonomic aspects of personal digital assistant (PDA) and laptop use. In: Proceedings of the 6th International Scientific Conference on Prevention of Work-related Musculoskeletal Disorders, 2007; August 2007. p. 17. Boston, USA, 27—30.

[32] Eapen C, Bhat AK. Prevalence of cumulative trauma disorders in cell phone users. J Musculoskelet Res 2010;13:137—45.

[33] Gram B, Andersen C, Zebis MK, Bredahl T, Pedersen MT, Mortensen OS, et al. Effect of training supervision on effectiveness of strength training for reducing neck/shoulder pain

and headache in office workers: cluster randomized controlled trial. Biomed Res Int 2014;2014:693013.
[34] Sjögren T, Nissinen KJ, Järvenpää SK, Ojanen TM, Vanharanta H, Mälkiä EA. Effects of a workplace physical exercise intervention on the intensity of headache and neck and shoulder symptoms and upper extremity muscular strength of office workers: a cluster randomized controlled cross-over trial. Pain 2005;116:119—28.
[35] Turker T, Thirkannad S. Trapezio-metacarpal arthritis: the price of an opposable thumb! Indian J Plast Surg 2011;44: 308—16.
[36] Connell DA, Pike J, Koulouris G, van Wettering N, Hoy G. MR imaging of thumb carpometacarpal joint ligament injuries. J Hand Surg Br 2004;29:46—54.
[37] Sakai N, Shimawaki S. Motion analysis of thumb in cellular phone use. Appl Bionics Biomech 2010;7:119—22.
[38] Pedersen MT, Andersen CH, Zebis MK, Sjøgaard G, Andersen LL. Implementation of specific strength training among industrial laboratory technicians: long-term effects on back, neck and upper extremity pain. BMC Musculoskelet Disord 2013;9:287.
[39] Blangsted AK, Sogaard K, Hansen EA, Hannerz H, Sjogaard G. One-year randomized controlled trial with different physical-activity programs to reduce musculoskeletal symptoms in the neck and shoulders among office workers. Scand J Work Environ Health 2008;34:55—65.
[40] Ludewig PM, Borstad JD. Effects of a home exercise programme on shoulder pain and functional status in construction workers. Occup Environ Med 2003;60:841—9.
[41] Andersen LL, Saervoll CA, Mortensen OS, Poulsen OM, Hannerz H, Zebis MK. Effectiveness of small daily amounts of progressive resistance training for frequent neck/shoulder pain: randomised controlled trial. Pain 2011;152:440—6.
[42] Moher D, Hopewell S, Schulz KF, Montori V, Gotzsche PC, Devereaux PJ, et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. BMJ 2010;340:c869.
[43] Caneiro JP, O'Sullivan P, Burnett A, Barach A, O'Neil D, Tveit O, et al. The influence of different sitting postures on head/neck posture and muscle activity. Man Ther 2010;15:54—60.
[44] Falla D, Jull G, Russell T, Vicenzino B, Hodges P. Effect of neck exercise on sitting posture in patients with chronic neck pain. Phys Ther 2007;87:408—17.
[45] Thigpen CA, Padua DA, Michener LA, Guskiewicz K, Giuliani C, Keener JD, et al. Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. J Electromyogr Kinesiol 2010;20:701—9.
[46] Andersen JH, Kaergaard A, Mikkelsen S, Jensen UF, Frost P, Bonde JP, et al. Risk factors in the onset of neck/shoulder pain in a prospective study of workers in industrial and service companies. Occup Environ Med 2003;60:649—54.
[47] Arendt-Nielsen L, Graven-Nielsen T. Muscle pain: sensory implications and interaction with motor control. Clin J Pain 2008;24:291—8.
[48] Andersen LL, Andersen CH, Sundstrup E, Jakobsen MD, Mortensen OS, Zebis MK. Central adaptation of pain perception in response to rehabilitation of musculoskeletal pain: randomized controlled trial. Pain Physician 2012;15:385—94.