ORIGINAL PAPER

Physiotherapy Quarterly (ISSN 2544-4395)
2022, 30(2), 1–7

Investigation of muscle imbalance among asymptomatic and symptomatic neck pain male office workers

DOI: https://doi.org/10.5114/pq.2021.108679

Haifah Nitayarak, Pornpimol Charntaraviroj, Jiraphat Nawarat
Department of Physical Therapy, School of Allied Health Sciences, Walailak University, Tha Sala, Thailand

Abstract

Introduction. Office workers tend to have a forward head and shoulder posture during prolonged use of a computer, which can develop into neck pain owing to the imbalance of neck and shoulder muscles. The aim of this study was to evaluate neck and scapular muscle imbalance including the muscle length and strength among male office workers.

Methods. Overall, 72 male office workers aged 20–45 years were recruited for this study. There were 34 participants in the neck pain group and 38 participants in the asymptomatic group. The study was conducted through a self-report questionnaire including demographic data and work characteristics, and a test on neck and shoulder muscle length and strength performed by means of passive movement and a hand-held dynamometer, respectively.

Results. Office workers with neck pain demonstrated a significantly longer duration of computer use than workers without neck pain (6.50 ± 1.78 hours) ($p = 0.016$) and less strength in the neck flexor (0.154 ± 0.051 kg/body weight [BW]) ($p = 0.017$), in the neck extensor (0.183 ± 0.044 kg/BW) ($p = 0.029$), and on both sides of the serratus anterior muscles (0.233 ± 0.079 and 0.234 ± 0.063 kg/BW) ($p < 0.05$). However, there was no significant difference in muscle length between the groups.

Conclusions. The study indicated that male office workers with neck pain had a greater imbalance in the neck and shoulder muscles than asymptomatic office workers. Specific treatment for neck pain should be considered to promote muscle balance among male office workers.

Key words: muscles, computer, neck pain

Introduction

The incidence of neck pain has increased particularly among office workers. Previous studies have shown that the highest incidence of neck pain experiences among office workers using computers ranges from 17.7% up to 82.7% [1–5]. Approximately 60–80% of workers reported suffering from neck pain within the previous year [2]. Neck pain causes sickness, disability, decreased quality of work, and absence from work [1, 5], which can result in great medical costs and economic problems [6].

Work in an office can involve computer use, prolonged sitting position, repetitive computer tasks, and poor work posture [2]. Long-lasting poor postures, such as forward head and shoulder posture, are commonly found in office workers [1, 4, 7–9]. Previous studies have reported a positive correlation between the occurrence of neck pain and sitting duration, as well as prolonged forward neck bending [10], showing that increased forward head and shoulder posture is a risk factor for neck pain [9]. Nejati et al. [8] reported a significant increase in forward head posture among a group with neck pain while working on a computer compared with an asymptomatic group.

Prolonged forward head and shoulder posture can develop muscle imbalance in the neck and shoulder. The concept of muscle imbalance denotes an impaired correlation between muscle tightness and muscle weakness. Muscle tightness is generally stronger than that in opposite muscles, which inhibits opposite muscle activation, creating the weakness [11]. The pattern of muscle imbalance in forward head posture includes the tightness of the upper trapezius, levator scapulae, and sternocleidomastoid muscles, as well as the weakness of the deep cervical flexor muscles. The pattern of forward shoulder posture includes the tightness of the pectoral muscles and the weakness of the serratus anterior and middle and lower trapezius muscles [9, 11]. Muscle imbalance causes pain and structural dysfunction [11]. The imbalance of the cervical and scapulothoracic muscles contributes significantly to neck pain [9, 12]. Because of poor posture when using a computer, office workers may develop imbalance in the neck and shoulder muscles [9].

The pattern of muscle imbalance among office workers has led us to ask about the difference in muscle imbalance between office workers with and without neck pain. If there is any difference, treatment including muscle stretching, strengthening, co-contraction training, and alternative therapies [13] should be provided for specific muscles in order to prevent neck pain in office workers. Previous studies have compared the strength and length of the neck and scapular muscles between neck pain and asymptomatic groups [14–18]. The results showed a reduction in the strength of the cervical [14], middle trapezius [14, 16], lower trapezius [19, 20], and serratus anterior muscles, as well as a reduction in the length of the pectoralis minor muscle [16]. Some previous studies have found no significant differences in the length of the sternocleidomastoid muscle [21] and the strength of the upper [18] and lower trapezius muscles [14, 15]. However, evidence is still scarce. First, there is a lack of investigation on the pattern of muscle imbalance, including the length of the muscles that are prone to tightness, such as the upper trapezius and levator scapulae. Second, participants were not particularly specified as office workers, being at risk of neck pain, which may be related to poor posture and muscle imbalance. Third, many previous studies were concerned with

Correspondence address: Haifah Nitayarak, Department of Physical Therapy, School of Allied Health Sciences, Walailak University, 80161, Tha Sala, Nakhon Si Thammarat, Thailand, e-mail: haifah.sa@wu.ac.th

Received: 12.01.2021
Accepted: 14.04.2021

Citation: Nitayarak H, Charntaraviroj P, Nawarat J. Investigation of muscle imbalance among asymptomatic and symptomatic neck pain male office workers. Physiother Quart. 2022;30(2):1–7; doi: https://doi.org/10.5114/pq.2021.108679.

neck pain and investigated muscle imbalance among female workers. A small number of studies investigated male workers with neck pain. Therefore, the purpose of this study was to compare muscle imbalance, including the length and strength of the neck and scapular muscles, between neck pain and asymptomatic male office workers who had conditions related to the contractile tissue. We hypothesized that male office workers with neck pain would exhibit greater muscle imbalance including muscle tightness and weakness than workers without neck pain.

Subjects and methods

Subjects

A total of 72 men were recruited through convenience sampling from an oil company exploration site in the Phitsanulok province, Thailand. There were 34 persons in the neck pain group and 38 persons in the asymptomatic group. The inclusion criteria comprised the following characteristics: (1) office work with computer use and with at least 1 year of professional experience; (2) age of 20–45 years; (3) for the neck pain group, neck pain related to computer use which had lasted for more than 3 months and had been present in the past 7 days, with a visual analogue scale (VAS) score greater than 3, and normal end feel with full range of motion for cervical and shoulder joints in all directions as evaluated by passive movement without radicular pain to the upper extremities; (4) for the asymptomatic group, no discomfort or neck pain in the previous 7 days and full range of motion for cervical and shoulder joints in all directions without radicular pain as evaluated by active and passive range of motion; and (5) no medical conditions such as history of fracture or operation involving the spine, cardiopulmonary disorders, musculoskeletal problems such as scoliosis or ankylosing spondylitis, and neuromuscular disorders. The allocation of participants to the neck pain and asymptomatic group was based on the history of neck pain information from a self-report questionnaire. The questionnaire was filled in before taking the muscle length and strength test. If a participant had current neck pain (VAS > 3) with a history of pain for more than 3 months, the passive movement of the neck was evaluated by examiners to rule out any pathology of joint or nerve distribution. Individuals with no restriction of the neck and shoulder were recruited into our study. We found that none of the participants with neck pain had moderate to severe pain (VAS > 5), and all patients reported that their neck pain was aggravated when using a computer. All subjects were informed on the study protocol.

Examiners

Each muscle length and strength test was evaluated by 2 physical therapist examiners with at least 3 years of clinical experience. Before performing the examination, they were trained for at least 1 week by 2 experts with 15 years of clinical experience. Moderate to high inter-rater reliability was observed for the muscle length test (kappa agreement: 0.7–1.0) and the muscle strength test (intraclass correlation coefficient$_{(3,1)}$: 0.68–0.96).

Procedure

The cross-sectional study was conducted in May and June 2015. A self-questionnaire was provided to record the participant's demographic and working information. The muscle length and strength tests were applied in a designated testing room, with room temperature control and the same duration of the testing methods. All subjects were asked to avoid drinking alcohol and to have a 7-hour good quality sleep prior to the muscle length and strength testing to obtain satisfactorily results.

Self-report questionnaire

A self-report questionnaire included the identification of areas with body pain, pain intensity, duration of neck pain occurrences (less or more than 3 months), pain cause, and aggravating factors such as computer or other tasks, demographic data (gender, age, weight, height, dominant side, work experience, medical history, and frequency of exercises), and work characteristics (type of work, use of a computer, duration of the sitting position, duration of the standing position, and duration of walking during work [hours/day]).

Muscle length test

Muscle length was measured by using passive movement on the basis of standard procedures [11]. Four muscles were considered, including both sides: the sternocleidomastoid, upper trapezius, levator scapulae (sitting position), and pectoralis major (lying position) (Figure 1). The length was reported in 2 categories: (1) normal length, as referred to the soft end feel with a full range of motion; and (2) tightness, as referred to the firm or hard end feel with a limited range of motion [11].

Muscle strength test

Muscle strength was measured by using a hand-held dynamometer (Lafayette, USA) with the make technique [22]. The muscles included the neck muscles (cervical flexors and extensors) (sitting position), both sides of the scapular muscles including the upper trapezius and serratus anterior (sitting position), and the middle and lower trapezius (prone lying position) (Figure 2) [22, 23]. The subjects were asked to perform the test 3 times, with at least 5-second break between the tests. The maximum score for each trial was recorded. The strength was presented as the absolute muscle strength divided by the individual's body weight (kg/BW) [24].

Statistical analysis

The data were analysed with the IBM SPSS software, version 20 (IBM Corp., USA). Descriptive statistics were used to report each variable (mean and standard deviation). A chi-squared test served to analyse the difference in categorical variables (number and percentage), and an independent *t*-test to compare the difference in continuous variables (mean and standard deviation). Statistical significance was assumed at the level of $p < 0.05$. The sample size was calculated with the following formula, in accordance with Alpayci et al. [25]:

$$n = 2(Z_\alpha + Z_\beta)^2\, \sigma^2 \div (\mu_1 - \mu_2)^2$$

where α – error level (two-sided) ($\alpha = 0.05$, $Z_\alpha = 1.96$), β – power level ($\beta = 0.8$, $Z_\beta = 0.84$), σ – standard deviation, $\mu_1 - \mu_2$ – mean difference.

The statistical values for the flexion/extension strength ratio were: $\mu_1 = 1.46$, $\mu_2 = 1.21$, and $\sigma = 0.35$. Assuming a 5% type 1 error with the statistical power of 80%, a sample size of approximately 30 participants was calculated for each group.

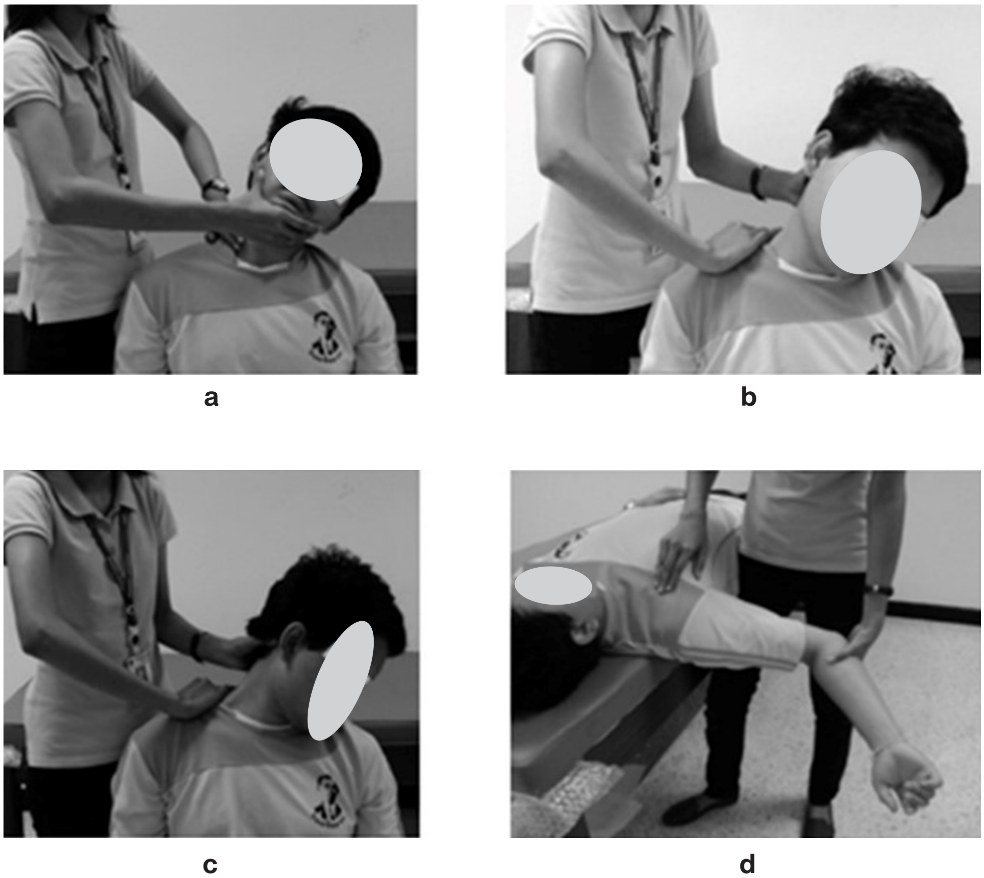

Figure 1. The assessment of muscle length: (a) sternocleidomastoid, (b) upper trapezius, (c) levator scapulae, and (d) pectoralis major

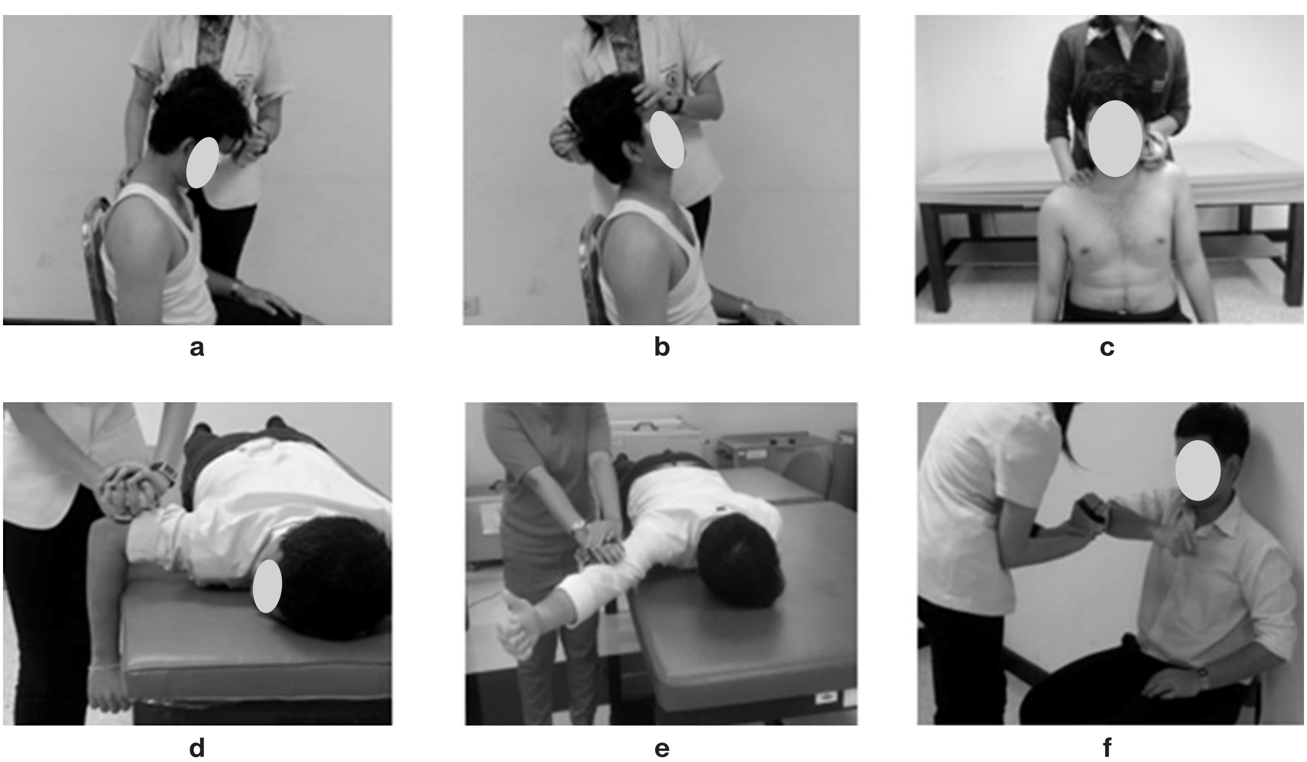

Figure 2. The assessment of muscle strength: (a) cervical flexors, (b) cervical extensors, (c) upper trapezius, (d) middle trapezius, (e) lower trapezius, and (f) serratus anterior

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of the Mahidol University Central Institutional Review Board (MU-CIRB COA, No. 2015/046.1604).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Patient characteristics

The analysis of demographic data showed no significant difference in age, weight, height, body mass index, hand dominance, or work experience between the neck pain group and the asymptomatic group. As for the duration of the work position, the results revealed a significantly higher duration of computer use in the neck pain group (6.50 ± 1.78 hours/day) when compared with the asymptomatic group (5.32 ± 1.61 hours/day) ($p < 0.05$) (Table 1).

Table 1. Participant characteristics

Characteristics	Neck pain group (n = 34)	Asymptomatic group (n = 38)	p
Age (years)	35.35 ± 7.83	36.66 ± 8.40	0.499
Weight (kg)	77.63 ± 13.43	73.92 ± 11.00	0.207
Height (cm)	173.35 ± 5.24	171.74 ± 5.91	0.226
Body mass index (kg/m^2)	25.77 ± 3.87	25.06 ± 3.39	0.407
Work experience (years)	6.47 ± 4.42	6.43 ± 5.20	0.741
Duration of computer use (hours/day)	6.50 ± 1.78	5.32 ± 1.61	0.016*
Duration of sitting (hours/day)	6.16 ± 2.70	5.39 ± 1.78	0.164
Duration of standing or walking (hours/day)	2.25 ± 1.79	2.87 ± 1.80	0.149

Verified with an independent t-test. Values are presented as mean ± standard deviation.
* significant value ($p < 0.05$)

Table 2. Comparison of muscle length between the neck pain and the asymptomatic group

Muscles	Neck pain group (n = 34)		Asymptomatic group (n = 38)		p
	Normal	Tightness	Normal	Tightness	
Sternocleidomastoid	14 (41.18)	20 (58.82)	21 (55.26)	17 (44.74)	0.233
Upper trapezius	8 (23.53)	26 (76.47)	9 (23.68)	29 (76.32)	0.988
Levator scapulae	11 (32.35)	23 (67.65)	13 (34.21)	25 (65.79)	0.867
Pectoralis major	8 (23.53)	26 (76.47)	8 (21.05)	30 (78.95)	0.801

Verified with a chi-squared test. Values are presented as number (%).

Table 3. Comparison of muscle strength (kg/body weight) between the neck pain and the asymptomatic group

Muscles	Neck pain group (n = 34)	Asymptomatic group (n = 38)	p
Neck flexors	0.154 ± 0.051	0.185 ± 0.056	0.017*
Neck extensors	0.183 ± 0.044	0.211 ± 0.061	0.029*
Right upper trapezius	0.243 ± 0.092	0.261 ± 0.094	0.395
Left upper trapezius	0.227 ± 0.073	0.253 ± 0.088	0.182
Right middle trapezius	0.194 ± 0.040	0.198 ± 0.057	0.721
Left middle trapezius	0.097 ± 0.047	0.209 ± 0.058	0.345
Right lower trapezius	0.101 ± 0.026	0.106 ± 0.033	0.527
Left lower trapezius	0.099 ± 0.031	0.100 ± 0.028	0.918
Right serratus anterior	0.233 ± 0.079	0.267 ± 0.068	0.050*
Left serratus anterior	0.234 ± 0.063	0.265 ± 0.070	0.048*

Verified with an independent t-test. Values are presented as mean ± standard deviation.
* significant value ($p < 0.05$)

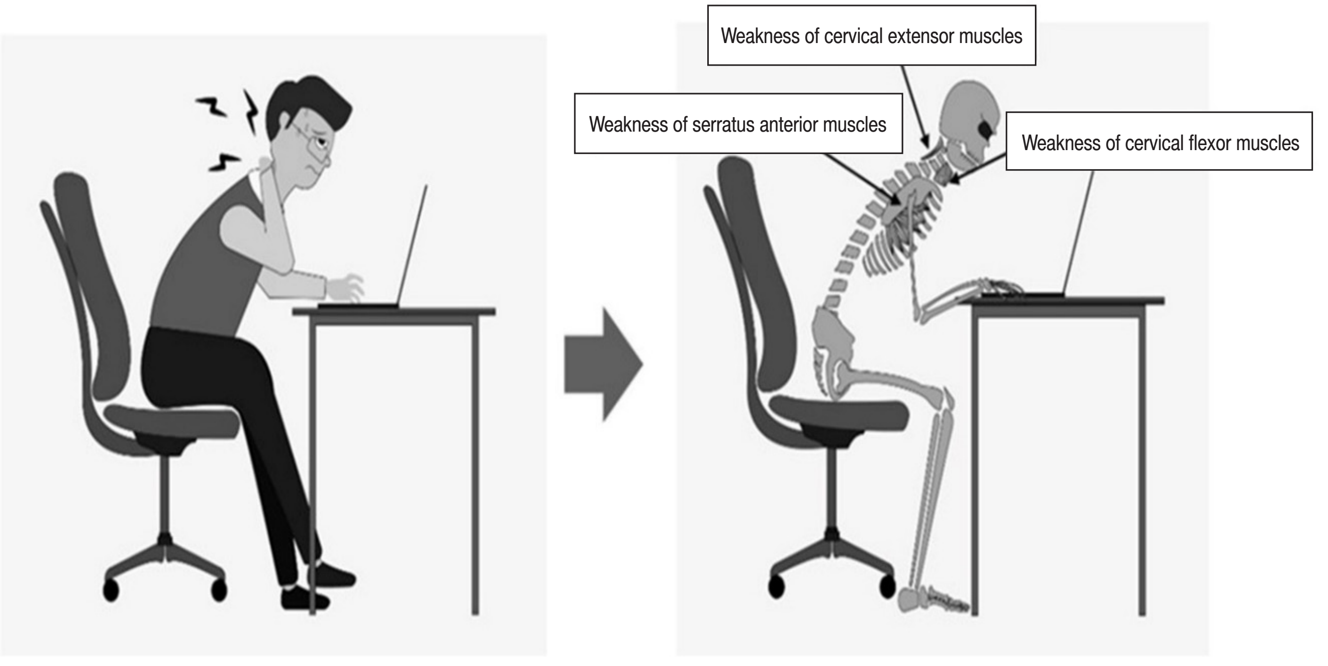

Figure 3. The overall negative impact of office work on neck pain

Muscle length and muscle strength tests

The muscle length test demonstrated no significant difference in the length of the sternocleidomastoid, upper trapezius, levator scapulae, and pectoral muscles between the groups (Table 2). The muscle strength test revealed a significantly lower strength of the cervical flexor, cervical extensor, and both sides of the serratus anterior muscles in the neck pain group when compared with the asymptomatic group (Table 3). The negative impact of office work on neck pain development is depicted in Figure 3.

Discussion

The current study found that there were significant differences in the duration of computer use and in the strength of the neck flexor, neck extensor, and both sides of the serratus anterior muscles between the neck pain and asymptomatic groups. The analysis of work duration revealed that office workers with neck pain used a computer for a longer period than those in the asymptomatic group. Our results further demonstrated that both groups used a computer for more than 5 hours per day and the neck pain group spent a longer time on computer use than the asymptomatic group. The duration of computer use that leads to neck pain among office workers is a topic of debate. In line with the present finding, similar previous studies interestingly pointed out that the duration of ≥ 3 hours of computer working per day was likely to increase the risk of neck pain [26–28].

It is surprising that there are few studies that investigated the length of the neck and shoulder muscles, particularly among neck pain and asymptomatic male office workers. However, a previous study by Cibulka et al. [17] demonstrated results similar to those of our study, i.e., no significant differences in the sternocleidomastoid muscle between the neck pain and the asymptomatic groups. In contrast, Shahidi et al. [14] reported a significant difference in the reduction of the pectoralis minor muscle in the neck pain group when compared with the asymptomatic group. Our findings further showed no differences in the muscle length test, which was most likely due to muscle tightness observed generally in people with an inadequate posture and without pain, especially in office workers [9]. Besides, this may be because we recruited participants who exhibited a full range of motion in the neck and shoulder without radicular pain; the symptomatic group presented less neck pain and tightness in the neck and shoulder muscles when compared with the asymptomatic group [17]. Finally, the results of the muscle length assessment were determined by a clinician in identifying normal muscle length and muscle tightness, which showed no difference of the length when compared with the quantitative scale of the measurement.

The results of the muscle strength test demonstrated a significantly lower strength of the cervical flexor, cervical extensor, and both sides of the serratus anterior muscles in office workers with neck pain than in the asymptomatic group. Previous studies have reported lower strength of the cervical flexor [19, 21] and extensor muscles [14, 19, 21] in a group with neck pain when compared with an asymptomatic group, corroborating our results. Cervical flexor and extensor muscles primarily coactivate to maintain the alignment and movement of the cervical spine and head. Office workers tend to increase forward head posture while using a computer as a result of lower cervical flexion and upper cervical extension. This leads to the elongated cervical flexor muscles becoming weak and the shortened cervical extensor muscles becoming tight, which increases the compression force exerted on the posterior vertebral body and on facet joints of the neck, resulting in neck pain [9]. Increased muscle activation during prolonged computer use can cause muscle fatigue and excessive stretching, which contributes to muscle reflex inhibition and, subsequently, to muscle weakness and pain [11]. The model of pain adaptation assumes that pain can inhibit muscle activity, which induces muscle weakness [20]. Therefore, office workers with neck pain have shown weakness in the cervical flexor and extensor muscles.

Previous studies have investigated scapular muscle strength in participants with neck pain. For example, Shahidi et al. [14] reported a significant difference in the strength of the middle trapezius and rhomboid muscles, but a non-significant difference in the strength of the lower trapezius muscle between the neck pain and healthy groups. Petersen and Wyatt [15] found a non-significant difference in the strength of the lower trapezius muscle between the side with neck pain and the non-neck-pain side. Petersen et al. [16] observed a significantly lower strength of the serratus anterior muscle and the middle and lower trapezius muscles in a group with neck pain when compared with an asymptomatic group ($p < 0.05$). We demonstrated only a significantly lower strength of the serratus anterior muscle in office workers with neck pain than in the asymptomatic group, which contrasts with previous studies. This may be because office workers with neck pain had greater scapular protraction than asymptomatic office workers while working for long hours with a computer [29]. Serratus anterior is a primary mover muscle that protracts the scapula. Prolonged scapular protraction during computer use leads to increased muscle activation that may cause muscle fatigue and excessive stretching, potentially contributing to pain, reflex inhibition, and muscle weakness [11].

Serratus anterior acts together with the upper trapezius as a force couple for scapular upward rotation during arm elevation [30]. The weakness of the serratus anterior leads to an increase in the activation of the upper trapezius, which results in increased stress in the cervical spine and contributes to neck pain [9, 11]. Although many previous studies have found less strength in the various cervical and scapular muscles of participants with neck pain, our findings showed that male office workers with neck pain had less strength in the cervical flexor, neck extensor, and both sides of the serratus anterior muscles when compared with office workers without neck pain. In addition, our study indicated that mild neck pain could significantly correlate with the imbalance of neck and scapular muscles among male office workers. This finding specifically highlights the need for strengthening exercises for muscle weaknesses to prevent further neck pain.

Limitations

There were several limitations in this study. First, we did not investigate the posture of individual office workers to reveal the extent of their forward head and shoulder posture in order to identify muscle imbalance more precisely. Second, we recruited our participants in the age range of 20–45 years and with professional working experience with a computer use of at least 1 year. However, the wide age range can be a confounding factor, so more specific age groups should be included in further investigation. Third, we recruited only men because a small number of studies among men had been performed before. Nevertheless, neck pain is common among women as well and there are differences in muscle strength between the genders; therefore, women should be recruited as participants in future studies. Finally, further research on the regression analysis of age, body mass index, working duration, and muscle imbalance should be seriously considered to evaluate the impact of the variables.

Conclusion

The current study suggested a lower strength of the cervical flexor, cervical extensor, and serratus anterior muscles in male office workers with neck pain when compared with asymptomatic office workers. The results indicated that male office workers with neck pain had a greater imbalance of the neck and shoulder muscles than asymptomatic office workers. A comprehensive future study with both genders on abnormal postures such as forward head and shoulder posture is recommended to better understand the prevention and control of neck pain and, for policymakers, to determine standard guidelines in addressing the impact of muscle imbalance among office workers.

Acknowledgements

We would like to especially thank Wattana Jalayondeja, Keerin Mekhora, and Chutima Jalayondeja for giving us the opportunity to perform this research. We would also like to thank all participants and all staff of occupational health for providing information during data collection.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Green BN. A literature review of neck pain associated with computer use: public health implications. J Can Chiropr Assoc. 2008;52(3):161–167.
2. Paksaichol A, Janwantanakul P, Purepong N, Pensri P, van der Beek AJ. Office workers' risk factors for the development of non-specific neck pain: a systematic review of prospective cohort studies. Occup Environ Med. 2012;69(9):610–618; doi: 10.1136/oemed-2011-100459.
3. Ehsani F, Mosallanezhad Z, Vahedi G. The prevalence, risk factors and consequences of neck pain in office employees. Middle East J Rehabil Health. 2017;4(2):e42031; doi: 10.5812/mejrh.42031.
4. Tantipanjaporn T, Yoonim Y, Tongmee Y, Keeratisiroj O. The effect of computer using workload on work-related upper extremity, neck and back musculoskeletal disorders among office workers [in Thai]. Srinagarind Med J. 2019;34(1):60–67.
5. Côté P, van der Velde G, Cassidy JD, Carroll LJ, Hogg-Johnson S, Holm LW, et al. The burden and determinants of neck pain in workers: results of the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and Its Associated Disorders. Eur Spine J. 2008;17(Suppl. 1): 60–74; doi: 10.1007/s00586-008-0626-9.
6. Furlan AD, Yazdi F, Tsertsvadze A, Gross A, Van Tulder M, Santaguida L, et al. A systematic review and meta-analysis of efficacy, cost-effectiveness, and safety of selected complementary and alternative medicine for neck and low-back pain. Evid Based Complement Alternat Med. 2012;2012:953139; doi: 10.1155/2012/953139.
7. Battecha KH, Abdel Raoof NA, Kamel DM, Tantawy SA. The effect of cranio-cervical flexion training and rest breaks on neck pain and functional performance in visual display unit users. Biosci Res. 2018;15(4):3708–3717.
8. Nejati P, Lotfian S, Moezy A, Nejati M. The study of correlation between forward head posture and neck pain in Iranian office workers. Int J Occup Med Environ Health. 2015;28(2):295–303; doi: 10.13075/ijomeh.1896.00352.
9. Singla D, Veqar Z. Association between forward head, rounded shoulders, and increased thoracic kyphosis: a review of the literature. J Chiropr Med. 2017;16(3):220–229; doi: 10.1016/j.jcm.2017.03.004.
10. Cagnie B, Danneels L, Van Tiggelen D, De Loose V, Cambier D. Individual and work related risk factors for neck pain among office workers: a cross sectional study. Eur Spine J. 2007;16(5):679–686; doi: 10.1007/s00586-006-0269-7.

11. Page P, Frank CC, Lardner R. Assessment and treatment of muscle imbalance: the Janda approach. Champaign: Human Kinetics; 2010.
12. Cagnie B, Struyf F, Cools A, Castelein B, Danneels L, O'Leary S. The relevance of scapular dysfunction in neck pain: a brief commentary. J Orthop Sports Phys Ther. 2014;44(6):435–439; doi: 10.2519/jospt.2014.5038.
13. Debre E, Alptekin K, Alptekin JÖ, Giritharan A. Study on the effect of TENS, exercise and friction massage on the masseter regarding masseter-derived cervical myofascial pain. Adv Rehabil. 2020;34(2):1–9; doi: 10.5114/areh.2020.94316.
14. Shahidi B, Johnson CL, Curran-Everett D, Maluf KS. Reliability and group differences in quantitative cervicothoracic measures among individuals with and without chronic neck pain. BMC Musculoskelet Disord. 2012;13(1):215; doi: 10.1186/1471-2474-13-215.
15. Petersen SM, Wyatt SN. Lower trapezius muscle strength in individuals with unilateral neck pain. J Orthop Sports Phys Ther. 2011;41(4):260–265; doi: 10.2519/jospt.2011.3503.
16. Petersen SM, Domino NA, Cook CE. Scapulothoracic muscle strength in individuals with neck pain. J Back Musculoskelet Rehabil. 2016;29(3):549–555; doi: 10.3233/BMR-160656.
17. Cibulka MT, Herren J, Kilian A, Smith S, Mahmutovic F, Dolles C. The reliability of assessing sternocleidomastoid muscle length and strength in adults with and without mild neck pain. Physiother Theory Pract. 2017;33(4):323–330; doi: 10.1080/09593985.2017.1302539.
18. Choudhari R, Anap D, Rao K, Iyer C. Comparison of upper, middle, and lower trapezius strength in individuals with unilateral neck pain. Spine. 2012;1(3):1000115; doi: 10.4172/2165-7939.1000115.
19. Chiu TTW, Sing KL. Evaluation of cervical range of motion and isometric neck muscle strength: reliability and validity. Clin Rehabil. 2002;16(8):851–858; doi: 10.1191/0269215502cr550oa.
20. Lund JP, Donga R, Widmer CG, Stohler CS. The pain-adaptation model: a discussion of the relationship between chronic musculoskeletal pain and motor activity. Can J Physiol Pharmacol. 1991;69(5):683–694; doi: 10.1139/y91-102.
21. Pearson I, Reichert A, De Serres SJ, Dumas J-P, Côté JN. Maximal voluntary isometric neck strength deficits in adults with whiplash-associated disorders and association with pain and fear of movement. J Orthop Sports Phys Ther. 2009;39(3):179–187; doi: 10.2519/jospt.2009.2950.
22. Michener LA, Boardman ND, Pidcoe PE, Frith AM. Scapular muscle tests in subjects with shoulder pain and functional loss: reliability and construct validity. Phys Ther. 2005;85(11):1128–1138; doi: 10.1093/ptj/85.11.1128.
23. Kolber MJ, Cleland JA. Strength testing using hand-held dynamometry. Phys Ther Rev. 2005;10(2):99–112; doi: 10.1179/108331905X55730.
24. McGrath R. Comparing absolute handgrip strength and handgrip strength normalized to body weight in aging adults. Aging Clin Exp Res. 2019;31(12):1851–1853; doi: 10.1007/s40520-019-01126-5.
25. Alpayci M, Şenköy E, Delen V, Şah V, Yazmalar L, Erden M, et al. Decreased neck muscle strength in patients with the loss of cervical lordosis. Clin Biomech. 2016;33:98–102; doi: 10.1016/j.clinbiomech.2016.02.014.
26. Sabeen F, Bashir MS, Hussain SI, Ehsan S. Prevalence of neck pain in computer users. Ann King Edw Med Univ. 2013;19(2):131–137; doi: 10.21649/akemu.v19i2.498.
27. De Loose V, Burnotte F, Cagnie B, Stevens V, Van Tiggelen D. Prevalence and risk factors of neck pain in military office workers. Mil Med. 2008;173(5):474–479; doi: 10.7205/milmed.173.5.474.
28. Lindgren Griffiths K, Mackey MG, Adamson BJ. The impact of a computerized work environment on professional occupational groups and behavioural and physiological risk factors for musculoskeletal symptoms: a literature review. J Occup Rehabil. 2007;17(4):743–765; doi: 10.1007/s10926-007-9108-x.
29. Szeto GPY, Straker L, Raine S. A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. Appl Ergon. 2002;33(1):75–84; doi: 10.1016/s0003-6870(01)00043-6.
30. Goldstein B. Shoulder anatomy and biomechanics. Phys Med Rehabil Clin N Am. 2004;15(2):313–349; doi: 10.1016/j.pmr.2003.12.008.