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Effects of Strength and Endurance Training of Superficial and Deep Neck Muscles on Muscle Activities and Pain Levels of Females with Chronic Neck Pain

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Abstract. [Purpose] To compare muscle activities and pain levels of females with chronic neck pain receiving different exercise programs. [Subjects and Methods] One hundred females with chronic neck pain participated in this study. They were randomly allocated into 4 groups (n = 25) on the basis of the exercises performed as follows: strength-endurance exercise, craniocervical flexion exercise, combination of strength-endurance and craniocervical flexion exercise and control groups. Pain, disability levels and changes in the muscle activities of the cervical erector spinae (CE), sternocleidomastoid (SCM), anterior scalenes (AS) and upper trapezius (UT) muscles were evaluated before and after the interventions. [Results] After 12 weeks of exercise intervention, all three exercise groups showed improvements in pain and disability. The muscle activities during the typing task were significantly different from the control group in all three exercise groups for all muscles except those of the extensor muscles in the craniocervical flexion exercise group. [Conclusion] The results of this study indicate that exercises for the cervical muscles improve pain and disability. The exercise programs reduced the activities of almost all cervical muscles.
Key words: Chronic neck pain, Exercise, Muscle activity

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INTRODUCTION

Neck pain is a common musculoskeletal disorder that leads to significant disability in the general population. In a 6-month period, 54% of adults suffer from neck pain, and 4.6% experience limitations of important activities because of neck problems[1)]. Borghouts et al. reported that 30% of men and 43% of women were affected by neck pain at some time in their lives, and that the symptoms became chronic among 10% of men and 17% of women[2)]. The prevalence of this condition increases with age and is greater in women than men[1)].

Musculoskeletal disorders of the neck are very common among office workers. Various factors have been identified as predisposing to neck pain, such as the duration of computer use, sustained awkward posture, and prolonged working with a visual display unit (VDU)[3, 4)]. A prolonged forward head posture is commonly adopted by this occupational group, and it may be associated with musculoskeletal disorders[5)]. Biomechanically, sustained forward flexion of the neck results in increased compressive loading on the cervical spine and a creep response in the surrounding soft tissues. Also the source of pain is excessive loading of the cervical and shoulder girdle muscles, especially in low-load repetitive work which promotes over-activity of low threshold motor units[6)]. Other mechanisms, such as nociceptor sensitization due to intra-muscular shear forces are also considered to play a role[7)]. These phenomena may concurrently increase electromyographic activity of the cervical musculature, such as neck extensor muscles and the levator scapulae. In addition, the superficial muscles of the neck-shoulder region, i.e., the sternocleidomastoid, anterior scalene and upper trapezius muscles, demonstrate increased activities compared to deeper postural stabilizers like the deep cervical flexors[8)]. Moreover, several studies have reported significantly lower maximal isometric strength of both the cervical flexors and extensors in patients with chronic neck pain compared to healthy controls[9–11)] and one study also found weakness of the neck rotator muscles[12)].

Recent studies have shown that the activities of the deep cervical flexor muscles, such as the longus colli and longus capitis, are impaired in persons with neck pain[13)]. Furthermore, the findings of a significant deficit in the ability to maintain low or moderate load by the CCF muscles suggests that head and neck postural orientation is challenged under prolonged or repetitive circumstances in neck pain patients. The CCF muscles may fatigue prematurely and be incapable of controlling cranio-cervical orientation. This potentially exposes cervical spine tissues to abnormal mechanical load[14)]. Indeed, evidence is emerging that persons with neck pain tend to adopt a more forward head position when distracted[15)]. This has been observed despite a lack

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of postural differences in erect sitting[16, 17]. Moreover, retraining the deep cervical flexor muscles has been shown to decrease neck symptoms and increase the activation of the deep cervical flexor muscles during performance of a cranio-cervical flexion test[18]. This may improve the capacity of the cervical spine to sustain an upright posture.

Physical exercise has been recommended as a treatment for musculoskeletal neck disorders[19, 20]. While several studies have demonstrated that pain can to some extent be reduced by strength training[19–22] or endurance training[21, 22], one study found no effect of physical training on nonspecific pain in the neck area[21]. A recent review showed limited evidence for the efficacy of physical exercise in the treatment of symptoms of the neck and/or shoulder due to the lack of high-quality research[23]. One meta-analysis concluded that there was unclear and insufficient evidence in support of the benefit of strengthening exercises for neck pain[24] and the relative benefit of different exercise approaches, such as cranio-cervical flexion of the deep cervical flexor muscles. Although there is some evidence of pain reduction occurring following strengthening, endurance or cranio-cervical flexion exercise[19, 20, 22], it is not known how the training influences the muscle activities of persons with chronic neck pain during working with a computer.

SUBJECTS AND METHODS

A randomized control trial compared outcomes among 3 neck muscle exercise programs and a control group.

Subjects who participated in this study were females, aged between 20 and 35 with a history of intermittent work-related neck pain lasting for more than 6 months. They worked with a computer at least 4 hours each working day. The pain level at the time of examination exceeded 30 mm on a visual analogue scale of 0–100 mm. Subjects were excluded if they had neck or shoulder pain from non-musculoskeletal causes, demonstrated neurological signs, or had a history of malignancy, pregnancy, or menstruation at the time of examination.

This study received approval from the Mahidol University Institutional Review Board and is in full compliance with International Guidelines for Human Research Protection, the Declaration of Helsinki, the Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice. All subjects received verbal and written information about the study and signed a consent form.

We used a visual analogue scale (VAS) to assess pain. The extremes were “no pain” and “pain as bad as it could be”. The Neck Disability Index (NDI) used in this study was the Thai version of NDI developed by Luckumnueporn et al[25]. This outcome measure was translated in accordance with cross cultural adaptation guidelines. Surface electromyography (sEMG) was used to obtain electromyograms of the: upper trapezius (UT)[26], cervical erector spinae (CE)[26], sternal head of the sternocleidomastoid (SCM)[27] and anterior scalenes (AS)[27] using pairs of standard adhesive surface electrodes.

EMG data were collected during standardized maneuvers to normalize of the EMG amplitude to maximum voluntary contraction (MVC). Each MVC task was performed for 10 seconds and repeated 3 times with 30 seconds rest between each repetition. MVC tasks for the normalization of SCM and AS were performed in supine lying. The subjects flexed the chin and lifted the head so that it just cleared the bed and held this position[13]. For the UT muscles, the subject performed shoulder elevation[26]. For the CE muscles, the subject raised and held her head 20 mm above the bed in prone lying[4].

Neck muscle activities were measured by an 8-channel surface EMG device (Myresearch XP master edition 1.06.64 program, Naroxon INC, USA© 2006) at a frequency of 1,000 Hz. The EMG signals were recorded using bipolar Ag-AgCl surface electrodes. Subjects were asked to sit on a chair with their backs supported in a comfortable position. The EMG electrodes were attached to the skin with hypoallergenic tape at an inter-electrode distance of 1 cm; the inter-electrode impedance was kept below 2 KΩ[26].

Subjects who met the criteria were invited to participate in the study and were randomized by the slot-drawing method into 4 groups: a strength-endurance exercise group (group 1), a cranio-cervical flexion exercise group (group 2), a combined exercise group (group 3), and a control group (group 4).

The strength-endurance exercise consisted of a progressive resistance exercise program for the neck muscles, especially the superficial neck flexor and extensor muscles (SCM, AS and CE). Neck flexion and extension were performed in the supine and prone positions, respectively, with the head supported in a comfortable resting position. Subjects slowly moved the head and neck through the total range of motion avoiding discomfort or symptom reproduction. This exercise program included two phases. The first phase of 4 weeks and the second of 8 weeks were recommended for initiating a weight program in untrained individuals[28]. In phase one, each subject performed 12–15 repetitions with a weight that they could lift 12 times on the first training session (12 repetitions maximum) and progress to 15 repetitions. They were maintained at this level for 4 weeks. In phase two, subjects performed 3 sets of 15 repetitions of the initial 12 repetitions at maximum load with one minute rest interval between sets.

The craniocervical flexion exercise consisted of a low load exercise for the cranio-cervical flexor muscles. Subjects lay supine and slowly moved the head to the inner range of cranio-cervical flexion, guided by feedback from an air filled pressure sensor placed suboccipitally behind the neck and inflated to a baseline pressure of 20 mmHg. Subjects moved the head to increase the pressure to between 22 to 30 mmHg; and maintained this position for 10 seconds in 15 repetitions. The subjects maintained the 10-second contraction with no pain. Ten seconds rest was allowed between each contraction. The targets of this exercise are the deep flexors of the upper cervical region, the longus capitis and colli, rather than the superficial flexors, which flex the neck but not the head.

The combined exercise group performed both strength-endurance and cranio-cervical flexion exercises. First, subjects lay supine and performed the cranio-cervical flexion exercise. A five minute rest was then taken before performing the strength-endurance exercise.

Subjects in each group performed exercise every day for 12 weeks and kept a log book for monitoring. Exercise compliance in this study was over 80% in all groups.

VAS and NDI were recorded before a copy-typing task. The sEMG were recorded in two sessions during a copy-typing task lasting 5 minutes. After exercise training of 12 weeks, VAS, NDI and sEMG were recorded again for all subjects. For the copy-typing task, subjects sat at a standard office desk on an adjustable office chair. They could adjust the chair and desk before the test to obtain the most comfortable position, but they were not allowed to move between tasks. The visual display monitor and keyboard were positioned directly in front of the subjects for the typing tasks. A copy-typing task was chosen over typing from a document holder to eliminate movement of the head or the need to change head position from document to screen as needed for eye-hand coordination activities. The copy-typing task was performed continuously for 5 minutes.

After finishing data collection, subjects in the control group were advised to perform both the strength-endurance and cranio-cervical exercises. In the strength-endurance exercise group, subjects were trained in how to perform deep cervical flexor muscle (CCF exercise) and subjects in the CCF exercise group were trained in how to perform strength-endurance exercise.

The statistical analyses of the data were performed using SPSS version 17.0. The VAS, NDI scores and the averages of root mean square (RMS) sEMG values were used in the analyses. Statistical significance was accepted for values of $p<0.05$. One-way ANOVA was used to identify differences in the characteristics of subjects using VAS, EMG and NDI values before the exercise interventions among the 4 groups. Two-way ANOVA was used to evaluate the effects of group (exercise groups) and time (pre-and post-intervention) on the outcomes. A post hoc multiple comparisons test with Bonferroni correction was used to identify differences among groups.

RESULTS

Subjects in this study were 100 females who had a history of intermittent work-related neck pain. The demographic data of all groups are presented in Table 1. All subjects completed 12 weeks of exercise intervention with no dropouts.

The Neck Pain and Disability scores showed that there was a significant interaction of group by time ($p<0.001$), and significant main effects of group ($p<0.001$) and time ($p<0.001$) in the VAS and NDI scores. Main effects analysis showed that there were significant differences in VAS between before and after in groups 1, 2 and 3 ($p = 0.002$), but there were no differences between before and after in the control group ($p = 0.575$). A post-hoc multiple comparison with Bonferroni correction was then performed. This showed that VAS of all groups after the intervention were significantly different except the VAS scores between group 1 and group 2. Similarly, there were significant main effects of group ($p<0.001$) and time ($p<0.001$). For NDI scores, main effects analysis of time (before and after 12 week) showed that there were significant differences group 1, 2 and 3 ($p = 0.001$), but there was no difference in the control group ($p = 0.091$). The post hoc multiple comparison with Bonferroni correction revealed that the control group after the intervention was significantly different from all the other groups, and that there were no differences among the NDI scores of group 1, 2 and 3. VAS and NDI scores of each group before and after exercise are presented in Tables 2 and 3.

Table 1. Characteristics of subjects

Characteristics	Group 1 (n = 25)	Group 2 (n = 25)	Group 3 (n = 25)	Group 4 (n = 25)
Age (year)	32.72 (3.11)	30.40 (3.54)	30.16 (2.96)	29.32 (3.11)
Weight (kg)	50.72 (7.76)	54.56 (9.14)	49.40 (5.91)	55.28 (10.97)
Height (cm)	158.02 (7.26)	158.16 (4.88)	156.88 (5.47)	157.24 (6.41)
BMI (kg/m^2)	20.32 (2.43)	22.51 (5.51)	20.24 (2.72)	23.47 (5.93)

Data are expressed in means (SD) group 1 = strength-endurance exercise, group 2 =craniocervical flexion exercise, group 3 = combination of endurance-strength and craniocervical flexion exercise, and group 4 =control

Table 2. Visual analogue scale (VAS) (mm) at the baseline and 12 weeks

Group	VAS	
	Baseline	12 weeks
1	55.00 (10.98)	38.68 (9.49)
2	56.04 (22.66)	43.04 (18.56)
3	61.48 (16.68)	16.88 (7.75)
4	59.04 (10.49)	61.32 (11.29)

Data are expressed in means (SD) group 1 = strength-endurance exercise, group 2 =craniocervical flexion exercise, group 3 = combination of endurance-strength and craniocervical flexion exercise, and group 4 =control

Table 3. Neck Disability Index (NDI) at the baseline and 12 weeks

Group	NDI score	
	Baseline	12 weeks
1	28.20 (5.56)	14.69 (4.64)
2	29.96 (4.51)	14.41 (4.94)
3	29.23 (5.27)	15.71 (3.01)
4	31.56 (5.14)	33.86 (5.04)

Data are expressed in means (SD) group 1 = strength-endurance exercise, group 2 =craniocervical flexion exercise, group 3 = combination of endurance-strength and craniocervical flexion exercise, and group 4 =control

The results of normalized RMS sEMG values of the cervical erector spinae, sternocleidomastoid, anterior scalenes and upper trapezius muscle during the copy-typing task reveal that there were significant interactions of group with time ($p<0.001$) for all muscles except the left AS muscle ($p=0.158$). The main effect of group ($p<0.001$) and time ($p<0.001$) was also significant for all muscles. RMS values of each group before and after exercise are presented in Table 4. Main effects analysis showed that there were significant differences in RMS between before and after the exercise interventions in groups 1, 2 and 3 for the cervical erector spinae and anterior scalenes, sternocleidomastoid ($p<0.05$); (both right and left sides) and in all groups for both the right and left of upper trapezius muscles ($p<0.05$). However, there were no other significant differences between before and after in the control group ($p = 0.332$, $p = 0.261$ for right and left cervical erector spinae; $p = 0.524$, $p = 0.775$ for right and left sternocleidomastoid; $p = 0.72$, $p = 0.985$ for right and left anterior scalenes). A post-hoc multiple comparison with Bonferroni correction was performed. The analysis showed that group 4 had significantly different RMS sEMG in all muscles from the other groups, except the left cervical erector spinae. However, there were no differences among the RMS sEMG values of groups 1, 2 and 3.

DISCUSSION

The results of this study support the recommendation to use strength-endurance and the cranio-cervical flexion (CCF) exercises for the cervical muscles as treatment interventions for patients with chronic neck pain[19, 20]. The results were also in agreement with previous studies that

Table 4. The root mean square (RMS) values at baseline and 12 weeks

Muscle	Side	Group	RMS values	
			Baseline	12 weeks
Cervical erector spinae	Right	1	14.73 (6.51)	5.91 (1.26)
		2	17.74 (7.67)	5.88 (0.94)
		3	14.46 (6.82)	6.57 (1.24)
		4	14.93 (6.98)	13.50 (4.18)
	Left	1	15.03 (5.59)	6.80 (1.11)
		2	16.49 (7.28)	6.60 (1.13)
		3	15.28 (7.04)	6.98 (0.98)
		4	14.44 (4.59)	12.95 (4.11)
Sternocleidomastoid	Right	1	7.75 (4.24)	2.19 (0.93)
		2	8.18 (5.07)	1.86 (0.65)
		3	7.13 (3.59)	2.37 (1.03)
		4	7.77 (6.35)	8.59 (8.15)
	Left	1	5.99 (5.74)	1.68 (0.63)
		2	7.24 (8.06)	1.42 (0.39)
		3	7.02 (7.21)	1.50 (0.62)
		4	7.33 (7.15)	6.89 (5.58)
anterior scalenes	Right	1	12.38 (6.62)	3.38 (0.81)
		2	13.41 (8.97)	3.61 (1.33)
		3	10.60 (4.91)	3.44 (0.57)
		4	12.88 (11.19)	12.26 (4.15)
	Left	1	7.72 (5.24)	4.08 (1.34)
		2	10.17 (12.01)	3.91 (1.13)
		3	8.37 (6.34)	4.10 (1.12)
		4	10.50 (10.82)	10.53 (7.75)
Upper trapezius	Right	1	22.53 (13.33)	5.90 (3.09)
		2	19.45 (10.42)	6.30 (3.43)
		3	16.60 (8.23)	4.83 (2.49)
		4	16.18 (8.77)	21.98 (13.68)
	Left	1	16.52 (11.26)	4.92 (1.89)
		2	14.34 (7.21)	5.06 (1.38)
		3	15.43 (9.12)	4.60 (1.76)
		4	13.59 (10.36)	23.66 (18.30)

Data are expressed in means (SD) group 1 = strength-endurance exercise, group 2 =craniocervical flexion exercise, group 3 = combination of endurance-strength and craniocervical flexion exercise, and group 4 =control demonstrated that pain can be reduced by strength training[19–22] and endurance training[21, 22]. Moreover, general exercises like strength and endurance training, as well as specific exercises such as cranio-cervical flexion of deep cervical flexor muscles have been shown to decrease neck symptoms[18].

In the present study, the neck pain and disability index significantly improved after 12 weeks of exercise intervention in all the exercise groups. This indicates that exercise caused the changes in VAS and NDI score of females who had chronic neck pain. This result was in agreement with previous studies[29, 30] which showed the same trend of decrease in NDI score and VAS after exercise interventions. The improvement in pain and disability in the three exercise groups were not only statistically, but also clinically significant. The decrease in VAS was 16.32 mm in the strength-endurance exercise group, 13 mm in the CCF exercise group and 44.6 mm in the combined exercise group. The decreases in NDI score were 13.51 in the strength-endurance exercise group, 15.55 in the CCF exercise group and 13.52 in the combined exercise group. The reductions in pain and neck disability were significantly different among the control and all three exercise groups. There was a tendency of greater reduction in neck pain in the combined exercise group compared to the strength-endurance exercise and CCF exercise groups.

The muscle activities during the typing task showed differences between before and after in all the exercise groups, but there was no significant difference between before and after the intervention in the control group in both the right and left cervical erector spinae, sternocleidomastoid, and anterior scalenes. This result indicates that the exercise interventions caused changes in muscle recruitment during the typing task. The upper trapezius muscle on both the right and left sides showed a significant reduction in muscle activity after the interventions in all the exercise groups. There was a trend of increased in RMS in the control group, which performed no exercise intervention, and there were no significant differences among the RMS values of the three exercise groups. The subjects in the control group had RMS values that were greater than those of the other groups. This indicates that the exercise interventions of groups 1, 2 and 3 had the effect of decreasing the RMS value, whereas, the control group showed no change in RMS values during the typing task.

The mechanisms involved in the improvement in the strength-endurance exercise group might have been improved coordination, increased motor unit recruitment, an increased firing rate in each unit[31], and an increase in the number of capillaries in the muscle within 10 weeks[32], all of which would have contributed to improvement of muscular fatigue in chronic neck pain. In the CCF exercise group, the benefits might have accrued from a combination of improvement in neuromuscular efficiency and cervical motor control strategies improving the deep cervical flexor muscle. Therefore, the decrease in of cervical muscle activation seen in this study might have been effected by these combined mechanisms operating on the neck extensor, superficial flexor and deep cervical flexor muscles. Moreover, several studies have shown that people with neck pain demonstrate decreased ability to relax the anterior scalene and sternocleidomastiod muscles following activation[9]. The upper trapezius has also been shown to have a reduced ability to relax following repetitive arm movements and has reduced muscle rest periods during repetitive tasks[33]. The present study revealed decreases in RMS of the cervical erector spinae, upper trapezius, anterior scalene and sternocleidomastoid muscles which might have improved the ability to relax the muscles and changed the motor control strategy during the typing task.

This study provided evidence of an exercise effect on the pain levels, NDI scores and RMS values of subjects who performed exercise for 12 weeks. The results of this study indicate that pain levels and NDI scores decreased after exercise intervention. The reduction of RMS after 12 weeks exercise intervention suggests that strength-endurance exercise and the combined exercise are effective at decreasing the muscle activities of the upper trapezius, cervical erector spinae (CE), sternal head of the sternocleidomastoid (SCM) and anterior scalenes (AS) when performing tasks. CCF exercise is effective at decreasing muscle activity in the superficial flexor muscles. The results should encourage therapists to prescribe strength-endurance exercise, cranio-cervical flexion exercise and combined exercise for patients with chronic neck pain.

A limitation of this study is that it is not possible to generalize the results to the general population because the subjects were females with chronic neck pain. Therefore, it might not be possible to extrapolate the results to subjects with neck pain disorders of other etiologies such as whiplash injuries.

Further study is necessary to investigate the effect of longer durations of training, such as 6 months or more, because the muscle activities seen in this study showed no significant difference among the exercise intervention groups. The effects might be varied in other neck pain conditions, or in men. Moreover, the severity of neck pain such as mild, moderate or severe pain may influence the muscle activities after exercise intervention.

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