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ORIGINAL ARTICLE

Effect of Proprioceptive Exercises along with Ergonomic Intervention on Middle Deltoid and Serratus Anterior Fatigue in Dentists with Non-Specific Chronic Neck Pain

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ABSTRACT

There are several risk factors in dentistry that among them repetitive movements, being in a position for a long time due to muscle imbalances, and work-related musculoskeletal disorders which can cause problems such as limited mobility, fatigue, job loss or even changing jobs. Muscle imbalance between the stabilizers and mobilizers of the neck and shoulders in dentists leads to increased work-related disorders, superficial muscle fatigue, and deep muscle atrophy, which in turn, leads to many health problems such as neck pain and disability. To prevent such disorders, a high endurance of the cervical stabilizer muscles is essential for repetitive movements in the distal and shoulder region. In this study, the exercise program, including postural exercises, simultaneous training of shoulder-neck, scapular movements, and co-contraction were designed for 48 dentists. The statistical analysis showed that there was a significant decrease in the median frequency slope of the middle deltoid muscle ($p = 0.004$) and for the group who received the proprioception training along with posture correction exercises and exercise therapy ($p = 0.004$). Neck pain increased in the control group who received no exercises, after six weeks ($p = 0.165$). Six weeks of corrective exercises with ergonomic intervention balance muscles activity and can be used to decrease musculoskeletal disorders and muscle fatigue in person with Non-Specific Chronic Neck Pain.

KEYWORDS: *Nonspecific Neck Pain; Muscle Fatigue; Middle Deltoid Muscle; Serratus Anterior Muscle; Proprioceptive Exercises*

INTRODUCTION

The majority of dentists have musculoskeletal symptoms in the neck. Bad working habits, repetitive tasks, and uncomfortable posture contributed to the development of neck pain.[۲-۱]

Nearly 70% of dentists have experienced this pain during their lifetime. Of 30% of adults have reported neck pain every year, and 5-10% of these people have suffered from a disability and physical inactivity due to neck pain [3].

To prevent such disorders, a high endurance of the cervical stabilizer muscles is essential for repetitive movements in the distal of the upper extreme and shoulder region [4]. The common musculoskeletal complications seen in dentists included muscle pain (pain, discomfort, contusion in the muscles of neck, shoulder, and arm and reduced range of movement), cervical spondylosis (numbness and stiffness, chronic and persistent pain in neck and shoulder regions along with tingling and itching, and arthritis and joint swelling) [5], thoracic outlet syndrome (pain in the shoulder, arm, hand, and numbness and itching of the fingers), cuff tearing and inflammation (pain and stiffness in the shoulder or swelling and tearing of shoulder soft tissue, and weakness in the rotator cuff), hand and wrist disorders (due to repeated and hard movements of the wrist, physical pressure on the nerves in the fingers, long-term use of instruments with vibrating movements, and long periods of work without adequate rest) [6], De Quervain syndrome (pain in the thumb or wrist when holding an object in the hand), tenosynovitis disease (pain in the fingers when moving them and especially touching the instruments), Carpal tunnel syndrome (senselessness and numbness of the hands or fingers, and ultimately hand pain and deformities), Guyon's syndrome (pain, weakness and numbness of the fingers at night and early in the morning), Raynaud's syndrome (intermittent and periodic spasms with numbness and pain in the fingers and sensitivity to low temperatures, and wrist pain) and disturbances in the back region (Lumbar disc disease, back and lower back pain, and sciatica) [6].

Janda was one of the first researchers to discuss the movement patterns for musculoskeletal disorders. He believed that the sensorimotor system functions as one unit to coordinate the central nervous system and musculoskeletal system in performing different activities. Cervical proprioceptive exercises were used as a retraining program with an emphasis on the coordination and retention of the strength of flexor and extensor muscles of the neck and shoulder girdle. These exercises were designed to increase proprioception, balance, and focus mainly on reducing the imbalance of superficial and deep muscles of the neck and shoulders [7-8].

Janda et al. believed that in the case of musculoskeletal disorders, a predictable pattern of muscle weakness and shortness happens in the neck and shoulder region in patients with chronic neck pain. Although the degree and severity of muscle weakness and shortness differs in different individuals, their patterns and causes rarely differ [9]. Besides, the cervical spine is a very complex structure and its stability and mobility are controlled by inactive structures such as joints and ligaments, and often by neuromuscular control.

Biomechanically, shoulders are connected to the neck through the superficial muscles of the neck, such as the upper trapezius, lateral scapula, and small rhombuses. Neurophysiologically, the eye, head, and hand function as a unit whose activities are coordinated through reflective neural pathways. Lots of information is transmitted to the central nervous system through the cervical structures and their sensory connections to the visual and vestibular systems to control the posture [1]. An increase in surface electromyographic signals during muscle contraction can be indicative of muscle impairment [10].

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Researchers showed that isometric strength and endurance of cervical and craniocervical muscles decreases in patients with neck pain [11]. In electromyographic evaluations, these patients showed higher levels of fatigability in the neck muscles compared to healthy people [12-13]. Fala et al., studied neck flexor muscle fatigue and concluded that the impact of neck pain on muscle function was completely side-specific, and fatigue showed a significant difference in myoelectric symptoms in the side with neck pain compared to the healthy side [14]. Some studies emphasized that the electromyographic activities of shoulder muscles increase in patients with neck and shoulder pain [15]. A great deal of studies suggests that the electromyography activity of the flexor and extensor muscles increases in patients with chronic neck pain during upper limb movements [14]. Ergonomic-related hazards included such factors as repetitive work, static and improper body positioning, excessive physical activities, occupational stress, and insufficient rest [4-5].

Ergonomics in dentistry emphasizes two main issues: the sources of physical and psychological stress. Therefore, dentists should be fully aware of the physical and psychological stressors and their adverse effects on their careers [5].

In general, there are several factors involved in postural control. Based on the Punjabi model, three subsets, namely inactive factors, including tendons and ligaments, active factors including muscles, and neural factors, contributes to the control of the posture. From this viewpoint, postural control is the result of the complex interaction of neural and musculoskeletal systems [16].

Repeated movements of dentists and maintaining a posture for a long time affect trapezius, cervical erector spinae, and sternocleidomastoid muscles and lead to increased intensity of the physical activity as well as dysfunction in these muscles and consequently injury. The manifestation of this muscle fatigue leads to a reduction in the capacity of the maximum force exerted by these muscles during dental work.

A study by Izquierdo et al., (2016) revealed that individuals with chronic neck pain had a diminished ability to maintain a standing position when they had pain. Targeted exercise intervention for flexor muscles of the craniocervical region in individuals with neck pain showed a significant improvement in their ability to maintain the neck structure in the neutral position when sitting for a long time [17]. Also, different researches have shown that stretching exercises reduce neck pain temporarily as a short-term treatment [18]. However, the effect of proprioceptive exercises was not fully identified.

Table 1. Mean and standard deviation of age, height, and weight of the groups under study

	Age		**Height**		**Weight**	
	Mean	SD	Mean	SD	Mean	SD
Experimental 1	33.92	2.49	1.64	0.02	64.42	2.47
Experimental 2	34.86	3.31	1.64	0.03	66.13	2.16
Control	33.92	2.78	1.63	0.02	64.85	2.62

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MATERIALS AND METHODS

48 homogeneous samples were randomly divided into three groups: experimental 1, experimental 2, and control so that the mean characteristics (including height, weight, sex, and work experience) were nearly the same among the three groups (Table 1).

Inclusion criteria included woman dentists with pain scale less than 3 and disability index less than 28 and subjects excluded if they had neck or shoulder pain from non-musculature causes and if they had undergone cervical spine surgery; reported any neurological signs. Iranian Registry of Clinical Trials (IRCT) registration information for this proposal was IRCT2017010119750N2.

Subjects randomly were divided into three groups. The first group received proprioceptive exercises with postural training and ergonomics intervention while the second group just received proprioceptive exercise and the third group received no intervention.

The exercise program for groups 1 and 2 included Joule et al., (2014) exercises [19] (including postural exercises, simultaneous training of shoulder-neck, scapular movements, and co-contraction) where most exercises were designed considering the principles of sensorimotor and corrective exercises with some changes in three parts of the body position, the center of gravity, and the support surface [20-21].

Eight-channel surface electromyography was used to measure muscle fatigue [10-15-22]. The muscle activity of the middle deltoid and serratus anterior was recorded. These muscles were selected because they were the primary and main muscles used to raise the arm and rotate the scapula upward.

Firstly, to prepare the skin, its surface was shaved using disposable razors, then that surface was disinfected via alcohol. Finally, the electrodes were placed in specific places based on the Seniam protocol.

During the experiment, the rough region of the deltoid and a reference point called the acromion were firstly detected through palpation. Then, the skin area of the deltoid was shaved and disinfected with alcohol. The bipolar electrode was placed on the deltoid heads by elastic adhesive bandages in order to reduce artefacts. To analyze the middle deltoid muscle, the electrodes were located on the midline between the deltoid tuberosity and the acromion process. The SENIAM protocol recommendation was followed for placements of SEMG sensors on the deltoid. The electrodes were placed on top of the external thorax 3 cm from the lower oblique scapula, upward, and in the posterior portion in order to get the serratus anterior muscle data [25-23-10]. Surface dipole electrodes made of chloride were placed 2cm apart. Surface electrodes transmit raw EMG data to the receiver unit after they were connected to the skin.

To specify the population needed for the study, the sample size was calculated for each goal of the research. The largest sample size was related to the electromyographic activities of the muscles. Therefore, based on the literature, 48 dentists were studied [15-26].

This research was carried out for a duration of six weeks at Firoozgar Hospital in Iran University of Medical Sciences.

The study variables were analyzed using both descriptive and inferential statistics using IBM SPSS software version 22.0. The Kolmogorov-Smirnov test was used to examine the normal distribution of the data. Since the data were not normally distributed, non-parametric tests were also used. For the inferential statistics, the Wilcoxon test was used to compare the results of pre-test and post-test. For the entire test, we considered the alpha value less than or equal to 0.05 for the significance level (alpha$\leq$ 0.05).

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RESULTS

The intra-group comparisons showed that there was a significant decrease in the median frequency slope of the middle deltoid muscle (p = 0.004) for the group who received the proprioception training along with posture correction exercises and exercise therapy (p = 0.004).

Neck pain increased in the control group who received no exercises, after six weeks (p = 0.165).

Since the obtained level of significance was less than 0.05 for groups 1 and 2, we concluded that there was a statistically significant difference between the two variables.

Table 2. Wilcoxon test, median frequency slope per unit time for middle deltoid muscle before and after six weeks of proprioceptive exercises in the groups 1, 2, and the control group

			Mean	SD	P value
Median frequency slope per unit time for middle deltoid muscle	Experimental 1	Pre-test	-0.46	0.05	0.001
		Post-test	-0.32	0.06	
	Experimental 2	Pre-test	-0.42	0.06	0.001
		Post-test	-0.31	0.07	
	Control	Pre-test	-4.78	0.057	0.752
		Post-test	-0.50	0.031	

Table 3. Wilcoxon test median frequency slope per unit time for serratus anterior muscle before and after six weeks of proprioceptive exercises in the groups 1, 2, and the control group

			Mean	SD	P value
Median frequency slope per unit time for serratus anterior muscle	Experimental 1	Pre-test	-0.002	0.00	0.009
		Post-test	-0.001	0.00	
	Experimental 2	Pre-test	-0.002	0.00	0.032
		Post-test	-0.001	0.00	
	Control	Pre-test	-0.002	0.00	0.083
		Post-test	-0.001	0.00	

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DISCUSSION

Previous studies found a region-specific manifestation of fatigue within some skeletal muscles. The differences in control strategies of the central nervous system (CNS) for different regions were considered as a major factor resulting in the region-specific manifestation of fatigue. In this study, the deltoid and serratus anterior muscle was targeted as the object, and the fatiguing characteristics of static isometric contraction tasks were investigated by means of the SEMG technique.

Even with the perfect ergonomic workspace and equipment, the dentist was in continuous uncomfortable positions, such as bending forward and repeated rotation of the head, neck, and body to one side.

Over time, the muscles responsible for turning the body to one side strengthen and shorten, and the muscles on the other side weaken. The short muscles under strain can be painful and ischemic and apply non-systemic forces to the vertebrae, which causes the spine not to keep in proper position and decreases the range of motion in one side compared to the other.

The results of the study conducted by Joule et al., showed that the proprioceptive exercises of the neck are a retraining program with an emphasis on the coordination and retention of the strength of flexor and extensors muscles of the neck and the shoulder girdle. These exercises were designed to increase proprioception, balance, and focus mainly on reducing the imbalance of superficial and deep muscles of the neck and shoulders [27-28].

Deep muscles are the most important stabilizers of the neck [29]. Impairment in muscle activity affects the balance between the stabilizer and superficial muscles. This will result in postural disorders, neck pain, and damage if continues for a long time [30]. In this case, the strength of the muscles around the neck decreases [31].

The exercises used in this study were designed based on the Joule et al., exercise with an emphasis on the coordination and retention of the strength of the cervical flexor, extensor, and shoulder girdle muscles [28-32]. The main focus of these exercises was to reduce the imbalance of the superficial and deep muscles of the neck. The study results showed that a targeted exercise intervention on the flexor muscles in the craniocervical region improves the ability of the neck structure to maintain postural stability and reduce neck pain in the long run.

The results of a study revealed that exercise therapy can affect musculoskeletal disorders in hard jobs that require repetitive movements. Proprioceptive exercises lead to the production of natural hormones which act on pain inhibition mechanisms and raise pain threshold and result in reduced neck disability. Results of the present study revealed that a 6-weeks proprioception training program based on advanced balance exercises had a positive effect on neck disability among dentists with hard physical working conditions.

The results of the Wilcoxon test showed that there was a significant difference between the deltoid and serratus anterior muscle fatigue in groups 1 and 2 in the pre-testing and post-testing stages.

Johnston et al., (2008) measured changes in neck muscle activity in healthy women and patients with neck pain during certain functional activities. The results revealed that neck pain patients showed a higher amplitude of electromyography activity in the extensor and flexor muscles of the cervical spine during the activities. The increased co-contraction of the superficial extensor and flexor muscles of the vertebra indicated a change in motor control strategies to compensate for the dysfunction of the deep extensor and flexor muscles in patients with neck pain [33].

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In a study conducted by Griffith et al., (2013) patients with neck pain undertook a series of general and proprioceptive exercises, and no effect on neck pain and disability were reported. This could be due to improper exercises, muscular imbalance, or changes in the activity of synergist muscles that affect the frequency spectrum [33].

In the present study, the frequency spectrum of deltoid and serratus anterior muscles decreased for 40 seconds while holding one kg weight, which indicated the fatigue of these muscles. An increase in median frequency of deltoid and serratus anterior muscles compared to before exercises can be due to increased activity of deeper and stabilizer muscles of the neck, which removed the excess load from the superficial muscles as a result of the exercise therapy. This change could be due to a possible reduction in the number of active muscle fibers after exercises. Also, the reduction of muscle fatigue could be the result of increased blood flow in the muscles and higher oxygen supply to the tissue involved. Based on the previous researches, the constant and long-term working posture of the dentist causes high levels of impairment in blood supply to the deltoid and serratus anterior muscles. Besides, proprioceptive exercises cause responses in neuromuscular activities through deep receptors, and in addition to the muscles of the head and neck, the movements of the eyes were involved in the exercises used in this study. Hence, modification of the adaptive responses of these muscles leads to a reduction in deltoid and serratus anterior muscle fatigue. In this regard, Roll et al., showed that patients with neck pain have impairments in the proprioceptive system of neck muscles [34]. Since proprioception had a significant contribution to the perception of head and neck movements; considering the decreased deltoid and serratus anterior muscle fatigue. It can be concluded that people with neck pain had a high ability to retrain the proprioceptive sense. Furthermore, performing exercises to improve muscle performance along with the improvement in retina information together with outer retina signals that were sent by the proprioceptive receptors of the extraocular and cervical muscles and the simultaneous head and eye movements could reduce muscle fatigue and improve their performance.

The reduction in the negative slope of the median frequency, compared to the situation with no exercises, also indicated increased deep muscle activity, decreased deltoid, and serratus anterior muscle activity. Thus, the occupants of this profession had the maximum pressure exerted on the deltoid muscle, due to the position of arms and hands relative to the body, serratus anterior muscle fatigue was not high.

According to the results obtained by Fala et al., slow-twitch (Type I) muscle fibers were converted to fast-twitch (Type II) in patients with chronic neck pain [35].

The relationship between pain and altered muscular activity patterns is pretty complicated. So, researchers have argued that muscle pain affects motor control and the transfer of load between tissues, which is the cause of muscle fatigue [32]. The modified motor control strategy was seen in the form of compensatory mechanisms, including the role replacement of the main mobilizer muscles with the synergist muscles, inhibition of some muscle activities, and increased activity of some others [36]. On top of that, neuromuscular changes in people with neck pain were associated with inhibition of deep cervical muscle and increased superficial muscle activities [14-37]. Although the myoelectric activity of the neck muscles was not measured in the current study, given the high degree of fatigue in the superficial muscles, these muscles were found to be responsible for deep muscle activities.

During fatigue, muscle movements were not well performed due to the combination of certain factors, such as reduction of proprioception, motor control, and psychological-cognitive factors, which can potentially cause irreparable damage to individuals. The present study revealed that active exercises would help to adjust neuromuscular activities in the neck. The major function of cervical spine muscles was to create motion at various levels and stabilize the head and trunk to maintain proper posture against gravity [34]. The results of this study indicated that proprioceptive exercises were effective in the

restoration of stability to the cervical spine by activating cervical stabilizer muscles and decreasing superficial muscle fatigue by affecting the fiber types of cervical muscles and engaging tonic muscles [38].

CONCLUSION

The results revealed that the proprioceptive exercise intervention and posture correction exercises were successful to decrease the median frequency slope. Considering the extremely large effect size of the proprioceptive exercise, we recommend this program for the treatment of patients with chronic neck pain and muscle imbalance.

CONFLICT OF INTEREST

The authors declare that they had no competing interest.

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