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The effect of tactile feedback along with corrective exercises on the degree of thoracic kyphosis in hyperkyphosis individuals

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Abstract

Introduction: The musculoskeletal and support systems and biomechanical factors lead to tissue adaptations in the skeletal, musculoskeletal, and nervous systems, resulting in changes in the movement pattern. This study aimed to investigate the effect of tactile feedback along with corrective exercises on the degree of thoracic kyphosis in people with hyperkyphosis.

Methods: Twenty patients with postural kyphosis greater than 42 were selected voluntarily and randomly divided into experimental and control groups. In the pretest and post test, the degree of kyphosis of both groups was measured using a flexible ruler. In the intervention phase, both groups performed corrective exercises for 8 weeks, 3 sessions per week, and each session for 30 to 45 min. The experimental group received tactile feedback, but the control group did not receive any feedback.

Results: The results of the 2-factor analysis of variance showed that tactile feedback along with corrective exercises (D= -12%) compared to corrective exercises (D= -8%) led to a reduction in kyphosis in people with Hyperkyphosis (*P*= 0.018).

Conclusion: It seems that tactile feedback with changes in sensory inputs can be an effective complement to corrective exercises to reduce the degree of kyphosis.

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1. Introduction

Abnormal increasing of the thoracic spine degree is one of the most common postural abnormalities and an essential factor affecting deviations in the upper body quarter. Hyperkyphosis is associated with stretching of the thoracic extensors of the spine and trapezius muscles, as well as shortness and inflexibility of the pectoral muscles, reduction of the space between the ribs and shortening of the upper and lateral tissues of the internal oblique muscle, shortening of the shoulder abductors, shortening of the pectoralis minor muscle and respiratory muscle weakness [1, 2]. People with hyperkyphosis have a slow walking pace, and difficulty climbing stairs [3], and their general body fluctuations increase due to imbalance. Hyperkyphosis increases the biomechanical stresses on the spine [4, 5]. Hyperkyphosis disorder is treated and corrected through various methods such as treatments [6], postural retraining [7], the use of tips and prostheses [8], and surgery and exercise therapy. Meanwhile, corrective exercises are standard methods. Specialists usually prescribe topical exercise programs and more recently manage kyphosis in patients by comprehensive and multifaceted exercises (strengthening exercises, mobility exercises, and spinal flexibility exercises simultaneously [9].

On the other hand, coordination in spinal movements is done by the neuromuscular control system. This system is composed of active and passive tissues being controlled by motor nerves (muscle activation) and modulated by sensory nerves (sensory feedback) [10]. This control system needs to consider the current state of the spine, the characteristics of passive tissue, and the control of the central and peripheral nervous systems. Therefore, the body uses several sensory receptors to regulate and monitor the movement of the spine. These receptors- such as the muscle spindle, the Golgi tendon organ, the joint receptors, atrium system, and the skin receptors- work in unison to keep the body informed of the position and movement of the body, tension or force, and the effort to maintain the body and balance. Receptors located in the skin have recently attracted the attention of many researchers in the field of touch and control for interaction with computers [11, 12, 13].

According to the Kinesiopathological model of the human locomotor system, various factors are involved in the development and spread of syndromes. The musculoskeletal system, supporting systems, and biomechanical factors lead to tissue adaptations in the skeletal, muscular, and nervous systems, resulting in movement patterns. Changing the movement pattern is a crucial factor. When a movement pattern is established, a common feature of the human body is a decrease in the degree of freedom followed by efficiency and minimal energy expenditure. Therefore, motor learning plays a vital role in these changes. These changes appear to occur in the locomotor system. Eventually, they unconsciously happen. One of the factors affecting motor learning is feedback. Feedback is called sensory information derived from movement. One type of feedback is Tactile feedback. Tactile feedback is the sensory information about the state of the body that can be provided by touching the body. Therefore, it seems that Tactile feedback can change body orientation and muscle activity [14]. However, little research has been done on Tactile feedback. In these type of researches, the effect of vibration and

Tactile feedback on maintaining proper posture during work have been examined. Little research has been based on biofeedback and vibration feedback to correct anomalies. For example, Lou et al. (2012), in a study entitled "Development of a smart garment to reduce kyphosis", studied the effect of ongoing treatment in helping to improve pediatric kyphosis. The results showed that vibration feedback could improve the kyphosis angle. Finally, only in one study, the effect of Tactile feedback based on physical contact was examined [15]. For example, Shin et al. (2018) showed that Tactile cues change trunk and scapular muscle activity, scapular winging, and thoracic kyphosis during knee push-up plus in subjects with scapular winging [16].

Therefore, since no study has used tactile feedback (tactile cues) to reduce kyphosis, it is necessary to conduct this study to fill the gap to determine whether tactile feedback can improve the quality of corrective exercises.

2. Materials and Methods

The method of the present study is applied in terms of purpose and quasi-experimental in terms of content. The research proposal is a pretest/ post-test with a control group. The statistical population of this study is all people with hyperkyphosis who were referred to the rehabilitation center of Modarres Hospital in Tehran, Iran. From this population, 20 people with kyphosis more than 42, without joint problems in the spine or history of fracture, no physical activity, or occupational history requiring special physical posture were selected as a sample [9]. They were randomly divided into experimental (n= 10) and control (n= 10) groups. It must be noted that health protocols were observed in the whole research process.

2.1. Research tools

To measure the degree of thoracic kyphosis, a 50 cm flexible ruler was used. The Borg RPE scale was used to measure fatigue from 6 (without perceived pressure) to 20 (maximum perceived pressure). A score above 16 on this scale indicates the peak of fatigue. Finally, a foam roll covered by leather with a diameter of 20 cm in the correction exercise program was used.

2.2. Data collection method

This research was conducted in three stages: pretest, intervention, and post-test. In the pretest stage, the degree of kyphosis of both groups was measured using a flexible ruler. Both groups performed corrective exercises for 8 weeks in the intervention stage, 3 sessions per week, each session 30 to 45 min. The experimental group received tactile feedback, but the control group did not receive any feedback. Finally, in the post-test, same as in the post-test conditions, the degree of kyphosis of participants in both groups was measured.

2.3. Measuring the degree of kyphosis

In pretest and post-test, first, the spinal processes of the second (T2) and twelfth (T12) vertebrae were identified and setted as the starting and ending point of the thoracic angle. The subject was then asked to look forward naturally and comfortably place the weight evenly on both feet. The flexible ruler was placed on the second and twelfth vertebrae of the Spinous process to form the degree of thoracic kyphosis. Then, the flexible ruler was placed on white paper without changing its position, and the shape of the arc was drawn. The distance between two points (L) and the depth of curvature (H) was measured in millimeters, and the kyphosis ɵ angle was calculated using 4Arctan (2H/L) trigonometric relations [17].

2.4. Exercise protocol

The first part of the exercise included high-intensity strength training to increase the strength of the spinal extensor muscles and stabilize the body in the correct direction. Dumbbells and Thera band increased the intensity of the exercises from slight to hard (maximum 70-80%). The exercises in the second part included integrating stabilization exercises into mobility exercises. Finally, exercises were performed using foam roller and the exercises to increase the range of motion to increase the extension and rotation of the spine and reduce the limitations related to the movement of the anterior shoulder, chest, and spine [9].

Table 1. Exercise protocol

Strength training	Stability exercises	Exercises to increase the range of movement
Laying on the foam roller (1×10) Raising the opposite arm and leg in all four (8×2) Spine extension while lying on the abdomen (8×2) Rotating the spine while lying on the side (8×2) Abduction and external rotation of the foot while lying on the side (8×2)	Foam roll cycling (1×10) Moving hands away from each other from a single side while lying on the foam (1×10) Moving hand downward while lying on the foam (1×10) Shoulder flexion and spine extension next to the wall (1×10) Press up on the wall (1×10) Standing on a single foot (1×10)	Stretching the spine and chest while lying on your back on the foam (30 sec×1) Stretching of the serine muscles (30 sec×1) Moving the feet up while lying on the back (30 sec×1) Quadriceps femoris muscle stretch (30 sec×1) Stretching the back in a four-legged position (30 sec×1) Stretching the neck and chest while standing (30 sec×1)

2.5. Tactile feedback protocol

The target area was set to present the tactile feedback in the posterior-thoracic area. The examiner tells to the subject during sessions with touch the posterior-thoracic area, contract the muscles and correct the shape of the dorsal area when dorsal kyphosis occurs. Also, in all movements, this feedback was provided by hand contact in the desired area [16].

2.6. Data analysis method

Mean, standard deviation, and graphs were used to describe the data. Kolmogorov–Smirnov test was used to test the hypothesis of normal data distribution. Finally, a mixed 2-factored analysis of variance was used to test the hypotheses at the level of 0.05 with SPSS software version 26.

3. Results

The results of the 2-factor analysis of variance (exercise × group) showed that corrective exercises had a significant effect on the rate of thoracic kyphosis in people with thoracic hyperkiphosis (η= 0.91, P= 0.000, $F_{(1\ 18)}$= 204.3; Table 2). In other words, corrective exercises led to a significant reduction in the rate of chest kyphosis in people with thoracic hyperkyphosis. Also, the effect of the group on the rate of thoracic kyphosis in people with thoracic hyperkiphosis was not significant (η^2= 0.07, P= 0.237, $F_{(1\ 18)}$= 1.49). Eventually, the interactive effect of corrective exercises and feedback on the rate of thoracic kyphosis in individuals with chest hyperkiphosis was significant (η^2= 0.27, P= 0.018, $F_{(1\ 18)}$= 6.82). In other words, tactile feedback along with corrective exercises (D= 0.12%) compared to corrective exercises (D= 0.8%) led to a significant reduction in the rate of thoracic kyphosis in people with thoracic hyperkyphosis (Figure 1).

As you can see, the average kyphosis decreased from pretest to post-test in both groups, which shows the effect of corrective exercises. Also, the mean kyphosis of the tactile feedback group with exercise (blue line) shows a greater decrease than the exercise-only group (red line), which indicates the interactive effect.

Table 2. Results of 2-factor analysis of variance

Source	SS	*df*	*MS*	F	Sig.	η^2
Time (exercise)	216.2	1	216.2	204.3	0.000	0.91
Time × Group	7.22	1	7.22	6.82	0.018	0.27
Error	19.05	18	1.058			
Group	5.62	1	5.62	1.49	0.237	0.077
Error	67.6	18	3.75			

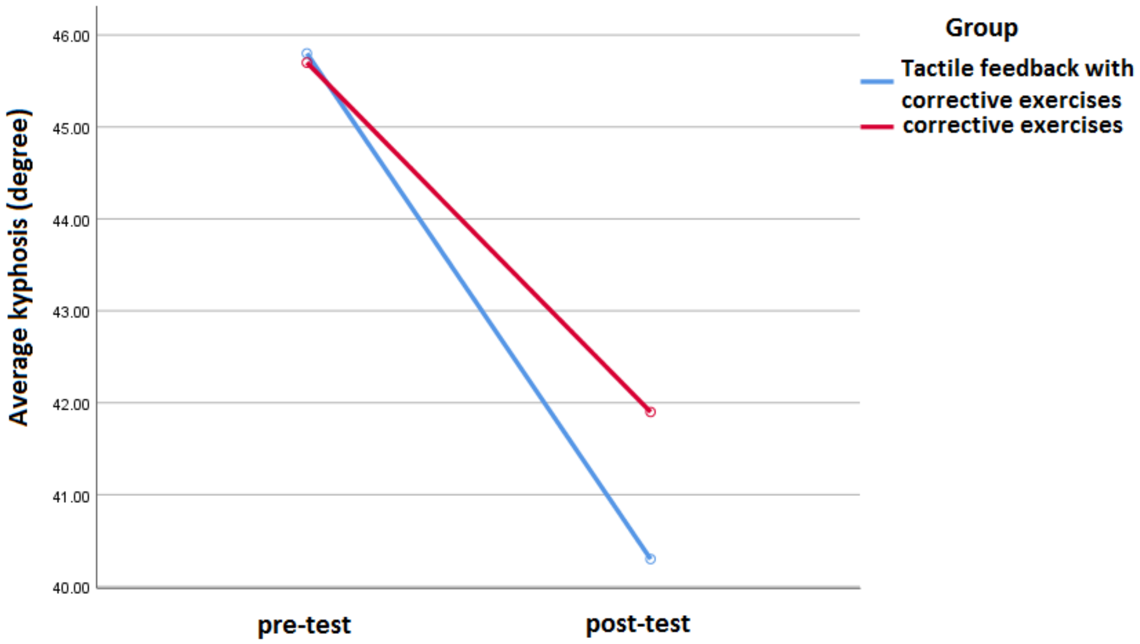

Figure 1. Interactive graph of mean kyphosis in pretest and post-test of the two test

4. Discussion

The etiology of hyperkiphosis is complex because many factors, such as poor posture, decreased spinal mobility, dehydration of the intervertebral discs, and reduced strength of the extensor muscles of the back, contribute to changes in the spine. Therefore, exercises that aim to increase the strength of the back-extensor muscles and the flexibility in combination with postural maintenance exercises can be more effective. In the present study, exercises were performed, namely, multidimensional strength exercises to increase the strength of the extensor muscles of the spine; Spine alignment exercises; and exercises using a foam roller to increase the range of motion to increase the amount of extension and rotation of the spine and reduce the limitations related to the mobility of the anterior shoulder, chest, and spine. The results of the present study showed that multidimensional spinal corrective exercises led to a significant reduction in thoracic kyphosis, which was consistent by the researches of Tarasi et al. (2019) [9], Khazaei et al. (2018) [17], Feng et al. (2018) [18], Katzman WB et al. (2017) [19], Bansal et al. (2014) [20], Jang et al. (2015) [21], Parveen et al. (2020) [22], Jain et al. (2020) [23] and Sedaghati et al. (2016) [24]. For example, in a review study, Bansal et al. (2014) showed that topical exercises that only focus on the strength of the back muscles has little effect on the correction of hyperkiphosis [20]. Katzman et al. (2017) also stated that the effect of multifaceted spinal strengthening exercises has been effective in improving hyperkiphosis [19]. Therefore, multidimensional exercise seems to be one of the necessities in managing patients with hypercyphosis because they have several goals due to the causes of kyphosis. Because the strength training section strengthens the muscles that straighten the spine and affects the length of the muscle-tendon, the different sections move the skeleton and cause the stability of the ligaments. On the other hand, flexibility training works as a coordinator of the same and opposite muscles. Finally, body alignment exercises are performed to integrate stabilization exercises into mobility exercises. Therefore, these exercises increase the length of the muscles on the concave side and the strength and accuracy on the convex side, resulting in a reduction in kyphosis [25].

This study showed that tactile feedback also led to a significant reduction in Hyperkyphosis. These results are consistent with the findings of Shin et al. (2018) [16], Lou et al. (2012) [15], and Park et al. (2016) [26]. For example, Shin et al. (2018) showed that tactile feedback in the dorsal and intra-shoulder vertebrae in push-up exercises could effectively reduce the winging scapula and correct compensatory dorsal kyphosis during push-up movement in subjects with the winging scapula [16]. Page et al. (2011) emphasized the importance of stimulating the whole sensory-motor system by the afferent and efferent mechanisms. They stated that environmental information must first be considered and corrected. They defined peripheral structures as tissues and organs outside the central nervous system and its cortex and considered the normalization and treatment of peripheral structures as the first step in the rehabilitation process. It is a prerequisite for improving the quality of afferent input the central nervous system. Improving afferent inputs is a priority. Recovery of this input completes the ability of the motion control system [14]. Tactile feedback through mechanical stimulation of the surface with hand pressure to touch the target area increases the activity of the target muscles by stimulating the mechanical receptors of the skin [27]. Therefore, tactile feedback can affect the quality of sensory inputs. Since the key to preventing and correcting thoracic spine motor system syndromes is (a) having muscular structures that position the vertebrae in the desired direction, (b) considering movements that confuse the spine, and (c) preventing repetitive movements in the more flexible thoracic segments during functional activity.

Multidimensional exercise seems to help people with hyperkyphosis achieve the muscle structures in the trunk that position the spine in the right direction. In addition, tactile feedback can change sensory input and reprogramming in the brain to prevent repetitive movements in the more flexible thoracic segments during functional activity [14].

In general, great advances have been made in developing surgical treatments for patients with spinal deformities so that surgery can improve the patient's pain and disability. Still, surgical treatments have a very high risk [28]. Non-surgical management must be carefully evaluated, which may affect the quality of life of individuals [29]. Therefore, increasing the likelihood of corrective exercises' success with tactile feedback is a critical issue in reducing kyphosis in the present study. The practical results of this study are helpful for corrective movement specialists, physiotherapists, and practitioners; they can use tactile feedback to complement routine corrective exercises to develop a more effective protocol for correcting abnormalities, especially hyperkyphosis.

One of the limitations of this study is the prevalence of Corona virus, which limited the selection of samples and associated the presence of participants in the laboratory and training sessions with anxiety and worry. Therefore, future researchers are advised to do similar research with larger sample size. In addition, research should be conducted focusing on the mechanism of effect of tactile feedback on muscles, such as measuring Electromyography (EMG). Finally, it is suggested to study tactile feedback and corrective exercises' effect on other postural musculoskeletal disorders.

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Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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