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The Effects of Lateral Shift Correction Squat on Muscle Activation and Dynamic Balance in Scoliosis

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ABSTRACT

Background/Objectives: The purpose of this study was to effects of the muscle activity of elector spinae and gluteus maximus and dynamic balance ability during lateral shift correction squat in scoliosis.

Method/Statistical Analysis: The subjects of this study were 17 female and 11 male who has scoliosis were recruited. Surface electromyography data were collected from the both of electer spinae(T6 and L3) and gluteus maximus. Dynamic balance was collected from bio-resque device. A Paired t - test was performed to examine the effect of both of elector spinae(T6 and L3) and gluteus maximus muscle activity and dynamic balance during lateral shift correction squat.

Findings: The results of this study show that the trunk lateral shift correction squat increased ratio of elector spinae(T6 and L3) and gluteus maximus compared with general squat. Also dynamic balance ability was increased during lateral shift correction squat compared with general squat.

Improvements/Applications: This study suggests that lateral shift squat maybe useful in subject with scoliosis.

Keywords: *Electromyography, Elector spinae, Level bar, scoliosis, Squat*

Introduction

Scoliosis is defined as a cobb's angle of 10 degrees or more, which is a three-dimensional deformity of the vertebral curvature that takes place in its normal posture [1]. Scoliosis exhibits reduced flexibility and balance compared to normal subjects due to asymmetrical posture and muscle imbalance of the trunk.

The treatment of scoliosis is divided into surgical and non - surgical conservative treatment. Conservative therapies include braces, electrical stimulation, traction, and exercise. Many researchers recommend exercising for scoliosis because it release or/and strengthens the muscles of the unbalanced spine to enhance a balanced posture. Therapeutic exercise for scoliosis can reduce the deformation of the vertebrae, preventing the decline in cardiopulmonary function and improving the unbalanced posture. Simon et al.(1999) stated that the muscular strengthening exercises around the spine and pelvis prevent the lateral bending of the spine. It has also been reported that sustained exercise therapy improves vertebral deformity and flexibility [2].

Exercise for scoliosis consists of breathing technique, muscular strengthening exercises to correct the lateral displacement and rotation deformation of the vertebrae. Squat is exercises to strengthen muscles around the spine and pelvis. In a squat exercise, the correct posture should be that the gaze is directed forward, the trunk is raised from the sagittal plane, and the knee is bent so that the knee does not cross the toe line. The squat movement is a closed kinematic chain in which is a movement wherein the distal part is fixed, as when the sole of the foot makes contact with the ground or the exercise equipment. Therefore, it is important to exercise in the right posture as the weight increases the risk of injury if you exercise with wrong posture. Mcconell (2002) showed that when Meconnell taping was intervened in a patient with patellofemoral pain syndrome, increased the ratio of muscle activity of the vastus medialis/vastus lateralis muscles Meconnell taping was recommended[3].

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Kim(2013) reported that squat exercises using visual feedback reduced the quadriceps-angle for knee femur pain syndrome and, reduction of the quadriceps-angle to be helpful in the hypermobility of the knee joint and in the knee joint instability [4].

In previous studies, squat-related exercise control studies are mostly related to the correction of knee joints. Squat exercises with incorrect trunk alignment cause back problems and pain. However, there is a lack of research on squat exercises using trunk correction intervention for scoliosis. The purpose of this study was to compare the muscle activity of elector spinae and gluteus maximus and dynamic balance ability during intervention during trunk correction intervention for scoliosis.

Method

Prior to this study, preliminary measurements were performed with five subjects and the problems of the measurement method were identified and corrected during the preliminary measurement. The subjects of this study were 28 men and women who had positive response to scoliosis test who agreed to participate and listen to the explanation and purpose of the study. The general characteristics of the subjects are as follows [Table 1].

Table 1: General characteristics of subjects (Mean ± SD)

	Male (11)	Female (17)
Height(cm)	171.08 ± 5.35	160.94 ± 38.50
Weight(kg)	66.83 ± 14.55	55.12 ± 15.26
Angle(°)	6.00 ± 2.41	5.94 ± 2.06
BMI(kg/m^2)	23.22 ± 5.56	20.00 ± 6.94

The inclusion criteria for this study are as follows.

- Subjects with a scoliometer angle more than 5 degrees.
- Subjects do not have orthopedic or neurological disorders in the lower extremity.
- Those without knee joint disease or surgical history.
- Subjects with a range of motion and strength who can perform a squat exercise
- The difference between the left and right leg lengths is less than 2cm

Measuring Tool

Test for Scoliosis: The method of measuring scoliosis is to bend the subject's back 90 ° forward and measure with a scoliometer at the maximum projecting area. When the angle of the scoliometer is 5 °, the vertebrae are warped about 11 ° on the X-ray [Figure 1, Figure 2].

Figure 1: Adam forward bending test

Figure 2: Scoliometer

Surface Electromyogram: The surface EMG WEMG-8 (LXM 5308, Laxtha, Korea) was used to measure muscle activity of both elector spinae and gluteus maximus muscles during squat exercise. The sampling rate of the signal was set at 1024Hz and a 60Hz notch filter was used. Telescan program was used for EMG signal storage processing. EMG signals of each muscle were analyzed by root mean square (RMS).

Bio-rescue: Bio-rescue was used for balance measurements during the squat exercise. The bio-rescue consists of a platform that can detect the COP (center of pressure), a data collection device and an analysis program. The moving area, distance, velocity and density are calculated using an analysis program. The composition of Bio-rescue is composed of 610 × 580 × 10mm force plate and computer. The pressure sensor of the force plate consists of 1600 pieces, and the sampling rate of the data through the force plate sensor is to be obtained at 100 Hz.

EMG Attachment: Before measuring the muscle activity of elector spinae and gluteus maximus on both sides, the hair was shaved off with a razor to reduce skin resistance, and the skin was cleaned with sterilized alcohol. gluteus maximus was attached to the middle of the caudal and large protrusions, and the attachment site of ES was attached to T6 and L3 [5]. EMG pads were attached according to the direction of muscle fibers [Figure 3].

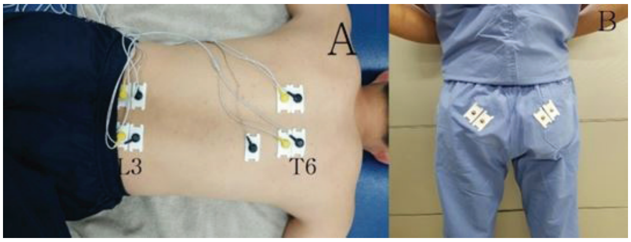

Figure 3: EMG attachment
(A) Elector (B) Gluteus maximus

Application: In this study, to improve the balance of right and left trunk during squat exercise, a mobile phone was attached to the weight bar to provide biofeedback to those with vertebrae. The biofeedback used a smartphone application, Bubble Level (Antoine Vianey, France) [Figure 4], and fixed with velcro in the center of the weight bar. In order to provide visual feedback, the slope of the weight bar was output to the notebook in real time using Side Sync(Samsung Electronics, Korea).

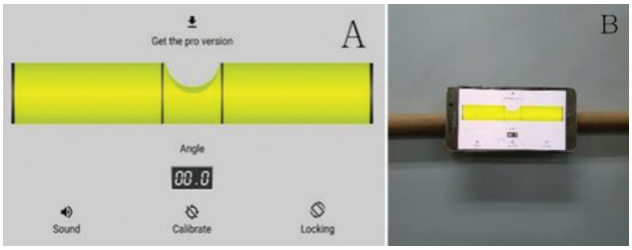

Figure 4: Application
(A) Bubble level (B) Bubble level attached to weight bar

Maximal Voluntary Isometric Contraction; MVIC): The maximum isometric contraction method was referenced to Kendall[Figure 5]. During the maximum isometric contraction of each muscle, muscle activity was measured three times for 5 seconds and treated with root mean square (RMS). Then, the mean EMG signal intensity for the middle 3 seconds except the first and last 1 second was used as% MVIC. The following is a formula for normalizing electromyogram signals

Figure 5: Maximal isometric contraction
(A) Thoracic spine 6 level (B) Lumbar spine 3 level(C) Gluteus maximus

Squat Exercise: The squat exercise was performed with the weight bar spread over the shoulder, with the feet spreading to the shoulder width. In this study, the knee angle was set to 70 °. A rod was used to apply the same knee angle between experiments. The total squat exercise time was 12 seconds, divided into the descending phase (0-4 seconds), the holding phase (4-8 seconds), and the ascending phase (8-12 seconds). All squat exercises were allowed to take one minute of rest for each measurement to minimize fatigue. All squats were performed three times.

General Squat: The subjects were given a comfortable and natural squat [Figure 6 A].

Lateral Shift Correction Squat: In order to apply trunk intervention during the squat exercise, we provided visual feedback in real time to the subject in front of the 13.3 inch notebook. The subject was squatted so that the trunk did not deviate to the left or right as much as possible through the level meter measured by the notebook.[Figure 6 B]

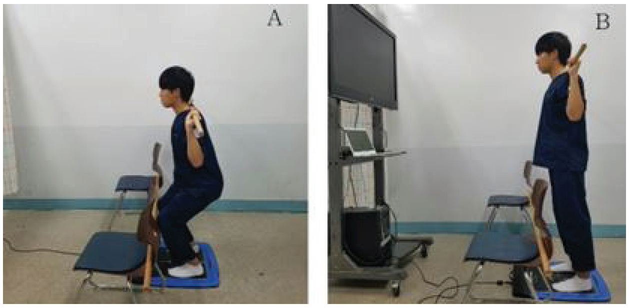

Figure 6: Squat exercise
(A) General Squat (B) Lateral shift correction squat

Analysis

A Paired t - test was performed to examine the effect of both T6 and L3 on elector spinae and gluteus maximus muscle activity and dynamic balance. The statistical significance was ą = 0.05. The collected data were analyzed using the SPSS statistics 18.0 software program for Windows

Results and Discussion

Results

Muscle activity of trunk and hip during descending phase of squat: There was a significant difference in elector spinaeand gluteus maximus muscle activity in descending phase[Table 2].

Table 2: Muscle activity of trunk and hip during descending phase of squat

Muscle	Squat	Corrective Squat	Squat ratio	Corrective Squat ratio	t	p
Left T6	20.28 ± 10.88	18.27 ± 8.62	0.57 ± 0.23	0.78 ± 0.15	4.6	.00*
Right T6	17.67 ± 11.72	17.72 ± 8.85				
Left L3	14.18 ± 7.55	13.91 ± 7.56	0.71 ± 0.14	0.87 ± 0.1	6.17	.00*
Right L3	14.35 ± 7.5	13.91 ± 7.56				
Left GM	4.14 ± 1.32	4.03 ± 1.36	0.77 ± 0.16	0.84 ± 0.13	2.6	.01*
Right GM	3.89 ± 1.13	4.03 ± 1.36				

Holding Phase: There was a significant difference in elector spinae in holding phase. (P<.05)[Table 3].

Table 3: Muscle activity of trunk and hip during holding phase of squat

Muscle	Squat	Corrective Squat	Squat ratio	Corrective Squat ratio	t	p
Left T6	24.56 ± 14.55	24.95 ± 13.92	0.61 ± 0.22	0.78 ± 0.15	5.1	.00*
Right T6	28.29 ± 16.47	24.95 ± 13.92				
Left L3	17.39 ± 7.66	17.1 ± 7.74	0.73 ± .013	0.86 ± 0.09	6.17	.00*
Right L3	18.1 ± 9.66	17.1 ± 7.74				
Left GM	4.32 ± 0.81	5.38 ± 5.64	0.75 ± 0.18	0.82 ± 0.12	1.47	.15
Rihgt GM	4.5 ± 1.78	5.38 ± 5.64				

Ascending Phase: There was a significant difference in elector spinae and gluteus maximus muscle activity in ascending phase(P<.05)[Table 4].

Table 4: Muscle activity of trunk and hip during Ascending phase of squat

Muscle	Squat	Corrective Squat	Squat ratio	Corrective Squat ratio	t	p
Left T6	17.31 ± 8.63	18.36 ± 8.89	0.61 ± 0.23	0.78 ± 0.15	4.06	.00*
Right T6	19.34 ± 8.31	18.36 ± 8.89				
Left L3	16.24 ± 6.67	16.22 ± 6.82	0.77 ± 0.14	0.86 ± 0.08	3.73	.00*
Right L3	16.11 ± 6.68	16.22 ± 6.82				
Left GM	5.5 ± 2.01	5.24 ± 2.24	0.76 ± 0.14	0.85 ± 0.12	3.05	.01*
Right GM	5.42 ± 3.18	5.24 ± 2.24				

Dynamic Balance: There was a significant difference in sway speed and sway length. (P<.05) [Table 5].

Table 5: Comparison of change in balance

Phase		Squat	Corrective Squat	t	p
descending	Swayspeed (mm/s)	1.82 ± 1.12	1.38 ± 0.97	4.04	.00*
	Sway length (mm)	6.29 ± 1.72	4.53 ± 1.38	6.83	.00*
holding	Sway speed (mm/s)	2.42 ± 0.77	0.72 ± 0.48	2.68	.01*
	Sway length (mm)	3.05 ± 1.05	0.84 ± 0.39	4.71	.00*
ascending	Sway speed (mm/s)	3.66 ± 1.1	1.06 ± 0.84	5	.00*
	Sway length (mm)	5.23 ± 1.59	1.53 ± 1.17	5.58	.00*

Discussion

Spinal deformity can be caused by weakness of the muscles supporting the spine due to lack of exercise. Therefore, therapeutic exercise is needed to prevent and treat scoliosis[6].

In this study, the ratio of muscle activity of left and right of T6 was significantly increased in the descending phase, holding phase, and ascending phase during the lateral shift correction squat movement compared to the general squat($p<.05$). Lee(2015) compared the muscle balance around the spine with asymptomatic patients and scoliosis, and confirmed muscle imbalance in scoliosis compared with asymptomatic [7]. As a result of applying the therapeutic exercise to the scoliosis, there were differences in muscle thickness and muscle activity of left and right T7. The deformity of the vertebrae is a fixed contralateral spinal coupling pattern associated with lateral bending and axial rotation of the vertebrae. The spinous processes rotate in a horizontal plane toward the concave surface of the fixed thoracic spine, which generally results in a rib hump in the convex surface in a frontal plane and the ribs follow the rotation of the spine. Due to the strong bending torque applied to the ribs, the upper lumbar region receives intensive bending stress. Therefore, correction of scoliosis is important because it may damage the bony structures.

In this study, the ratio of muscle activity of left and right elector spinae of T6 was significantly increased during lateral shift correction squat exercise that the stress of the bony structure in the ribs could be reduced.

In this study, the ratio of muscle activity of left and right of L3 was significantly increased in the descending phase, holding phase, and ascending phase of the lateral shift correction squat compared to the general squat. Kennelly and Stokes (1993) reported that the cross-sectional area of the multifidus in the concave and convex parts of the vertebrae differs between the scoliosis and asymptomatic subjects [8]. This means that the ability to adjust the balance of the trunk is decreased in scoliosis compared to asymptomatic. The importance of exercise has been emphasized because elector spinae is developed to maintain the posture and stability of the spine and pelvis when the therapeutic exercises to improve muscle imbalance are applied to the scoliosis.

In this study, when we applied the lateral shift correction squat to scoliosis, the ratio of left and right elector spinae muscle activity of L3 was significantly increased, so that the left and right unbalance of the trunk was reduced and the spine was stabilized. In this study, the muscle activity ratio of GM increased significantly in the descending and ascending phase of the trunk correction squat. Hip joint muscles are very helpful in maintaining the stabilization of the trunk. This is because the muscles origin or insertion on the pelvis plays a role in controlling the balance of the body, which regulates the movement of the pelvis along the axis of the hip joint [9]. Mahaudens et al. (2005) reported that a scoliosis affects the pelvic dysfunction and pain during daily gait and gait due to GM imbalance [10]. In this study, it was suggested that the left and right GM muscle activity ratio of the vertebral flexion patients was significantly increased during the trunk correction squat, so that the left and right imbalance of the pelvis would be reduced to help decrease the pelvic dysfunction.

In this study, the dynamic balance was significantly increased in descending, holding, and ascending phase during the lateral shift correction squat compared to the general squat. According to a study, on the balance ability of scoliosis show a much greater trunk sway area, as well as more sway, surging, and sway radius. Muscle imbalances affect reflexes, postural sway due to muscle weakness, flexibility and decreased co-ordination in the ankle and knee. Compared lateral shift correction squat, during the general squat, the shaking of the trunk during the dynamic balance test will be increased due to the muscle tension due to the unbalance of the left and right muscles and the deformation of the center of gravity due to skeletal misalignment. During the general squat movement, skeletal misalignment would be caused by the imbalance of the left and right muscles, and the dynamic balance would be degraded due to the deformation of the center of gravity. On the other hand, it seems to be possible to improve the dynamic balance ability of all the squat phase by keeping the equilibrium without side shift due to the muscle balance of left and right sides of the trunk and pelvic muscles during the lateral shift correction squat.

The limitations of this study are as follows. First, only the cross - sectional study was conducted in this study. The lateral shift correction squat should proceed in the long term in scoliosis. In the next study, it is necessary to study long term intervention.

Second, it is necessary to investigate the kinematical phenomenon in order to investigate the effects of direct trunk correction squat. In this study, however, only the left and right muscle activity ratio and balance ability were confirmed. Future studies will require a kinematical study to determine the correct curvature enhancement.

Conclusions

In this study, we compared the muscle balance and dynamic balance of the trunk and hip extensor muscles during lateral shift correction squat. Compared to the general squat, the ratio of muscular activity of left and right elector spinae and gluteus maximus was increased, and dynamic balance ability was significantly increased. Therefore, we recommend a lateral shift correction squat to increase the balance between the trunk and pelvis for those with scoliosis.

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Source of Funding: Self

Conflict of Interest: Nil

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