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Original Article

Comparative analysis of trunk muscle activities in climbing of during upright climbing at different inclination angles

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Abstract. [Purpose] This study was performed to provide evidence for the therapeutic exercise approach through a compative analysis of muscle activities according to climbing wall inclination. [Subjects and Methods] Twenty-four healthy adult subjects without climbing experience performed static exercises at a therapeutic climbing at with various inclination angles (0°, 10°, 20°), and the activities of the trunk muscles (rectus abdominis, obliquus externus abdominis, obliquus internus abdominis, erector spinae) were measured using surface electromyography (EMG) for 7 seconds. [Results] Significant differences were found between the inclination angles of 10° and 0°, as well as 20° in the rectus abdominis, obliquus internus abdominis, right obliquus externus abdominis, and right erector spinae. [Conclusion] Based on measurements of trunk muscle activity in a static climbing standing position at different angles, significant changes in muscle activity appear to be induced at 10 degrees. Therefore, the results appear to provide clinically relevant evidence.

Key words: Climbing, Trunk muscle activity

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INTRODUCTION

The human lumbar region is a core region of the human body for strength generation in all activities[1)]. However, recent sedentary lifestyles and too much time working with poor postures are promoting muscle weakness and shortening[2)]. Maintaining a bent posture for a long time leads to reductions in blood and nutrient supplies, due to posterior lumbar compression in addition to facilitating the atrophy of lumbar extensors[3)]. Chronic lower back pain causes weakness in the paraspinal muscles, which reduces the potential for activities and decreases the size of muscles. This is attributed to two mechanisms: the non-use of muscles due to low back pain and immobilization causeing atrophy[4, 5)], and afferent stimulation by reflective inhibition of contraction without pain results in the atrophy of muscles due to inhibition of the alpha motor neurons that modulate the muscles through spinal reflexes[6)]. Most spinal stress originates from the erector spinae muscle and other muscles of the abdominal wall. That is, immoderate use of erector spinae and abdominal wall muscles is believed to cause lower back pain[7)]. Histomorphologic and structural alterations occur in the paraspinal muscles in chronic low back pain patients, and weakness and atrophy of muscle fibers is predominantly observed in the erector spinae[8, 9)]. For the treatment of chronic low back pain, medication, injections, physical therapy, and exercise therapy have been widely used. In recent years, therapeutic climbing is being increasingly prescribed for patients with orthopedic diseases and injuries[10)]. Unlikely sports climbing, therapeutic climbing is not dependent on the climbing route. One advantage of climbing is that it may be more exciting than other types of physical or exercise therapies because of its adventurous component, resulting in higher levels of adherence[11)].

It has been argued that climbing may be useful for neurological rehabilitation since complex cognitive problems have to be solved due to the constantly changing sequence of movements[12)]. Climbing may also increase the strength of the spinal muscles and improve muscular balance[13)]. However, the benefits of therapeutic climbing have been determined not by scientific study results but by individual experience and discretion. Most studies to date have examined the effects of therapeutic climbing on psychological health, and studies are lacking on its physical effects through comparative analyses of activity levels between therapeutic climbing and lumbar stabilization exercises.

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Therefore, this study performed to identify the appropriate angle for performing exercise by comparing the muscle activities of normal subjects while using a climbing wall at different inclinations.

SUBJECTS AND METHODS

In this study, twenty-four young adult patients (21 males, 3 females, age 28.1±4.8, weight 70.5±12.2, height 172.4±7.8) with no climbing experience, no physical defects, no history of lower back pain within the past 6 months, and no orthopedic abnormality participated (Table 1). The subjects understood the principles objective, and method of this study and voluntarily provided their written informed consent before participating. The study protocol was approved by the institutional review boards of Catholic University of Daegu.

This study compared the surface activities of the obliquus internus abdominis, obliquus externus abdominis, rectus abdominis, and erector spinae of the healthy subjects who adopted a standing position on a climbing wall.

Subjects performed static exercise on a 4×3 m, inclination-adjustable therapeutic climbing wall at various angles ranging from vertical (0 degree) to overhanging (30 degrees). The wall inclination (0 degree, 10 degrees, and 20 degrees) was measured using Goniometers (HiRes™Goniometers, Kineman Enterprises, USA). The holds used for therapy were large and easy to grab. They were also arranged symmetrically. An exercise mat was place on the floor for safety purposes. The posture was as follows: both hands and feet on the wall, slightly wider than shoulder width and shoulders flexed at 90 degrees, elbows extended[14]. Each trial consisted of 3 consecutive measurements lasting 7 seconds and spanning a period of 30 seconds with rest. The activities of the trunk muscles were measured using surface electromyography (LXM5380, LAXTHA, KOREA) for 7 seconds. The first and last seconds of data were discarded, and the middle 5 seconds were used in the analysis. The RMS (root mean square), which is considered to indicate the power output[15], of the EMG signals was calculated.

The RMS value is, a parameter frequently chosen for analysis because it reflects the level of physiological activities in the motor units during contraction[16].

All statistical analyses were performed using SPSS 20.0 software. The significance of differences in muscle activities (obliquus internus and externus abdominis, rectus abdominis, and erector spinae) among the different to wall inclinations were analyzed by two-way ANOVA, and Tukeys HSD was performed as post hoc analysis. A significance level of $\alpha = 0.05$ was chosen.

RESULTS

In this study, there were significant differences in RALT (rectus abdominis left) (F=11.9, p=<0.05), RART (rectus abdominis right) (F=11.2, p<0.05), IOLT (internus obliquus left) (F=7.3, p<0.05), IORT (Internus obliquus right) (F=7.6, p<0.05), EORT (externus obliquus right) (F=14.8, p<0.05), and ESRT (erector spinae right) (F=3.8, p<0.05) at 10 degrees, but EOLT (externus obliquus left) (F=1.4, p>0.05), and ESLT (erector spinae left) (F=2.4, p>0.05) did not show significant differences.

The magnitudes of the muscle activities of RART, RALT, IORT, IOLT, and EORT were in the order of 10>20>0 degrees (p<0.01). ESRT muscle activity was in the order of 10>20>0 degrees (p<0.05). The magnitudes of the EOLT and ESLT's muscle activities were in the order of 10>20>0 degrees (p>0.05, Tables 2 and 3).

Table 1. General characteristics of the subjects (n=24)

	Subjects
Age (yrs)	28.1±4.8
Weight (kg)	70.5±12.2
Height (cm)	172.4±7.8

Mean±SD

Table 2. Average right side muscle activities of the different wall inclinations (Units:)

	Rt							
	RA		IO		EO		ES	
0'	9.2±1.4	** (0'–10')	15.3±5.0	** (0'–10')	12.8±4.5	** (0'–10')	51.4±15.5	* (0'–10'); * (0'–20')
10'	16.4±11.8	** (10'–20')	20.9±7.6	** (10'–20')	19.0±5.8	** (10'–20')	60.2±17.0	
20'	10.9±3.2		17.6±6.4		15.2±5.0		59.9±15.6	

*p<0.05, **p<0.01; Rt: right; RA: rectus abdominis; IO: internus obliquus; EO: externus obliquus; ES: erector spinae

Table 3. Average left side muscle activities of the different wall inclinations (Units:)

	Lt					
	RA		IO		EO	ES
0'	10.3±1.8	** (0'–10')	16.4±7.5	** (0'–10')	17.3±16.1	53.2±16.6
10'	19.3±14.5	** (10'–20')	24.0±12.3	** (10'–20')	23.7±18.8	61.3±17.9
20'	12.1±3.8		17.7±8.2		18.8±18.2	58.2±15.2

**p<0.01; Lt: left; RA: rectus abdominis; IO: internus obliquus; EO: externus obliquus; ES: erector spinae

DISCUSSION

Isometric exercise utilizing gravity as resistance is one type of exercises that strengthens the trunk muscles involved in spinal stabilization. Because gravity is always active in the vertical direction, patterns of muscle activities depend on the direction and degree of inclination of the body[17]. Sports climbing is an exercise on artificial rock climbing walls, with effort exerted against gravity the upper and lower limbs[18], and it leads to even development of upper and lower limb muscles and improvement of balance[19]. Sports climbing has recently been utilized therapeutically, especially in Germany, as interest in the sport has increased[20]. Kim et al.[21] reported that trunk muscle activity of patients with chronic low back pain was significantly increased by therapeutic climbing exercise (0 degree) compared to mat exercise. However, Grzybowski et al.[20] reported that exercise on a vertical wall (0 degree) allowed weight-bearing through the lower extremity. Therefore, this study was performed to identify the appropriate angle for rehabilitation exercise performance via the comparison of muscle activities of healthy subjects at different wall inclinations (0, 10, and 20 degrees).

The activities of trunk muscles at the three wall inclination angles (0, 10, and 20 degrees) were significantly different at the angle of 10 degrees. This result was consistent with the result of a study by Grzybowski et al.[20] who used six wall inclination angles (0°, 4°, 8°, 12°, 15°, 18°). They reported muscle activity differed significantly at 12° and higher. Crommert et al.[22] reported that muscle activity increased at the imposed flexion moment, i.e. with arms extended horizontally forward at the level of the shoulder joints, compared to at the imposed moment, i.e. arms inclined forward or backward, during a study on the activity of the erector spinae during load-bearing by the upper limbs in an orthostatic posture. In this study, measurements of the activities of the erector spinae with the shoulders flexed at 90 degrees were similar to those reported by previous studies. Given that reduced extensor muscle endurance in patients with low back pain is the result of stress, tremor, dysfunction and inhibition of the erector spinae[23], therapeutic climbing on a 10-degree wall should be effective in improving the muscle strength of the erector spinae. The obliquus externus abdominis is involved in spinal stabilization and trunk rotation as well as maintaining minimal isometric contraction to stabilize the trunk in a standing position while utilizing the climbing wall. The obliquus internus abdominis plays a role similar to that of a corset by contracting with the transversus abdominis and is initially activated with sudden load bearing due to the movement of the lower limbs[23]. In this study, no significant differences were found for the left obliquus externus abdominis. This was because of fixation of the trunk to maintain the standing position, and the small amount of load placed on the trunk due to stabilize the turnk during movement of the upper and lower limbs. In conclusion, the measurements of trunk muscle activity in a static climbing standing position at different angles show significant changes in muscle activity are induced at 10 degrees. Therefore, this result provides clinically relevant evidence. Further evidence for a patient-directed approach to therapy should be obtained through comparison of muscle activities using smaller increments of inclination angle in future studies. A limitation of this study was that measurements were performed in the same posture, since muscle activity may vary with movement.

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