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Research Article

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Effect of Weak-part Strengthening Training and Strong-part Relaxation Therapy on Static Balance, Muscle Strength Asymmetry, and Proprioception in the Gluteus Medius: Immediate Effect Analysis

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| Abstract |

PURPOSE: This study investigated the immediate effects of gluteus medius strengthening training and relaxation therapy on the static balance, muscle strength asymmetry, and proprioception.

METHODS: In this research, 38 healthy adults were assigned randomly to strengthening groups (SG) and relaxation groups (RG). The static balance, muscle strength asymmetry, and proprioception were measured as a pre-measurement. The same measurements were performed after the intervention and follow-up. An independent sample t-test was used to compare each group, and one-way repeated ANOVA was used to compare the changes within the group.

RESULTS: In the static balance, the comparison between groups SG was more significant than RG, and only SG showed significant differences in the intra-group comparisons. There was no significant difference in muscle strength asymmetry between SG and RG. On the other hand, the comparison within the group revealed only SG to be significant. In proprioception, SG produced more significant results than RG, and only SG had significant values in the within-group comparison.

CONCLUSION: Strengthening training affects the changes in static balance, muscle strength asymmetry, and proprioception.

Key Words: Gluteus medius, Muscle strength asymmetry, Proprioception, Static balance, Strengthening

Ⅰ. Introduction

Balance is a complex process that includes motions adjusted from several sensory, motor, and biomechanical components [1]. Balance is largely divided into dynamic balance and static balance. Static balance refers to maintaining the center of gravity (COG) within a fixed support base without sway [2]. Because the human body is not rigid enough to sustain balance, the COG position changes constantly based on the distribution of mass

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throughout the body and the position of the limbs as a function of the activity, impacting balance, and stability [3].

One of the several senses involved in balance, the proprioception, is generally located in muscles, tendons, and joints and is distributed widely throughout the spinal nerves. In addition, it is involved in balance control by allowing one to sense where the body part is in response to changes in length and position of the torso, limbs, and head structure [4].

Balance motion includes movements of the ankle, knee, and hip joints and is controlled by coordinating movements of the muscles of the ankle, thigh, and lower trunk [1]. Among these muscles, the gluteus medius is the primary hip abductor that provides pelvic stability during walking and other functional activities. During a one-legged phase, through the contraction, it prevents the contralateral pelvis from falling and provides stability in the proximal part of the body [5]. If one side of the gluteus medius is weakened, the muscle strength is lowered compared to that of the opposite side, so muscle strength asymmetry between the muscles will occur [6]. This muscle strength asymmetry causes body sway during the functional activities [7] and acts as a risk factor for falls by affecting the postural stability [8]. Therefore, this study conducted strengthening training and relaxation therapy for the gluteus medius as an intervention for this muscular asymmetry.

Previous studies examined the effects of hip abductor strengthening training in patients with patella femoral syndrome associated with weakening of the gluteus medius and reported that strengthening training reduced pain [9,10] and was effective for improving muscle strength [11]. Relaxation therapy is an intervention that reduces the muscle tone, pain index, and anxiety index, according to previous studies [12], and hip joint foam roller stretching reduces the muscle tone [13]. On the other hand, there are no reports comparing the application of strengthening training to the weak part and the application of relaxation therapy to the strong part. Therefore, this study conducted muscle strengthening training with more effective exercise for the gluteus medius than gluteus minimus and compared them using foam rollers stretching [14].

Long-term training and corrections are required to improve the balance ability and postural control. Previous studies showed that the static balance ability measured after the short-term complex movement of the gluteus medius had a positive effect [15]. Therefore, this research examined the immediate effect of strengthening training on the weak part and relaxation therapy on the strong part of gluteus medius on the static balance, muscle strength asymmetry, and proprioception

Ⅱ. Materials and Methods

1. Participants

This research was conducted on 38 healthy adult males and females among 20-year-old students enrolled at S University in Asan-si, Chungcheongnam-do. The number of participants required for the study was calculated to be the number of subjects required for an Independent T-test. The number of subjects was determined by a calculation using G power 3.1.9.7 (Heine Heinrich University, Düsseldorf, German) with a significance level (a) .5, power of .80, and an effect size of 1 considering a 20% dropout rate. All participants were recruited through 1:1 interviews, and the screening criteria were set as those who could control gait and balance independently, those who did not have a history of surgery for hip and knee joints, and those who had not developed inflammatory diseases or pain within the last six months. After sufficient explanation of the research contents, those who agreed to the research and voluntarily wanted to participate were selected as subjects. After measuring the subjects' age, height, and weight, they were assigned randomly to two groups: strengthening and relaxation (Table 1). The research design was within each group to measure and

Table 1. General Characteristics of the Subjects (N = 38)

Division	MeanSD	
	Strengthening group (SG)	Relaxation group (RG)
Age(year)	22.841.80	22.161.71
Height(cm)	171.537.08	164.216.55
Weight(kg)	69.4310.33	59.6312.81

SD: standard deviation

compare the muscle strength, proprioception, and static balance pre, post, and follow-up. This research was approved by the Institutional Review Board (IRB) of Sunmoon University.

2. Measurement Equipment

1) Balance assessment

The balance ability was evaluated using Tetrax (Tetra-ataxiometric posturography, Ramat Gan, and Sunlight Medical, Tel-Aviv, Israel), which detects posture vibrations using the movement pattern of the center of pressure measured by the pressure sensor using the force plate, which is the independent four ground reaction force devices of the heel and toes of the left and right feet [16]. When measuring the static balance, the weight distribution index (WDI) and stability index (ST) was measured in a front-facing posture with the eyes open(normal eye open, NO) [17]. In addition, because the posture stability occurs when information flowing from the center of the visual organs, proprioception, and the vestibular organs causes involuntary reactions, a normal eyes close (NC), a pillow with eyes open (PO), and a pillow with eyes closed (PC) were also measured [18]. At this time, the participants were instructed to stare at a point in front of their eyes without speaking and moving their arms. Each measurement method was divided into three phases for approximately 32 seconds and was made before the intervention (pre), immediately after the intervention (post), and after a five-minute break by measurements (follow-up). Among the values measured, a higher WDI indicated a more non-uniform weight distribution, and a higher ST value indicated greater shaking of the posture. In other words, the lower both values, the more stable the body balance [19].

2) Muscle strength Asymmetry assessment

To measure the muscle strength asymmetry of both gluteus medius on CSMI (Computer Sports Medicine, Inc., HUMAC NORM, USA, 2010), which is an isokinetic strength measuring device, the hip joint was placed in a side-lying position with 0° flexion, extension, abduction, and adduction. Hip abduction motion was then performed. In addition, the upper body and pelvis were belted to minimize the participants' body movements and compensation for other muscles [20]. The knee was extended, and the ankle was in 90° dorsal flexion to derive a more accurate measurement during the abduction. The abduction angle was set to 30° [21], and the angular speed was set to 60°, which is the default, to generate the maximum force. This study measured the muscle asymmetry. The difference in the peak torque values measured left and right was calculated. Therefore, a smaller average value indicated greater symmetry.

3) Proprioception test

Based on previous research that measured proprioception in the lower extremities by applying a Joint Position Error test [4], attaching a laser under the medial malleolus on both sides and the laser of the legs in the supine position were set to match the origin of the target plate attached

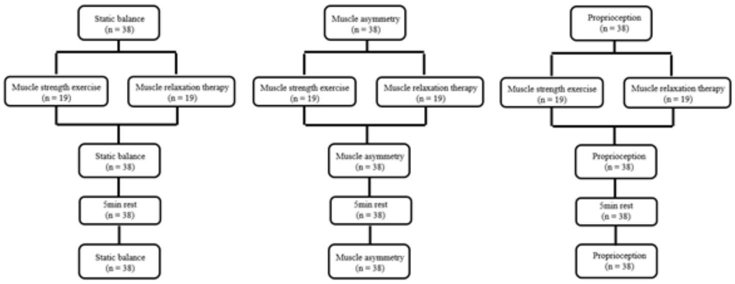

Fig. 1. Experimental procedures.

to the wall [22]. The participants were instructed to hold their heads up and memorize the location of the laser with their head down. The legs to be measured and those not measured were placed in abduction and adduction three times each. When returning to the origin, the laser position was marked immediately on the target plate, and the distance of the nearest point among the marked was measured. A shorter distance to the origin meant better proprioception.

3. Experimental Procedures

After sufficiently explaining the research procedure and intervention, the subjects were assigned randomly in advance to the strengthening training group and relaxation therapy group of the gluteus medius. Based on the CSMI results for each group, the strengthening training group performed the intervention with a leg with a high PK value and the relaxation therapy group with a leg with a low PK value. To ensure that the results of static balance and proprioception, which have an immediate effect and did not affect each other, the muscle strength asymmetry and static balance were measured in the first week using Tetrax and CSMI, and only proprioception was measured in the second week. To standardize the repetition rate in each group, set to a metronome was set to 60 bpm [14], and movement for one minute was considered one set. Three sets of interventions were applied equally to measure again. A break of five minutes was applied, and the measurements were performed once more (Fig. 1).

1) Muscle strengthening training

Based on the previous research that the muscle strength increased more in the group that performed strengthening training using an additional elastic band, a thera band, a type of elastic band, was used for strengthening training [23]. After tying the thera band in a loop shape, it was fixed to the knee in a side-lying position with the hips in a neutral position and the knees in extension and adduction. After fixing the lower leg to the floor, the abduction and adduction of the upper leg were repeated as much as 30°, the value set in the CSMI. This was performed adjusting to the metronome beat of 60bpm, and three sets of eccentric and concentric contractions were performed for each of the 15 repetitions for two seconds [14]. The rest time between sets was 20 seconds.

2) Muscle relaxation therapy

Relaxation therapy used a foam roller. The posture was performed by sitting on the foam roller, with the relaxing side placed on the floor and allowing the ankle of the non-relaxing side on the knee of the opposite leg to move back and forth to perform stretching. The participants were then instructed to place their hands on the floor behind their backs to support their balance. This was performed by repeating three sets of moving back and forth for one second in line with the metronome beat of 60 bpm for one minute, and the break time between each set was set to 20 seconds, the same as strengthening training.

4. Data analysis

The mean and standard deviation of each measurement item were calculated using the SPSS statistical software (version 20.0; IBM) program. After performing normality verification, an independent t-test was conducted to compare the groups, and repeated measures of ANOVA were used to compare the intragroup changes pre, post, and follow-up. Post-hoc analysis was performed using a Fisher's LSD. All statistical significance levels (a) were set to .05 or less.

Ⅲ. Results

1. Static Balance

A statistically significant difference in WDI-NC Post and WDI-PO Post values was observed between the groups. The post mean value of WDI-NC was 5.07 ± 2.69 in the strengthening group and 7.55 ± 3.44 in the relaxation group (P < .05). The post mean values of WDI-PO were significant in the strengthening group, 4.09 ± 2.70, and in the relaxation group, 5.87 ± 2.06 (p < .05). The results within each group

Table 2. Comparison of the Static Balance Between and Within Strengthening Group and Relaxation Group

Variable	Time	Intervention			
		SG	RG	t	p
ST – NO (points)	pre	13.54 ± 4.05	14.10 ± 6.48	.320	.751
	post	13.31 ± 2.78	13.97 ± 4.18	.576	.568
	follow-up	12.95 ± 3.85	14.14 ± 4.56	.865	.393
	p	.698	.952		
ST – NC (points)	pre	15.52 ± 5.05	17.57 ± 5.25	1.226	.228
	post	16.20 ± 6.26	17.62 ± 6.06	.710	.482
	follow-up	16.15 ± 6.26	18.15 ± 6.62	.957	.345
	p	.779	.712		
ST – PO (points)	pre	15.18 ± 4.55	17.04 ± 9.33	.785	.438
	post	16.06 ± 5.02	15.77 ± 5.75	-.162	.872
	follow-up	16.71 ± 6.33	15.84 ± 4.92	-.473	.639
	p	.379	.682		
ST – PC (points)	pre	26.54 ± 9.92c	25.61 ± 7.25	-.329	.744
	post	23.36 ± 8.51	26.53 ± 9.98	1.053	.299
	follow-up	22.91 ± 6.95[a]	23.29 ± 4.47	.201	.842
	p	.032*	.061		
WDI – NO (points)	pre	5.82 ± 3.21	6.58 ± 2.99	.758	.453
	post	5.90 ± 2.65	7.96 ± 3.53	2.031	.050
	follow-up	6.57 ± 3.60	7.30 ± 3.08	.677	.503
	p	.252	.082		
WDI – NC (points)	pre	5.44 ± 2.28	6.80 ± 2.49	1.757	.087
	post	5.07 ± 2.69	7.55 ± 3.44	2.477	.018*
	follow-up	5.56 ± 3.16	7.41 ± 2.59	1.966	.057
	p	.426	.470		
WDI – PO (points)	pre	5.49 ± 2.65b	4.83 ± 2.13	-.795	.432
	post	4.09 ± 2.70a	5.87 ± 2.06	2.286	.028*
	follow-up	4.70 ± 2.31	5.65 ± 2.19	1.303	.201
	p	.044*	.076		
WDI – PC (points)	pre	4.99 ± 2.69	5.06 ± 2.66	.085	.933
	post	3.86 ± 2.36	4.93 ± 1.50	1.657	.106
	follow-up	4.45 ± 2.29	4.63 ± 2.11	.259	.797
	p	.080	.821		

*p < .05(Mean ± SD), SG: Strengthening Group, RG: Relaxation Group, ST: Stability Index, WDI: Weight Distribution Index, (NO, Normal eye open), (NC, Normal eye close), (PO, Pillow with eye open), (PC, Pillow with eye close). [a]Statistically different from pre, b Statistically different from post, c Statistically different from follow-up.

Table 3. Comparison of Peak Toque between and Within Strengthening Group and Relaxation Group

Variable	Time	Intervention			
		SG	RG	t	p
PK (m/sec)	pre	7.74 ± 5.96	8.42 ± 4.61	.396	.695
	post	5.84 ± 4.29	6.21 ± 4.01	.274	.786
	follow-up	4.42 ± 3.24	9.47 ± 8.17	2.507	.191
	p	.104	.184		

*p < .05(Mean ± SD), SG: Strengthening Group, RG: Relaxation Group, PK: Peak Toque. [a]Statistically different from pre, [b]Statistically different from post, [c]Statistically different from follow-up

Table 4. Comparison of Proprioception between and within the Strengthening Group and Relaxation Group

Variable	Time	Intervention			
		SG	RG	t	p
ABD (cm)	pre	3.56 ± 3.40	4.25 ± 3.55	.611	.545
	post	3.81 ± 4.51	4.81 ± 4.12	.714	.480
	follow-up	3.01 ± 2.95	6.17 ± 3.91	2.820	.008**
	p	.421	.168		
ADD (cm)	pre	5.77 ± 4.82[bc]	5.12 ± 3.08	-.493	.625
	post	3.12 ± 3.79[a]	4.34 ± 4.43	.917	.365
	follow-up	1.78 ± 2.38[a]	5.53 ± 4.09	3.458	.002**
	p	.000**	.597		

*p < .05(Mean ± SD), **p < .01(Mean ± SD), SG: Strengthening Group, RG: Relaxation Group, ABD: Abduction, ADD: Adduction, [a]Statistically different from pre, [b]Statistically different from post, [c]Statistically different from follow-up

showed a significant difference in both ST-PC and WDI-PO only in the SG group, with .03 ($p < .05$) for ST-PC and .04 ($P < .05$) for WDI-PO (Table 2).

2. Muscle strength asymmetry

The PK values between each group and the PK values within the groups were not statistically significant (Table 3).

3. Proprioception

Each group showed a statistically significant difference in the follow-up values of ABD and ADD. The mean follow-up of ABD was 3.07 ± 2.95 in the strengthening group and 6.17 ± 3.91 in the relaxation group ($P < .05$). The mean value of follow-up of ADD was 1.78 ± 2.38 in the strengthening group and 5.53 ± 4.09 in the relaxation group ($P < .05$). The results within the group were significant only in the SG group, with a significant probability value of .00 ($P < .05$) (Table 4).

Ⅳ. Discussion

This study examined the immediate effects of gluteus medius strengthening training and relaxation therapy on the static balance, muscle asymmetry, and proprioception. Two interventions were conducted for three weeks in previous research that evaluated the effects of abdominal strengthening exercise and abdominal muscle stretching on the spinal flexibility in healthy adults. This resulted in a significant increase in the results after 21 days compared to pre-results in the flexibility of the sacrum and vertebral column and the length of the vertebral column[24].

Therefore, the effect could not be verified after applying exercise of a completely different personality in this research conducted on normal adults.

In the static balance test, the post value of strengthening training in NC and PO of WDI was more significant than that of relaxation therapy. In balance, a lower the ST means less body sway, and a lower WDI means a change in the rate of weight on the floor. Therefore, lower indices imply that the center of the body fluctuated less, providing better balance ability. Muscles have a strong influence on the ability to control balance. Therefore, it was assumed that strengthening training of the gluteus medius was effective because it increased the muscle strength. Indeed, a higher muscle strength of the lower extremity meant less body sway and improved ability to balance control [25]. Among them, the ankle muscle is the first muscle involved in posture control, and the hip joint is used to control the balance ability if the ankle joint is in an unacceptable range. This suggests a close correlation between the ankle and hip muscles for posture control. Son et al. reported that four weeks of isokinetic ankle strengthening training improved the balance of one leg [26], and Smith et al. showed that four weeks of supervised resistance band exercise aimed at improving the hip abductor and external rotator muscle strength improved the static and dynamic balance of individuals with CAI [27]. The presence or absence of visual blocking was also applied as an important variable in balance. These results showed significantly improved results in the posture of closing the eyes on the stable support surface and opening the eyes on the unstable support surface. Therefore, it is expected to strengthen muscle strength of the gluteus medius unconsciously and immediately show involuntary effects, reducing the variability of visual blocking. When visual information is blocked, the length and speed of agitation appear larger, but according to previous studies, the static balance was increased in the posture measured with the eyes closed after strengthening the hip abductor muscle with an elastic band [28]. Zouita et al. reported that both values measured with the eyes open and eyes closed at an unstable support in the eight-week strength and balance training group reduced the body sway [29]. Therefore, the results of strengthening training were significant. In the case of relaxation therapy, the strength of the strong part was lowered to induce an increase in static balance ability. On the other hand, it was assumed that self-myofascial relaxation therapy using foam rollers affected the ROM increases due to the short-term effects but did not have a positive effect based on previous studies that did not degrade the muscle performance [30].

In the proprioceptors, muscle spindles play a major role in sensing the changes in muscle length and velocity. In addition, the skin, joints, and ligaments provide additional information about joint position and motion. Proprioception senses limb movement, perception of the limb position, and the force generated by the muscles. In this research, it was presumed that the results above were due to repetitive motor learning because both joint positions sensory error test and strengthening training were conducted at the same angle. This is based on previous research showing that strengthening training with the same intensity improves the sense of position compared to strengthening training at various angles. Moreover, the proprioception score improved immediately after exposure to the AMEDA stance of a normal ankle [31,32]. Relaxation therapy did not show a positive effect by gradually decreasing over time rather than increasing the proprioception. In previous research that applied the HR-PNF technique, a relaxation technique, measurements of proprioception immediately after the intervention showed a decrease in the sensations [33]. The present study also showed that the sensations were further reduced when re-measured after a five-minute rest [33].

Nevertheless, the results for muscle asymmetry were statistically insignificant, suggesting that neither strengthening training nor relaxation therapy could reduce the difference in muscle asymmetry. Long-term interventions are very effective in increasing muscle strength, but short-term interventions of three minutes do not have sufficient influence to increase the muscle strength. A previous study showed that muscle strength increased when isometric and isotonic exercises were performed for 10 minutes each [34]. Jensen et al. reported that muscle strength was increased using an elastic band through an eight-week intervention [35].

Overall, strengthening training was superior in improving the static balance and proprioception to relaxation therapy. This can be seen as a positive effect on physical ability when strengthening training is applied to a weakened gluteus medius.

This study has several limitations. First, the intervention time was too short to produce a clear effect. As in previous research, if the intervention period is sufficient, the asymmetry of muscle strength would be reduced, and a positive effect on static balance and proprioception would be shown. Second, the intervention method of relaxation therapy did not have a significant effect on the gluteus medius. The participants reported that they felt the strengthening training on the intended hip region, but relaxation therapy produced more pain in the wrist region than in the hip region. This was attributed to foam rolling not having a positive effect on static balance, reduction of muscle strength asymmetry, and proprioception because the body weight was distributed in places other than the gluteus medius during relaxation therapy. Third, when checking the standard deviation of each measurement for a completely different result in one intervention, it was judged that the large difference between individuals was a limitation that influenced the result.

Ⅴ. Conclusion

Strengthening training, as an intervention method, immediately affects the static balance and proprioception. The group with strengthening training in the weak part of the subjects produced significantly better results than those with relaxation therapy in the strong part. Therefore, this research suggests a new approach to clinical intervention that can be used as basic clinical data for strengthening training and relaxation therapy of the gluteus medius.

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