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Iliotibial Band Stretching in the Modified Thomas Test Position Changes Hip Abduction Angle and Vastus Medialis Activity in Individuals With Tight Iliotibial Band

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Abstract

Background: A tight iliotibial band (ITB) may lead to lateral patellar maltracking, compression, and tilt, and dominant vatus lateralis (VL) muscle activation relative to vastus medialis oblique (VMO) can laterally displace the patella, which leads to anterior knee pain. Therefore, an effective management technique is needed to stabilize the patella in individuals with tight ITB. Increased stability during the modified Thomas test has the potential to decrease compensatory motion and thus to selectively stretch the ITB.

Objects: The purpose of this study was to determine the effects of ITB stretching in the modified Thomas test position on ITB flexibility, patellar translation, and muscle activities of the VMO and VL during quadreceps-setting (QS) exercise in individuals with tight ITB.

Methods: Twenty-one subjects with tight ITB were recruited. Digital inclinometer was used to measure the hip adduction angle during the modified Ober test. Universal goniometer was used to measure the hip abduction angle during the modified Thomas test. Ultrasonography was used to measure the patella-condylar distance. Electromyography was performed to collect data of muscle activities. Paired t-test was used to determine the statistical significance between pretest and posttest.

Results: The range of hip adduction in modified Ober test increased ($p=.04$) and the range of hip abduction in the modified Thomas test decreased after ITB stretching ($p<.01$). There was no difference between lateral patellar translation ($p=.18$). VMO muscle activity significantly increased after ITB stretching during QS ($p<.01$). VL muscle activity had no difference after stretching.

Conclusion: The ITB stretching in the modified Thomas test position can be suggested as a management method for improving ITB flexibility and VMO muscle activity in individuals with tight ITB.

Key Words: Iliotibial band stretching; Modified Thomas test position; Tight iliotibial band; Vastus medialis oblique.

Introduction

The iliotibial band (ITB) runs down the lateral side of the thigh and distally inserts on Gerdy's tubercle, the anterolateral patellar retinaculum, and tuberosity of the tibia; thus, many studies reported the important connection between the ITB and the patella (Cruells Vieira et al, 2007; Merican and Amis, 2008; Merican and Amis, 2009). The ITB also provides the attachment of the gluteal muscles, tensor fascia lata, and vastus lateralis (VL). Most of the lateral retinaculum arises from the ITB; therefore,

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the ITB indirectly provides lateral stabilization and acts as a passive restraint to the medial patella glide (Gray et al, 2005). However, a tight ITB may lead to lateral patellar maltracking, compression, and tilt (Hudson and Darthuy, 2009; Kang et al, 2014; Puniello, 1993). Therefore, an effective management technique is needed to stabilize the patella in individuals with tight ITB.

ITB stretching rehabilitation programs are planned to increase ITB flexibility in individuals with tight ITB (Fredericson and Weir, 2006; Fredericson et al, 2002; Fredericson and Wolf, 2005; Kim, 2012; Lucas, 1992; Strauss et al, 2011). ITB stretching management can provide the advantage of increased muscle flexibility (Godges et al, 1993; Muragod et al, 2015; Winters et al, 2004). The ITB was stretched in the standing position in previous studies, which resulted in significant increases in ITB length and hip adduction range (Fredericson and Weir, 2006; Fredericson and Wolf, 2005; Muragod et al, 2015; Strauss et al, 2011). The Ober test and modified Ober test are known to be assessment tools for ITB tightness in the side-lying position (Ferber et al, 2010; Harvey, 1998; Herrington and Payton, 1997). The Ober test and modified Ober test positions are also used as ITB stretching methods (Wang et al, 2006). ITB tightness can also be confirmed using the modified Thomas test; in addition, the modified Thomas test position can be utilized as a stretching position. The modified Thomas test is performed in the supine position, which increases the base of support as compared with the standing and side-lying positions. Increased stability during the modified Thomas test has the potential to decrease compensatory motion (Sahrmann, 2002) and thus to selectively stretch the ITB.

The quadriceps muscles are the active stabilizer of the patella, with the VL muscle being the lateral stabilizer in contrast to the vastus medialis oblique (VMO) muscle, which is the medial stabilizer (Puniello, 1993). Although a tight ITB is known to be the contributing factor to the lateral pull of the patella, no previous studies measured VMO and VL muscle activities before and after ITB stretching. VMO is considered important owing to its role of medial pull on the patella (McConnell, 1996). The decreased VMO muscle activity causes a patellar displacement of 5 mm in the lateral direction (Ahmed et al, 1983) and imbalance of the VMO and VL muscle activities results in patellofemoral pain (Bowyer et al, 2008); therefore, activating the VMO is often important when planning the rehabilitation exercise for patients with knee pain. McConnell (1996) suggested patellar taping and passive stretching of lateral structures to facilitate the VMO activity for patients with knee pain. Douciette and Goble (1992) reported that VMO strengthening and ITB stretching could improve patellar maltracking. From a functional standpoint, few daily or recreational activities occur with the leg in an open chain system. Training the leg muscles in a closed kinetic chain system such as the quadriceps-setting exercise (QS) (Earl et al, 2001) is considered more beneficial. Thus, comparison of VMO and VL muscle activities during QS between the pretest and posttest may be valuable.

The purpose of this study was to determine the effects of ITB stretching in the modified Thomas test position on ITB flexibility, patellar translation, and muscle activities of the VMO and VL during QS in individuals with tight ITB. We hypothesized hip adduction would increase in the modified Ober test, hip abduction would decrease in the modified Thomas test, and lateral patellar translation would decrease. VMO muscle activity would increase, and VL muscle activity would decrease during QS.

Methods

Participants

The G*power software package (ver. 3.1.9.2; Franz Faul, Kiel University, Kiel, Germany) was used to conduct power analyses. The required sample size of 10 was calculated from five participants to observe an alpha level of .05, an effect size of .89, and a

Table 1. Descriptive characteristics of the participants (N=21)

Variables	
Age (years)	20.7±1.73[a]
Height (㎝)	167.9±7.73
Weight (㎏)	61.8±7.99
Body mass index (㎏/㎡)	21.9±2.27

[a]mean±standard deviation, [b]iliotibial band.

power of .80. As a result, total 21 (9 males, 12 females, the results were compared according to gender, and there was no significant difference, we proceeded to one group regardless of gender) participants with tight ITB were recruited (Table. 1). Tight ITB was assessed using the modified Ober test. A hip adduction angle of <10° was verified as a tight ITB (Lee et al, 2014; Wang et al, 2006). Participants were excluded if they had a previous surgery of the patellofemoral joint (Crossley et al, 2002) and current back, hip, knee, or ankle pain (Hudson and Darthuy, 2009). All the participants were informed of the experimental protocol and consent form. The experimental protocol was approved by the Yonsei University Wonju Institutional Review Board (approval number: 1041849-201812-BM-126-03).

Procedure

The range of hip adduction in the modified Ober test, hip abduction in the modified Thomas test, and lateral patellar translation were measured twice. The VMO and VL muscle activities during QS were measured three times before and after ITB stretching in the modified Thomas test position with the average and intra-class correlation coefficients (ICC) calculated for the data analysis. The participants performed tests in random order using randomization sequence created with Microsoft Excel (Microsoft corp., Roselle, IL, USA). A 2-min rest time was provided between the trials in all the measurements. The participants were familiarized with ITB stretching in the modified Thomas test until they could maintain the stretching position for 30 seconds.

ITB flexibility

The hip range of motion measured in the modified Ober test and modified Thomas test were used to identify ITB flexibility (Fredericson and Wolf, 2005).

The hip adduction angle was measured with a digital inclinometer (GemRed DBB, Gain Express Holdings, Ltd., Hong Kong, China) during the modified Ober test. The participants were in the side-lying position on the treatment table with the tested leg on the top. To stabilize the pelvis, the participant was instructed to flex the bottom leg in 45° hip flexion and 90° knee flexion (Herrington et al, 2006). The examiner placed one hand on the top pelvis to provide additional stability and the other hand to abduct the participant's hip passively. Then, the participant was instructed to relax the leg by lowering it passively into the hip adduction direction (Herrington et al, 2006). While lowering the leg, the adduction was controlled by the examiner at the medial knee joint. When the leg was in the last range of the hip adduction due to the ITB tightness, the leg was held by the examiner, and the second examiner placed the digital inclinometer at the lateral aspect of the thigh, at the halfway position of the anterior superior iliac spine (ASIS) and patella (Ferber et al, 2010). As the examiner held the leg to prevent pelvic tilt or hip internal rotation, the second examiner read the hip adduction angle for data collection (Wang et al, 2006) (Figure 1). The ICC (95% confidence interval [CI]) for the pretest and posttest hip adduction angles were .94 (.85-.97), and .92 (.81-.97), respectively.

The range of hip abduction was measured using a universal goniometer (Baseline, Pakistan) during the modified Thomas test. The participant was instructed to sit at the end of the treatment table and then to roll back on to the table while holding both knees to the chest to flatten the lumbar spine by posteriorly tilting the pelvis. Next, the participant lowered the tested leg to the treatment table while holding the untested leg with the arms. While holding the position, the examiner placed the axis of the goniometer at the ASIS on the tested side. The stationary arm

Figure 1. Measuring the range of hip abduction.

was along the line between the two ASISs, and the movable arm was parallel to the femur (Harvey, 1998) (Figure 1). The ICC (95% CI) for the pretest and posttest hip abduction angles were .90 (.77-.96) and .89 (.73-.96), respectively.

Lateral patellar translation

Lateral patellar translation was calculated on the basis of the patella-condylar distance (PCD). The PCD is defined as the distance between the lateral condyle of the femur and the lateral border of the patella (Figure 2). The formula was lateral patellar translation = PCD at neutral - PCD at 20° hip adduction (Kang et al, 2014).

Ultrasonography (US; SonoAce X8, Medison Co. Ltd., Seoul, Korea) was used to measure the PCD. The neutral position was performed in a long-sitting position with 20° knee flexion, which was maintained by placing a roller under the knee (Kang et al, 2014). Then, the examiner marked the point of the lateral superior border of the patella to measure the PCD. A US probe (L5-12EC, 8-12 MHz) in B-mode was placed perpendicular to the skin with water-soluble transmission gel placed over the probe head. To provide static compression, the examiner placed the transducer at the marked point with constant pressure in a vertical direction without horizontal shift (Thomas et al, 2006). The hip adduction position was performed with the participant adducting hip by 20° by determining the

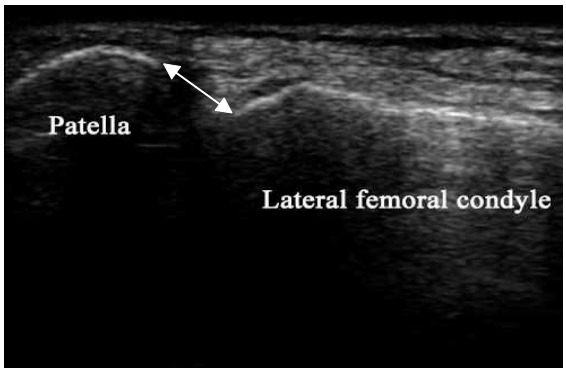

Figure 2. Patella-condylar distance (PCD) on ultrasonography.

degree with a universal goniometer. The axis, stationary arm, and movable arm were the same as those in the hip abduction angle measurement during the modified Thomas test. During the procedure, the participant was assisted by the examiner to maintain a neutral position of the hip or ankle. And the compensation movements of the pelvis (Kang et al, 2014).

After stretching, the transducer was placed at the same marked point with the same procedure as that in the pretest (Figure 3). The ICC (95% CI) for the pretest and posttest lateral patellar translations were .73 (.44-.88), and .67 (.34-.85), respectively.

VMO and VL muscle activity

Surface electromyography (EMG) signals were collected using Noraxon Telemyo 2400T (Noraxon Inc., Scottsdale, AZ, USA) with a MyoResearch Master Edition software package (ver. 1.06 XP, Noraxon Inc., Scottsdale, AZ, USA). The data sampling rate was 1,000 ㎐, with band-pass filtering between 50 and 450 ㎐, notch-filtered at 60 ㎐, with the root mean square calculated using a moving window of 50 ㎳. Data were collected from the VMO and VL on the participant's stretching side. Before the electrode attachment, the skin was shaved and cleansed with alcohol to diminish the skin impedance of the EMG signal. Disposable electrodes (Ag/AgCl) with a 2-㎝ inter-distance were attached to the muscle site.

Surface EMG electrodes were placed over the following muscles: 1) VMO, 2 ㎝ medially distant from

Figure 3. Measuring patella-condylar distance.

the superior rim of the patella at the medial aspect of the thigh in 55° and, 2) VL, 6 ㎝ above the knee cap at the lateral surface of the lower third of the thigh (Criswell, 2010). The maximum voluntary isometric contraction (MVC) was obtained using the manual muscle testing position (Kendall et al, 2005). The positions were as follows: First, the participants were instructed to sit with their knees over the treatment table. Then, the resistance was applied against the ankle in the direction of knee flexion. By giving verbal cues, the examiner instructed the participant to engage maximum effort against the resistance. The MVC was held for 5 seconds in 3 trials (Bowyer et al, 2008), and the middle 3-second periods was calculated for analysis. The ICC (95%CI) for the MVCs of the VMO and VL were .97 (.88-.98), and .97 (.94-.97), respectively.

The EMG activities of the VMO and VL were measured during QS. The participant lay supine on the treatment table and instructed by the examiner to extend the knee to push the treatment table without using hip extension. The hip joint was in 10° abduction and 0° internal and external rotations (Zakaria et al, 1997). The QS was performed for 5 seconds in three trials, and the middle 3-second periods was analyzed. The EMG activities of the VMO and VL during QS were expressed as percentage of the mean MVC (%MVC).

Figure 4. Iliotibial band stretching in modified Thomas test position.

ITB Stretching

The side with a tight ITB was selected for the stretching exercises for the participants (15 right, 6 left). The stretching procedure was started with the same position as that in the modified Thomas test (Harvey, 1998). To provide pelvic stabilization, the examiner applied a pelvic belt around the participants' pelvis. Then, the examiner stood on the side with tight a ITB by placing one hand on the ASIS and the other hand on the lateral aspect of the distal thigh to adduct the hip joint. As the examiner passively adducted the participant's hip joint, the examiner felt the resistance from the tight ITB (Figure 4), and the stretching was applied until the participant felt a "good stretch" without discomfort (Bandy et al, 1997). Four repetitions of stretching was applied for 30 seconds with a 15-second resting time (DePino et al, 2000).

Statistical Analysis

The analyses were performed by using the SPSS software ver. 22.0 (IBM Corp., Armonk, NY, USA). A Kolmogorov-Smirnov Z test was performed to determine whether the continuous data follows a normal distribution. All the continuous variables followed a normal distribution (Kolmogorov-Smirnov Z test, $p>.05$). A paired t-test was used to determine the statistical significance between pretest and

posttest. The statistical significance was set at α level of .05.

Results

ITB flexibility significantly increased after ITB stretching. The range of hip adduction in the modified Ober test increased (t=2.27, p=.04) and the range of hip abduction in modified Thomas test decreased after ITB stretching (t=4.40, p<.01). No significant difference was found between the lateral patellar translation (t=.85, p=.18). The VMO muscle activity significantly increased after ITB stretching during QS (t=-3.66, p<.01). The VL muscle activity showed no significant difference after stretching (Table 2).

Discussion

The purpose of this study was to investigate whether ITB flexibility, patellar translation, and muscle activities of the VMO and VL during QS would be different after ITB stretching in the modified Thomas test position in individuals with tight ITB. We hypothesized that hip adduction would increase in the modified Ober test, hip abduction would decrease in the modified Thomas test and lateral patellar translation would decrease. VMO muscle activity would increase, and VL muscle activity would decrease during QS. The results indicated that ITB flexibility and VMO muscle activity were significantly increased after ITB stretching in the modified Thomas test position.

The range of hip adduction measured during the modified Ober test significantly increased by 44% as compared with that at baseline. Wang et al. (2006) investigated the stretching effectiveness of the modified Ober test by measuring the ITB width on ultrasonography. The results showed that the modified Ober test can effectively stretch the ITB. A significant decrease in ITB width was observed especially in the "hip adducted with weight" position than in the neutral or adducted position during the modified Ober test. The present study showed correspondent results that indicated increased hip adduction angles after ITB stretching. The improvements made by passive stretching may be the results of both the autogenic inhibition and tensile stress applied to the muscle. With autogenic inhibition, the muscle being stretched is inhibited and thought to simultaneously relax, resulting in an increase in range of motion (Tanigawa, 1972). The applied stress over a constant period during stretch may influence the fibrous tissue of the ITB and gradually increase the length that results in increased range of motion

Table 2. Comparisons of ITB flexibility, lateral patellar translation, and the muscle activities in pre- and post-test (N=21)

Variables	Outcome		t	p
	Pre-test	Post-test		
ITB[a] flexibility				
Modified Ober test (° hip abduction [-])	-8.45±4.56[b]	-4.90±6.14	2.27	.04*
Modified Thomas test (° hip abduction [+])	24.4±6.20	19.5±5.26	4.40	<.01*
Lateral Patellar Translation (㎝)	.07±.09	.04±.07	1.38	.18
VMO[c] (%MVC[d])	21.2±11.4	26.5±18.8	-3.66	<.01*
VL[e] (%MVC).	36.5±27.5	26.4±16.6	.04	.97

[a]iliotibial band, [b]mean±standard deviation, [c]vastus medialis oblique, [d]maximal voluntary contraction, [e]vastus lateralis, *p<.05.

(Winters et al, 2004). Therefore, ITB stretching in the modified Thomas position provides an increase in ITB flexibility.

The range of hip abduction measured during the modified Thomas test significantly decreased by 20% as compared with that at baseline. A previous study reported the mean of the hip abduction angles (15.6°) measured in the modified Thomas test in elite athletes (Harvey, 1998). No previous study measured the hip abduction angle during the modified Thomas test after ITB stretching, so a direct comparison with the hip abduction angle results from the previous study is difficult. The present study showed that in individuals with tight ITB, the hip abduction of 24.4° during the pretest, which is 8.8° greater than that in the previous study group of athletes, and 19.5° during the posttest, which is similar to that in the previous group of athletes. The ITB resides at the lateral aspect of the lower limb; therefore, decreased tightness of the ITB might reduce the hip abduction angle in the modified Thomas test.

The VMO activity during QS significantly increased by 25% as compared with that at baseline. During QS, decreased ITB tightness may increase the medial patellar movement, thereby providing a more favorable length-tension relationship of the medial patellar stabilizer, with the VMO activity facilitated, thus leading to increased VMO muscle activation. In this study, lateral patellar translation was not statistically significant; however, lateral patellar translation was passively measured, whereas the VMO was actively measured during QS. Considering that no change in VL muscle activity was observed, the lateral patellar movement during QS may not have increased. Therefore, the present study shows that ITB stretching itself facilitates the VMO activity during QS, which could decrease the lateral patellar maltracking in individuals with tight ITB and provide an active medial pull of the patella.

This study has several limitations. First, it was designed as a cross-sectional study; thus, the long-term effects of ITB stretching cannot be determined. Future research must consider a longitudinal study to investigate the long-term effects of ITB stretching. Second, this study had a one-sample pretest-posttest design. We only considered the modified Thomas test position to stretch the ITB. Future studies may consider other ITB stretching methods to compare their positional effects. Third, we did not measure patellar movement during QS. Increased VMO may reflect the medial pull of the patella; however, patellar alignment was not measured during QS. Measuring patellar tracking during active performance may provide a more accurate understanding of the relationship between VMO and VL muscle activities and the patella.

Conclusion

The purpose of this study was to determine the effects of ITB stretching in the modified Thomas test position on ITB flexibility, lateral patellar translation, and VMO and VL muscle activities during QS. The results demonstrated that ITB stretching in the modified Thomas position improved hip range of motion by increasing and decreasing the adduction angle in modified Ober test and modified Thomas test, respectively. The VMO muscle activity during QS also increased after ITB stretching. Thus, ITB stretching in the modified Thomas test position can be suggested as a management method for improving ITB flexibility and VMO muscle activity in individuals with tight ITB.

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