한국전문물리치료학회지 2016년 23권 4호 01-08 ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
Phys Ther Korea 2016;23(4):01-08 https://doi.org/10.12674/ptk.2016.23.4.001

The Effect of Patellar Inferior Gliding on Knee Flexion Range of Motion in Individuals With Rectus Femoris Tightness

Jun-hee Kim[1,2], BPT, PT, Moon-hwan Kim[3], PhD, PT, In-cheol Jeon[1,2], MSc, PT, Ui-jae Hwang[1,2], BPT, PT, Oh-yun Kwon[1,4,5], PhD, PT

[1]Kinetic Ergocise Based on Movement Analysis Laboratory
[2]Dept. of Physical Therapy, The Graduate School, Yonsei University
[3]Dept. of Rehabilitation Medicine, Wonju Severance Christian Hospital
[4]Dept. of Physical Therapy, College of Health Science, Yonsei University
[5]Dept. of Ergonomic Therapy, The Graduate School of Health and Environment, Yonsei University

Abstract

Background: Various methods are used for recovery of knee flexion range of motion (ROM) due to a tightened rectus femoris muscle (RFM) or limited inferior glide of the patella. Stretching methods are common interventions for restoring the tightened RFM length. Also patellar inferior gliding (PIG) technique can recover tightened RFM length too. However, effect of applying the PIG to passive knee flexion (PKF) has not been studied.

Objects: The purpose of this study was to investigate the effect of combining PIG with RFM stretching for improving knee flexion ROM in subjects with RFM tightness.

Methods: Twenty-six subjects with RFM tightness were recruited. Two different methods of knee stretching were tested: 1) PKF during modified Thomas test (MTT) and 2) PKF with PIG during MTT. The passive stretching forces was controlled by hand-held dynamometer. The knee flexion ROM angle was measured by a MTT with ImageJ software. Differences between the conditions with and without PIG were identified with a paired t-test.

Results: The knee flexion ROM was significantly greater for PKF with PIG (114.44±9.33) than for PKF alone (108.97±9.42) ($p<.001$).

Conclusion: A combination of passive knee flexion exercise and PIG can be more effective than PKF in increasing knee flexion ROM in individuals with RFM tightness.

Key Words: Knee flexion range of motion; Modified Thomas test; Passive knee flexion; Patellar inferior gliding; Rectus femoris tightness.

Introduction

The rectus femoris muscle (RFM) is a two-joint muscle located in the most superficial layer of the quadriceps muscle. It originates from the area of the antero-inferior iliac spine and crosses the hip to insert on the upper pole of the patella. The main actions of this muscle are knee extension and hip flexion (Bianchi et al, 2002). The RFM causes flexion of the hip, especially pre-swing, and affects walking speed, as the RFM activity increases with increasing walking speed during the initial phase (Nene et al, 1999). During standing, the RFM also controls the amount of flexion at the knee and causes knee extension through a reverse muscle draw on the femur (Kisner and Colby, 2012).

Several studies have shown that the RFM can easily become tight (McDonald, 1998; Norris, 1995). A rapid knee extension movement can cause over-activation of RFM than vastus muscles, such as vastus lateralis during sports activities and make RFM tightness (Richardson and Bullock, 1986). Also incorrect postures including an excessive lumbar lordosis

Corresponding author: Oh-yun Kwon kwonoy@yonsei.ac.kr

or anterior tilt of pelvis cause tightening of the RFM muscle (Janice et al, 1996). This tightness reduces knee flexion range of motion (ROM) and shifts the pelvis anteriorly, which can induce lumbar lordosis and cause low back pain (Gajdosik, 1985; Lénárt and Kullmann, 1974; Norris, 1995). RFM tightness during the bone growth phase in adolescence can also induce Osgood Schlatter syndrome (de Lucena et al, 2011). Previous study reported that 61% of patients with patellofemoral pain syndrome patients had RFM tightness (Sutherland and Davids, 1993). The tightened RFM also pulls the patella superiorly, due to the connection between the RFM and the patella and can result in the condition called patella alta, which can cause patellar instability and limitation of knee flexion motion (Dejour et al, 1994; Sutherland and Davids, 1993).

The most commonly used tests for assessing RFM flexibility are the modified Thomas test (MTT) and prone knee flexion (Gajdosik, 1985; Kim and Ha, 2015; Peeler and Leiter, 2013). The MTT is widely used to assess the flexibility of the RFM (Kendall et al, 2005; Magee, 2014; Peeler and Anderson, 2008) and is popular among clinicians, sports medicine practitioners, and orthopedic researchers for identifying RFM tightness (Clapis et al, 2008; Harvey, 1998; Vigotsky et al, 2015; Young et al, 2004). According to Kendall et al (2005) in the MTT position, a person with iliopsoas muscle tightness will have the lower back and sacrum flat on the table and the posterior thigh will not touch the table regardless of the knee state (Kendall et al, 2005). By contrast, a person with RFM tightness can touch the posterior thigh to the table and the knee flexion angle is less than 80 degrees (Kendall et al, 2005). The flexibility of the RFM can also be evaluated by the prone knee flexion (Butler, 2000; Maluf et al, 2000; Nadler et al, 2001). A tightened RFM can contribute to pelvic motion in the sagittal plane because the RFM makes a connection between the pelvis and the knee joint (Scholtes et al, 2009). During knee flexion in a prone position, if the innominate bones tilt anteriorly, this represents a tightening of the RFM (Cibulka et al, 1988).

Many methods are available for recovery of knee flexion ROM due to a tightened RFM, including patellar gliding, friction massage, proprioceptive neuromuscular facilitation techniques, and manual resistance techniques (Hammer, 2005; Knott and Voss, 1968; Liebenson et al, 2007; Maitland et al, 2005). Stretching methods are one of the most common interventions for restoring the tightened RFM length and for regaining knee flexion ROM (Higgins, 2011; Mason et al, 2011; Wiktorsson-Moller et al, 1983). Stretching methods for relief of a tightened RFM are conducted in various body positions, such as: 1) prone hip extension with knee flexion on the table, where the ankle is moved to the ipsilateral buttock (Clarkson, 2000); 2) hip extension with knee flexion against a wall in standing position, where the knee is placed on the floor to create maximum knee flexion (Young et al, 2004); and 3) hip extension with knee flexion on the edge of a table so that the sound hip and knee move toward the chest and the involved leg undergoes hip extension and knee flexion (Björklund et al, 2001).

Another way to increase the length of the RFM and restore the knee flexion ROM is by using the patellar gliding technique. Limited knee flexion may result from a limited inferior glide of the patella; thus, limited knee flexion ROM can be recovered by PIG (Maitland et al, 2005). A previous study on interventions to restore limited knee flexion due to RFM tightness examined the effects of knee flexion exercise and PIG on knee flexion ROM and lengthening of the RFM. The findings indicated that the tightened RFM pulled the patella superiorly, thereby disrupting knee flexion motion (Dejour et al, 1994). However, many kinds of knee flexion exercises can be conducted in different positions, regardless of patellar position. The aim of the present study was therefore to investigate the effect of knee flexion exercise with PIG in the MTT position, as this position allows the application of knee flexion simultaneously with PIG. We compared the effectiveness of passive stretching with PIG and passive RFM stretching alone in the MTT position. This concept of stretching has many similarities with Mulligan's movement with a mobilization concept. We hypothesized that knee flexion with PIG in the MTT position would restore a greater ROM than would be obtained with simple application of passive knee flexion (PKF).

Methods

Subjects

Twenty-six subjects with RFM tightness volunteered to participate in this study. All subjects were informed of the purpose of the study and its possible risks. The subjects confirmed their consent to participate in this research by filling out a research consent form. All participants met the inclusion criteria of a MTT angle of less than 80 degrees, with no history of rheumatologic, orthopedic, or neurologic disorders or of trauma or surgery to the hip, knee, or ankle region. During the study, the subjects refrained from strenuous exercise and excessive stretching exercise. The demographics of the subjects are shown in Table 1. This study was approved by the Yonsei University Wonju institutional review board (approval number: 1041849-201512-BM-067-02).

Procedure

The examiner held practice training sessions to reduce measurement error. The participant's initial position and the landmark point where a reflective marker was attached were the same for each session (Kim and Ha, 2015).

All participants were asked to attend two testing sessions at two-day intervals to eliminate the stretching wash-out effect. Two different PKF methods were administered in random order. One stretching protocol required that the subjects conduct PKF motions while in the MTT position and the PKF ROM was measured. The other stretching protocol involved knee flexion ROM during PKF with PIG. All PKF trials utilized a hand-held dynamometer (Mobie MT-100, SAKAI Medical Co., Ltd., Tokyo, Japan) to apply a constant passive stretching force. This dynamometer was applied to the distal end of the tibia and the examiner applied a 7 ㎏ pressure. During two methods of PKF stretching, the examiner maintained the stretching force for 10 seconds.

The MTT position was the initial position. The subject lay in a supine position on the edge of a treatment table. In this position, the subject's gluteal fold was located at the end of the table. The knee of the non-dominant leg was held with both hands and pulled toward the chest (Godges et al, 1989). (Figure 2) The subject maintained this position, as relaxed as possible. A pelvic belt was used to lock the pelvic position to prevent compensatory pelvic anterior tilt motion (Kim and Ha, 2015).

The PIG movement moves the patella in a caudal direction. The PIG was applied as follows: The subject lay in a supine position and assumed the MTT position at the edge of the table. The examiner's right hand was then placed against the superior margin of the patella and the left hand was placed at the inferior margin of the patella, covering the right hand. The examiner applied an inferior force as the subject started an active knee flexion motion or while another examiner applied a PKF motion force. The examiner's right hand applied force upon the patella in the inferior direction, while the left hand guided the patellar direction of the movement (Maitland et al, 2005).

Table 1. General characteristics of the subjects (N=26)

Parameters	Mean±SD[a]
Age (year)	23.3±1.9
Height (㎝)	176.4±4.4
Weight (㎏)	74.5±10.1
MTT[b] angle (degree)	22.8±3.0
Dominant leg	Right=26/Left=0

[a]mean±standard deviation, [b]modified Thomas test.

1) Passive knee flexion (PKF)

The only difference with PKF was that the knee flexion motion was conducted by the examiner. The subject maintained an initial position and stayed as relaxed as possible. The examiner then pushed the subject's ankle toward the knee flexion motion while controlling the force with a hand-held dynamometer (Figure 1).

2) Passive knee flexion with patellar inferior gliding (PKFPIG)

This knee flexion motion was conducted in the same way as described for PKF. At the same time, PIG was applied by the examiner. The PKF force was controlled with the hand-held dynamometer (Figure 2).

Outcome measures

Prior to each testing session, reflective markers were attached at the following landmarks: in the greater trochanter of the femur (located 4-6 inches below the mid-point of the iliac crest), the fibular head of the lateral knee, and the lateral malleolus of the ankle (Peeler and Leiter, 2013; Young et al, 2004).

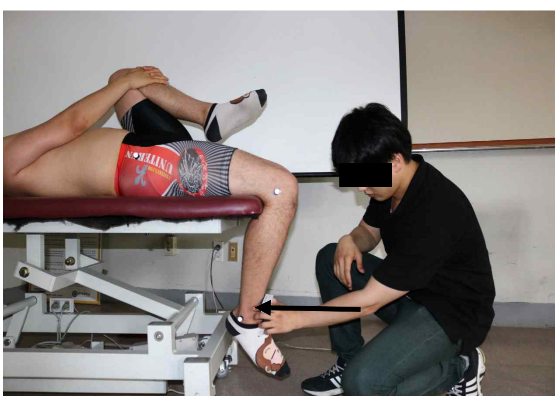

Figure 1. Passive knee flexion (PKF).

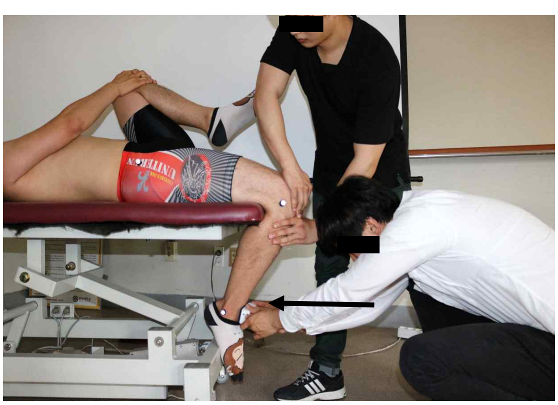

Figure 2. Passive knee flexion with patellar inferior gliding (PKFPIG).

While the subject performed the stretching in the MTT position, a photographer recorded sagittal view photographs using a digital camera on a tripod. The tripod height was set at 36 inches, and the camera was located 6 feet perpendicularly away from a 30-inch high bobath table (Peeler and Anderson, 2007).

The knee flexion ROM was formed using a 3-point landmark (greater trochanter, fibular head, and lateral malleolus). The knee flexion ROM was quantified using free ImageJ software (U.S. National Institute of Health, Maryland, USA).

Statistical analysis

The data are expressed as means standard deviations. All statistical analyses were performed using SPSS ver. 21.0 software (SPSS Inc., Chicago, IL, USA). All data were tested for normal distribution with the Kolmogorov-Smirnov normality test. Values of the measured angles were compared using paired t-tests. Paired t-tests were also used to determine the differences between the angle of PKF and PKFPIG. The level of significance was set at α=.05.

Results

Knee flexion range of motion (ROM) angle

A significantly greater angle of knee flexion ROM in the MTT position was obtained with passive stretching with PIG than with passive stretching alone ($p<.001$). The PKF ROM with PIG was 114.44°±9.33° in the MTT position and was 108.97°±9.42° without PIG (Table 2).

Discussion

The RFM is a two-joint postural muscle that is susceptible to tightness (McDonald, 1998; Norris, 1995). Many kinds of clinical disorders related to knee joint

Table 2. Passive knee flexion range of motion (ROM) (Unit:°)

PKF[a]	PKFPIG[b]	p
108.97±9.42[c]	114.44±9.33	<.001

[a]passive knee flexion, [b]passive knee flexion with patellar inferior gliding, [c]mean±standard deviation.

problems are associated with RFM tightness (Gajdosik, 1985). For example, RFM tightness can reduce hip extension ROM. The resulting limited hip extension extensibility causes pelvic anterior tilt and lumbar lordosis during running (Klein and Roberts, 1976; Schache et al, 2000). An increased lumbar lordotic curve due to RFM tightness results in low back pain (Cibulka et al, 1988). Knee pain around the anterior region of the patella can also be triggered by RFM tightness (Longjohn and Dorr, 1998).

The purpose of the present study was to investigate the effect of passive stretching with PIG in the MTT position on subsequent knee flexion ROM. Most previous studies that conducted interventions for RFM tightness to improve knee flexion ROM provided stretching and PIG separately (Björklund et al, 2001; Magee, 2014; Maitland et al, 2005; Pourahmadi et al, 2015). The present study examined the effects of simultaneous application of stretching and PIG. All subjects recruited for this study had RFM tightness that caused limited knee flexion ROM in the MTT position. These subjects participated in two protocols (PKF and PKFPIG) while in the MTT position.

Generally, the MTT position has been used to examine the limited knee flexion ROM due to tight RFM in clinical or athletic treatments (Gabbe et al, 2004; Harvey, 1998; Lee et al, 1997; Smith et al, 1991; Winters et al, 2004; Young et al, 2004). The MTT position allows the practitioner to apply RFM stretching with PIG, but the MTT position is not frequently investigated in RFM stretching, even though pelvic stabilization is easy and prevents pelvic compensations, such as anterior or posterior tilting (Kim and Ha, 2015). This is why the MTT position was chosen for the RFM stretching with PIG in the present study.

The significant result from the present study was a greater increase in knee flexion ROM achieved by adding PIG to the passive stretching, compared to passive stretching alone. The knee flexion ROM during passive stretching combined with PIG was 114.44°±9.33° and passive stretching was 108.97°±9.42°.

Roberts and Wilson (1999) previously investigated passive RFM stretching in healthy subjects. After 5 weeks of passive stretching sessions, the knee flexion ROM increased from 146.96° to 153.46° (Roberts and Wilson, 1999). Björklund et al (2001) found that a two-week passive RFM stretching program increased the knee flexion ROM from 121.50° to 123.00° (Björklund et al, 2001). An accurate comparison of the effects of RFM stretching on knee flexion ROM is difficult, due to differences in stretching exercise duration, posture, and intensity. Nevertheless, our results showed that passive RFM stretching combined with PIG increased the knee flexion ROM, indicating that this combination is an effective treatment strategy.

The RFM is connected to the patella through the patellar tendon. Tightness in the RFM therefore drags the patella in the superior direction and can result in patella alta (Bhave and Baker, 2008; Dejour et al, 1994). In this condition, the knee flexion ROM may decrease due to a decreased inferior glide of the patella (Dejour et al, 1994; Sutherland and Davids, 1993). The natural knee flexion ROM is no longer possible if a tight RFM pulls the patella in the superior direction. Therefore, PIG should also be considered for increasing knee flexion ROM. During passive knee stretching, PIG might prevent the patella from being pulled in the superior direction, thereby allowing knee flexion motion. PIG could also increase the RFM stretch force because the RFM is connected with the tibia via the patella. For this reason, the combination of passive RFM stretching and PIG may direct the patella in the inferior direction, so that it situates in the correct position (Bhave and Baker, 2008).

The present study has some limitations. First, the participants were only those who had tight RFMs without patellar pain or alta, which prevents generalization of the results to those patients with tight RFMs and patellar pain or alta. Second, no comparison was made to a group that underwent PIG only. Third, the participants in this study were all young people; utilizing patients of different ages or enrolling senior patients is difficult. Fourth, this study confirmed immediate improvement by the stretching with and without gliding. Therefore, the next research will incorporate subjects of different ages and allocate a portion of these to a group that undergoes only PIG. A long-term study should also be done to determine the follow-up effect of RFM stretching with PIG.

Conclusion

This is the first study to show that the RFM stretching with PIG can increase the knee flexion ROM in cases of RFM tightness. Statistically significant differences were noted between the RFM stretching alone and RFM stretching with PIG in terms of knee flexion ROM, and the combination of RFM stretching and PIG was more effective than RFM muscle stretching alone. Therefore, adding PIG to an RFM stretching protocol would appear to be an effective strategy for increasing PKF ROM in subjects with RFM tightness.

References

Bhave A, Baker E. Prescribing quality patellofemoral rehabilitation before advocating operative care. Orthop Clin North Am. 2008;39(3):275-285. https://doi.org/10.1016/j.ocl.2008.03.004

Bianchi S, Martinoli C, Waser NP, et al. Central aponeurosis tears of the rectus femoris: Sonographic findings. Skeletal Radiol. 2002;31(10):581-586.

Björklund M, Hamberg J, Crenshaw AG. Sensory adaptation after a 2-week stretching regimen of the rectus femoris muscle. Arch Phys Med Rehabil. 2001;82(9):1245-1250.

Butler DS. The Sensitive Nervous System. 1st ed. Adelaide, Noigroup publications, 2000:302-303.

Cibulka MT, Delitto A, Koldehoff RM. Changes in innominate tilt after manipulation of the sacroiliac joint in patients with low back pain an experimental study. Phys Ther. 1988;68(9):1359-1363.

Clapis PA, Davis SM, Davis RO. Reliability of inclinometer and goniometric measurements of hip extension flexibility using the modified Thomas test. Physiother Theory Pract. 2008;24(2):135-141. https://doi.org/10.1080/09593980701378256

Clarkson HM. Musculoskeletal Assessment: Joint range of motion and manual muscle strength. 2nd ed. Philadelphia, PA, Lippincott Williams & Wilkins, 2000:323-324

de Lucena GL, dos Santos Gomes C, Guerra RO. Prevalence and associated factors of Osgood-Schlatter syndrome in a population-based sample of Brazilian adolescents. Am J Sports Med. 2011;39(2):415-420. https://doi.org/10.1177/0363546510383835

Dejour H, Walch G, Nove-Josserand L, et al. Factors of patellar instability: An anatomic radiographic study. Knee Surg Sports Traumatol Arthrosc. 1994;2(1):19-26.

Gabbe BJ, Bennell KL, Wajswelner H, et al. Reliability of common lower extremity musculoskeletal screening tests. Phys Ther Sport. 2004;5(2):90-97.

Gajdosik RL. Rectus femoris muscle tightness: Intratester reliability of an active knee flexion test. J Orthop Sports Phy Ther. 1985;6(5):289-292.

Godges JJ, Macrae H, Longdon C, et al. The effects of two stretching procedures on hip range of motion and gait economy. J Orthop Sports Phys Ther. 1989;10(9):350-357.

Hammer WI. Functional Soft Tissue Examination and Treatment by Manual Methods: New perspectives. 3rd ed. Sudbury, MA, Jones and Barlett Publishers, 2005:463.

Harvey D. Assessment of the flexibility of elite athletes using the modified Thomas test. Br J Sports Med. 1998;32(1):68-70.

Higgins M. Therapeutic Exercise: From theory to practice. 1st ed. Philadelphia, PA, FA Davis, 2011:435-438.

Kendall FP, McCreary EK, Provance PG, et al. Muscles: Testing and function with posture and pain. 5th ed. Baltimore, Lippincott Willams & Wilkins, 2005:359-464.

Kim GM, Ha SM. Reliability of the modified Thomas test using a lumbo-plevic stabilization. J Phys Ther Sci. 2015;27(2):447-449. https://doi.org/10.1589/jpts.27.447

Kisner C, Colby LA. Therapeutic Exercise: Foundations and techniques. 6th ed. Philadelphia, FA Davis, 2012:768.

Klein KK, Roberts CA. Mechanical problems of marathoners and joggers. Cause and solution. Am Correct Ther J. 1976;30(6):187-191.

Knott M, Voss DE. Proprioceptive Neuromuscular Facilitation: Patterns and techniques. 2nd ed. New York, Medical Department Harper & Row, 1968:98-104.

Lénárt G, Kullmann L. Isolated contracture of the rectus femoris muscle. Clin Orthop Relat Res. 1974;(99):125-130.

Lee LW, Kerrigan DC, Della Croce U. Dynamic implications of hip flexion contractures. Am J Phys Med Rehabil. 1997;76(6):502-508.

Liebenson C, Rehabilitation of the Spine: A practitioner's manual. 2nd ed. Baltimore, Lippincott Wiliams & Wilkins, 2007:407.

Longjohn D, Dorr LD. Soft tissue balance of the hip. Arthroplasty. 1998;13(1):97-100.

Loudon JK., Jenkins W, Loudon KL. The relationship between static posture and ACL injury in female athletes. J Orthop Sports Phys Ther. 1996;24(2):91-97.

Magee DJ. Orthopedic Physical Assessment. 6th ed. Saunders, Elsevier, 2014:728-729.

Maitland GD, Hengeveld E, Banks K. Maitland's Peripheral Manipulation. 4th ed. Boston, Butterworth-Heinemann, 2005:512.

Maluf KS, Sahrmann SA, Van Dillen LR. Use of a classification system to guide nonsurgical management of a patient with chronic low back pain. Phys Ther. 2000;80(11):1097-1111.

Mason M, Keays SL, Newcombe PA. The effect of taping, quadriceps strengthening and stretching prescribed separately or combined on patellofemoral pain. Physiother Res Int. 2011;16(2):109-119. https://doi.org/10.1002/pri.486

McDonald CM. Limb contractures in progressive neuromuscular disease and the role of stretching, orthotics, and surgery. Phys Med Rehabil Clin N Am. 1998;9(1):187-211.

Nadler SF, Malanga GA, Stitik TP, et al. The crossed femoral nerve stretch test to improve diagnostic sensitivity for the high lumbar radiculopathy: 2 case reports. Arch Phys Med Rehabil. 2001;82(4):522-523.

Nene A, Mayagoitia R, Veltink P. Assessment of rectus femoris function during initial swing phase. Gait Posture. 1999;9(1):1-9.

Norris CM. Spinal stabilisation: 4. Muscle imbalance and the low back. Physiotherapy. 1995;81(3):127-138.

Peeler J, Anderson JE. Reliability of the Thomas test for assessing range of motion about the hip. Phys Ther Sport. 2007;8(1):14-21.

Peeler JD, Anderson JE. Reliability limits of the modified Thomas test for assessing rectus femoris muscle flexibility about the knee joint. J Athl Train. 2008;43(5):470-476. https://doi.org/10.4085/1062-6050-43.5.470

Peeler J, Leiter J. Using digital photography to document rectus femoris flexibility: A reliability study of the modified Thomas test. Physiother Theory Pract. 2013;29(4):319-327. https://doi.org/10.3109/09593985.2012.731140

Pourahmadi MR, Takamjani IE, Hesampour K, et al. Effects of static stretching of knee musculature on patellar alignment and knee functional disability in male patients diagnosed with knee extension syndrome: A single-group, pre-test-posttest trial. Man Ther. 2016;22:179-189. https://doi.org/10.1016/j.math.2015.12.005

Richardson C, Bullock MI. Changes in muscle activity during fast, alternating flexion-extension movements of the knee. Scand J Rehabil Med, 1986:18(2):51-58.

Roberts JM, Wilson K. Effect of stretching duration on active and passive range of motion in the lower extremity. Br J Sports Med. 1999;33(4): 259-263.

Schache AG, Blanch PD, Murphy AT. Relation of anterior pelvic tilt during running to clinical and kinematic measures of hip extension. Br J Sports Med. 2000;34(4):279-283.

Scholtes SA, Gombatto SP, Van Dillen LR. Differences in lumbopelvic motion between people with and people without low back pain during two lower limb movement tests. Clin Biomech (Bristol, Avon). 2009;24(1):7-12. https://doi.org/10.1016/j.clinbiomech.2008.09.008

Smith AD, Stroud L, McQueen C. Flexibility and anterior knee pain in adolescent elite figure skaters. J Pediatr Orthop. 1991;11(1):77-82.

Sutherland DH, Davids JR. Common gait abnormalities of the knee in cerebral palsy. Clin Orthop Relat Res. 1993;288:139-147.

Vigotsky AD, Lehman GJ, Contreras B, et al. Acute effects of anterior thigh foam rolling on hip angle, knee angle, and rectus femoris length in the modified Thomas test. PeerJ. 2015;3:e1281. https://doi.org/10.7717/peerj.1281

Wiktorsson-Moller M, Öberg B, Ekstrand J, et al. Effects of warming up, massage, and stretching on range of motion and muscle strength in the lower extremity. Am J Sports Med. 1983;11(4): 249-252.

Winters MV, Blake CG, Trost JS, et al. Passive versus active stretching of hip flexor muscles in subjects with limited hip extension: A randomized clinical trial. Phys Ther. 2004;84(9):800-807.

Young W, Clothier P, Otago L, et al. Acute effects of static stretching on hip flexor and quadriceps flexibility, range of motion and foot speed in kicking a football. J Sci Med Sport. 2004;7(1): 23-31.

This article was received July 5, 2016, was reviewed July 5, 2016, and was accepted October 25, 2016.