# Research Paper: Comparison of Q Angle and Tibial Torsion Among Premier League Futsal Players with & without Hamstring Tightness

Hooman Minoonejad[1], Ehsan Tasoujian[2*], Hossein Amiri[3], Reza Manteghi[3]

*1. Department of Health and Sports Medicine, Faculty of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran.*
*2. Department of Sports Injury and Corrective Exercises, Faculty of Physical Education and Sport Sciences, Kharazmi University, Tehran, Iran.*
*3. Department of Sports Injury and Corrective Exercises, Faculty of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran.*

**Citation:** Minoonejad H, Tasoujian E, Amiri H, Manteghi R. Comparison of Q Angle and Tibial Torsion Among Premier League Futsal Players With and Without Hamstring Tightness. Physical Treatments. 2016; 6(1):51-58. https://doi.org/10.18869/NRIP.PTJ.6.1.51

doi: **https://doi.org/10.18869/NRIP.PTJ.6.1.51**

Article info:
Received: 03 Nov. 2015
Accepted: 27 Feb. 2016

**Keywords:**
Tibia torsion, Q angle, Hamstring tightness, Athletes, Futsal

## ABSTRACT

**Purpose:** Hamstring muscle is a two-jointed muscle, which is attached to the pelvis at one end and to tibia at the other. Contractures of the hamstring muscles affect the position of proximal and distal joints. The present study aims to compare the value of quadriceps angle (‘Q angle’) and tibial torsion among Premier League Futsal players with and without hamstring tightness.

**Methods:** In this expost facto study, 30 male players, aged 18 to 25 years old, were non-randomly and purposefully selected as subjects. They were assigned to two 15-member groups, one containing players with hamstring tightness and the other without hamstring tightness. The goniometer was used to check the hamstring muscle tightness and measure the Q angle and tibial torsion. Independent t-test was used to analyze the data at a significance level of 0.05. SPSS version 21.0 was used for statistical analysis.

**Results:** According to the findings of the present study, there was a significant difference in the value of Q angle and tibial torsion between the healthy athletes and group with hamstring tightness ($P \leq 0.05$).

**Conclusion:** To prevent injuries in Futsal players with hamstring muscles tightness, special attention should be paid to the Q angle and tibial torsion.

## 1. Introduction

Flexibility is one of the factors of physical fitness as well as a key component in preventing sporting injury and improving athletic performance. Flexibility is defined as the ability of a joint to move through a normal range of motion, without causing any overpressure on the muscle-tendon unit [1, 2]. Connective tissue “tightness” is a common clinical problem. Tightness may be due to scarring or adaptive shortening of the connective tissues resulting from a disease, injury, or immobilization. Tightness may limit the motion of the affected joints resulting in clinical syndromes [3]. Knee and hamstring muscle play

*** Corresponding Author:**
***Ehsan Tasoujian, MSc.***
***Address:*** *Department of Sports Injury and Corrective Exercises, Faculty of Physical Education and Sport Sciences, Kharazmi University, Tehran, Iran.*
***Phone:*** *+98 (935) 7037875*
***E-mail:*** *ehfarehsan@gmail.com*

an important role in the lower extremity movements, especially during walking [4, 5]. Several studies have reported high incidence of tightness and injuries of this muscle. Tightness and injuries of hamstring muscle are caused by several reasons such as strength imbalance between hamstrings and quadriceps, repetitive muscle strain, immobilization of lower extremity and scarring in the tissue [6, 7].

The skeletal structure of a person may be a risk factor for injuries [8]. Scar tissue and improper movement patterns resulting from a previous injury that could lead to impaired kinetic chain are the possible mechanisms that reveal the occurrence of musculoskeletal impairment based on kinetic chain system. Injury in one part of the body may lead to muscular imbalances around the joints, eventually resulting in musculoskeletal disorders [9, 10]. Research suggests that abnormalities may damage the anatomical structure [11].

Some abnormalities are congenital and gradually lead to more energy consumption, fatigue in athletes, and development of secondary postures. However, there still exist many ambiguities regarding the effects of these malalignments on athlete's performances [11]. Many past studies have investigated lower extremity alignment. For instance, Haim et al. (2006) investigated the validity of clinical and radiological features of patellofemoral pain syndrome (PFPS) [12]. Samu Kawa et al. (2007) also examined the effect of tibial rotation on the presence of instability in case of anterior cruciate ligament deficiency [13].

Hamstring muscles are antigravity muscles, and whose decreased flexibility is associated with a wide range of sports injuries from strains to ligament ruptures [5]. Furthermore, a contracture of this muscle may further lead to various problems such as functional abnormalities in the knee, disruption of lumbopelvic rhythm, postural deviations of trunk, lower back, and plantar fasciitis [12, 14-17]. Accordingly, Cibulka, Rose, Delitto and Sinacore (1986) suggested that not only muscle but also sacroiliac joint and distal and proximal joints should be considered for the treatment of hamstring disorders [4]. It can, therefore, be said that appropriate length of this muscle group is necessary for the prevention of several sports-related functional disorders and injuries [18].

On the other hand, lower extremities are a chain of columns and connections that bear the body weight and make shock absorption and walking possible. This chain includes hip, knee, ankle, toes, and their joints, which enable an individual to adapt to the static and dynamic conditions and help them maintain proper body dynamics during the sports activities [11]. Therefore, it is important to understand the lower extremity biomechanics and pathomechanics for preventing any injury during the sports activities [19].

Explosive activities, repeated running, and nature of the game of Futsal imposes a lot of pressure and force on the hip, leg, foot joints, and abdomen [20]. The abnormal adaptation of the body to such movements results in functional abnormalities in athletes [21]. Since appropriate alignment of lower extremity facilitates joint motions, one of the important aims of physical activities is to have an appropriate physical posture and keep normal body alignment [22, 23]. When this alignment is distorted, the joints undergo bad postures and consequently lose their optimum rotation. These changes lead to the distortion of the joint structure and as well as common physical postures in athletes [23].

It is noteworthy that deviation from the desirable physical posture results in decreased mechanical efficiency of the individual, thus making them vulnerable to muscular or nerve injuries [24, 25]. While several past studies have reported that the loss of alignment in a part of the body for a longer duration causes lengthened or shortened muscles, some researchers believe that abnormal alignment may be even caused by muscle imbalance or change in ligament complex, articular capsule or musculotendinous structures [26]. However, not much clarity has been gained on the effect of lower extremity alignment on hamstring performance.

The present study was conducted to gain a better understanding of the risk factors and symptoms of these disorders and designing of rehabilitation programs to cater to these health issues. We believe that hamstring length is one of the key factors for appropriate kinematics of knee. In this paper, we further hypothesize that hamstring tightness may affect the amount of Q angle and tibial torsion among Premier League Futsal players.

## 2. Materials and Methods

### Setting

This study was of descriptive-comparative nature.

### Subjects

Thirty male participants aged 18 to 25 years were non-randomly and purposefully (no probable convenience sampling) selected from among Premier League Futsal players of Karaj City and assigned to two 15-member groups, with and without hamstring tightness, respectively. According to the reports of Alborz Province Football Association, this province has 50 futsal players, who



**Figure 1.** Flexion of the knee until the thigh touches the horizontal PVC bar.



**Figure 2.** Knee position during AKE test.

had played at least for one season in Premier League in the past five years. Cochran's formulas were applied to determine the sample size of the subjects in this study.

The exclusion criteria included a history of the spine and lower extremity trauma or surgery, severe injury in knee joint such as anterior cruciate ligament injury (ACL) and meniscus ruptures and a history of any pain in the anterior knee. Prior to any measurement, the procedures were explained to the subjects in detail, and they were asked to give a written consent and information about their age, sports activities, training sessions per week, and injury history.

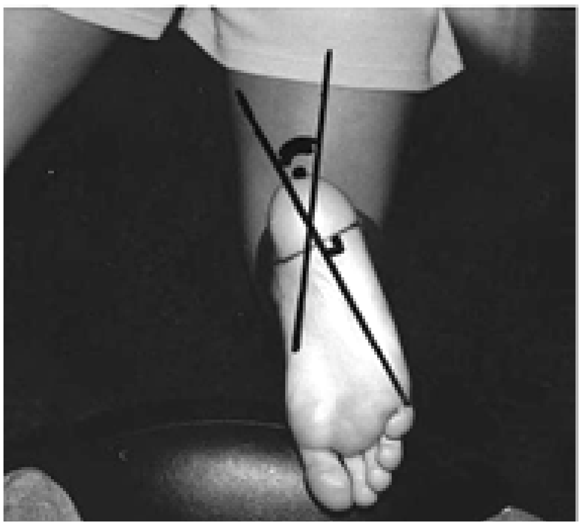



**Figure 3.** Measurement of tibial torsion by Thigh-malleoli Method.

## Measurements

A goniometer (MSD model, Sweden) was used to determine the hamstring tightness and value of Q angle. Each variable was measured three times, and the average was recorded as the individual's score.

## AKE (Active Knee Extension) test

The participants were assessed on a plinth in the supine position. Each assessor marked the greater trochanter, and another to the lateral knee joint line with washable ink. Two lines were drawn from this point. The first was drawn to the greater trochanter, and another to the apex of the lateral malleolus. The participants were asked to flex the hip until the thigh touched the horizontal PVC bar (Figure 1).

While maintaining the contact between the thigh and horizontal PVC bar, the participants were asked to extend the leg as much as possible while keeping their foot relaxed and to hold the position for about five seconds. The goniometer was placed over the previously marked joint axis with its arms aligned along the femur and fibula (Figure 2). The test was positive if the person felt severe tension on his back, knee and thigh before reaching the last 250 [27, 28].

## Measurement of Q angle

Q angle or action angle of quadriceps is the angle between the line drawn from anterior superior iliac spine (ASIS) to the middle of the patella and the line drawn from the middle of the patella to the center of tibial tubercle [27]. In order to measure the Q angle, the first line marking was drawn from the ASIS to the middle of the patella and the second line was drawn from the mid patella to the tibial tubercle [29]. The midpoint of the patella was determined by the intersection of the line from the medial to the lateral patella and the line from the inferior to the superior patella [30]. The axis of a manually extendable arm goniometer was placed over the center of the right patella, with its proximal arm placed over the anterior superior iliac spine and the distal arm over the center of the tibial tubercle [31].

### Tibial torsion

In order to measure tibial torsion, Thigh-malleoli Method was used. The participants were positioned in the prone position with both knees held in 90-degree flexion. Centers of medial and lateral malleoli were connected with a line drawn from the cross of the foot. The arms of the goniometer were aligned with the bimalleolar axis (vertical line on this line) and the longitudinal axis of the thigh. The angle formed between bimalleolar and longitudinal axis was reported as the angle of tibial torsion [32] (Figure 3).

### Statistical analysis

Independent T-test was used to compare the parameters of the normal distribution at P=0.05. Normal distribution of data and homogeneity of variance were explored by Shapiro–Wilk and Leven Tests, respectively. SPSS, version 21.0, was used for statistical analysis.

## 3. Results

Subject characteristics including age, body height and weight, and sports activity history are shown in Table 1. In the pilot study conducted on 10 futsal players, Repeatability ICC (Intraclass Correlation Coefficient) was reported to be 0.96 and 0.90 for Q angle and tibia torsion measurements, respectively. The Shapiro-Wilk Test indicated that Q angle and tibial torsion data had the normal distribution in both the groups.

A summary of the independent T-test results is presented in Table 2. According to these results, there is a statistically significant difference between two groups in terms of Q angle and tibial torsion variables (P≤0.05). In the present study, the Q angle and tibial torsion were found to be significantly higher in futsal players with short hamstring as compared to the normal futsal players (without short hamstring).

## 4. Discussion

According to the results of the present study, tibial torsion and Q angle was found to be higher in the futsal players with hamstring tightness as compared to those without hamstring tightness.

The normal range of tibial torsion is reported to be about 13-18 degrees. More than 18 degrees is defined as the external torsion, and less than 13 degrees is considered as internal torsion [33, 34]. The present study was consistent with the reports of Samu Kawa et al. [13] and indicated that futsal players with hamstring tightness had increased tibial torsion as compared to the control group. On the other hand, the later consisting of 20 normal subjects and 20 subjects with ACL-deficient knees, showed that the amount of tibial rotation was higher in ACL ruptured knees than in uninjured knees, and such

**Table 1.** Subject characteristics.

| Group | n | Age (Years)±SD | Weight (kg)±SD | Height (M)±SD | Sports Activity History (Years)±SD |
|---|---|---|---|---|---|
| With hamstring tightness | 15 | 22.33±1.95 | 69.4±8.95 | 176.4±6.16 | 3.8±1.26 |
| Without hamstring tightness | 15 | 22.33±1.83 | 70.6±9.95 | 175.1±8.64 | 4.26±1.33 |
| t-test | | 0.00 | 0.34 | 0.46 | 0.98 |
| P-value | | 1.0 | 0.73 | 0.65 | 0.33 |

PHYSICAL TREATMENTS

**Table 2.** Independent T-test results.

| Variable | With Hamstring Tightness M±SD | Without Hamstring Tightness M±SD | T | P |
|---|---|---|---|---|
| Q angle (degree) | 15.06±5.03 | 10.4±8.04 | 2.12 | 0.043 |
| Tibial torsion (degree) | 21.33±6.86 | 16.46±3.87 | 2.39 | 0.026 |

PHYSICAL TREATMENTS

higher amounts of tibial rotation affected the figure-of-eight running index. Furthermore, the hamstrings may be vital anterior and rotational stabilizers of the tibia, a role similar to that of the anterior cruciate ligament [35]. Given the weakness and tightness in hamstring muscles in both the groups (ACL ruptured group and futsal players with hamstring tightness), it seems that the effect of hamstring length on knee joint kinematics is one of the possible reasons for such similar results.

The results of this study indicated that Q angle was significantly higher in futsal players with hamstring tightness than in the control group, which is consistent with Haim et al. [12], who suggested that the Q angle higher than 20 degrees was associated with anterior knee pain. Since imbalance of muscles is one of the reasons for knee injuries and pain, we can conclude that tightness in hamstrings against quadriceps resulted in such malalignments (increased Q angle).

Increased Q angle may be due to anteversion of hip or increased external tibial torsion, which further leads to lateral stretch from the rectus femoris muscle to the patella. Due to the naturally wider pelvis, women tend to have higher Q angle. The normal Q angle is about 15 and 10 degrees in women and men, respectively [12].

Muscle tightness or hyperactivity of one muscle or group of muscles is often the initial cause of muscle imbalances that initiates a predictable pattern of kinetic dysfunction [36-38]. Agonist muscle tightness and hyperactivity combined with inhibited and weak antagonist muscles result in disrupted normal force-couple relationship between them thereby implying muscular imbalance [36, 37]. Initial disruption in the normal force-couple relationship between these muscles stimulates a series of events that further perpetuates the altered force-couple relationship. Due to the force imbalance between agonist and antagonist muscles, the joint tends to position itself in the direction of the tight agonist muscle that has an adverse effect on the normal postural alignment [36, 37].

There are several possible mechanisms describing musculoskeletal impairment based on the kinetic chain system, which includes scar tissue and improper movement patterns caused by a previous injury resulting in impaired kinetic chain. Injury in one part of the body may lead to muscular imbalances around the joints, eventually resulting in musculoskeletal disorders. Also, to compensate disruption, the other parts of the body away from the injured part are activated to take over some of the lost action. However, this involvement is one of the possible reasons for disruption in weight bearing and improper distribution of plantar pressure [9, 10].

Prentice (2011) stated that in the case of postural malalignments, the athletic trainers (ATs) should take into consideration those patterns of muscle tightness and weakness that would well correspond to such malalignments [39]. It should be noted that the condition of postural malalignments arising due to muscular imbalance may be addressed through physical rehabilitation techniques [34]. Muscular imbalances can cause both altered postural alignment and bony deformity [36, 37]. Therefore, it is very crucial that the athletic trainers determine the correct cause of postural malalignments, as it might influence the rehabilitation options.

The present study showed that the gradual hamstring tightness can lead to reduced load-bearing capacity of this muscle [40]. Hamstring is one of the major muscles controlling tibial torsion [41]. Decreased load-bearing ability of these muscles results in increased tibial torsion, which further results in increased value of patellar tendon angle with tibia and Q angle [42].

Therefore, to prevent injuries in athletes, especially futsal players, it is much necessary that the coaches and sports science experts pay special attention to these variables. Since, these impairments can be easily detected and corrected by the coaches and sports medicine professionals, the activity of designing and executing the preventive programs should be integrated into the daily programs of athletes.

Some limitations of this study include participation of less number of Futsal player subjects, and lack of electromyography (EMG) measurement, which perhaps could have helped gain a better understanding of the muscle compatibility involved in lower limb movements.

## Acknowledgements

This paper had no financial support. The authors express their sincere thanks to all the Futsal players who participated in this study and coaches of Premier League futsal team of Karaj City.

## Conflict of Interest

The authors declared no conflict of interests.

## References


[1] Feland JB, Marin HN. Effect of submaximal contraction intensity in contract-relax proprioceptive neuromuscular facilitation stretching. British Journal of Sports Medicine. 2004; 38(4):18-27. doi: 10.1136/bjsm.2003.010967

[2] Marek SM, Cramer JT, Fincher AL, Massey LL, Dangelmaier SM, Purkayastha S, et al. Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. Journal of Athletic Training. 2005; 40(2):94-103. PMID: 15970955

[3] Reed BV, Ashikaga T, Fleming BC, Zimny NJ. Effects of ultrasound and stretch on knee ligament extensibility. Journal of Orthopaedic & Sports Physical Therapy. 2000; 30(6):341-47. doi: 10.2519/jospt.2000.30.6.341

[4] Cibulka MT, Rose SJ, Delitto A, Sinacore DR. Hamstring muscle strain treated by mobilizing the sacroiliac joint. Physical Therapy. 1986; 66(8):1220-223.

[5] Scherier I, Gossal K. Myths and truths of stretching for improved physical performance and prevention of sport related injuries. Journal of Sports Medicine. 1985; 2(4):267-87.

[6] Nourbakhsh MR, Arabloo AM, Salavati M. The relationship between pelvic cross syndrome and chronic low back pain. Journal of Back & Musculoskeletal Rehabilitation. 2006; 19(4):119-28. doi: 10.3233/bmr-2006-19403

[7] Prior M, Guerin M, Grimmer K. An evidence-based approach to hamstring strain injury: A systematic review of the literature. Sports Health: A Multidisciplinary Approach. 2009; 1(2):154-64. doi: 10.1177/1941738108324962

[8] Kishali NF, İmamoglu O, Burmaoglu G, Atan T, Yildirim K. Q-angle values of elite soccer and taekwondo athletes. Pain Clinic. 2004; 16(1):27-33. doi: 10.1163/156856904322858675

[9] Nordin, M, Frankel, VH. Basic biomechanics of the musculoskeletal system. 3rd ed. Philadelphia: Lippincott Williams & Wilkins; 2001.

[10] Richardson C, Hodges P, Hides J. Therapeutic exercise for lumbopelvic stabilization: A motor control approach for the treatment and prevention of low back pain. 2nd ed. London: Churchill Livingstone; 2004.

[11] Riegger-Krugh C, Keysor JJ. Skeletal malalignments of the lower quarter: Correlated and compensatory motions and postures. Journal of Orthopaedic & Sports Physical Therapy. 1996; 23(2):164-70. doi: 10.2519/jospt.1996.23.2.164

[12] Haim A, Yaniv M, Dekel S, Amir H. Patellofemoral pain syndrome: validity of clinical and radiological features. Clinical orthopaedics and related research. 2006; 451:223-28. doi: 10.1097/01.blo.0000229284.45485.6c

[13] Samukawa M, Magee D, Katayose M. The effect of tibial rotation on the presence of instability in the anterior cruciate ligament deficient knee. Journal of Sport Rehabilitation. 2007; 16(1):2-17. doi: 10.1123/jsr.16.1.2

[14] Fatemy E, Bakhtiary A, Amozadeh Khalili M, Ghorbani R. [Effects of vibration training on hamstring muscle shortness (Persian)]. Koomesh. 2010; 11(4):312-16.

[15] Carregaro RL, Coury HJ. Does reduced hamstring flexibility affect trunk and pelvic movement strategies during manual handling? International Journal of Industrial Ergonomics. 2009; 39(1):115-20. doi: 10.1016/j.ergon.2008.05.004

[16] Mazidi M, Sarafraz H, Mazidi H. [The effect of sex on pain and hamstring length in patient with patellofemoral pain (Persian)]. Journal of Sport. 2013; 10(1):31-33.

[17] White LC, Dolphin P, Dixon J. Hamstring length in patellofemoral pain syndrome. Physiotherapy. 2009; 95(1):24-28. doi: 10.1016/j.physio.2008.05.009

[18] Li G, Rudy TW, Sakane M, Kanamori A, Ma CB, Woo SY. The importance of quadriceps and hamstring muscle loading on knee kinematics and in-situ forces in the ACL. Journal of Biomechanics. 1999; 32(4):395-400. doi: 10.1016/s0021-9290(98)00181-x

[19] Arnason A, Engebretsen L, Bahr R. No effect of a video-based awareness program on the rate of soccer injuries. American Journal of Sports Medicine. 2005; 33(1):77-84. doi: 10.1177/0363546503262688

[20] Cozzier J. The benefits of physical conditioning for your soccer performance [Internet]. 2009 [Cited 2008 September 22]. Available from: http://EzineArticles.com/?expert=Jeff_Cozzier

[21] Neto Júnior J, Pastre CM, Monteiro HL. Postural alterations in male Brazilian athletes who have participated in international muscular power competitions. Revista Brasileira de Medicina do Esporte. 2004; 10(3):195-98. doi: 10.1590/s1517-86922004000300009

[22] Watinks J. Structure and Function of the Musculoskeletal System [V. Dabidy Roshan, Persian trans]. 1st ed. Tehran: Omid-e Danesh; 2009.

[23] Hadadnezhad M, Letafatkar A. [The relationship between genu varum abnormality and lower extremity's performance and strength in teenage footballers (Persian)]. Research in Rehabilitation Sciences. 2011; 7(2):188-196.

[24] Hrysomallis C, Goodman C. A review of resistance exercise and posture realignment. Journal of Strength & Conditioning Research. 2001; 15(3):385-90. doi: 10.1519/1533-4287(2001)015<0385:arorea>2.0.co;2

[25] Young M, Michael L. A review on postural realignment and its muscular and neural components. British Journal of Sports Medicine. 2002; 9(12):51-76.

[26] Renstrom P, Ljungqvist A, Arendt E, Beynnon B, Fukubayashi T, Garrett W, et al. Non-contact ACL injuries in female athletes: An International Olympic Committee current concepts statement. British Journal of Sports Medicine. 2008; 42(6):394-412. doi: 10.1136/bjsm.2008.048934

[27] Reider B. The orthopedic physical examination. 1st ed. Philadelphia: Sunders; 1999.

[28] Mohamad Shariff AH, Mohamed Razif MA, Ashril Y. Interrater and intrarater reliability of the active knee extension (AKE) test among healthy adults. Journal of Physical Therapy Science. 2013; 25(8):957–61. PMCID: PMC3820221

[29] Biedert RM, Warnke K. Correlation between the Q angle and the patella position: A clinical and axial computed tomography evaluation. Archives of Orthopaedic & Trauma Surgery. 2001; 121(6):346-49. doi: 10.1007/s004020000239

[30] Sarkar A, Razdan S, Yadav J, Bansal N, Kuhar S, Pahuja P. Effect of isometric quadricep activation on "Q" angle in young females. Indian Journal of Physiology & Pharmacology. 2009; 53(3):275–278. doi: 10.5958/j.0973-5674.8.1.010

[31] Weiss L, de Forest B, Hammond K, Schilling B, Ferreira L. Reliability of goniometry-based Q-angle. PM&R. 2013; 5(9):763-68. doi: 10.1016/j.pmrj.2013.03.023

[32] Staheli LT. Rotational problems of the lower extremities. The Orthopedic Clinics of North America. 1987; 18(4):503-12.

[33] Bonci CM. Assessment and evaluation of predisposing factors to anterior cruciate ligament injury. Journal of Athletic Training. 1999; 34(2):155-169.

[34] Magee DJ. Orthopedic physical assessment. Philadelphia: Saunders; 1992.

[35] Kwak SD, Ahmad CS, Gardner TR, Grelsamer RP, Henry JH, Blankevoort L, et al. Hamstrings and iliotibial band forces affect knee kinematics and contact pattern. Journal of Orthopaedic Research. 2000; 18(1):101-08. doi: 10.1002/jor.1100180115

[36] Clark M. Muscle energy techniques in rehabilitation. In Techniques in musculoskeletal rehabilitation. New Jersey: McGraw-Hill; 2001.

[37] Clark M, Russell A. Optimum performance training for the performance enhancement specialist. Calabasas: National Academy of Sports Medicine; 2001.

[38] Richardson C, Jull G, Hodges P, Hides J. Therapeutic exercise for spinal segmental stabilization in low back pain. Edinburgh: Churchill Livingstone; 1999.

[39] Prentice W. Rehabilitation techniques in sports medicine. 5th ed. New York: McGraw-Hill; 2011.

[40] Bahr R, Engebretsen I. Handbook of sports medicine and science, sports injury prevention. 1st ed. Philadelphia: Wiley & Sons; 2009.

[41] Hicks J, Arnold A, Anderson F, Schwartz M, Delp S. The effect of excessive tibial torsion on the capacity of muscles to extend the hip and knee during single-limb stance. Gait & Posture. 2007; 26(4):546-52.

[42] Levangie P, Norkin C. Joint structure and function: A comprehensive analysis. 4th ed. Philadelphia: Davis Company; 2005.