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A New Clinical Design Measuring the Vertical Axial Rotation Through Tibial Shaft Resulting from Passive Knee and Subtalar Joints Rotation in Healthy Subjects: A Reliability Study

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The main purposes of the study are to determine the intra-inter rater reliability of a new special designed clinical evaluation system; to measure the amount of the vertical axial rotation of the tibia resulting from passive rotation of knee and subtalar joints. To achieve this, the Measuring the Vertical Axial Rotation Tibial Shaft (MVARTS) system was designed. The system apparatus is applied to each knee and measured the vertical axial rotation of the tibia and subtalar rotations together. Fifty healthy subjects were examined using the suggested system. Two evaluators measured the tibial internal and external rotations, passively. The pure tibial rotation was also measured radiologically on the X-Ray in only 24 subjects. The intra and inter observer variation was calculated between 2.1 and 3.8 degrees with high correlation (0.84-0.98). There was no significant difference between intra and inter observers' results ($p>0.05$). On the other hand, amount of the internal combined rotations was lower than the external rotation ($p<0.01$). The radiological external pure tibial rotations are 19.8±6.2 deg (right), 17.0±4.6 deg (left) for the males whilst 28.7±4.0 deg (right), 23.0±5.3 deg (left) for the females. The difference between the male and female subjects was also seen to be significant ($p<0.05$). The results showed that the MVARTS system is an appropriate, noninvasive, fast to measure combined tibial and subtalar joint rotation in addition to be economically very efficient.

Key words: Subtalar joint, tibial rotation, clinical goniometry, biomechanics

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INTRODUCTION

Assessment of the amount of the pure/combined tibial rotation by clinical examination is generally rather difficult. Even the most reliable clinical methods are somewhat inaccurate due to movement between soft tissues and bones. The normal amount of passive tibial rotation is still not agreed (Armour *et al*., 2004; Freeman and Pinskerova, 2003; Johal *et al*., 2005; Martelli and Pinskerova, 2002; Meyer and Haut, 2005; Nakagawa *et al*., 2000; Osternig *et al*., 1980; Viola *et al*., 2000).

In literature there are several methods to assess the tibial rotation such as clinical Computerized Tomography (CT) (Jakob *et al*., 1980; Nordt *et al*., 1999) Magnetic Resonant Imaging (MRI) (Freeman and Pinskerova, 2003; Nakagawa *et al*., 2000) clinical goniometry (Cameron and Saha, 1996; Lawand *et al*., 2004; Tamari *et al*., 2005), gravity goniometers (Lang and Volpe, 1998), videotaping (Lin *et al*., 2004), surface curvature (Liu *et al*., 2005), electronic digital inclinometers (Tamari and Tinley, 2003), roentgenographs (Herold and Marcovich, 1976), fluoroscopy (Clementz and Magnusson, 1989) and ultrasound (Butler *et al*., 1992), experimental set up (Park *et al*., 2005) and so on. In addition to their well known advantages, they also have many disadvantages such as being expensive, difficulty of usage, time consuming and restrictions in use etc. The clinical goniometry is very preferable method since being economical, easy to use, common and fast. However, it is important to point out that in the conventional clinical goniometry; it is difficult to determine a reference point for the rotation. In addition to that it is also difficult to stabilize the joints or bones. To minimize disadvantages of the conventional clinical goniometry and to be able to measure the passive combined axial tibial and subtalar rotation; we designed a new clinical system Measuring the Vertical Axial Rotation through Tibial Shaft (MVARTS) resulting from passive rotation of the knee and subtalar joints in healthy subjects.

The main purposes of the study are (1) to determine the intra-inter rater reliability of the MVARTS system, (2) to measure the amount of the passive vertical axial tibial rotation when the knee joint is fixed at 90 degree flexion in sitting position.

MATERIALS AND METHODS

Participants: All participants were selected among 400 healthy physical therapy students from Dumlupinar University. The sample included 50 volunteer healthy subjects (26 males, 24 females). All gave informed consent for participation. Each participant was informed about the apparatus and the procedures and was examined individually in a test room by a trained physical therapist who has at least three years experiences in physical therapy. The information about the sample was collected before testing and socio-demographics were recorded.

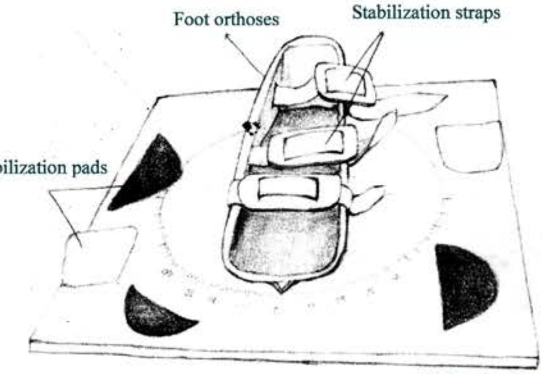

Fig. 1: Apparatus of MVARTS system

Table 1 demonstrates physical characteristics including age, mass, height and dominant lower limb by gender. All subjects studied in the current work had no any musculoskeletal, neurological and systemic disease that might have an effect on testing. Volunteers had also not got any known pathologies of the knees in usage.

The MVARTS system: The MVARTS system consists of the following two parts:

- Foot orthosis with stabilization pads,
- A surface table with fixed clinical goniometry.

The MVARTS apparatus was used to measure the total tibial rotation (Fig. 1). Each subject was tested in a sitting position on an armless chair. The knee is at the position 90 degrees of flexion and the foot is placed in the foot orthosis, which is a part of the apparatus (Fig. 2). The evaluators measured the tibial external and internal rotations passively and the score was recorded in degree (Fig. 3 and 4).

Radiological measurements: The tibial rotation was also measured radiologically on the X-Ray. The subjects' lower limb was just placed as aforementioned in the system. In order to show geometrical models and the points of the references, four points of the references were placed on the lower limb (2 points on the femur and 2 points on the external and internal malleolus of the ankle joint) (Fig. 2). Radiological cassette holder was placed under the surface table of the MVARTS system. We

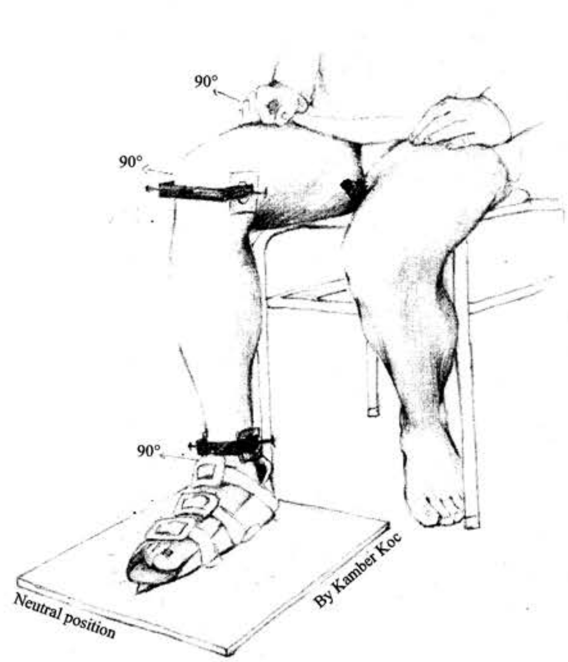

Fig. 2: MVARTS system with radiological markers

Fig. 3: Measurement of medial tibial and subtalar rotations in MVARTS system

Fig. 4: Measurement of lateral tibial and subtalar rotations in MVARTS system

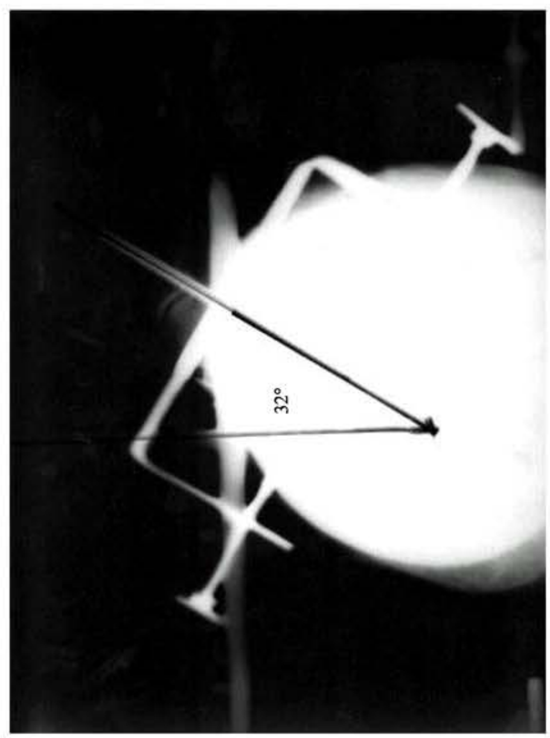

Fig. 5: Calculation of tibial rotation on X-Ray film

exposed during the rotation both the tibia and foot anterior-posterior. The angle of the rotation was calculated on the X-Ray film (Fig. 5).

Statistical analysis: Statistical analysis was performed using the SPSS version 10.0 (SPSS Inc, Chicago, US). Descriptive statistics describe the test subjects' baseline variables. ANOVA and correlation analyzes were used to determine the intra-inter reliability of the MVARTS system. Independent t-test and Mann Whitney U test were used for comparing the groups. Data were presented as mean±SD. A value of $p<0.05$ was accepted as significant.

RESULTS

Demographic data belonging to the subjects are presented in Table 1. There has not been found any statistical differences in terms of intra-inter observer measurements of the MVARTS system ($p>0.05$). The highest difference (3.8^0) of the intra rater was found in the second tester on the right leg external rotation (Table 2). Intra-inter observer measurements of the system were found to be very high correlation (84-98%) except the left leg internal rotation result of the first tester (76%) (Table 3). Only the left internal rotation degrees were found to be in agreement with the results point of view in

Table 1: Demographic data of the subjects (N: 50)

	Male (N: 28)	Female (N: 22)
Age (year)	20.9±1.5 (18-23)	20.0±1.1 (19-22)
Height (m)*	1.81±0.59 (1.67-1.88)	1.65±0.21 (1.62-1.70)
Weight (kg)*	74.5±9.6 (53-88)	57.2±5.1 (52-67)
Dominant side (R/L)	28/0	22/0

Data are presented Mean±SD (min-max), *p<0.05

Table 2: Intra-inter observer of measurement of MVARTS System (N: 50)

Passive tibial motion	1st measure	2nd measure	Difference	p
1st tester				
External rotation**				
Right leg	45.2±8.5 (30-62)	46.7±8.2 (35-63)	2.6±2.3	NS
Left leg	46.4±10.8 (25-66)	47.6±9.9 (27-65)	2.1±2.0	NS
Internal rotation				
Right leg	36.9±10.7 (20-58)	37.3±10.9 (20-58)	2.5±2.0	NS
Left leg	35.9±7.5 (24-52)	36.0±8.1 (24-50)	3.4±4.1	NS
2nd tester				
External rotation**				
Right leg	45.1±8.6 (31-62)	46.5±8.5 (34-63)	3.8±3.2	NS
Left leg	46.3±9.6 (24-52)	47.9±9.8 (29-67)	2.9±2.6	NS
Internal rotation				
Right leg	37.2±10.4 (18-60)	37.1±10.7 (18-60)	3.1±2.7	NS
Left leg	36.0±7.4 (23-52)	35.9±7.2 (24-48)	2.9±2.0	NS

Data are presented Mean±SD (min-max), MVARTS: Measuring Vertical Axial Rotation through Tibial Shaft, * No statistically differences between intra-inter observer of measurement of MVARTS system (p>0.05), **In both legs external rotation statistically higher than internal rotation (p<0.01)

Table 3: Evaluation of intra and inter rater correlation (N: 50)

	Intra rater		
Passive tibial motion	1st tester	2nd tester*	Inter rater*
External rotation			
Right leg*	0.91	0.84	0.94
Left Leg*	0.96	0.93	0.98
Internal rotation			
Right leg*	0.95	0.93	0.98
Left leg	0.76	0.88	0.98

*Higher correlations (p<0.01)

Table 4: Radiological and MVARTS measurements by gender (N: 12)[a]

	Pure tibial rotation (Radiological measurements)		Combined rotations (From knee and subtalar joints) (MVARTS system)	
	Male (N: 6)	Female (N: 6)	Male (N: 6)	Female (N: 6)
External rotation* **				
Right leg	19.8±6.2	28.7±4.0*	40.6±6.1	50.9±7.5**
Left leg	17.0±4.6	23.0±5.3*	41.3±6.8	56.0±5.8**
Internal rotation				
Right leg	26.7±9.9	21.8±7.3	32.6±9.3	42.6±9.2**
Left leg	28.5±7.4	27.2±4.8	35.8±7.9	36.1±7.3
Total external and internal rotation				
Right leg	46.5±11.6	50.5±9.8*	73.2±13.7	93.5±10.9**
Left leg	45.5±12.3	50.2±10.1*	77.1±11.1	92.1±11.7**

Data are presented Mean±SD, MVARTS: Measuring Vertical Axial Rotation through Tibial Shaft, *p<0.05, **p<0.001, ***External rotation statistically higher than internal rotations in all measurement of the MVARTS system (p<0.05) and statistically lower than internal rotation except female right leg rotation in all measurements of radiological tibial rotations (p<0.05) in both sexes. However no statistically differences were found between total rotations of right and left knee joints (p>0.05), [a] Mann-Whitney U-test was used both genders and in both measurements (p>0.05). On the other hand, the rest of measurements in both radiological and the MVARTS system were found to be higher in female subjects than the male subjects. In addition; while the external rotation in the MVARTS system is higher than the internal rotation (p<0.01), in the radiological measurements these results come out to be in an opposition way (p<0.05). Nevertheless, it was found that these have not been seen any significant difference between the internal and external rotations of the legs in total (p>0.05) (Table 4).

DISCUSSION

Excessive tibial motion is very important factor leads to knee pathologies especially ligament injuries, among the sedentary or athletic people. Evaluation of the knee after an ACL reconstruction using the semitendinosus and gracilis auto-grafts has primarily focused on flexion and extension (Frank and Jackson, 1997; Hiemstra *et al*., 2000; Keays *et al*., 2000; Marder *et al*., 1991). The semitendinosus and gracilis muscles also contribute to internal tibial rotation (Marder *et al*., 1991; Shoemaker and Markolf, 1982). It has been suggested that the harvest of these tendons for the purpose of an ACL reconstruction controls the internal tibial rotation weakness. As well known the internal tibial rotation is essential to the normal biomechanics of the knee and is necessary during walking (Perrin, 1993). It also follows the ankle in pronation and supination. If the tibial rotation initiate from the ankle, it will transfer to the knee. The valgus and external tibial rotation of the knee joint is accepted as a risk factor producing an ACL injury. In this position, the tibial internal rotators are working eccentrically to counteract forces on the ACL. The knee is subjected repeatedly to challenge involving the tibial external rotation in any cutting sport such as soccer, basketball and volleyball. In sports requiring the tibial rotation such as alpine skiing, it is also possible that these deficits would be clinically significant (Armour *et al*., 2004). As reported in this study as well as some earlier studies (Armour *et al*., 2004; Hester and Falkel, 1984; Meyer and Haut, 2005; Osternig *et al*., 1980; Viola *et al*., 2000), it is difficult to obtain normative torque data for internal/external tibial rotation because of variation in testing protocols (Viola *et al*., 2000). The main reason of that there has not been in literature an easy and economical method assessing the motion of the tibia. In recent studies some technologies such as computerized tomography, ultrasound, MRI etc. have been used by means of this aim. However, high cost of these methods is the most important drawback. Therefore especially clinicians do not prefer to use the aforementioned technologies in daily routines.

Knee motions take place mainly between 10 and 120 degrees. The femur external condyle tends to roll back producing the tibial internal rotation with flexion (Freeman and Pinskerova, 2003). Johal *et al*. (2005) measured tibio-femoral movement by using the MRI during the hyperextension to 120 degrees; the external, femoral condyle was seen to move posterior 22 mm. From 120 degrees to full squatting there was another 10 mm of posterior translation. During flexion of the knee to 120 degrees, thus, the femur rotated externally through an angle of 20 degrees. In addition Nakagawa *et al*. (2000) studied active flexion from 90 degrees to 133 degrees and measured passive flexion to 162 degrees using MRI in 20 unloaded knees among Japanese subjects. Flexion over this arc is accompanied by backward movement of the internal femoral condyle of 4.0 mm and by backward movement externally of 15 mm.

Nordt *et al*. (1999) measured the tibial translation and rotation using CT in the tibia 20 degrees of flexion in patients with/without anterior curciate ligament-reconstructed. In their study the internal rotation was seen to be between 8.7 and 10.8 for various subjects while the external rotation was seen to be between 9.1 and 7.4 degrees. In addition, Meyer and Haut (2005) studied in cadavers and found internal rotation in tibia to be 7.8±7.0 degrees during the 90 degrees flexed knee. In contrast of these studies, the amount of the combined external rotation using the MVARTS was found to be between 40.6 and 56.9 degrees, whilst the combined internal rotation is between 32.6 and 42.6 degrees. In addition, the present study also found that radiological passive pure tibial external rotation between 17 and 28.7 degrees and internal rotation between 21.8 and 28.5 degrees. Although no more studies have been evaluated the combined tibial rotation, present data were found to be higher than the studies carried out in literature. However, in a study carried out by Park *et al*. (2005) women showed significantly higher laxity in tibial external with larger terminal rotation (31.9±4.2° vs. 19.5±2.2) and lager intermediate rotation (28.1±4.2° in women vs 15.5±2.4° in men).

Even if a standardized and widely accepted protocol exists to test flexion and extension, there are some limitations when they are in use to measure the passive internal and external tibial rotation. These include variation in patients' positioning and stabilization, use of a modified clinical knee-testing apparatus. The pragmatic purpose of the current study is to evaluate the amount of the internal/external tibial rotation minimizing the effects of the anterior and posterior knee muscles during testing.

Recently, there are several studies showed displacement of the femur and tibia. While in those studies the MRI system was commonly used and the amount of displacement (mm) was measured, we used the MVARTS system to measure the pure passive tibial rotations in degrees. Whilst the displacement in the corresponding works was planar, in the present work the displacement measured is axial and rotational. As a consequence of this difference, it can be said that our method is clinically more usable.

This study was only carried out when the knee is fixed in flexion position of 90 degrees. Some various degrees of knee flexion could also have been tried. Since this study focused to investigate the reliability of the MVARTS system, we did not try to measure the vertical axial rotation in various degrees of the knee flexion.

Epidemiologic researches have demonstrated that the female athletes have a 4- to 6-fold increased risk for ACL injury compared with their male counterparts playing at similar levels (Arendt and Dick, 1995; National Federation of State High School Associations, 2002; National Collegiate Athletic Association, 2002). The present study showed that the female subjects had more tibial and subtalar ROM than the male subjects. This part of present findings is in agreement with most of previous works. Viola *et al.* (2000) evaluated internal and external tibial rotation torque at 60°/s, 120°/s and 180°/s in 23 subjects with ACL reconstruction using hamstring tendons. They found that subjects who had undergone an ACL reconstruction using the semitendinosus and gracilis tendons demonstrated internal tibial rotation weakness in their reconstructed limb when compared to their contra external normal limb. In this study, the authors pointed out that a lack of adequate foot stabilization and the inability to control unwanted subtalar and midtarsal foot motion may change the results.

As was pointed out by Park *et al.* (2005) the authors also saw that the finding mentioned gives rise to more risky for knee injuries for the females comparison to the males.

The obtained results showed that the MVARTS system is therefore easily usable and economical comparison to its rival methods. Consequently; the MVARTS system is reliable, effective, useful and economical and provides important clinical data about the vertical axial rotation through tibial shaft resulting from passive knee and subtalar joints rotation. In order to improve our model, a biomechanical study should be conducted to determine the effectiveness and validity of the MVARTS system in various knee degrees and pathologies.

REFERENCES

Arendt, E. and R. Dick, 1995. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. Am. J. Sports Med., 23: 694-701.

Armour, T., L. Forwell, R. Litchfield, A. Kirkley, N. Amendola and PJ. Fowler, 2004. Isokinetic evaluation of internal/external tibial rotation strength after the use of hamstring tendons for anterior cruciate ligament reconstruction. Am. J. Sports Med., 32: 1639-1643.

Butler-Manuel, P.A., R.L. Guy and F.W. Heatley, 1992. Measurement of tibial torsion a new technique applicable to ultrasound and computed tomography. Brit. J. Radiol., 65: 119-126.

Cameron, J.C. and S. Saha, 1996. External tibial torsion: An underrecognized cause of recurrent patellar dislocation. Clin. Orthop. Relat Res., 328: 177-84.

Clementz, B. and A. Magnusson, 1989. Assessment of tibial torsion employing fluoroscopy, computed tomography and the cryosectioning technique. Acta Radiol., 30: 75-80.

Frank, C.B. and D.W. Jackson, 1997. Current concepts review: The science and reconstruction of the anterior cruciate ligament. J. Bone Joint Surg. Am., 79: 1556-1576.

Freeman, M.A. and V. Pinskerova, 2003. The movement of the knee studied by magnetic resonance imaging. Clin. Orthop. Relat. Res., 410: 35-43.

Herold, H.Z. and C. Marcovich, 1976. Tibial torsion in untreated congenital clubfoot. Acta Orthop. Scand., 47: 112-117.

Hester, J.T. and J.E. Falkel, 1984. Isokinetic evaluation of tibial rotation: Assessment of a stabilization technique. J. Orthop. Sports Phys. Ther., 6: 46-51.

Hiemstra, L.A, S. Webber, P. Macdonald and D.J. Kriellars, 2000. Knee strength deficits after hamstring tendon and patellar tendon anterior cruciate ligament reconstruction. Med. Sci. Sports Exerc., 32: 1472-1479.

Jakob, R.P., M. Haertel and E. Stussi, 1980. Tibial torsion calculated by computerized tomography and compared to other methods of measurement. J. Bone Joint Surg., 62: 238-242.

Johal, P., A. Williams, P. Wragg, D. Hunt and W. Gedroyc, 2005. Tibio-femoral movement in the living knee. A study of weight bearing and non-weight bearing knee kinematics using 'interventional' MRI. J. Biomech., 38: 269-276.

Keays, S.L., J. Bullock-Saxton and A.C. Keays, 2000. Strength and function before and after anterior cruciate ligament reconstruction. Clin. Orthop., 373: 174-183.

Lang, L.M.G. and R.G. Volpe, 1998. Measurement of tibial torsion. J. Am. Podiatr. Med. Assoc., 88: 160-165.

Lawand, S.J., A.R. Júnior and R.L. Smith, 2004. Evaluation of a new device for measuring the leg torsion angle. Acta. Ortop. Bras., 12: 70-76.

Lin, F., G. Wang, J.L. Koh, R.W. Hendrix and L.Q. Zhang, 2004. *In vivo* and noninvasive three-dimensional patellar tracking induced by individual heads of quadriceps. Med. Sci. Sports Exercise, 36: 93-101.

Liu, X., W. Kim, B. Drerup and A. Mahadev, 2005. Tibial torsion measurement by surface curvature. Clin Biomech. (Bristol, Avon), 20: 443-450.

Marder, R.A., J.R. Raskind and M. Carroll, 1991. Prospective evaluation of arthroscopically assisted anterior cruciate ligament reconstruction. Patellar tendon versus semitendinosus and gracilis tendons. Am. J. Sports Med., 19: 478-484.

Martelli, S. and V. Pinskerova, 2002. The shapes of the tibial and femoral articular surfaces in relation to tibiofemoral movement. J. Bone Joint Surg. Br., 84: 607-613.

Meyer, E.G. and R.C. Haut, 2005. Excessive compression of the human tibio-femoral joint causes ACL rupture. J. Biomech., 38: 2311-2316.

Nakagawa, S., Y. Kadoya, S. Todo, A. Kobayashi, H. Sakamoto, M.A. Freeman and Y. Yamano, 2000. Tibiofemoral movement 3: Full flexion in the living knee studied by MRI. J. Bone Joint Surg. Br., 82: 1199-200.

National Federation of State High School Associations, 2002. (National Federation of State High School Associations, Indianapolis, IN).

National Collegiate Athletic Association, 2002. (National Collegiate Athletic Association, Indianapolis, IN).

Nordt, W.E., 3rd, P. Lotfi, E. Plotkin and B. Williamson, 1999. The *in vivo* assessment of tibial motion in the transverse plane in anterior cruciate ligament-reconstructed knees. Am. J. Sports Med., 27: 611-616.

Osternig, L.R., B.T. Bates and S.L. James, 1980. Patterns of tibial rotary torque in knees of healthy subjects. Med. Sci. Sports Exercise, 12: 195-199.

Park, H.S., C. Ahn and L.Q. Zhang, 2005. Passive knee joint properties in men and women. ISB XXth Congressn-ASB 29th Annual Meeting July 31-August 5, Cleveland, Ohio.

Perrin, D.H., 1993. Interpreting An Isokinetic Evaluation. In: Isokinetic Exercise and Assessment. Champaign, IL., Human Kinetics Publishers, pp: 50-61.

Shoemaker, S.C. and K.L. Markolf, 1982. *In vivo* rotary knee stability: Ligamentous and muscular contributions. J. Bone Joint Surg. Am., 64: 208-216.

Tamari, K. and P. Tinley, 2003. A new concept of estimating tibiofibular torsion: An *in vivo* reliability study. J. Orthop. Sports Phys. Ther., 33: 85-90.

Tamari, K., P. Tinley, K. Briffa and S. Raine, 2005. A new concept of indexing tibiofibular torsion: A pilot study using dry bones. J. Am. Podiatr. Med. Assoc., 95: 481-485.

Viola, R.W., W.I. Sterett, D. Newfield, J.R. Steadman and M.R. Torry, 2000. Internal and external tibial rotation strength after anterior cruciate ligament reconstruction using ipsiexternal semitendinosus and gracilis tendon autografts. Am. J. Sports Med., 28: 552-555.