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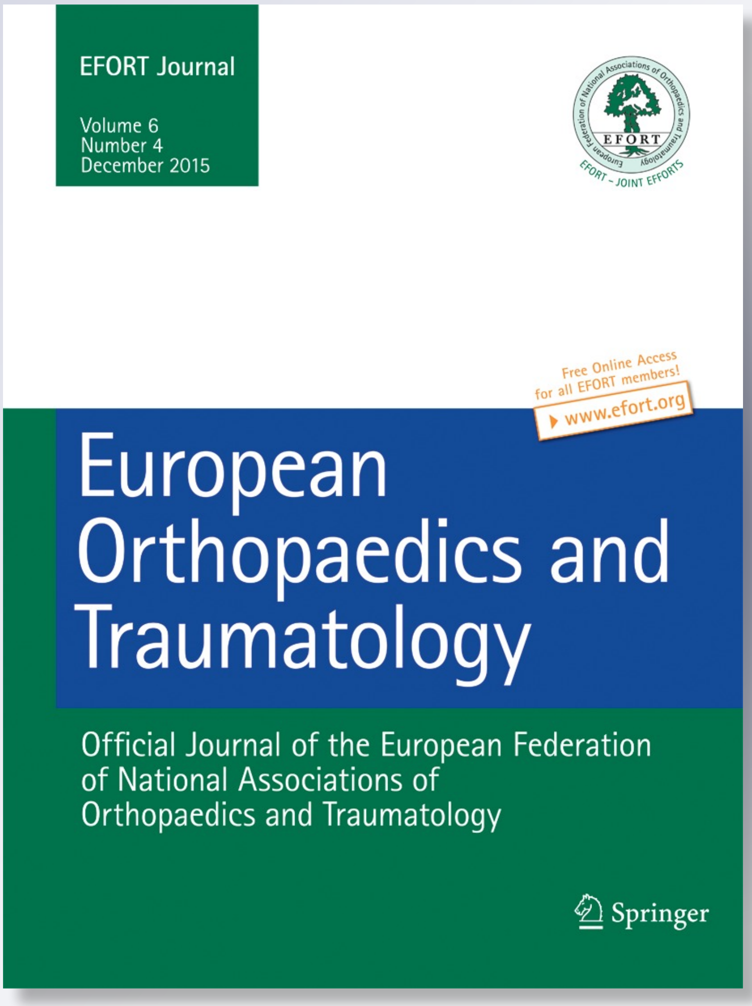

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ORIGINAL ARTICLE

Can Khan's new method using MRI integrable to detect tibial plateau slope and depth as risk factors for anterior cruciate tear?

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Abstract
Context ACL injury continues to be the largest single problem in orthopedic sports medicine. MRI has become the prime diagnostic tool of the various knee pathological and anatomical variability conditions.
Aim To test the integrity of the new combined method for assessment of tibial plateau anatomic variables using conventional MRI.
Settings and design Retrospective control study.
Methods We evaluated the medial tibial plateau slope (MTPS), lateral tibial plateau slope (LTPS), and medial tibial plateau depth (MTPD) in ACL-injured group of patients (156) and non-ACL-injured control group (93) using MRI scan. Inclusion criteria for ACL-injured group—as surgically confirmed—were isolated ACL injury, while inclusion criteria for non-ACL-injured group were minor trauma, bruises, etc.
Statistical analysis used Student's *t* test and ICC were used. A *p* value of <0.05 was assigned as significant.
Results Both male and female patients in the ACL-injured group showed increased LTPS in comparison to control group (p=0.0197), whereas no significant difference in MTPS and MTPD was detected (p=0.75 and 0.9, respectively). Steeper LTPS was detected in males of the patient group than in control group (p=0.0001). Control group males had less steep MTPS (p=0.002) and LTPS (p=0.035) and deeper MTPD (p=0.004) than control group females.
Conclusion We conclude that the combined method conducted by Khan et al. (Int Orthop (SICOT) 2011 35(8):1251–1256) using conventional MRI for measurement of MTPS, LTPS, and MTPD as risk factors for ACL injury is solid and reproducible.

Level of evidence: III. Diagnostic study

Keywords ACL · MRI knee · Tibial platue slope · LTPS · Tibial platue depth

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Introduction

The anterior cruciate ligament (ACL) is one of the most commonly disrupted ligaments in the knee [1]. Each year in the USA, there are approximately 300,000 ACL injuries in the general population [2, 3]. It is also estimated that 38,000 ACL injuries occur each year in female athletes [4]. Apart from the obvious short-term implications, the injury also presents with substantial longer term morbidities. Radiological signs of osteoarthritis, for example, appear in more than 50 % of ACL-deficient knees as early as 5 to 15 years after injury [5, 6].

Renstrom et al. [3] reported that ACL injury continues to be the largest single problem in orthopedic sports medicine, with the incidence of non-contact ACL tears being much higher in female athletes in sports such as basketball and team handball than in male athletes.

Understanding the underlying causes—or risk factors—for one of the more severe sports-related knee injuries—an ACL disruption—is important for the development of intervention strategies and for identifying those at increased risk of injury. This provides a target group for intervention.

Radiographic study of the knee joint has long been used to speculate the anatomic factors of the knee joint associated with increased risk for ACL injury; several factors and measurements have been proposed by the literature; nevertheless, they showed great variability in figures with no single satisfactory value.

Dating years back, MRI has become the prime diagnostic tool of the various knee pathological and anatomical variability conditions, affecting either soft tissue or bony components; hence, it becomes the imaging modality of choice for measuring various length, thickness, and angles through the knee.

The aim of this work is to test the integrity and reproducibility of the new combined method for assessment of tibial plateau anatomic variables using conventional MRI as risk factors for ACL injury conducted by Khan et al. [7].

Patients and methods

The present work was conducted in a retrospective fashion to evaluate the medial tibial plateau slope (MTPS), lateral tibial plateau slope (LTPS), and medial tibial plateau depth (MTPD) in ACL-injured group of 156 patients and non-ACL-injured control group of 93 patients. The research was stretched over a period of 45 months (from February 2011 till October 2014) through review of patients' surgical and medical records as well as MR knee scan and included 249 subjects.

Inclusion criteria for patient group were as follows: (1) surgically confirmed isolated ACL injury, (2) no collateral ligament injury, (3) no posterior cruciate ligament (PCL) injury, (4) no meniscal injury, (5) no bony abnormality, (6) no osteoarthritis, and (7) no patellofemoral pain.

Inclusion criteria for control group were as follows: (1) knee minor trauma, (2) bruises, (3) other medical causes for knee MR scanning, (4) no meniscal injury, and (5) no osteoarthritis.

All patients and control group undergone MR scan of the knee in our institution. For patient group, the preoperative MR scan was assessed.

Patient (ACL-injured) group included 156 patients (120 male and 36 female) with mean age 31 years (age range 15–46 years), while the control group included 93 subjects (68 male and 25 female) with mean age 29 years (age range 15–43 years).

All knee—ACL—surgeries were performed and confirmed arthroscopically (Figs. 1, 2, 3, 4, 5, 6, 7, 8, and 9).

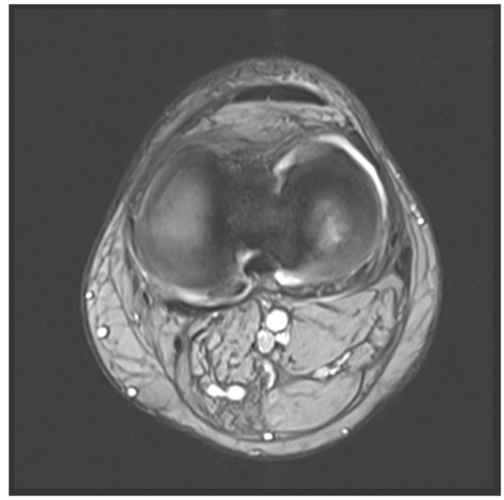

Fig. 1 Axial GRE image of the knee joint showing the most proximal transverse image of the tibia at the tibiofemoral joint to identify the central sagittal plane

Results

ICC was calculated prior to the actual interpretation of tibial plateau slopes and depth to measure the intrarater and interrater reliability of the combined method adopted by Khan et al. [7] with the results shown in Table 1.

In our study population, both male and female patients in the ACL-injured group showed increased LTPS in comparison to control group (p=0.0197), whereas no significant difference in MTPS and MTPD was detected

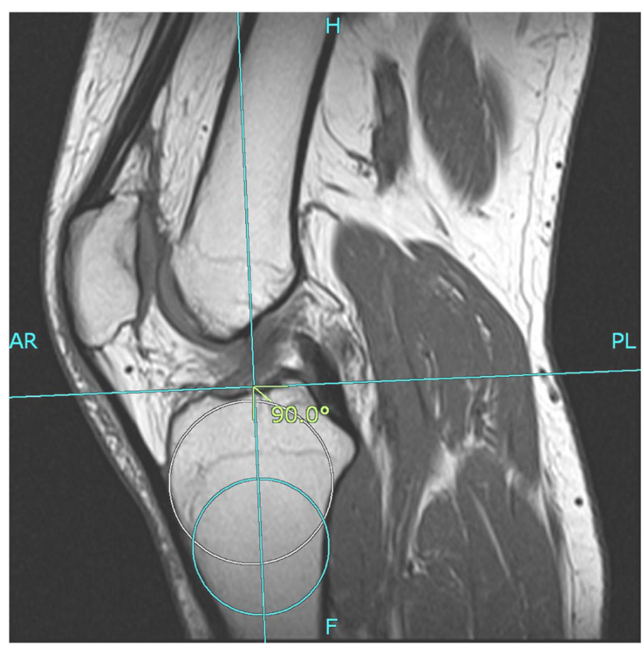

Fig. 2 Sagittal T1WI of the knee joint showing method of circle drawing, identification of tibial axis (TA) with the overlying perpendicular line

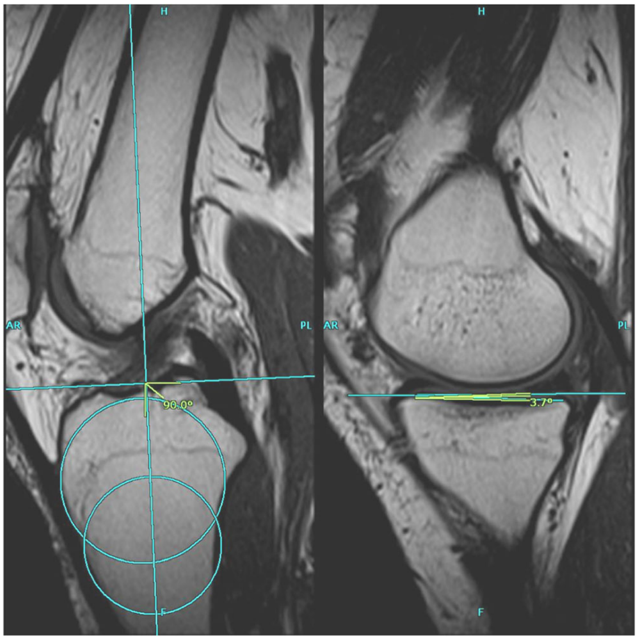

Fig. 3 Sagittal T1WI of the knee joint showing method of calculating value of MTPS

(p=0.75 and 0.9, respectively). Steeper LTPS was detected in males of the patient group than in control group (p=0.0001), while females in patient group had significantly shallower MTPD than females in control group (p=0.002) and males in patient group (p=0.0005). Control group males had less steep MTPS (p=0.002) and LTPS (p=0.035) than control group females yet deeper MTPD (p=0.004) (Tables 2, 3, and 4).

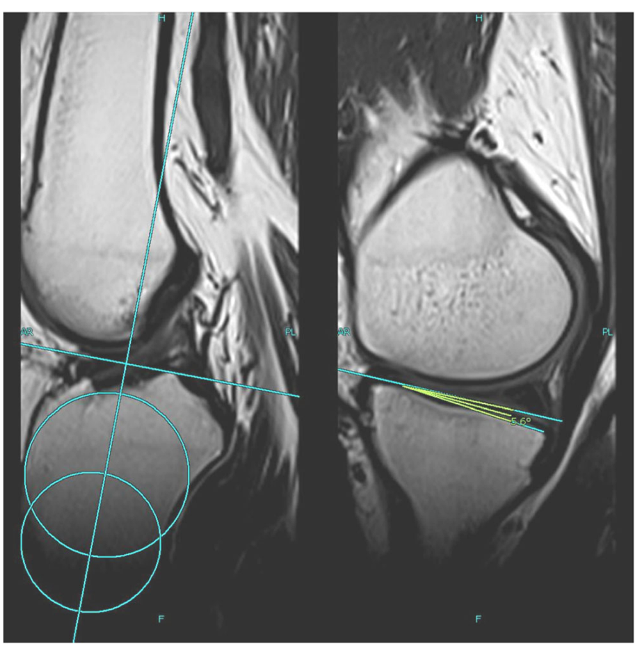

Fig. 4 Sagittal T1WI of the knee joint showing method of calculating value of MTPS in another patient

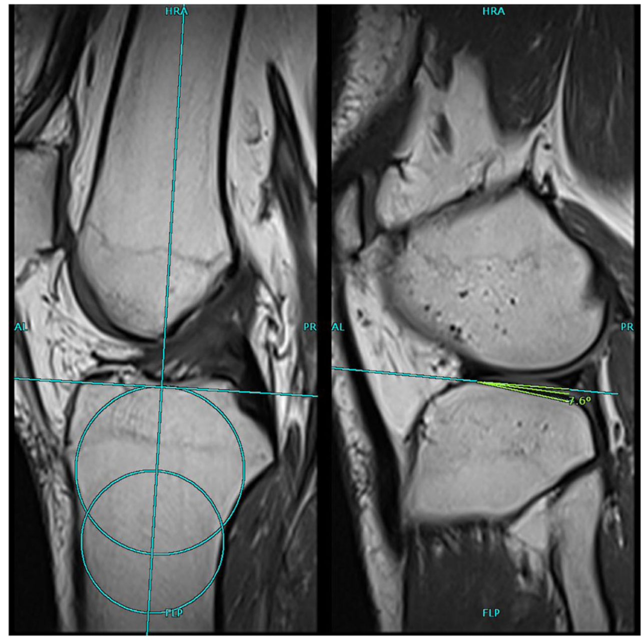

Fig. 5 Sagittal T1WI of the knee joint showing method of calculating value of LTPS

Discussion

The risk factors for ACL injury have been considered as either internal or external to an individual. External risk factors include type of competition, footwear and surface, and environmental conditions. Internal risk factors include anatomical, hormonal, and neuromuscular risk factors [3]. Among anatomical risk factors, most studies have been conducted on

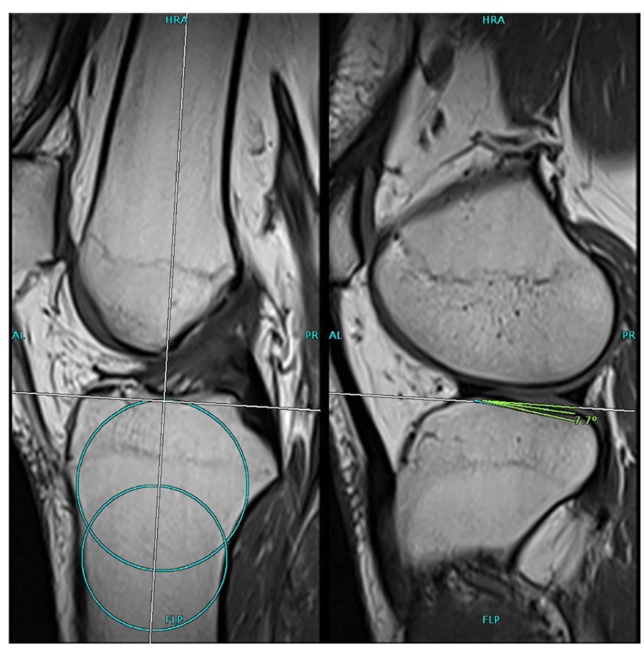

Fig. 6 Sagittal T1WI of the knee joint showing method of calculating value of LTPS in another patient

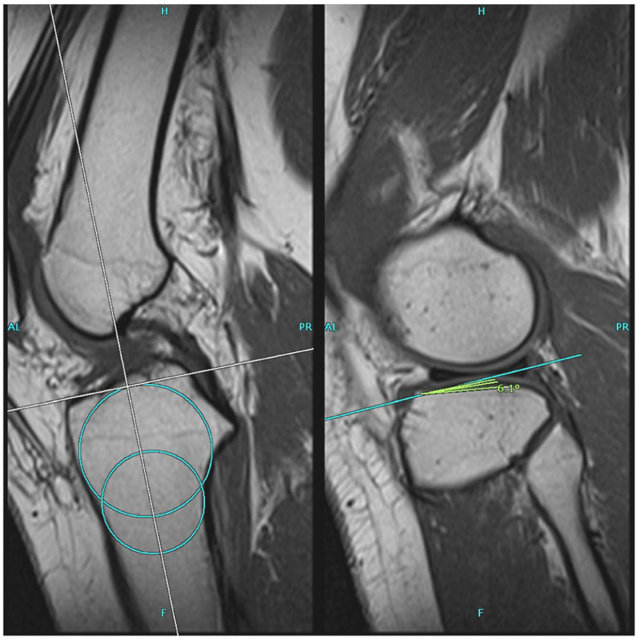

Fig. 7 Sagittal T1WI of the knee joint showing method of calculating value of LTPS in another patient with higher posterior than anterior peak with resultant negative angle

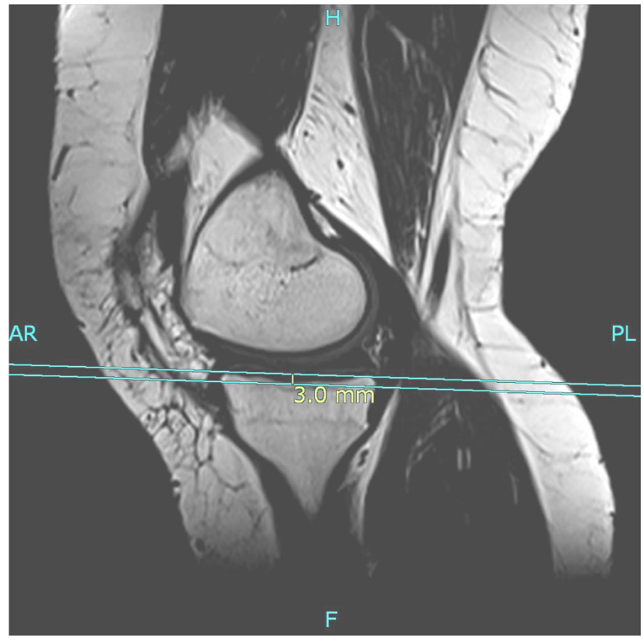

Fig. 9 Sagittal T1WI of the knee joint showing method of calculating value of MTPD in another patient

the size of the intercondylar notch [9–11], but recently, posterior tibial slope (PTS) has also been identified as an important risk factor [8, 12]. Tibial plateau slopes—MTPS and LTPS—independently are important determinants of knee biomechanics [7]. A highly significant correlation has been reported between the posterior inferior tibial slope and anterior tibial translation, and this is supported by the evidence that in arthroplasty, an inappropriate cutting angle of the PTS results in polyethylene wear, component loosening, and PCL strain [13–15].

The posterior inclination of the tibial plateau, which is referred to as posterior tibial slope, is determined routinely on lateral radiographs. However, radiographically, it is not always possible to reliably recognize the lateral plateau, making a separate assessment of the medial and lateral plateaus difficult [16].

One recent case-control study suggested that subjects with ACL-deficient knees had a significantly greater slope of the lateral tibial plateau and a lower slope of the medial tibial plateau than a control group. This paper suggests that the tibial slope of the medial and lateral condyle should be compared separately [3, 17, 18]. The increased tibial anterior translation results in increased joint contact force, specifically its anterior shear component, leading to substantially increased strain on the ACL [7].

Lately, shallower MTPD has also been recognized as a risk factor [7].

Hashemi et al. [12] and Hudek et al. [16] have studied the MTPS, LTPS, and PTS with two different methods using conventional MRI; however, Khan et al. [7] have stated that the

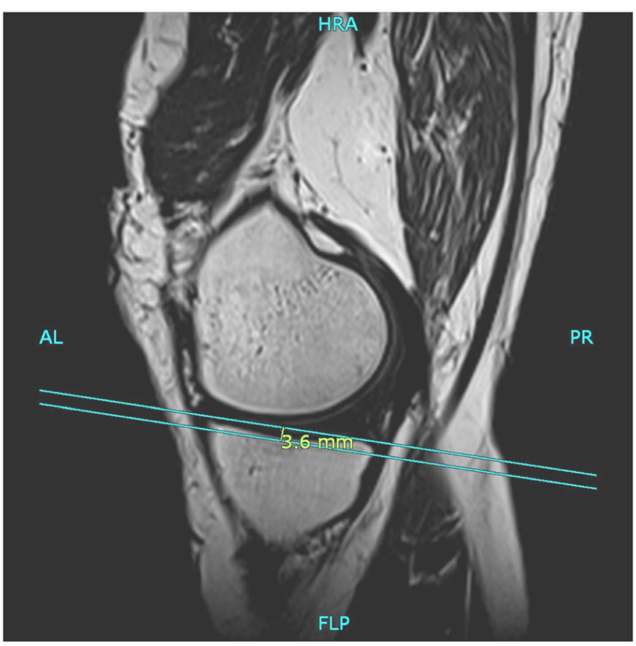

Fig. 8 Sagittal T1WI of the knee joint showing method of calculating value of MTPD

Table 1 Intrarater and interrater reliability of the combined method

	MTPS	LTPS
Observer 1 intrarater	0.89	0.93
Observer 2 intrarater	0.92	0.93
Interrater	0.93	0.90

Table 2 Control group mean, SD, and range for MTPS, LTPS, and MTPD illustrating sex difference

	Mean	SD	Range
MTPS (°)			
Male	4.3	2.4	0.9–8.3
Female	5.2	2.9	2–14
Total	4.3	2.5	0.9–13
LTPS (°)			
Male	3	2.32	−2.2–6.7
Female	3.4	2.4	−0.64–9
Total	2.6	2.8	−2.5–9
MTPD (mm)			
Male	2.5	0.9	1.3–3.7
Female	1.5	0.57	0.93–3.5
Total	1.96	0.7	0.91–3.5

former method necessitates at least 150 mm of bone below the knee joint gap should be available for assessing the longitudinal axis which is not normally provided by conventional MRI of the knee joint, while the later method describes an ambiguous selection of sagittal image for measurements; hence, they proposed a new combined method using both methods in a modified way by choosing the central sagittal image and midarticulating sagittal images of the medial and lateral tibial plateau described in the former method and then drawing the TA using the later method, hence, avoiding the drawbacks of each method.

Intraclass correlation coefficient (ICC) calculation in our study was almost perfect for both interrater and intrarater reliability with values ≥0.9 which matches Khan et al. [7] results.

In the present study, we found that the LTPS was steeper in ACL-injured patients than control group subjects in accordance with Khan et al. [7] as well as other workers [12, 16].

Table 3 Patient group mean, SD, and range for MTPS, LTPS, and MTPD illustrating sex difference

	Mean	SD	Range
MTPS			
Male	5.1	2.3	0.96–9.5
Female	4.9	2.6	−0.27–9.8
Total	5.1	2.5	−0.25–9.6
LTPS			
Male	4.6	3.07	−1.09–11.4
Female	5	3.1	0.5–10.4
Total	4.7	3.03	−1.07–11.5
MTPD			
Male	2.3	1	0.5–7.3
Female	1.52	0.65	0.35–2.88
Total	2.21	1.3	0.35–7.2

Table 4 *p* Value for injured and control group males and females

	MTPS	LTPS	MTPD
I vs C	0.75	0.0197	0.9
Male I vs female C	0.08	0.574	0.09
Male I vs female I	0.764	0.156	0.0005
Female I vs female C	0.21	0.366	0.002
Male I vs male C	0.06	0.0001	0.922
Male C vs female C	0.002	0.035	0.004

I injured, *C* control

Also, LTPS in injured men was steeper than control group men supported by work of Khan et al. [7] as well as other workers [12, 18, 19].

Using the combined method, MTPS difference was not significant between ACL-injured patients and control group either in our study or Khan et al. [7] study and also in other studies [18, 19]. Yet, Hashemi et al. [12] stated that "male cases had increased medial tibial slope ($p = 0.02$) compared with controls."

On the other hand, we found significantly shallower MTPD in injured females than control females and injured males; this is supported by the results of Khan et al. [7] and Hashemi et al. [12].

Khan et al. [7] postulated that steeper LTPS combined with shallow MTPD will result in anterior translation of the tibia and external rotation of the femur under joint loading conditions, which will put the ACL under excess strain. Each one of the former parameters will explain the increased incidence of ACL injury in males and females having steeper LTPS and shallower MTPD, respectively.

Conclusion

From our study testing the integrity and reproducibility of the new combined method for assessment of tibial plateau anatomic variables using conventional MRI as risk factors for ACL injury conducted by Khan et al. on larger number of patients than in the study of Khan et al. [7], we conclude that the combined method is solid and reproducible regarding measurement of MTPS, LTPS, and MTPD in different ACL-injured patients and uninjured subjects and can be used as a reference to prospect the more prone individuals to injuries of the ACL for early protective measures to be undertaken; however, threshold fixed values should be attested to establish an evaluation chart for those at high risk of ACL injury. Also, we agree—with Khan et al. [7]—that LTPS and MTPD in males and females, respectively, are the most important determinants for ACL injury.

Compliance with ethical standards

Conflict of interest Authors declared no conflict of interest.

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