JOURNAL OF ATHLETIC PERFORMANCE AND NUTRITION

e-ISSN:2148-7488

Original Article Journal of Athletic Performance and Nutrition

Volume: 5 Issue: 1 pp:1-13 2018

Ultrasound characteristics of patellar tendon and femoral condylar cartilage thickness in football and basketball players*

M. Emin Kafkas[1], Egemen Kızılay[2], Armağan Şahin Kafkas*[,1], Fatma Kızılay[1], Bekir Durmuş[3], Atilla Pulur[4]

Received Date: 30.03.2018
Accepted Date: 28.05.2018

Abstract

Objectives: Our purpose in the current study was to provide information about quadriceps and hamstrings muscle strength and morphology as well as patellar tendon and femoral condylar cartilage morphological properties of basketball and football players.

Methods: Twelve football and eleven basketball players participated to the study. Football player's age was 23.70 ± 6.40 years, height was 171.30 ± 10.75 cm and weight was 67.55 ± 11.10 kg. Basketball players' age was 25.90 ± 8.10 years, height was 186.40 ± 15.80 cm, and the weight was 83.25 ± 16.5 kg. Patellar tendon width was measured along the long transverse axis. Short axis diameter was measured from the midpoint of transverse measurement of this tendon. Femoral cartilage thickness, which is including 3-points (midpoint) lateral condyle, medial condyle and the intercondylar area, was measured in the fully flexed position of knee. All measurements were performed using "Linear Array" probes (8-16 ve 5-10 MHz Diasus Dynamic Imaging Ltd, Scotland, United Kingdom) on "GE Logiq P5 Ultrasound" device.

Results: Patellar tendon thickness was found 2.16 ± .43 mm in basketball and 2.06 ± .32 mm in football players. In basketball players' isokinetic muscle strength was 196.40 ± 8.19 Nm and in football players it was 210.45 ± 23.15 Nm. Among the branches, dominant knee flexion and extension isokinetic muscle strength which was measured at $60°/s^{-1}$ angular

[1] Inonu University, Faculty of Sport Science, Department of Movement and Training Sciences Turkey
[2] Kadirli State Hospital PMR Clinic
[3] Erenköy PMR Education and Research Hospital.
[4] Gazi University, Faculty of Sports Sciences,

**This study partly was partly presented as a poster presentation at the 16th National Congress of Anatomy, 11-14 September 2014 - Turkey.*

***Corresponding Author:** Armağan ŞAHİN KAFKAS, Inonu University, Faculty of Sport Sciences, Department of Movement and Training Sciences, armagan.sahin@inonu.edu.tr

velocity and Hamstring: Quadriceps Ratio (H:Q) were not found to be statistically significantly different (p> 0.05).

Conclusion Determining patellar tendon, femoral cartilage thickness and imbalance of H:Q muscle strength would allow both basketball and football players to make training more effective and suitable for the purpose during the season.

Key Words: *Football, basketball, tendon thickness, isokinetic strength.*

Introduction

The incidence of knee injuries is high in some sports branches such as football and basketball. The incidence of knee injuries in football was reported to be 8% to 27% [1], while it was 15.8% in basketball [2]. Knee pain in front of the knee is one of the major factors limiting performance in sportsmen. In sport branches including sudden maneuvers and leaps such as football, basketball and handball, infrapatellar tendinopathy is cited as the most common cause of anterior knee pain [3]. Lian et al. in 2005 has been reported that infrapatellar tendinopathy is encountered at 45% frequency in this sport branches [4]. Patellar tendinopathy that is seen in both professional and recreational sportsmen due to the overuse of the patellar tendon or trauma is characterized by loss of function [3]. The mechanical stimuli obtain adaptation may be different for tendon than for muscle tissue [5]. Thus, it is reasonable to argue that the development of the muscle-tendon unit within the course of athletic training may be characterized by imbalances of muscle capacity and tendon properties, resulting in episodes of high tendon strain and stress. The above argumentation can be supported by clinical evidence that early manifestations of overload injuries like patellar tendinopathy concern adolescent athletes [6].

Tendon and cartilage pathology is a common issue in everday clinical practice for sport medicine physicians [7]. The prevalence of such pathologies is in constant rise due to the increase in sport practice involving young and elderly sportsmen. Both tendons and cartilages, although able to sustain huge mechanical stresses, have limited healing potential, so that when the damage occurs [8]. Diagnosis of infrapatellar tendinopathy is a clinical application which sonography, ultrasonography and magnetic resonance imaging are pointed out as important diagnostic tools. Ultrasound is considered as a reliable, non-invasive and economical method for observing or diagnosis of soft tissue [9,10]. Tendons have higher acoustic contrast than other tissues in ultrasound imaging [11]. Therefore, ultrasound is often used for anatomical and functional assessment of tendons [12,13]. Especially in sports such as football and basketball that have higher risk of lower extremity injury due to intensive use, it is important to determine and compare the structural causes of soft tissue injury, anatomical-functional tendon cartilage thickness and isokinetic muscle strength measurement that may arise muscle imbalance. As a result of this determination, taking preventive precautions will help protection from major injuries (example: tear of anterior cruciate ligament) [14]. In recent years, it is known that in health control of sportsmen, not only scanning patellar tendon but also measurements of cartilage thickness have been used to assess knee. The studies regarding validity and reliability of the cartilage ultrasound are also available [15,16]. But, especially in sportsmen, there are no adequate studies about detection of cartilage thickness. Cartilage thickness and lesions are issues that should not be overlooked. Therefore, it has been reported that, cartilage lesions cause meniscus injury and even rupture of anterior cruciate ligament in the later stages [14,17,18]. Besides it has been reported that the muscle imbalance of sportsmen is important in the survey of both tendon and patellar cartilage injury [19,20]. For many years isokinetic testing is used as a reliable method for measurement and evaluation of muscle imbalance and strength [21-24]. There are useful studies in the literature concerning muscle strength imbalance and it's effects in sportsmen [20,25-27]. But, these studies do not provide information about the comparative strength and muscle imbalance in football and basketball branches. Also the studies regarding tendons and cartilage thickness in the literature for these branches are very limited. Structural patellar tendon, muscle strength imbalance and femoral cartilage thickness may be important factors for the lesions that formed during trauma in these branches. These both branches include requiring high power movements such as sprint, changing direction, agility, and jumping. Therefore, this study is very important to examine in terms of muscle strength and patellar tendon and femoral condylar cartilage thickness. Because, there are no studies examine patellar tendon and femoral condylar cartilage thickness in the literature. Generally, tendinopathies have not been proven effective, which may be because the etiology and injury mechanisms are largely unknown [28]. Some studies have been indicated that the development of tendinopathy is related to repetitive tensile load, strain of the tendon fascicles and fibrils [29,30]. Owing to the lack of clinical and experimental verification, no obvious scientific agreement has been reached specifically on muscular strength and patellar tendon and femoral condylar cartilage. However, we know that patellar tendon thickness has been increased as a result of repitetive micro trauma. Therefore, this study can reveal important results about potential risks. Our purpose in the current study was to provide information about quadriceps and hamstrings muscle strength and morphology as well as patellar tendon and femoral condylar cartilage morphological properties of basketball and football players. We hypothesized that would be differ between football and basketball players in terms of quadriceps and hamstrings muscle strength and patellar tendon and femoral condylar cartilage.

Method

Participants

A previous power analysis with an alpha of 0.05 and power of 80%, utilizing effect sizes from our study, determined that the smallest sample size adequate to detect high effect sizes (20%) for groups would be 12 participants for each group. The sample size virtually guaranteed that the effect would be observed. The sample size of the study was determined by GPOWER 3.1 trial version (power 80%, two-sided significant level, 5%). Twelve football and eleven basketball players participated to the study. Football player's mean age was 23.70 ± 6.40 years, mean height was 171.30 ± 10.75 cm and mean weight was 67.55 ± 11.10 kg. Basketball players' mean age was 25.90 ± 8.10 years, mean height was 186.40 ± 15.80 cm, and the mean weight was 83.25 ± 16.5 kg. Inclusion criteria of research; a) to be playing football and basketball regularly for 5 years, b) they have Tegner Activity Levels between 8 and 10 [31], c) not to have any inflammatory rheumatic diseases, d) not to be osteoarthritis, and e) had not undergone surgery or trauma from related tendons, environmental joints and soft tissue. Sportsmen who want to leave work on a voluntary basis excuded from the study. Before starting the research participants were informed about the content of the study, its purpose, application and the potential risks. Voluntary consent forms were distributed and were signed to all participants. Consent was obtained from "Malatya Clinical Research Ethics Committee " for this research.

Ultrasound Imaging Method

All imaging measurements of the sportsmen of both branch were applied in the pre-season period by a physical medicine and rehabilitation specialist physician experienced in musculoskeletal ultrasonography. All measurements were performed using "Linear Array" probes (8-16 ve 5-10 MHz Diasus Dynamic Imaging Ltd, Scotland, United Kingdom) on "GE Logiq P5 Ultrasound" device. Patellar tendon thickness measurements; participants were lied in supine position on the treatment table and dominant knee was taken to 30^0 flexion. Linear image of distal patellar tibial tendon was obtained by observing in insertion. The deepest point of the tendon fiber inserted into the tibia was called "*x point*". From 1 cm proximal of x point the long axis of the tendon was obtained in a vertical cross-view. Measurements were applied in this area. The width was evaluated along the long transverse axis of the tendon. Tendon short axis diameter was estimated from the midpoint of the transverse measurement. Femoral condylar cartilage thickness measurements (dominant knee); evaluations were done axially with linear prob in full flexion position of knee from suprapatellar window including 3-points; lateral condyle, inter-condylar area and medial-condyle, (mid-point). All received evaluations were measured and recorded as millimeter (mm).

Isokinetic Tests

Isokinetic muscle strength measurements; dominant side knee isokinetic peak torque was measured by a Biodex system 3 isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA, 2000). During data collection, device calibration settings made in accordance with the manufacturer's recommendations on a regular basis. Participants were placed on a chair in the sitting position for the test. To prevent upper body movement, individually adjustable, cross, chest and hip belt was used. Trunk/thigh angle was set to be 85°. Participants were asked verbally whether they were comfortable on measurement position. Directory anatomical position of knee in 90° flexion, and 70° range of motion (from 90° flexion to 20° flexion; 0°=full extension) were measured using a goniometer. Participants started to test with audio warning given by the dynamometer and ended with the same voice. Participants were orally encouraged in order to strive maximum effort during the test. Knee flexor - extensor torque of participant's were measured at $60°/s^{-1}$ angular velocity. One set including 5 repetition concentric isokinetic exercise at $60°/s^{-1}$ angular velocity was made to participants. All measurements estimated and recorded as Newton. meter (Nm). Hamstring: Quadriceps (H:Q) ratio of muscle strength was obtained by dividing the concentric maximum flexion (hamstring) knee torque to concentric maximum extension (quadriceps) knee torque at $60°/s^{-1}$ angular velocity [24].

Statistical analysis

Statistical analysis procedures started with "Kolmogorov-Smirnov" analysis for testing homogeneity of the available data. "Mann-Whitney U Test" was used for comparisons between two branches since there is no normal distribution. All statistical analyses were performed using SPSS 17.0 software package. In this study obtained data were expressed as mean ± standart deviation (SD). Level of significance in the research was considered $p < 0.05$.

Results

Dominant knee cartilage and tendon thickness of the participants were presented in figure 1.

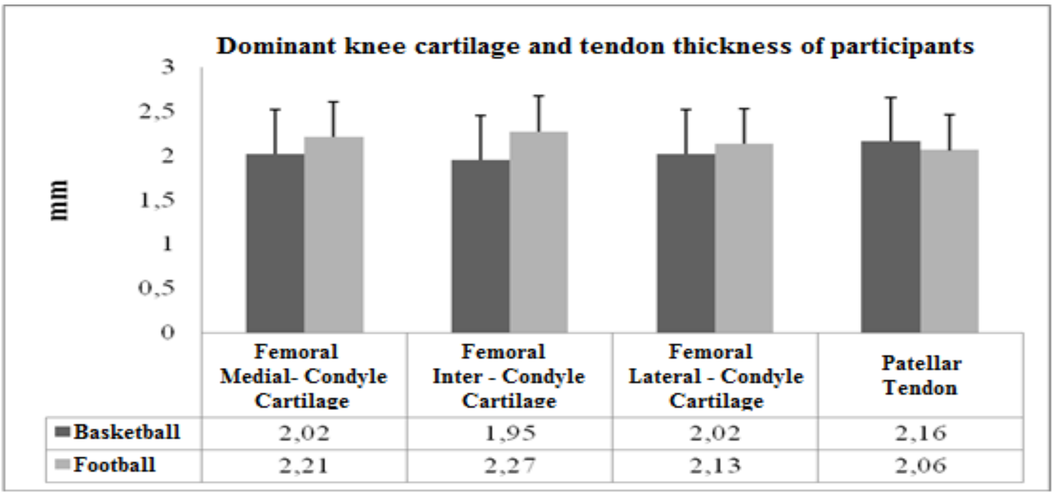

Fig. 1: Dominant Knee Cartilage and Tendon Thickness of Participants

When dominant knee femoral cartilage thickness compared to football and basketball medial-condyle (p=.532); lateral condyle (p=.783) and inter-condyle area (p =.218) there was no significant difference between groups. The patellar tendon thickness measurements were not found to be statistically significantly different between two groups either (p=.766). Dominant knee muscle strength measurements of the participants were presented in figure 2.

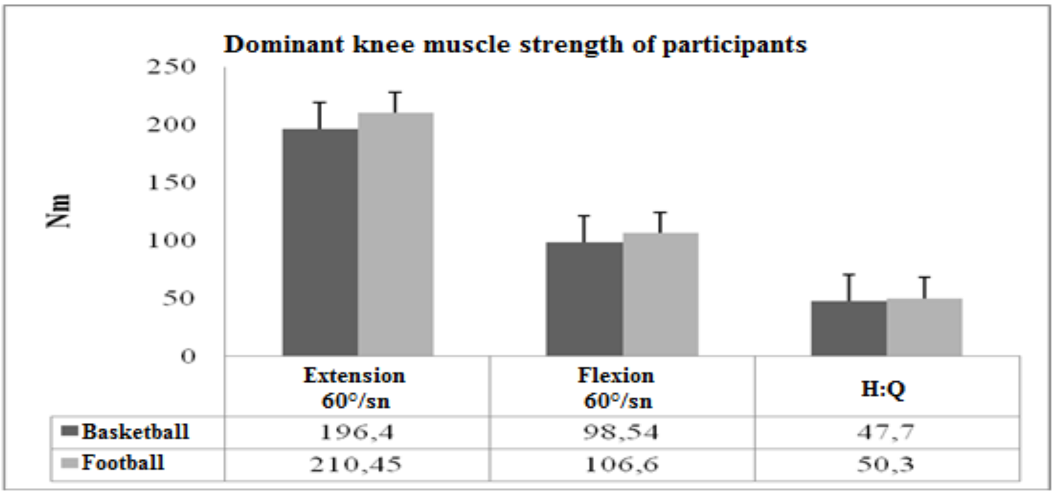

Fig. 2: Dominant Knee Muscle Strength Measurements of the Participants

When compared dominant knee flexion and extension isokinetic muscle strength of basketball and football players which measured in $60°/s^{-1}$ angular velocity were not found to be statistically significant difference between groups (p=.459, p=.221). Also, when compared in terms of branch variety, H:Q ratios were not found to be statistically significantly different (p=.885).

Discussion

Femoral condylar cartilage and patellar tendon thickness, knee flexion-extension muscle strength and H:Q ratios of football and basketball players were compared in this study. There are no data in the literature for ultrasonographic femoral condylar cartilage thickness measurement between these two branches. The studies conducted on non-athletic population are more purposeful to determine current degeneration than cartilage thickness [32-34]. According to limited studies about reference values of femoral condylar cartilage thickness in the literature, human femoral condyle cartilage thickness is 1.65-2.65 mm. These results belong to a study conducted on 11 cadavers (Caucasian) with mean age of 65.1 and mean BMI (Body Mass Index) of 19.3 [35]. Frisbee et al in 2006 found in their study based on 6 cadavers, in 5 local region of people knee joint including medial trochlear ridge and the medial condyle, cartilage thickness was 2.2-2.5 mm [36]. When this study compared with the samples from literature, femoral condylar cartilage thickness mean values of 23 sportsmen were between 1.95- 2.27 mm. The survey results were consistent with the literature, but narrower ranges of values obtained according to the literature. Homogeneous study groups occur from sportsmen who have no gender difference and physiological properties may explain why obtained values that are close together. Mean age of the cadavers of Shepherd and Seedom's [35] study was so higher than our study group including healthy sportsmen. There may be other factors that affect the range. It is stated that the thickness of the cartilage is associated with activity levels. Hall and Wyshak in 1980 reported in their study that is done with arthrography method which cartilage thickness is compatible with person's weight and activity status in weight-bearing joints [37].

There are also studies that report, regardless of weight values, cartilage thickness is higher at some weight-bearing points of joints [38]. This conflict with the research results of the studies can be explained by using different measurement methods and device variants. In this study cartilage thickness was measured by ultrasound method, because there are studies revealing the validity and reliability about measuring cartilage thickness [15,16]. At the same time assessment of the tendon thickness is very important in the evaluation of sportsmen knee health, at detection of current lesions or risk of lesion formation. Fredberg and Bolvig in 2002 found 17% risk of tendinopathy in their study by examining asymptomatic 54 elite football players with tendon ultrasonography [39]. They reported that ultrasonography could be preferred to predict the risk of tendinopathy and development of symptoms. The aim of our study was to compare and identify these risks in terms of football and basketball players. But there was no deficit in the tendon examined in 23 sportsmen according to the survey results. Therefore, risk comparisons could not be made. For this purpose, it is thought that large trials can be executed to make comparisons.

Schmidt et al investigated 102 healthy volunteers in their study. They measured patellar tendon thickness from 2 cm distal of distal patella [40]. Patellar tendon thickness minimum reference value was determined 1.2, average value was 3.2 mm and maximum value was 5.5 mm. Toprak et al compared patellar tendon thickness by using Doppler ultrasound method of 60 female volleyball sportsmen aged 11-16 years with same age group of sedentary controls [41]. Measurements were made from 6 mm distal of proximal point of the long axis. They measured proximal thickness as 2.8-6.2 mm. Our study findings were partially consistent with the literature results. But, points of measurement, research groups and the mean age of the study groups were not similar with our study. Thus, tendon diameter was measured based on the midpoint of the transverse axis in this study. In addition, characteristics (age, sex, physical activity status) of the study group that consisted of sportsmen were homogeneous. In this study tendon thickness of 23 sportsmen was 1.4-2.7 mm. In football players mean thickness of the tendon was 2.06 ± .32 mm, and it was 2.16 ±.43 mm in basketball players. Weinberg et al. [42] examined a total of 14 patients of patellar tendinosis in their studies. They detected patellar tendon thickness values 2-8 mm (mean 4.4 ± 1.7mm). This range is wider than both our study findings and data obtained from healthy individuals examined in the literature. This group that extends the range of values that patellar tendinosis patient is seen as an important factor. The mean thickness value of normal patellar tendon has been evaluated as a broad range of 1.2-6.2 mm in this literature [40,41]. According to the findings in the patellar tendon thickness measurements there was no statistically significant difference between football and basketball branches. It is considered that the lack of statistically significant differences is caused by similar activity of knee and tendon thickness associated with muscle strength in both branches. With the respect, our study findings are an original study when examining the literature.

There was no statistically significant difference between isokinetic knee flexor and extensor muscle strength between two branches. H:Q peak torque ratios are used extensively in the determination of the muscle strength of sportsmen. H:Q ratios of peak torque, especially indicates the functional ability of agonist and antagonist muscles of the knee and the balance between hamstring and quadriceps muscles [43,44]. Muscle imbalance measured over H:Q peak torque ratios is an important parameter in the rehabilitation process of both the physical condition status and sports injury [45]. It has been proved that H:Q muscle strength imbalance can lead to lesions of the knee when faced with trauma in sportsmen [46]. Some researchers reported that there is a high correlation between the incidence of lower extremity injuries and H:Q peak torque imbalance in their study. In most of these studies in the literature, H:Q peak torque ratio is emphasized that it should be 0.50 and 0.80 range. High incidence of knee injuries has been reported among sports activities especially branch such as football, basketball, and volleyball [47-49]. Knee flexion muscle strength has been measured at $60^0/sec^{-1}$ angular velocity was found 98.54 ± 13.2 Nm /sec in basketball, while it was 106.60 ± 12.4 Nm /sec in football. Knee extensor muscle strength was determined as 196.40 ± 19.8 Nm $/sec^{-1}$ in basketball players while 210.45 ± 23 Nm /sec in football players. However, there was no statistically significant difference, knee muscle strength values were relatively higher in football players according to basketball players. This data can be show that football players use knee joint more intense than basketball players. H:Q ratios of 23 sportsmen were found to be 47.70 ± 8.4 in basketball players, while 50.30 ± 10.1 in football players. The findings of the other studies in the literature are close to the value obtained from the study, but it is not at the desired level. Obtained H:Q values were close to the lower limit of the values obtained from the literature.

Conclusions

We therefore concluded that determining patellar tendon, femoral cartilage thickness and imbalance of H:Q muscle strength would allow both basketball and football players to make training more effective. Also, determining H:Q imbalance in the pre-season process would provide to determine the need of additional hamstring-quadriceps training and follow up the development in the next periods. In this context, the research is important and has an original structure in terms of limited resources in the literature about pre-season determination of femoral condyle cartilage, patellar tendon thickness of football and basketball players. In addition to other findings, H:Q values bring differences to the study. But further studies that will be conducted on sportsmen of similar or different sports are required to test the data obtained from this study.

Limitations

Working on a small group of volunteers was the first limitation of this study. Another weakness of this study was the diversity of the measurement reference points obtained from literature. Reference points of measurement and differences in evaluation technics made it difficult for us to make comparisons.

Conflict of Interest Statement: The authors declare that they have no conflict of interest.

Financial Disclosure: The authors declared that this study has received no financial support.

Acknowledgments: The author would like to thank the players who volunteered for this study. The author would also like to thank “Imaging and Isokinetic Test Experts” for isokinetic testing and imaging procedure.

References

1. Wong, P., & Hong, Y. (2005). Soccer injury in the lower extremities. Br J Sports Med, 39(8),473-82.
2. Kujala, UM., Taimela, S., Antti-Poika, I., Orava, S., Tuominen, R., Myllynen, P. (1995). Acute injuries in soccer, ice hockey, volleyball, basketball, judo and karate: analysis of national registry data. BMJ, 311 (7018), 1465-68.
3. Peace, KA., Lee, JC., Healy, J. (2006). Imaging the infrapatellar tendon in the elite athlete. Clin Radiol, 61(7), 570-8.
4. Lian, OB., Engebretsen, L., Bahr, R. (2005). Prevalence of jumper’s knee among elite sportsmen from different sports: A cross-sectional study. Am J Sports Med, 33, 561-7.
5. Arampatzis, A., Monte, GD., Karamanidis, K., Morey-Klapsing, G., Stafilidis, S., Brüggemann, G-P. (2006). Influence of the muscle-tendon unit’s mechanical and morphological properties on running economy. J Exp Biol, 209, 3345-57.
6. Le Gall, F., Carling, C., Reilly, T., Vandewalle, H., Church, J., Rochcongar, P. (2006). Incidence of injuries in elite French youth soccer players: a 10-season study. Am J Sports Med, 34, 928-38.
7. Peers, KH., & Lysens, RJ. (2005). Patellar tendinopathy in athletes. Sports Med, 35 (1),71-87.
8. Kon, E., Filardo, G., Roffi, A., Andriolo, L., Marcacci, M. (2012). New trends for knee cartilage regeneration: from cell-free scaffolds to mesenchymal stem cells. Curr Rev Musculoskelet Med, 5 (3), 236-43.
9. Grassi, W., Filippucci, E., Farina, A., Cervini, C. (2000). Sonographic imaging of tendons. Arthritis Rheum, 43 (5), 969-76.
10. Möller, I., Bong, D., Naredo, E., Filippucci, E., Carrasco, I., Moragues, C., et al. (2008). Ultrasound in the study and monitoring of osteoarthritis. Osteoarthr Cartilage, 16 (3), 4-7.
11. Martinoli, C., Bianchi, S., Derchi, LE. (1999). Tendon and nevre sonography. Radiol Clin North Am, 37 (4), 691-711.
12. O'Connor, PJ., Grainger, AJ., Morgan, SR., Smith, KL., Waterton, JC., Nash, AF. (2004). Ultrasound assessment of tendons in asymptomatic volunteers: a study of reproducibility. Eur Radiol, 14 (11), 1968-73.

13. Fredberg, U., Bolvig, L., Andersen, NT., Stengaard-Pedersen, K. (2008). Ultrasonography in evaluation of achilles and patella tendon thickness. Ultraschall Med, 29 (1), 60-5.
14. Røtterud, JH., Sivertsen, EA., Forssblad, M., Engebretsen, L., Årøen, A. (2011). Effect of gender and sports on the risk of full-thickness articular cartilage lesions in anterior cruciate ligament injured knees: A nationwide cohort study from Sweden and Norway of 15 783 patients. Am J Sports Med, 39 (7), 1387-94.
15. Abraham, AM., Goff, I., Pearce, MS., Francis, RM., Birrell, F. (2011). Reliability and validity of ultrasound imaging of features of knee osteoarthritis in the community. BMC Musculoskelet Disord, 12 (1),70.
16. Naredo, E., Acebes, C., Möller, I., Canillas, F., de Agustín, JJ., de Migue, l. E., et al. (2009). Ultrasound validity in the measurement of knee cartilage thickness. Ann Rheum Dis, 68 (8), 1322-27.
17. Keays, SL., Newcombe, PA., Bullock-Saxton, JE., Bullock, MI., Keays, AC. (2010). Factors involved in the development of osteoarthritis after anterior cruciate ligament surgery. Am J Sports Med, 38 (3), 455-63.
18. Øiestad, BE., Engebretsen, L., Storheim, K., Risberg, MA. (2009). Knee osteoarthritis after anterior cruciate ligament injury: A systematic review. Am J Sports Med, 37 (7), 1434-43.
19. Grace, TG., Sweetser, ER., Nelson, MA., Ydens, LR. (1984). Skipper BJ. Isokinetic muscle imbalance and knee-joint injuries. A prospective blind study. J Bone Joint Surg Am, 66 (5), 734-40.
20. Devan, MR., Pescatello, LS., Faghri, P., Anderson, J. A. (2004). Prospective study of overuse knee injuries among female sportsmen with muscle imbalances and structural abnormalities. J Athl Train, 39 (3) ,263-7.
21. Montgomery, LC., Douglass, LW., Deuster, PA. (1989). Reliability of an isokinetic test of muscle strength and endurance. J Orthop Sports Phys Ther, 10 (8), 315-22.
22. Pincivero, DM., Lephart, SM., Karunakara, RA. (1997). Reliability and precision of isokinetic strength and muscular endurance for the quadriceps and hamstrings. Int J Sports Med, 18 (2), 113-7.
23. Feiring, DC., Ellenbecker, TS., Derscheid, GL. (1990). Test-retest reliability of the biodex isokinetic dynamometer. J Orthop Sports Phys Ther, 11 (7), 298-300.
24. Sole, G., Hamrén, J., Milosavljevic, S., Nicholson, H., Sullivan, SJ. (2007). Test-Retest Reliability of Isokinetic Knee Extension and Flexion. Arch Phys Med Rehabil, 88 (5), 626-31.
25. Croisier, JL., Ganteaume, S., Binet, J., Genty, M., Ferret, JM. (2008). Strength imbalances and prevention of hamstring injury in professional soccer players. Am J Sports Med,36 (8), 1469-75.

26. Knapik, JJ., Bauman, CL., Jones, BH., Harris, JM., Vaughan, L. (1991). Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate sportsmen. Am J Sports Med, 19 (1), 76-81.
27. Newton, RU., Gerber, A., Nimphius, S., Shim, JK., Doan, BK., Robertson, M. et al. (2006). Determination of functional strength imbalance of the lower extremities. J Strength Cond Res, 20 (4), 971-7.
28. Couppé, C., Kongsgaard, M., Aagaard, P., Vinther, A., Boesen, M., Kjaer, M., et al. (2013). Differences in tendon properties in elite badminton players with or without patellar tendinopathy. Scand J Med Sci Sports, 23 (2), 89-95.
29. Riley, G. (2004). The pathogenesis of tendinopathy. A molecular perspective. Rheumatology (Oxford), 43, 131-42.
30. Magnusson, SP., Langberg, H., Kjaer, M. (2010). The pathogenesis of tendinopathy: balancing the response to loading. Nat Rev Rheumatol, 6, 262-8.
31. Tegner, Y. & Lysolm, J. (1985). Rating Systems in the Evaluation of Knee Ligament Injuries. Clin Orthop Relat Res, 198, 43-9.
32. Aagaard, P., Simonsen EB, S., Magnusson, P., Larsson, B., Dyhre-Poulsen, P. (1998). A new concept for isokinetic hamstring: quadriceps muscle strength ratio. Am J Sports Med, 26 (2), 231-7.
33. Nieminen, HJ., Saarakkala, S., Laasanen, MS., Hirvonen, J., Jurvelin, JS., Töyräs, J.(2004). Ultrasound attenuation in normal and spontaneously degenerated articular cartilage. Ultrasound Med Biol, 30(4),493-500.
34. Lu, MH., Zheng, YP., Huang, QH., Ling, C., Wang, Q., Bridal, L., et al. (2009). Noncontact evaluation of articular cartilage degeneration using a novel ultrasound water jet indentation system. Ann Biomed Eng, 37 (1),164-75.
35. Shepherd, DE.,& Seedhom, BB. (1999). Thickness of human articular cartilage in joints of the lower limb. Ann Rheum Dis, 58 (1), 27-34.
36. Frisbie, DD., Cross, MW., Mcllwraith, CW. (2006). A comparative study of articular cartilage thickness in the stifle of animal species used in human pre-clinical studies compared to articular cartilage thickness in the human knee. Vet Comp Orthop Traumatol, 19 (3), 142-6.
37. Hall, FM., & Wyshak, G. (1980). Thickness of articular cartilage in the normal knee. J Bone Joint Surg Am, 62 (3), 408-13.
38. Karvonen, RL., Negendank, WG., Teitge, RA., Reed, AH., Miller, PR., Fernandez-Madrid, F. (1994). Factors affecting articular cartilage thickness in osteoarthritis and aging. J Rheumatol, 21 (7), 1310-8.

39. Fredberg, U., & Bolvig, L. (2002). Significance of ultrasonographically detected asymptomatic tendinosis in the patellar and achilles tendons of elite soccer players. Am J Sports Med, 30 (4), 488-91.

40. Schmidt, WA., Schmidt, H., Schicke, B., Gromnica-Ihle, E. (2004). Standard reference values for musculoskeletal ultrasonography. Ann Rheum Dis, 63 (8), 988-94.

41. Toprak, U., Üstüner, E., Uyanık, S., Aktaş, G., Kınıklı, GI., Baltacı, G., et al. (2012). Comparison of ultrasonographic patellar tendon evaluation methods in elite junior female volleyball players: Thickness versus cross-sectional area. Diagn Interv Radiol, 18 (2), 200-7.

42. Weinberg, EP., Adams, MJ., Hollenberg. (1998). GM. Color doppler sonography of patellar tendinosis. AJR Am J Roentgenol, 171 (3), 743-4.

43. Wong, PL., Chaouachi, A., Chamari, K., Dellal, A. (2010). Wisloff U. Effect of preseason concurrent muscular strength and high-intensity interval training in professional soccer players. J Strength Cond Res, 24 (3), 653-60.

44. Cheung, RT., Smith, AW., Wong del, P. (2012). H:Q ratios and bilateral leg strength in college field and court sports players. J Hum Kinet, 33, 63-71.

45. Andrade, Mdos S., De Lira, CA., Koffes, Fde C., Mascarin, NC., Benedito-Silva, AA., Da Silva, AC. (2012). Isokinetic hamstrings to quadriceps peak torque ratio: the influence of sport modality, gender and angular velocity. J Sports Sci, 30 (6), 547-53.

46. Yeung, SS., Suen, AM., Yeung, EW. (2009). A prospective cohort study of hamstring injuries in competitive sprinters: preseason muscle imbalance as a possible risk factor. Br J Sports Med, 43 (8), 589-94.

47. Bennell, K., Wajswelner, H., Lew, P., Schall-Riaucour, A., Leslie, S., Plant, D., et al. (1998). Isokinetic strength testing does not predict hamstrings injury in Australian Rules footballers. Br J Sports Med,32 (4), 309-14.

48. Calmels, PM., Nellen, M., Van der Borne, I., Jourdin, P., Minaire, P. (1997). Concentric and eccentric isokinetic assessment of flexor–extensor torque ratios at the hip, knee, and anklein a sample population of healthy subjects. Arch Phys Med Rehabil, 78 (11), 1224-30.

49. Rosene, JM., Fogarty, TD., Mahaffey, BL. (2001). Isokinetic hamstrings quadriceps ratios in intercollegiate sportsmen. J Athl Train, 36 (4), 378-83.