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Is Blumensaat Inclination Angle (BIA) and Angle between Blumensaat line and Tibal Slope (BATS) a Risk Factor for ACL Injury?

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Abstract

Introduction: Femoral and tibial morphology posted as anatomical risk factors for ACL injuries. Samora et.al found out that a decreased BIA was associated with ACL rupture. Alentorn-Geli *et al.* found that the angle between the Blumensaat line and the anterior tibial slope (BATS angle) was significantly greater in men with ACL injury. However, other authors were not able to reproduce the similar findings. Our study aimed to determine the Blumensaat inclination angle (BIA) and angle between Blumensaat line and tibial slope (BATS) in patients with or without anterior cruciate ligament injury. We also explored the factors influence them. Method: We elavuated 142 MRI knee done in Hospital Sultan Ismail from January 2017 to November 2020. Study group was patient with ACL injuries, with or without meniscus and cartilage injuries. Control group was patient with no ACL injuries. 57 patients with history of fracture around the knee joint, multiligamentous injuries, inflammatory arthritis and tumour were excluded from the study. We recorded their age, gender, BIA, and BATS angle. BIA and BATS angle were measured in sagittal plane MRI as described by Koji Iswasaki *et al.* and Alentorn-Geli *et al.* Result: 54 patients were in study group and 31 years in control group. The mean age for study group was 32.7 (8.95) year old, and for control group was 42.5 (14.54). The mean BIA for study group was 36.20 (4.542) degree, and control group was 37.25 (4.941). The mean BATS for study group was 36.33 (5.78) degree, and control group was 25.26 (6.047) degree. BIA and BATS angle did not differ in both groups, age and gender. Conclusion: Our study did not show BIA and BATS angle as an anatomical risk factor for ACL injuries. Age and gender did not affect these angles.

Keywords

BIA, Anterior Tibial Slope, ACL

1. Introduction

Anterior Cruciate Ligament (ACL) injuries are among the most prevalent injuries in sports medicine. This injury have seen a sharp increase in incidence lately as more individuals are becoming more active and involved in sporting activities. Generally, ACL injury are often associated with sporting activities that could either involves non contact injury such as pivoting knee injuries or a direct injury to the knee. This injure can be challenging to treat and often leads to significant downtime and long term complication particularly among the athletes. It was primarily thought that the ACL injury is caused by a traumatic mechamism with rotation, hyperextension, or by contraction of the quadriceps muscle [1] [2]. However, in some studies a morphological predisposition is shown to have a correlation with risk of ACL injury and, as a consequence, some authors have started to measure the intercondylar notch dimensions [3] [4]. Where else, in some patients with an injured ACL, Fernández-Jaén *et al.* observed that the angle between the longitudinal femoral axis and Blummensaat line increases compared with that of patients with a normal ACL [5].

Despite extensive research, the exact mechanisms and risk factor that contribute to the ACL injuries remains complex and multifaceted. One of the emerging area of interest is the Blumeensaat inclination angle (BIA) and angle between the Blumeensaat line and Tibial slope (BATS). These anatomical features might play a significant role in influencing the risk of ACL injuries in individuals.

The Blumeensaat Inclination Angle (BIA) is a specific anatomical feature observed in the sagittal plane of the knee. This angle is formed by the intersection of the line along the roof of intercondylar notch and the horizontal plane, which has been hypothesized to influence the likelihood of ACL injury [6]. Study by Samora *et al.* concluded that a steeper BIA could be associated with higher risk of ACL injury [7]. The rationale is that a steeper angle will alter the biomechamics of the knee, hence increasing the stress on the ACL during dynamic movement.

BATS as the name suggests an angle formed by blumeensaat line and the tibial slope. This angle offers a more comprehensive understanding of the risk of ACL injury. Research has shown that an increase in posterior tibial slope has a significantly higher risk of ACL injury [8]. Alentorn-Geli *et al.* found that the angle between the Blumensaat line and the anterior tibial slope (BATS angle) was significantly greater in men with ACL injury [9]. However, other authors were not able to reproduce the similar findings.

Our study aimed to determine whether the blumeensaat inclination angle (BIA) and angle between blumeensaat line and tibial slope (BATS) influence the risk of ACL injures. We hypothesize that a larger angle will certainly increase the risk of ACL injury.

2. Material and Method

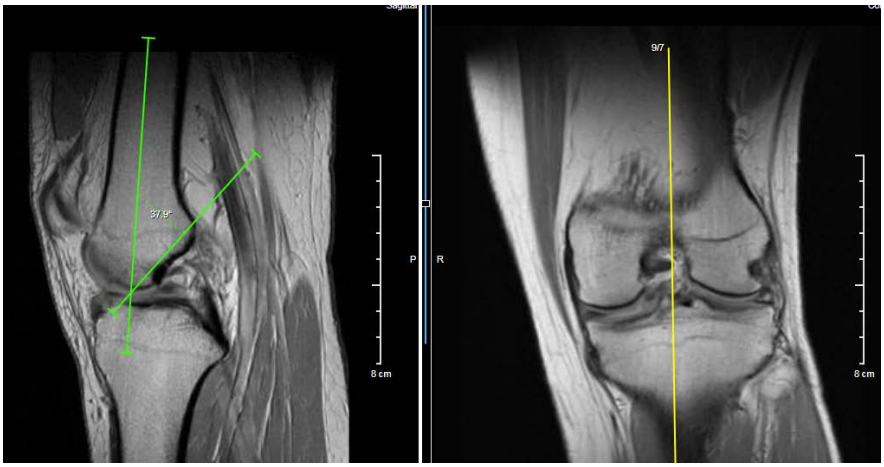
We retrospectively collected and elavuated 142 knee MRI done in Hospital Sul-

tan Ismail spanning from January 2017 to November 2020. A total of 57 patients with history of fracture around the knee joint, knees with multiligamentous injuries, inflammatory arthritis, tumour and duplicates were excluded from the study. The remaining 85 knee MRIs were taken for this study.

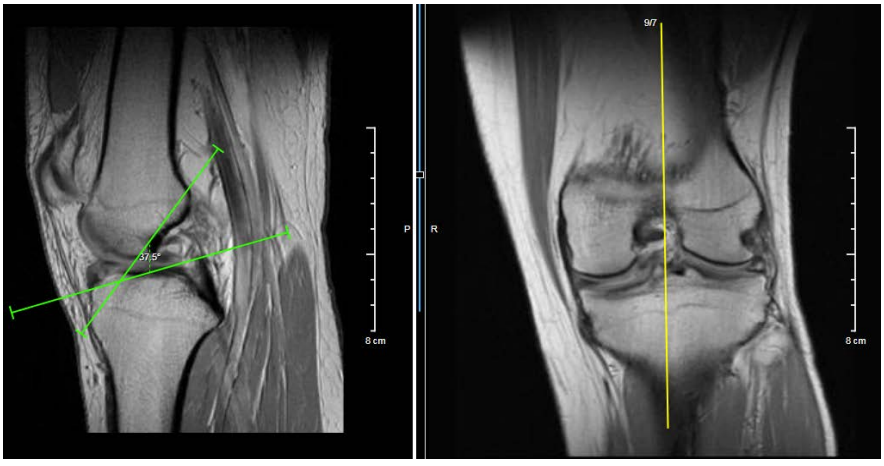
These numbers were then divided into 2 groups; a study group was patient with ACL injuries, with or without meniscus and cartilage injuries, and a control group was patient with no ACL injuries (**Figure 1**).

The demographical details such as age and gender were extrapolated and recorded. The BIA and BATS angle were measured in sagittal plane MRI as described by Koji Iswasaki *et al.* and Alentorn-Geli *et al.* (**Picture 1** and **Picture 2**). The data is then recorded.

Statistical analysis performed using the R software (version 3.6.1; Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics performed for variable interest + t.



Picture 1. Sagittal t-1 weighted image of Blumensaat Inclination Angle (BIA) taken at the center of sagittal cut in MRI.



Picture 2. Sagittal t-1 weighted image of the angle between the Blumensaat line and the anterior tibial slope (BATS angle), an angle formed by Blumensaat line and a line running along the tibial slope.

An independent t test were used to compare the age, the blumeensaat inclination angle and the angle between Blumensaat line and tibial slope based on ACL injury group and control group. Chi square test is use to evaluate the gender proposition between these 2 groups.

3. Result

A total of 85 patients out of 142 patients were included in our study group which was divided into 2 groups. In ACL injury group, there were 54 patients, where else in the control group, there were 31 patients respectively as shown in Figure 1.

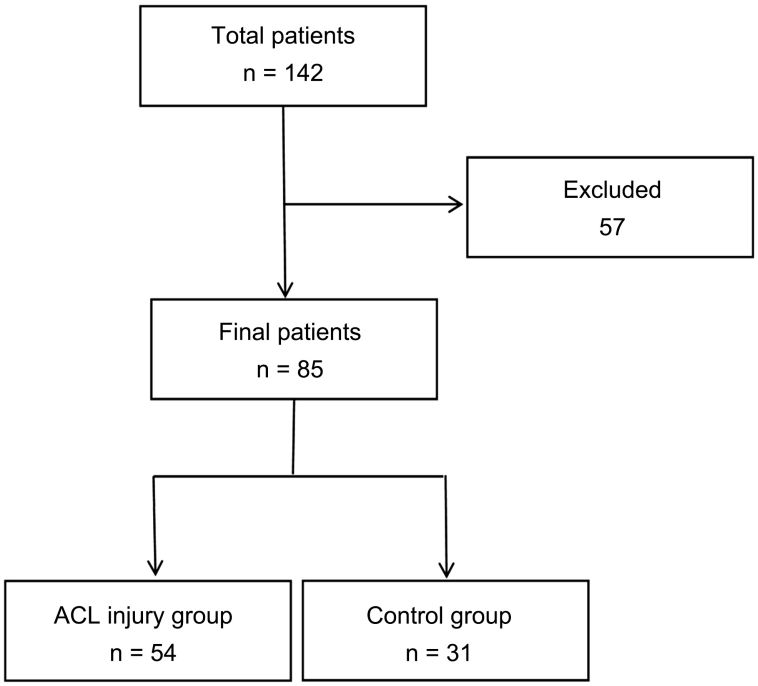


Figure 1. Flow chart showing the inclusion/exclusion of patients.

Table 1 compares both the ACL injured group and the control group against age, gender, the BIA and the BATS results using independent test and chi-square test. Based on Table 1, the age comparison between the ACL injured group and control group shows that the mean age of ACL injured group is 32.7 years (SD = 8.95) and mean age for the control group is 42.5 years (SD = 14.54). This difference in mean age between the 2 group is statistically significant (p-value = 0.004), indicating the individuals with intact ACL are generally older than those who have injured their ACL.

Based on the gender distribution, ACL injured group has 46 males (73%), and 8 females (36%) and the control group has 17 males (27%) and 14 females (64%). The gender distribution difference between these 2 groups is not significant (p-value > 0.05)

As for the Blumensaat Inclination Angle (BIA), the mean BIA for ACL injured group is 36.20˚ (SD = 4.542˚) and the mean BIA for the control group is 37.25˚

(SD = 4.941˚). The difference in BIA between the ACL injured and control group is statistically not significant (p-value = 0.32)

Meanwhile, in the measurement of the angle between Blumeensaat line and Tibial Slope (BATS), it shows the mean Bats measurement is 26.33˚ (SD = 5.78˚) in the ACL injured group and 25.26˚ (SD = 6.047˚) in the ACL intact group. this reading are also not statistically significant (p-value = 0.423).

Table 2 depicts the correlation between Age and BIA/BATS. Spearman correlation between Age and BIA is −0.18 (p-value > 0.05) and the Spearman correlation between Age and BATS is 0.145 (p-value > 0.05). Both correlations are not statistically significant, indicating no strong relationship between age and BIA or BATS.

Table 3 shows gender comparison for BIA and BATS. The mean Blumensaat Inclination angle for males is 36.48˚ (SD = 4.645˚) and for female is 36.85˚ (SD = 4.944˚). The difference in BIA between males and females are not statistically significant (p-value = 0.748). The mean BATS for males and females is 25.84˚ (SD = 5.853˚) and 26.35˚ (SD = 5.953˚) respectively. This too does not show any statistical significance (p-value = 0.731).

Table 1. Comparison of both the ACL injured group and the control group against age, gender, the BIA and the BATS.

	ACL injury (N = 54)	Intact ACL (N = 31)	p-value
Age (mean, sd)	32.7 (8.95)	42.5 (14.54)	[1]0.004
Gender male	46 (73%)	17 (27%)	[2]>0.05
female	8 (36%)	14 (64%)	
BIA (mean, sd)	36.20 (4.542)	37.25 (4.941)	[1]0.320
BATS (mean, sd)	26.33 (5.78)	25.26 (6.047)	[1]0.423

[1]Independent t-test, [2]Chi-square test.

Table 2. Correlation between Age and BIA/BATS.

	BIA	BATS	p-value
Age	−0.18	0.145	[2]>0.05

[2]Spearman correlation test.

Table 3. Gender comparison for BIA and BATS.

	Male (N = 63)	Female (N = 22)	p-value
BIA (mean, sd)	36.48 (4.645)	36.85 (4.944)	[1]0.748
BATS angle (mean, sd)	25.84 (5.853)	26.35 (5.953)	[1]0.731

[1]Independent t-test.

4. Discussion

There are numerous studies done to evaluate the anatomical risk factor for ACL injury. The femoral intercondylar notch evaluation is the most researched anatomical risk factor for ACL injury [6] [9]-[12]. The blumensaat line and the tibial slope are gaining popularity when it comes to consideration of anatomic risk factors for ACL injury [6] [13].

BATS angle was first describe by Alentorn Geli *et al.* in year 2015 [9]. He found out that increase in BATS angle poses a greater risk of ACL injury in patients. In year 2021, Huang *et al.* also demonstrated similar result in his study. He thought that ACL injured knee will be in hyperextension and lead to increase in BATS angle [14]. However, during MR study knee was commonly position in neutral position, hence this does not support his theory.

Our data reveals that there is a statistically significant difference in age between patients with ACL injury group and ACL intact group. The mean value of ACL injured group was 32.7 years which was lower as compared to the non injured group which was 42.5 years. This finding is consistent with the literature suggesting that the younger individuals are more susceptible to ACL injuries [15] [16]. This is probably due to younger individuals are more prone to engage in higher activity level or high-risk sporting activities which in turn increases the risk of ACL injuries. Conversely, the older population with intact ACL may reflect on individuals those are not involved in such activity due to maturity on injury avoidance technique or they lead a more sedentary lifestyle.

Gender distribution between the ACL injured group and ACL intact group does not show any statistical differences in our study. While males constitute a larger portion of the ACL injured group (73%), the intact ACL group has a higher percentage of females (64%). Studies have indicated that although males often have a higher incidence of ACL injury due to more participation to high-risk sports and activities, females are relatively at higher risk of obtaining a similar ACL injury if they participated in the similar activities [17]-[20]. Our study suggests that gender alone is not a decisive factor contributing to the risk of ACL injury. Other factors such as biomechanical effect, hormonal changes and training technique may influence the outcome of ACL as well.

In year 2012, Freddie Fu and Musahl postulated that ACL impingement in femoral notch is major factor for ACL injury [4]. Tomás Fernández-Jaén associated increased BIA as risk factor for ACL injury [5]. Meanwhile, Samora *et al.* and Huang *et al.* found smaller BIA in ACL injured group [7] [14]. Bouras *et al.* were not able to find significant difference in BIA between 2 groups but his study only included female patients [21]. Due to the difference in previous studies, we decided to look into our local population to gain more insight of this theory. The comparison of BIA between the injured ACL and the intact ACL group did not yield a statistically significant difference. The mean BIA in our study showed a slightly lower value (36.20˚) in the ACL injured group compared to the ACL intact group (37.25˚). The Blumensaat line, is the inclination of the

intercondylar roof, has been hypothesized to influence the risk of ACL injury due to the impact on the biomechanics of the knee joint [14]. Mas Matas *et al.* reported that a BIA angle of more than 38.5˚ causes the ACL to be placed more horizontally, hence increase the ACL impingement over the anterior intercondylar notch, eventually leading to ACL injury [22]. However, the lack of significant difference in our study may suggest that BIA alone is not a sufficient predictor for ACL injury. Our study corresponds to study done by Bouras *et al.*, but his study subject are only consists of female patients and found there was no significant difference between the injured and the non injured ACL group [21] as this indicator reveals that they are mixed findings, it is a weak indicator to assess the risk of ACL injury. Moreover, the exact mechanism on how the BIA affects the ACL injury in unknown. So, further biomechanics study is needed to evaluate the relationship of BIA and ACL injury.

Surprisingly, there are discrepancies between the value of BIA measured in different studies. Huang *et al.* and Uozumi *et al.* recorded values closes to ours which was 39.8˚ and 35˚ respectively. Whereas Bouras *et al.* and Fernández-Jaén *et al.* showed 44˚ and 57˚ [8] [14] [21] [23]. There is a huge discrepency between these study that measures about 13˚ but with using the same measurement technique [20]. We can only postulate that our study recorded a lower value as Asian knees are much smaller compared to westerners. However, more studies have to be done to come to a conclusion.

On the other hand, our study did not find any significant difference in BATS angle between the ACL intact group and ACL injured group (p-value = 0.423). The ACL intact group group had a mean BATS angle of 26.33˚ while the injured group had a mean BATS angle of 25.26˚. Previous researches have suggested that a steeper tibial slope may contribute to increase in the risk of ACL injury by affecting the anterior tibial translation and knee joint stability [8] [24]-[26]. Newer studies have divided the tibial slope to lateral tibial slope and medial tibial slope and found the lateral tibial slope shows a significant difference in predicting ACL rupture but not in medial tibial slope [14] [27].

This finding in our study goes on to show that the risk of ACL injury does not only depend on anatomic morphometric, but it arises from multivariant factors.

Furthermore, our study also indicates that variation in age does not significantly impact the BIA or BATS angle within our population. This finding aligns with the concept that anatomical features such as inclination angle and tibial slope are relatively a stable trait and not significantly altered by age [28]. Our results also demonstrated that neither of these angles is influenced by gender [14]

ACL injury does not only confine to non modifiable risk, but it's a multifactorial event which leads to failure of the native ACL. Here it is important to highlight the prevention strategies, implementations of evident-based training programs and knowledge of injury [29] [30]. Regular screening and monitoring along with education would also help athletes in preventing unwanted ACL injury [29].

Limitation in our study begins from the limited sample size to imbalance grouping between the female and the male. There are significantly more males in our sample as they are the predominant group that comes with knee pain that requires MRI. Plus all our subjects that are included are those that underwent MRI of the knee. Other limitation in our study is that we included only 2 parameters to conclude the risk of ACL. We also did not dwell into the details of the tibial slope as been done in some studies that include the medial and lateral tibial slope. All our measurements are done in 2D images and not 3D image and this does not reflect the true anatomy of the individual.

5. Conclusions

In summary, this study only identifies age as a significant factor differentiating induviduals with ACL injury with those with intact ACL, with younger individuals being more prone for ACL injury. Our study did not show BIA and BATS angle as an anatomical risk factor for ACL injuries. Additionally, age and gender did not affect these angles.

These findings highlight the complexity of having ACL injury, suggesting that BIA and BATS alone are not sufficient predictors but it goes beyond that. In the future, this research should explore the multifactorial nature of ACL injury such as biomechanical, genetics and training related factors to develop a more comprehensive approach for injury prevention strategies.

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Ethical Clearance

Ethical clearance from NMRR and MREC. NMRR-21-1650-61038(IIR).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Chambat, P., Guier, C., Sonnery-Cottet, B., Fayard, J. and Thaunat, M. (2013) The Evolution of ACL Reconstruction over the Last Fifty Years. *International Orthopaedics*, **37**, 181-186. https://doi.org/10.1007/s00264-012-1759-3

[2] Pappas, E., Zampeli, F., Xergia, S.A. and Georgoulis, A.D. (2012) Lessons Learned from the Last 20 Years of ACL-Related *in Vivo*-Biomechanics Research of the Knee Joint. *Knee Surgery, Sports Traumatology, Arthroscopy*, **21**, 755-766. https://doi.org/10.1007/s00167-012-1955-0

[3] Dienst, M., Schneider, G., Altmeyer, K., Voelkering, K., Georg, T., Kramann, B., *et al.* (2006) Correlation of Intercondylar Notch Cross Sections to the ACL Size: A High Resolution MR Tomographic *in Vivo* Analysis. *Archives of Orthopaedic and*

Trauma Surgery, **127**, 253-260. https://doi.org/10.1007/s00402-006-0177-7

[4] Fu, F.H. and Musahl, V. (2013) Preface. *Clinics in Sports Medicine*, **32**, 15-16. https://doi.org/10.1016/j.csm.2012.10.001

[5] Fernández-Jaén, T., López-Alcorocho, J.M., Rodriguez-Iñigo, E., Castellán, F., Hernández, J.C. and Guillén-García, P. (2015) The Importance of the Intercondylar Notch in Anterior Cruciate Ligament Tears. *Orthopaedic Journal of Sports Medicine*, **3**. https://doi.org/10.1177/2325967115597882

[6] Iwasaki, K., Inoue, M., Kasahara, Y., Tsukuda, K., Kawahara, H., Yokota, I., *et al.* (2019) Inclination of Blumensaat's Line Influences on the Accuracy of the Quadrant Method in Evaluation for Anterior Cruciate Ligament Reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy*, **28**, 1885-1893. https://doi.org/10.1007/s00167-019-05619-8

[7] Samora, W., Beran, M.C. and Parikh, S.N. (2016) Intercondylar Roof Inclination Angle: Is It a Risk Factor for ACL Tears or Tibial Spine Fractures? *Journal of Pediatric Orthopaedics*, **36**, e71-e74. https://doi.org/10.1097/bpo.0000000000000631

[8] Hashemi, J., Chandrashekar, N., Mansouri, H., Gill, B., Slauterbeck, J.R., Schutt, R.C., *et al.* (2009) Shallow Medial Tibial Plateau and Steep Medial and Lateral Tibial Slopes: New Risk Factors for Anterior Cruciate Ligament Injuries. *The American Journal of Sports Medicine*, **38**, 54-62. https://doi.org/10.1177/0363546509349055

[9] Alentorn-Geli, E., Pelfort, X., Mingo, F., Lizano-Díez, X., Leal-Blanquet, J., Torres-Claramunt, R., *et al.* (2015) An Evaluation of the Association between Radiographic Intercondylar Notch Narrowing and Anterior Cruciate Ligament Injury in Men: The Notch Angle Is a Better Parameter than Notch Width. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, **31**, 2004-2013. https://doi.org/10.1016/j.arthro.2015.04.088

[10] Stein, V., Li, L., Guermazi, A., Zhang, Y., Kent Kwoh, C., Eaton, C.B., *et al.* (2010) The Relation of Femoral Notch Stenosis to ACL Tears in Persons with Knee Osteoarthritis. *Osteoarthritis and Cartilage*, **18**, 192-199. https://doi.org/10.1016/j.joca.2009.09.006

[11] van Eck, C.F., Martins, C.A.Q., Vyas, S.M., Celentano, U., van Dijk, C.N. and Fu, F.H. (2010) Femoral Intercondylar Notch Shape and Dimensions in ACL-Injured Patients. *Knee Surgery, Sports Traumatology, Arthroscopy*, **18**, 1257-1262. https://doi.org/10.1007/s00167-010-1135-z

[12] Al-Saeed, O., Brown, M., Athyal, R. and Sheikh, M. (2012) Association of Femoral Intercondylar Notch Morphology, Width Index and the Risk of Anterior Cruciate Ligament Injury. *Knee Surgery, Sports Traumatology, Arthroscopy*, **21**, 678-682. https://doi.org/10.1007/s00167-012-2038-y

[13] Dejour, H. and Bonnin, M. (1994) Tibial Translation after Anterior Cruciate Ligament Rupture. Two Radiological Tests Compared. *The Journal of Bone and Joint Surgery. British Volume*, **76**, 745-749. https://doi.org/10.1302/0301-620x.76b5.8083263

[14] Huang, M., Li, Y., Guo, N., Liao, C. and Yu, B. (2019) Relationship between Intercondylar Notch Angle and Anterior Cruciate Ligament Injury: A Magnetic Resonance Imaging Analysis. *Journal of International Medical Research*, **47**, 1602-1609. https://doi.org/10.1177/0300060518824447

[15] Griffin, L.Y., Agel, J., Albohm, M.J., Arendt, E.A., Dick, R.W., Garrett, W.E., *et al.* (2000) Noncontact Anterior Cruciate Ligament Injuries: Risk Factors and Prevention Strategies. *Journal of the American Academy of Orthopaedic Surgeons*, **8**, 141-150. https://doi.org/10.5435/00124635-200005000-00001

[16] Hewett, T. and Myer, G. (2010) Reducing Knee and Anterior Cruciate Ligament Injuries among Female Athletes—A Systematic Review of Neuromuscular Training Interventions. *The Journal of Knee Surgery*, **18**, 82-88. https://doi.org/10.1055/s-0030-1248163

[17] Jin, X., Wu, X., Xu, W., She, C., Li, L. and Mao, Y. (2024) Gender Differences in the Impact of Anatomical Factors on Non-Contact Anterior Cruciate Ligament Injuries: A Magnetic Resonance Study. *BMC Musculoskeletal Disorders*, **25**, Article No. 264. https://doi.org/10.1186/s12891-024-07390-5

[18] Parsons, J.L., Coen, S.E. and Bekker, S. (2021) Anterior Cruciate Ligament Injury: Towards a Gendered Environmental Approach. *British Journal of Sports Medicine*, **55**, 984-990. https://doi.org/10.1136/bjsports-2020-103173

[19] Devana, S.K., Solorzano, C., Nwachukwu, B. and Jones, K.J. (2021) Disparities in ACL Reconstruction: The Influence of Gender and Race on Incidence, Treatment, and Outcomes. *Current Reviews in Musculoskeletal Medicine*, **15**, 1-9. https://doi.org/10.1007/s12178-021-09736-1

[20] Mountcastle, S.B., Posner, M., Kragh, J.F. and Taylor, D.C. (2007) Gender Differences in Anterior Cruciate Ligament Injury Vary with Activity: Epidemiology of Anterior Cruciate Ligament Injuries in a Young, Athletic Population. *The American Journal of Sports Medicine*, **35**, 1635-1642. https://doi.org/10.1177/0363546507302917

[21] Bouras, T., Fennema, P., Burke, S. and Bosman, H. (2017) Stenotic Intercondylar Notch Type Is Correlated with Anterior Cruciate Ligament Injury in Female Patients Using Magnetic Resonance Imaging. *Knee Surgery, Sports Traumatology, Arthroscopy*, **26**, 1252-1257. https://doi.org/10.1007/s00167-017-4625-4

[22] Mas Matas, B., Barberà, I.C., Marsico, S., Claramunt, A.A., Torres-Claramunt, R. and Solano López, A. (2021) Importance of Posterior Tibial Slope, Medial Tibial Plateau Slope and Lateral Tibial Plateau Slope in Anterior Cruciate Ligament Injury. *Open Journal of Orthopedics*, **11**, 233-248. https://doi.org/10.4236/ojo.2021.119022

[23] Uozumi, Y., Nagamune, K., Nakano, N., Nagai, K., Nishizawa, Y., Hoshino, Y., *et al.* (2014) An Automated Determination of Blumensaat Line Using Fuzzy System Based on Physician Experience from Femur CT Image. 2014 *IEEE International Conference on Fuzzy Systems* (*FUZZ-IEEE*), Beijing, 6-11 July 2014, 1831-1836. https://doi.org/10.1109/fuzz-ieee.2014.6891742

[24] Yue, D.B., Wang, B.L., Wang, W.G., Guo, W.S. and Zhang, Q.D. (2013) Effects of Posterior Tibial Slope on Non-Contact Anterior Cruciate Ligament Rupture and Stability of Anterior Cruciate Ligament Rupture Knee. *Chinese Medical Journal*, **93**, 1309-1312.

[25] Shen, L., Jin, Z., Dong, Q. and Li, L. (2018) Anatomical Risk Factors of Anterior Cruciate Ligament Injury. *Chinese Medical Journal*, **131**, 2960-2967. https://doi.org/10.4103/0366-6999.247207

[26] Bernhardson, A.S., Aman, Z.S., Dornan, G.J., Kemler, B.R., Storaci, H.W., Brady, A.W., *et al.* (2019) Tibial Slope and Its Effect on Force in Anterior Cruciate Ligament Grafts: Anterior Cruciate Ligament Force Increases Linearly as Posterior Tibial Slope Increases. *The American Journal of Sports Medicine*, **47**, 296-302. https://doi.org/10.1177/0363546518820302

[27] Dean, R.S., DePhillipo, N.N. and LaPrade, R.F. (2022) Posterior Tibial Slope in Patients with Torn ACL Reconstruction Grafts Compared with Primary Tear or Native ACL: A Systematic Review and Meta-Analysis. *Orthopaedic Journal of Sports Medicine*, **10**. https://doi.org/10.1177/23259671221079380

[28] Goldblatt, J.P. and Richmond, J.C. (2003) Anatomy and Biomechanics of the Knee. *Operative Techniques in Sports Medicine*, **11**, 172-186. https://doi.org/10.1053/otsm.2003.35911

[29] Bradsell, H. and Frank, R.M. (2022) Anterior Cruciate Ligament Injury Prevention. *Annals of Joint*, **7**, 1-1. https://doi.org/10.21037/aoj-2020-01

[30] Garvey, K.D., Lowenstein, N.A. and Matzkin, E.G. (2022) Anterior Cruciate Ligament Injury Prevention. In: Frank, R.M., Ed., *The Female Athlete*, Elsevier, 49-63. https://doi.org/10.1016/b978-0-323-75985-4.00005-2