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INTERCONDYLAR NOTCH MORPHOLOGY IN REGARD TO ANTERIOR CRUCIATE LIGAMENT INJURIES

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Abstract
Non-contact ACL injuries are more common in female, than in male athletes. One of the possible risk factors discussed were morphologic variations in intercondylar notch height and width. The supposed pathomechanism of injury was related to a narrower and higher built intercondylar notch in female in regard to male athletes. We measured 2 intercondylar notch morphometric parameters and their indices of 100 dry human femora as to estimate the values and differences of intercondylar notch morphology in men and women. We determined that there is a difference between linear morphometric parameters of the intercondylar notch between male and female samples. The mean for both samples, regarding ICW, was 18.71±3.82 mm with the maximum value being 32 mm and minimum 10 mm. For male ICW values the mean was 19.32±4.25 mm with the maximum value being 32 mm and minimum 10 mm. Female ICW value mean was 18,04±3.40 mm with the maximum value being 25 mm and minimum value being 10 mm. The ICH value mean in both genders was 28,00±4.48 mm with the maximum value of 40 mm and minimum 15 mm. The male ICH values mean was 29.05±5.58 mm with maximum value being 40 mm and minimum 15 mm. Female ICH values mean was 26. 85±4.12 mm with the maximum value of 35 mm and minimum value 16 mm. No gender difference was found between intercondylar notch geometrical indices and as such the intercondylar notch geometrical indices cannot be used to explain the more often occurence of non- contact injuries in female athletes.

Key words: **Orthopaedics, Anthropometric, Non-contact injuries, Sports traumatology, Knee**

Introduction

Anterior cruciate ligament (ACL) injuries are one of the most common injuries in sports traumatology. Anterior Cruciate ligaments play a restricting role in both physiological axis of movement in the knee and their injuries are the main reason the third pathological axis is described (Kapandji, 1972). Injuries regarding ACL have been categorized as contact and non-contact with the former being more common (Alentrorn-Geli et al., 2009; Murray, 2013). Non-contact injuries are associated with a number of risk factors including developmental and hormonal (gender, family history, injury history, joint laxity, neuromuscular shant, preovulatory hormonal status), neuromuscular (relative muscular strength, hip abduction strength, trunk proprioception), anatomical (Q-angle, Intercondylar Notch Size, ACL Size, Genu Recurvatum, BMI), biomechanical (knee abduction, lateral body movement, anterior translation, external rotation) (Alentrorn-Geli et al., 2009). One of the possible anatomical risk factors is the Intercondylar notch size. The status of Intercondylar Notch size as a risk factor is uncertain seeing that some authors confirm it as legitimate risk factors and others deny its value in prognosing and preventing ACL injuries. It has been postulated that smaller intercondylar notch sizes result smaller ACL which have less tensile strength and are susceptible to non- contact injury. Other than that it is possible that a narrow intercondylar notch results in anterior or posterior impigiment of the ACL during rotational movement and results in ACL rupture (Martin et al., 1962; Norwood and Cross, 1977). Which is understandable since biomechanically, ACL injuries occur either during hyperextension or external rotation (Kapandji, 1972). During external rotation the ACL becomes taut and is susceptible to injuries while in contact with the medial condyle. The Posterior Cruciate ligament (PCL) is tensed and results in movement of the medial meniscus anteriorly. The relationship of the cruciate ligaments in the sagittal plane is described as that they are more crossed but lose contact resulting in opening of the joint space and lack of rotational constraint by the cruciate ligaments. The rotational constraint in external rotation is regulated by the collateral ligaments because of the fiber orientation. In recent studies it has been confirmed by methods of clinical, cadavers, in vitro and video analysis studies that the most non- contact ACL injuries occur during change of direction while deccelareting, landing an extended or near extended knee or pivoting on a leg with a planted foot. Other biomechanical factors are valgus and varus forces, hyperflexion and anterior translational forces (Alentrorn-Geli et al., 2009). Multiple factors explain why caution is advised when examining risk factors for ACL injuries seeing that isolated conclussions might be questionable. The aim of the study was to determine the values of forementioned morphometric parameters of the intercondylar notch and their correlation with each other. We sought to determine whether there are gender differences between those parameters and to provide a review of literature regarding the relevance of those differences in non-contact ACL injuries.

Methods and materials

We examined 100 adult dry human femora, 52 of which were male and 48 female. The femora were taken from the Department of Anatomy, Medical School, University of Sarajevo. Femora with visible pathological alterations were excluded from the study. Two morphological parameters were measured, in accordance to Martin et al. (1962), using sliding calipers, the measurements were recorded in milimeters. The morphological parameters were Intercondylar notch width (ICW) and Intercondylar notch height (ICH), in addition to the two parameters we calculated their relevant indices, Notch Width index (NWI) and Notch Shape index (NSI). Notch Width Index was defined as the ratio of ICW and Epicondylar Breadth Width (EBW). Notch Shape Index was defined as the ratio of ICW and ICH. The recorded measures were then sorted by gender and statistical measures were applied. We determined descriptive statistical measures, correlation methods and ascertained the differnce between male and female femora using paired t- tests using the IBM SPSS programme. We have taken values of p as $0.01< p < 0.5$ as significant, $0.001< p < 0.01$ as very significant, values $p< 0.001$ were taken as very highly significant. Values $0.5< p$ were taken as unsignificant.

Results

Intercondylar notch width values for both genders were as follows (Table 1). The mean was 18.71±3.82 mm with the maximum value being 32 mm and minimum 10 mm with the correlation coefficient being 0.006 which shows that ICW and EBW correlate poorly (Table 2) and cannot as such be deduced from one another. For male ICW values (Table 3) the mean was 19.32±4.25 mm with the maximum value being 32 mm and minimum 10 mm. The correlation factor between male ICW and EBW values was -0.266 hence the negative correlation between male ICW and EBW values (Table 4). Female ICW value mean (Table 5) was 18.04±3.40 mm with the maximum value being 25 mm and minimum value being 10 mm. The correlation coefficient between female ICW and EBW values was -0.422 confirming that female ICW and EBW correlate negatively (Table 6). The difference between male and female ICW value was significant ($p<0.05$) but with a noticeable overlap of values (10-35 mm for male and 10-25 mm for female femora). The Intercondylar notch height value mean in both genders was 28000±4.48 mm with the maximum value of 40 mm and minimum 15 mm (Table 1). Correlation coefficient between ICH and EBW for both genders was 0.087 resulting in a positive but poor correlation (Table 2). The male ICH values mean was 29.05±5.58 mm with maximum value being 40 mm and minimum 15 mm (Table 3). Male ICH and EBW values correlate negatively with the correlation coeficient of -0.23 (Table 4). Female ICH values mean was 26.85±4.12 mm with the maximum value of 35 mm and minimum value 16 mm (Table 5). Female ICH and EBW correlate negatively with the correlation coefficient of -0.144 (Table 6). The difference between male and female ICH values was significant ($p< 0.05$) and with a major overlap (male values 15- 40 mm, female values 16-35 mm). We calculated the NWI and NSI for both genders and subsequently for male and female femora. Notch Width Index mean for both genders was 0.24±0.05 with the maximum value 0.40 and minimum 0.11 (Table 1). For male femora the NWI mean was 0.23±0.05 with maximum value 0.40 and minimum 0.11 (Table 3). The NWI mean for female femora was 0.25±0.05 with the maximum value 0.38 and minimum 0.13 (Table 5). The difference between male and female NWI indices was was unsignificant ($p\geq0.05$). Notch Surface Index mean was 0.68±0.19 with the maximum value of 1.66 and minimum 0.40 (Table 1). For male femora the NSI mean was 0.67±0.19, maximum 1.67 and minimum 0.43 (Table 3). For female femora the NSI mean was 0.69±0.19, maximum 1,25 and minimum 0.40 (Table 5). The difference between male and female femora was unsignificant ($p\geq0.05$).

Table 1 Descriptive statistics for parameters values in both genders

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
ICW	100	0	100	10.00	32.00	18.71	3.82
ICH	100	0	100	15.00	40.00	28.00	4.48
EBW	100	0	100	62.00	92.00	77.77	6.46
NWI	100	0	100	0.11	0.40	0.24	0.05
NSI	100	0	100	0.40	1.66	0.68	0.19

Table 2 Correlation matrix for parameters in both genders

Variables	ICW	ICH	EBW	NWI	NSI
ICW	**1**	**0.29**	-0.26	**0.98**	**0.64**
ICH	**0.29**	**1**	-0.23	**0.32**	**-0.48**
EBW	-0.26	-0.23	**1**	**-0.44**	-0.04
NWI	**0.98**	**0.32**	**-0.44**	**1**	**0.60**
NSI	**0.64**	**-0.48**	-0.04	**0.60**	**1**

Table 3 Descriptive statistics in male samples

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
ICW	49	0	49	10.00	25.00	18.10	3.39
ICH	49	0	49	16.00	35.00	26.95	4.14
EBW	49	0	49	62.00	82.00	72.67	4.17
NWI	49	0	49	0.13	0.38	0.25	0.05
NSI	49	0	49	0.40	1.25	0.69	0.19

Table 4 Correlation matrix in male samples

Variables	ICW	ICH	EBW	NWI	NSI
ICW	**1**	0.16	0.00	**0.92**	**0.67**
ICH	0.16	**1**	0.08	0.10	**-0.57**
EBW	0.00	0.08	**1**	**-0.37**	-0.05
NWI	**0.92**	0.10	**-0.37**	**1**	**0.64**
NSI	**0.67**	**-0.57**	-0.05	**0.64**	**1**

Table 5 Descriptive statistics in female samples

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
ICW	52	0	52	10.00	32.00	19.32	4.10
ICH	52	0	52	15.00	40.00	29.05	4.57
EBW	52	0	52	76.00	92.00	82.65	3.96
NWI	52	0	52	0.11	0.40	0.23	0.05
NSI	52	0	52	0.43	1.66	0.67	0.19

Table 6 Correlation matrix in female samples

Variables	ICW	ICH	EBW	NWI	NSI
ICW	**1**	-0.09	-0.09	**0.95**	**0.75**
ICH	-0.09	**1**	-0.04	-0.07	**-0.69**
EBW	-0.09	-0.04	**1**	**-0.38**	-0.03
NWI	**0.95**	-0.07	**-0.38**	**1**	**0.70**
NSI	**0.75**	**-0.69**	-0.03	**0.70**	**1**

Discussion

The results we obtained correlate will with similiar studies about morphometric parameters of the intercondylar notch and their indices. Anthropologic differences in male and female distal femoral morphology has been established in many studies, although scarcse in the domain of the intercondylar notch (Tilman et al., 2002). The ever growing participation of females in sports resulted in the need to identify the reason that non-contact injuries are more common in female than in male athletes. Some authors (Souryal and Freeman,1993; LaPrade et al., 1994; Shelbourne et al., 1997; Anderson et al, 2001; Stiljak et al., 2014) have confirmed and other denied the difference in intercondylar notch morphology (Schickendantz and Weiker, 1993; Teitz, et al., 1997). This study confirms the difference in linear morphometric parameters between genders but denies the difference in regard to intercondylar notch indices. This is confirmed by LaPrade et al. (1994) who confirmed that intercondylar notch stenosis can be a risk factor in ACL ruptures, they confirm that there is no difference in geometrical notch indices between genders. Stiljak et al. (2014) conducted a smiliar study using imaging methods where they compared normal knee with ones that suffered ACL ruptures andmeasured their intercondylar notch indices. They found that the NWI and NSI values were larger in control groups than in the group with ACL rupture with the mean for NWI being 0.28 in control groups and 0.30 in the studied sample and for NSI 0.67 and 0.73. Other than that they reported that the difference between male NWI and NSI in control and studied groups were significant while that was not the case in female samples. Similiar results were obtained by Anderson et al. (2001). Teitz et al. (1997) confirmed that there is no difference between genders regarding the geometrical indices and disagree that there is a difference in geometrical indices between control groups and studied groups. Shelbourne et al. (1997) concluded that the narrow notch of female athletes could result in more common non-contact ACL injuries. Muneta et al (1997) confirm the fact that NWI cannot explain the difference between injury rates in male and female athletes due the lack of significant differences in their values. Other approaches have been taken in determining the intercondylar notch morphology as a risk factor for ACL injuries. Houseworth et al. (1987) used radiographs to determine the area of the intercondylar notch rather than just the linear morphometric parameters in the previous studies. They determined that a lower posterior arch of the intercondylar notch might pose a risk for ACL injuries. A similiar approach was taken by Tillman et al. (2002) who used another index, the Notch Area Index (NAI) to quantify the area of the intercondylar notch and to determine the difference between race and gender. They concluded that there are is no difference in NAI between race and gender. Tillman et al. measured the NSI to quantify the variate shapes of the intercondylar notch. The shape of the notch varies from A to U shape and in some studies an Ω shape intercondylar notch dependent on age of the subjects knee (Hirtler et al., 2016). They determined that there is no difference in NSI between male and female samples although after standardization for height, the male intercondylar notches tended to be more round than the female ones. A low NSI results in possible impigiment of the cruciate ligaments in the anterior portion of the intercondylar notch which is in this case narrower. Norwood and Cross (1977) confirmed the fact that the cruciate ligaments contact with the intercondylar roof when in full extension. Such a mechanism could explain the more common injuries in people of European in contrast to African descent (Tilman et al., 2002). Other possible mechanisms include the fact that notch width does not correlate with the size of the ACL, as previously thought (Muneta et al., 1997). The smaller the notch, the narrower the space for the ACL and as such a larger risk for cruciate ligament injuries.

Conclusion

We concluded that a difference in linear morphometric parameters of the intercondylar notch exists with female intercondylar notches being narrower and more superficial than their male counterparts. No correlation with mediolateral parameters was found. Intercondylar notch geometric indices (NWI, NSI) have shown no difference between genders and as such cannot be used to ascertain the reason for more often non- contact injuries in female athletes, although some theories provide a plausible reason that regards shape and size of the intercondylar notch.

References

Alentrorn-Geli, E., Myer, G.D., Silvers, H.J., Samitier, G., Romero, D., & Cugat, R. (2009). Prevention on non-contact anterior cruciate ligament injuries in soccer players. Part 1: Mechanicsms of injury and underlying risk factors. *Knee Surg Sports Traumatol*, 17:705- 729.

Anderson, A.F., Dome, D.C., Gautam, S., Awh, M.H., & Rennirt, G.W. (2001). Correlation of Anthropometric Measurement, Strength, Anterior Cruciate Ligament Size, and Intercondylar Notch Characteristics to Sex Differences in Anterior Cruciate Ligament Tear Rates. *The American Journal of Sports Medicine*, 29, 1.

Hirtler, L., Rorich, S., & Kainberger, F. (2016). The Femoral Intercondylar Notch During Life: An Anatomic Redefinition With Patterns Predisposing to Anterior Cruciate Impigiment. *American Journal of Roentgenology*, 207.

Houseworth, S.W., Mauro, V.J., Mellon, B.A., & Kieffer, D.A. (1987). The intercondylar notch in acute tears of the anterior cruciate ligament: a computer graphic study. *The American Journal of Sports Medicine*, 15, 3.

Kapandji, I.A. (1972). The Physiology of the Joints. Vol. 2, New York, NY: Churchill Livingston

LaPrade, R.F., & Burnett Q.A. (1994). Femoral Intercondylar Notch Stenosis and Correlation to Anterior Cruciate

Ligament Injuries. *The American Journal of Sports Medicine*, 22, 2.

Martin, R. (1962). Lehrbuch der Anthropologie, in systematicher darstellung der anthropologischen Methoden. Stuttgart.

Muneta, T., Kakuda, T., & Yamamoto, H. (1997). Intercondylar Notch Width and its Relation to the Configuration and Cross- Sectional Area of the Anterior Cruciate Ligament. *The American Journal of Sports Medicine*. 21, 1.

Murray,M. (2013) The ACL Handbook, New York, NY: Springer.

Norwood, L.A., & Cross, M.J. (1977). The intercondylar shelf and the anterior cruciate ligament. *The American Journal of Sports Medicine*, 5, 4.

Schickendantz, M.S., & Weiker, G.G. (1993). The predictive value of radiography in the evaluation of unilateral and bilateral anterior cruciate ligament injuries. *Am J Sports Med*, 21:110–113.

Shelbourne K.D., Acibene, W.A., & Hunt, J.J. (1997). Radiographic and intraoperative intercondylar notch width measurements in men and women with unilateral and bilateral anterior curicate ligrament tears. *Knee Surgery, Sports Traumatology, Arthroscopy,* 5:229- 233.

Souryal, T.O., & Freeman, T.R. (1993). Intercondylar notch size and anterior cruciate ligament injuries in athletes. *American Journal of Sports Medicine*, 21, 4.

Stiljak, L., Nikolic, V., Blagojevic, Z., Radonjic, V., Stankovic, G., & Popovic, N. (2014). Morfometrijski parametri interkondilarne jame i njihova veza sa povređivanjem prednje ukštene veze. *Acta Chirurgica Iugoslavica*, 71:271- 276.

Teitz, C.C., Lind, B.K., & Sacks, B.M. (1997). Symetry of the Femoral Notch Width Index. *The American Journal of Sports Medicine*, 25, 5.

Tilman, M.D., Smith, K.R., Bauer, J.A., Cauraugh, J.A., Falsetti, A.B., & Patisshall, J.B. (2002) Differences in three intercondylar notch indices between males and females: a cadaver study. *The Knee*, 9:41- 46.

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