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Research Article

Hamstrings Tendons Thickness in ACL Reconstruction: Is it Possible to Predict it By Isometric Torque in Soccer Athletes?

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Abstract

Objective: To acess the relationship between knee flexor and extensor torques and the thickness of the quadruple hamstrings tendons, extracted during anterior cruciate ligament (ACL) reconstruction surgery, in amateur soccer athletes.

Materials and Methods: This is a cross-sectional study in which 38 amateur soccer athletes of both genders, diagnosed with recent and isolated ACL ligament injury, participated. Epidemiological (gender, age, and dominant limb), anthropometric (height, weight, and BMI), and biomechanical data of the injured lower limb (isometric extensor and flexor torques of the ipsilateral knee) were evaluated. Pearson's correlation test was used to analyze the correlation of torques with the quantitative variables of the study, and the multivariate analysis was performed using the linear regression test with one-way ANOVA and the calculation of R2. The level of statistical significance was set at 5% ($p < 0.05$).

Results: The final study sample (33 participants) had a mean age of 30 years, with 81.8% males. Significant correlations were observed between knee flexor torque and height ($p=0.002$), weight ($p=0.01$) and graft diameter ($p<0.001$). In multivariate analysis a statistically significant result was observed for flexor torque ($p=0.007$).

Conclusion: Knee flexor torque can be tool for preoperative analysis of flexor tendon thickness during surgical programming of knee ligament reconstructions

Keywords: Knee Joint; Anterior Cruciate Ligament Injuries; Soccer; Isometric Contractions

Introduction

The anterior cruciate ligament (ACL) lesion has a high incidence in orthopedic practice [1], especially in young and physically active population [2,3], with an incidence of approximately 85 per 100,000 people aged 16 to 39 years [4,5]. In soccer these injuries are common [5] and occur mainly due to the rotational movements characteristic of the dynamics of the sport, which has also motivated the emergence and use of injury prevention protocols [6]. The treatment of ACL injuries takes into account mainly the current and future functional demands of the patient. However, in most cases, the recommended treatment is surgical [7]. Among the graft options for ACL reconstruction there are allografts and autografts. Allografts are used basically in cases of multiligamentous injuries and successive ACL reconstruction revisions, because it is known to be associated with a higher rate of graft rupture [8]. Among the autografts, the options are the patellar, quadriceps, and hamstrings tendons (gracilis and semitendinosus). Currently, surgeons prefer the hamstrings tendons, which are used in approximately 50% of cases, followed by the patellar and quadriceps tendons [9], the latter with a recent increase in popularity. The total thickness of a graft depends basically on anatomic and biomechanic factors [10,11] and needs a minimum measurement that provides joint stability and survival. In relation to the patellar and quadriceps tendons, the graft corresponds to a fraction of the tendon, which guarantees, therefore, a satisfactory final thickness. However, regard to the hamstring's tendons, the graft is equivalent to the total volume of the gracilis and semitendinosus tendons, usually in quadruple final shape. This causes, during surgical programming, a greater dependence on knowing this measure more precisely, because it is known that grafts smaller than 08 mm evolve with higher rates of rupture [12]. The evaluation of objective anthropometric and/or biomechanical parameters with good clinical accuracy in the preoperative period would be fundamental to help the surgeon to decide the type of graft to be used. Some works have tried to make this association [13-16], but we still observed low clinical employability. The direct measurement of the biomechanical function of the tendon, through the evaluation of strength using validated instruments, such as the portable isometric dynamometer [17,18], can be an additional tool for this purpose.

The general objective of this study was to evaluate the relationship between torque (using a hand-held isometric dynamometer) of the thigh muscles (flexors and extensors of the knee) and the thickness of the hamstring's tendons in quadruple format, used as graft in ACL reconstruction surgery, in amateur soccer athletes. The hypothesis was that higher flexor and extensor torques of the knee are associated with greater thickness of the flexor tendons.

Materials and Methods

This is an observational, cross-sectional study, in which amateur soccer athletes (minimum practice of three times/week) from a city in the interior of the State of Minas Gerais (Brazil), of both genders, with diagnosis of recent ACL injury participated. The study was approved by the Research Ethics Committee of the University of Uberaba (CAAE n°. 97858718.6.0000.5145). All participants signed the Informed Consent Form.

Inclusion criteria were amateur soccer athletes of both genders, aged between 18 and 50 years, with primary and isolated ACL ligament injury (based on clinical history, physical examination and confirmed by magnetic resonance imaging and/or arthroscopy procedure) with indication for surgical treatment. The exclusion criteria were for those with posterior thigh muscle injury, ACL rupture more than 6 months after surgery, ACL injury that occurred outside the sports environment, previous intrinsic knee injury (ligament, meniscal or chondral), chronic and limiting knee pain without confirmed diagnosis, current injury of another knee ligament complex besides the ACL and histories of fracture and surgery that occurred previously, all these criteria related to the lower limb and/or knee ipsilateral to the ACL injury. The sample was selected by convenience, as it was a limited public, with strict inclusion and exclusion criteria used to reduce information bias during biomechanical assessment of the injured limb. This selection occurred during 14 months after the study was accepted by the Research Ethics Committee of the University of Uberaba.

Procedure

In the preoperative period, epidemiological (gender, age, and dominant limb), anthropometric (height, weight, and BMI) data were evaluated using an electronic scale (Welmy, W200A), and biomechanical data of the injured lower limb (isometric extensor and flexor torques of the ipsilateral knee). The knee torques were performed with a portable dynamometer (Lafayette Instrument, Model 01165, USA), positioned perpendicular to the body surface and through which the peak force was evaluated. The dynamometer support point was standardized, and the lever arm was calculated by the distance, in meters, between this point and the center of the knee joint, using a flexible anthropometric tape measure (Sanny®). A specific angulation of the knee was defined to perform the tests, optimized according to the length x tension curve of the muscle group evaluated [19,20], with confirmation using a goniometer (Sanny®).

The test to evaluate the isometric strength of the flexors was performed with the knee in 60º position and the dynamometer positioned posteriorly in the calcaneal region, five centimeters from the medial malleolus [21,22] (Figure 1). For extensor assessment, the dynamometer was positioned in the anterior region of the distal third of the tibia, also five centimeters proximal to the medial malleolus, with the knee flexed at 60º [21,22] (Figure 1). The device was stabilized by the examiner's hand and fixed with the help of a rigid belt, which eliminated measurement bias due to the force exerted by the examiner.

As a warm-up before the tests, we initially requested a submaximal isometric contraction for each muscle group to familiarize them with the procedure and the equipment. After this process, three maximum isometric contractions were requested, with continuous verbal stimulation from the examiner, and the average strength between the three measurements was considered for analysis. The duration of each contraction was standardized in five seconds, followed by 30 seconds' rest. The data were recorded in Newtons (N). The tests were performed by the same examiner.

The torque, which is the biomechanical variable of choice for the study of joint forces, was calculated by the product between the average of the three maximum forces (both knee extension and flexion) and the lever arm of the knee, with the result established in N/m.

The surgical technique was performed in a standardized way by the same surgeon, who is a specialist in Knee Surgery and a full member of the Brazilian Knee Surgery Society. The first stage of the ACL reconstruction surgery is based on the removal of the tendon graft, which in this study were the gracilis and semitendinosus tendons. This procedure was performed through a vertical incision of approximately 2 cm on the anteromedial side of the proximal tibia (Figure 2).

The tendons were prepared on a surgical table (Figure 3), with removal of the muscle remnants, and then the thickness of their quadruple shape was measured through a standardized guide (Figure 4), whose holes have graduations every 05 mm. The thickness was defined as the value following the measure in which the quadruple graft was not able to cross longitudinally the hole of the guide.

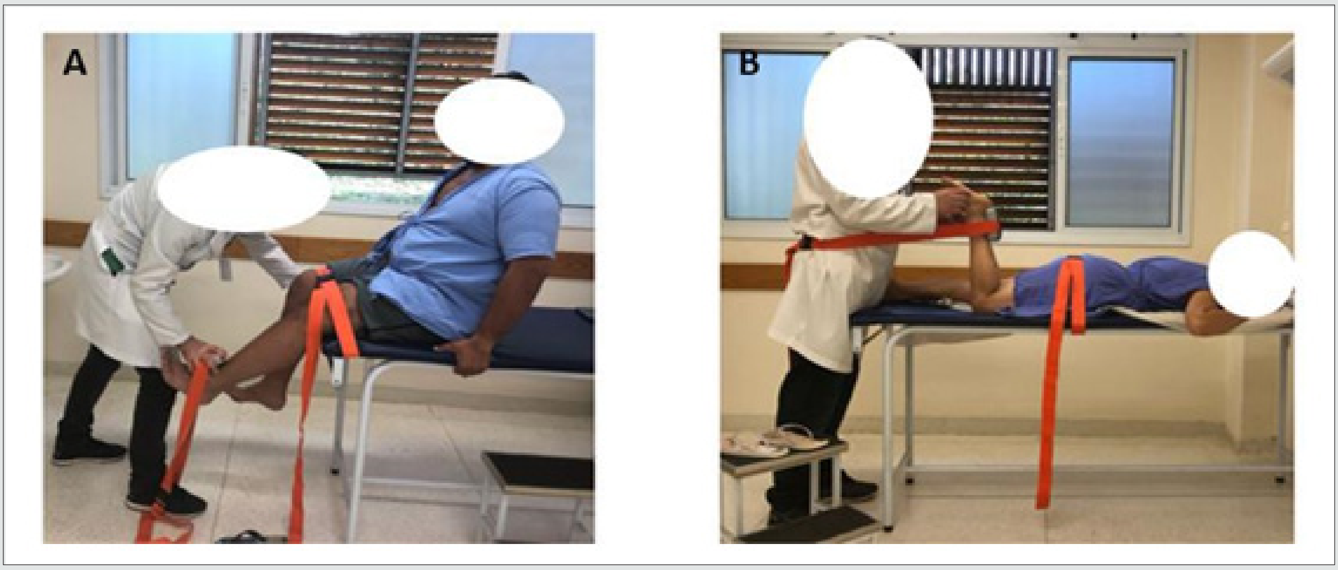

Figure 1: Steps for evaluating the maximum isometric extension (A) and knee flexion (B) forces, with the appropriate positioning of the dynamometer, rigid straps and examiner. The figures do not represent the angulation of the knee for performing the tests.

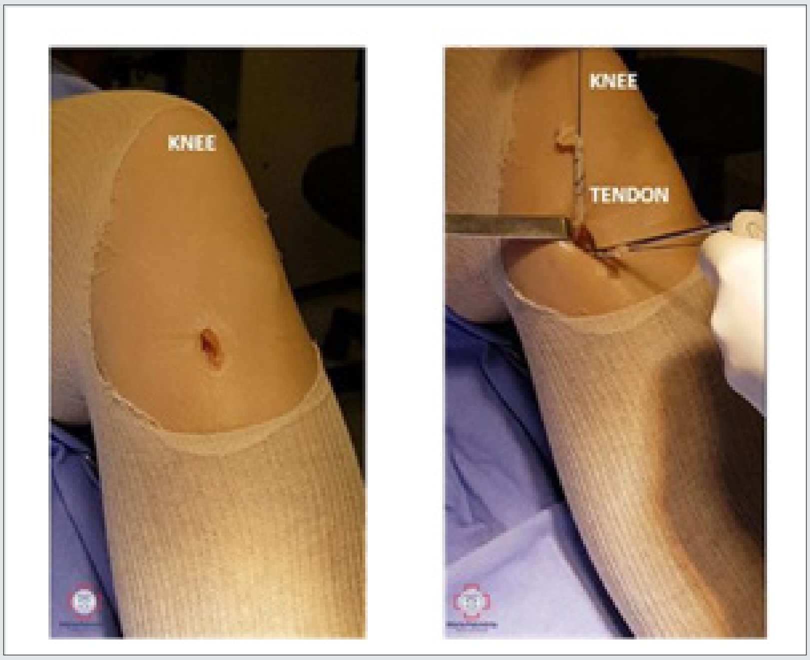

Figure 2: Intraoperative image during the removal of the knee flexor tendons, in the first stage of the anterior cruciate ligament reconstruction surgery.

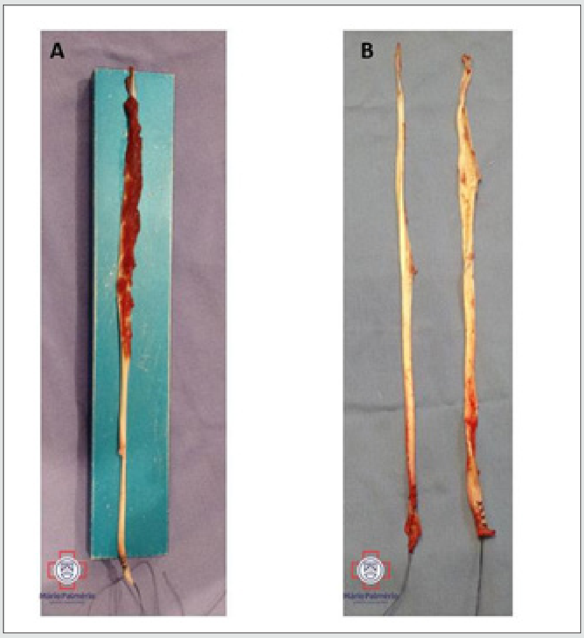

Figure 3: Intraoperative aspect of flexor tendons before (A) and after (B) removal of muscle remnants.

Figure 4: Guide used to check flexor tendon thickness.

Statistical analysis

Data were processed in Excel® and SigmaStat®2.0 software (GraphPad Software Jandel, SPSS, Chicago, IL, USA). The Kolmogorov-Smirnov test was used to verify the normality of the data distribution. Continuous variables with normal distribution were presented as mean and standard deviation. The results were organized in tables.

Student's t-test was used to compare quantitative variables regarding flexor and extensor torques according to gender. Pearson's correlation test was used to analyze the correlation of the torques with the quantitative variables of the study, and the multivariate analysis was performed using the linear regression test with the ANOVA one-way test and the calculation of R2. The linear regression test was also used for the prediction of a formula for preoperative estimation of the diameter of flexor tendon grafts. The level of statistical significance was set at 5% ($p < 0.05$).

Results

The study was attended by 38 amateur field soccer athletes. The exclusion rate was 13% (Figure 5).

The study variables showed low variability coefficient, therefore classified as homogeneous data. In the flexor torque analysis, the male athletes presented means with statistically significant values in relation to the female athletes (Table 2). Significant correlations were observed between knee flexor torque and the height ($p=0.002$) and weight ($p=0.011$) of the participants and also with the graft diameter ($p<0.001$) (Table 3 and Figure 6).

Table 1: Characterization of the study sample, according to gender (M = male, F = female), age (years), dominant limb (D = right and E = left), height (m = meters), weight (Kg = kilograms), BMI (Body Mass Idex) and diameter of the graft (mm = millimeters).

Gender	Age (Years)	Dominant limb	Height (m)	Weight (Kg)	BMI (Kg/ m^2)	Diameter of the graft (mm)
M	28	D	1,64	77	28,63	8,0
M	19	D	1,73	71	23,72	8,5
M	44	D	1,80	84	25,93	9,0
M	22	D	1,77	97	30,96	8,5
M	23	D	1,73	63	21,05	8,0
F	30	D	1,63	61	22,96	7,0
F	21	D	1,76	55	17,76	7,0
M	28	D	1,69	94	32,91	8,0
F	24	D	1,64	66	24,54	6,0
M	21	D	1,79	73	22,78	8,0
M	22	D	1,90	77	21,33	10,0
M	21	D	1,81	74	22,59	8,5
M	37	D	1,70	98	33,91	8,0
F	25	D	1,70	60	20,76	8,0
M	36	D	1,65	71	26,08	8,0
M	40	D	1,75	96	31,35	8,0
M	22	D	1,86	95	27,46	8,0
M	30	D	1,90	107	29,64	9,0
F	37	D	1,63	82	30,86	7,0
M	34	D	1,70	94	32,53	8,0
M	30	D	1,77	120	38,30	9,0
F	50	D	1,56	67	27,53	6,0
M	25	E	1,72	70	23,66	8,0
M	42	E	1,82	100	30,19	8,5
M	28	D	1,71	70	23,94	8,0
M	32	D	1,70	65	22,49	9,0
M	33	D	1,75	108	35,27	8,0
M	31	D	1,85	90	26,30	8,0
M	22	D	1,82	100	30,19	9,0
M	42	D	1,80	87	29,41	8,0
M	40	D	1,72	68	22,99	9,0
M	28	D	1,77	72	22,98	8,0
M	24	D	1,75	68	22,20	8,0

Table 2: Comparison of mean flexor and extensor torques according to sex, using Student's t test.

	Gender	Average (Nm)	Standard deviation	p-value
Flexor Torque	M	166,7	43,7	<0,001
	F	91,9	31,2	
Extension Torque	M	184,4	62,5	0,065
	F	129,0	71,2	
M: male; F: female; Nm: Newton x meter; CV: coefficient of variation				

Table 3: Correlation of flexor and extensor torques with the quantitative variables of the study, according to the Pearson correlation test.

	Flexor Torque		Extension Torque	
	Corr (r)	P-value	Corr (r)	P-value
Age (Years)	0,058	0,748	0,054	0,764
Height (m)	0,529	0,002	0,285	0,108
Weight (kg)	0,438	0,011	0,414	0,017
BMI (kg/m²)	0,231	0,197	0,324	0,066
Diameter of the graft (cm)	0,597	<0,001	0,260	0,144
M: meters; kg: kilograms; cm: centimeters; Corr: correlation				

Table 4: Linear regression for flexor and extensor torques, according to the variables under study.

	Flexor Torque (Nm)		Extension Torque (Nm)	
	Coef. (B)	p-value	Coef. (B)	p-value
Constant	-296,80	0,69	-309,00	0,80
Men	29,50	0,30	21,60	0,64
Age	0,96	0,37	0,12	0,94
Height	136,80	0,75	202,30	0,77
Weight	0,44	0,92	-0,20	0,97
BMI	-0,38	0,97	4,55	0,84
Diameter of the graft	16,50	0,26	0,53	0,98
ANOVA		0,007		0,402
R2		46,7%		19,9%

Table 5: Linear regression models according to graft diameter.

		Coef. (B)	p-value	R^2
Model 1	Constant	6,56	<0,001	35,7%
	Flexor Torque	0,01	<0,001	
Model 2	Constant	7,51	<0,001	4,8%
	Extension Torque	0,01	0,22	
Model 3	Constant	7,07	<0,001	19%
	Relationship between flexor torque/extension torque	1,05	0,01	

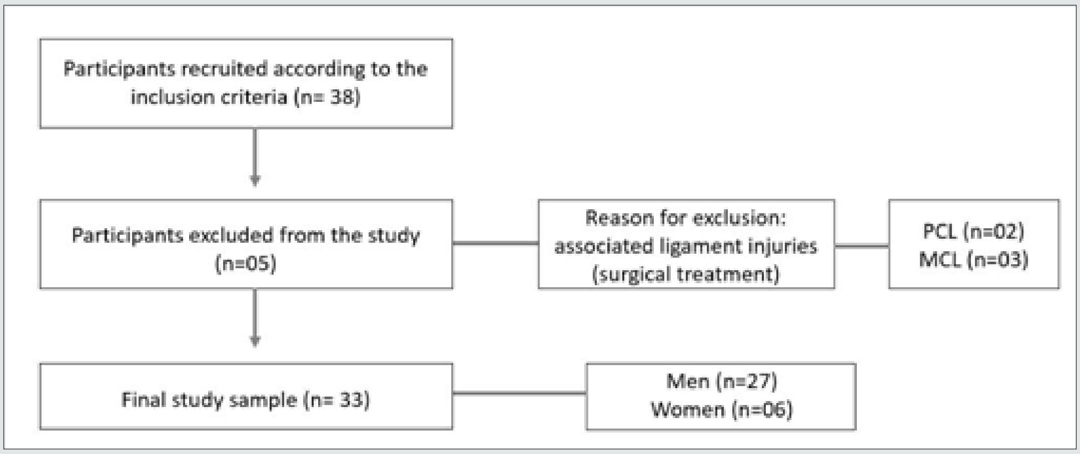

Figure 5: Flowchart showing the study participants

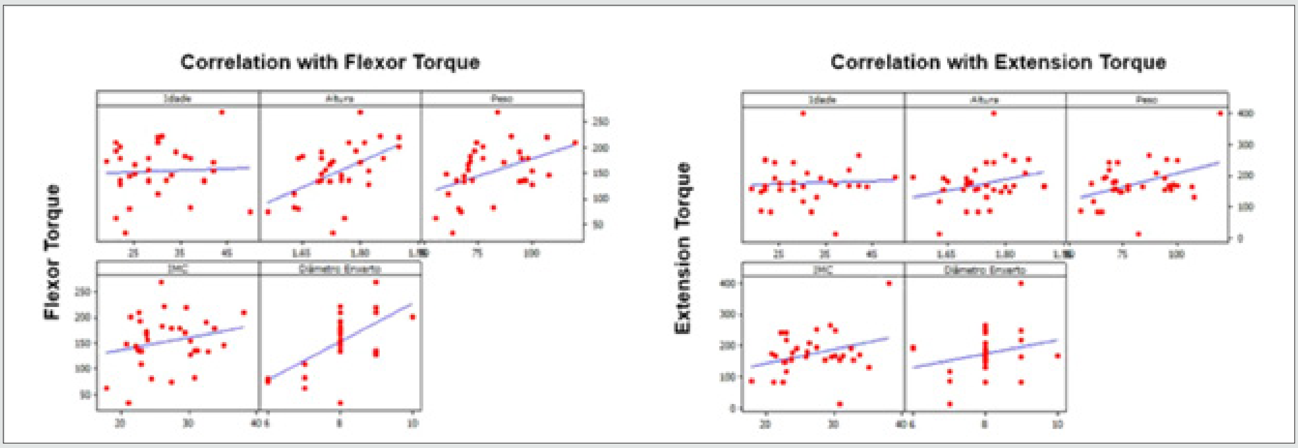

Figure 6: Linear correlation between flexor and extension torques with the study variables.

In the multivariate analysis, through the linear regression between the flexor and extension torques and the study variables, statistically significant results were observed for the flexor torque (p=0.007), but without statistical significance of the predictive variables (Table 4). The best statistical model to predict the diameter of the quadruple graft was from the flexor torque (Table 5), and with this the following equation was developed:

Graft Diameter= 6.57 + (0.01 x Flexor Torque)

Discussion

The main finding of this study was the positive and statistically significant correlation between flexor tendon graft thickness and isometric knee flexor torque in amateur soccer athletes. Through this finding, this physical valence can be used as a parameter to estimate the diameter of the hamstring's tendons in knee ligament reconstructions surgeries. In soccer players, regardless of their performance level, the standard treatment for ACL injuries is surgery. In this public, the choice of the most appropriate graft remains controversial [23,24]. The existing consensus is that the use of allografts should be avoided [25]. The use of hamstrings tendons grafts, despite potentially causing knee flexion strength deficit in specific tests [26,27] and also presenting biomechanical disadvantages compared to bone/tendon grafts [28], is the preferred graft for surgeons in practitioners of this sport [23,29].

Besides hamstrings tendons being one of the main autograft options, in some situations they are also the priority of choice [30,31], provided they present minimum diameters that guarantee stability in the postoperative period. It is known that grafts in ACL reconstruction surgery with diameters less than or equal to 8 mm are associated with higher rates of rerruptures [32]. For this reason, different techniques have been developed to compensate intraoperatively the unsatisfactory thickness of flexor tendons, such as intrinsic adaptations to transform them into fivefold and sixfold formats [33,34], solidarization with autografts or allografts (hybrid graft) [35], and more recently, the preservation of muscle remnants [36].

However, in some situations it is not possible to perform these techniques, mainly when there is a scarcity of adequate instruments or anatomic limitations of the graft itself. For reasons of this nature, it is prudent that the knee surgeon has at hand, in a practical and reproducible way and prior to surgery, tools that provide a guarantee of the average thickness of the flexor tendons. However, up to now, there is no objective and commonly used method in clinical practice to guide the surgeon in estimating the thickness of the hamstring's tendons preoperatively. Some imaging tests have been studied with this objective [15,16]. Nuclear magnetic resonance (NMR), considered the gold standard in diagnosing ACL injury, can be used as an auxiliary measure in the preoperative evaluation of tendon diameter. For this, one of the criteria with good clinical accuracy is the measurement of tendon thickness at its greatest diameter in the axial plane, with the medial epicondyle of the femur as an anatomical reference [15]. Another possible imaging method is ultrasonography (USG), which can be performed based on anteroposterior and transverse diameters (measured in mm) and cross-sectional area (mm^2) [13,14]. However, unlike MRI, USG is not a test of choice for the patient with knee ligament injury and, in this case, would be performed only for the purpose of assessing the thickness of the hamstring's tendons. Moreover, the results of USG with this purpose present conflicting results in the literature [13,14] and, so far, it is not routinely used.

The relationship between epidemiological and anthropometric parameters of easy practical execution, such as gender, age, weight, height, lower limb length, body mass index, among others, and hamstrings tendons thickness have also been studied [10,11,37,38]. However, among all these parameters, height is the only factor that presents a significant association and reproducible results [37,38], as observed in the current study, in which height presented a positive and significant correlation with flexor torque. As it is an easily evaluated parameter, even in a hospital environment, it should be evaluated preoperatively as one of the ways to consider the choice of graft in ACL reconstruction.

It is known that a physical training program with musculoskeletal demands like soccer, based on aerobic and anaerobic overloads, leads to gains not only in strength and muscle hypertrophy of the segments worked, but also in hypertrophy of the tendinous unit, but at a lower intensity [39-41]. This data from the literature justifies the finding of a significant correlation between graft thickness and knee flexor torque observed in the current study. Moreover, it is a factor that corroborates the use of this biomechanical resource as an adjuvant measure to predict the diameter of hamstrings tendons in active populations.In this study, whose main objective was to analyze the efficacy of a practical and additional resource to analyze hamstrings tendons thickness in a specific population, we used the isometric hand-held dynamometer, which is a tool well validated in the literature for strength analysis [17,18,22] and has a much lower cost than the isokinetic dynamometer.

The main precautions that must be taken when using this portable instrument are the standardization of the test time, the adequate positioning in the limb, the use of rigid belts, and joint angulation. Of these, the biomechanical importance of defining the lever arm, which is the measurement that will provide the calculation of torque and whose size can change the peak force produced, and the joint angulation, which should be optimized according to the length x tension curve of the muscle grouping analyzed, must be emphasized [19,20].

The main limitations of the study were its cross-sectional design and gender bias, still common in studies with soccer players [42,43]. Another limiting factor was the non-blinding of the evaluators regarding the graft thickness because the procedure was always performed and recorded by the surgeon and the same evaluator. Moreover, the measurement of the graft thickness was not performed continuously, but by intervals of 0.5 mm according to the standardization of the specific guide. Further research with this theme, in different populations, will be important for future comparisons with the findings of the current study, as it is suggested that soccer athletes have higher flexion and extension torques of the knee in relation to the population in general.

Conclusion

Associated with the analysis of anthropometric characteristics, especially the patient's height, knee flexor torque can be another tool for preoperative analysis of hamstrings tendons thickness during the surgical programming of ACL reconstruction.

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