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Correlation of muscle strength and reported knee function after Anterior Cruciate Ligament (ACL) graft, unrepaired ACL injury, and healthy knees

Correlação da força muscular e função relatada do joelho após enxerto do Ligamento Cruzado Anterior (LCA), lesão não reparada do LCA e joelhos saudáveis

Correlación de la fuerza muscular y la función de la rodilla informada después de un injerto de Ligamento Cruzado Anterior (LCA), una lesión del LCA no reparada y rodillas sanas

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Abstract
Introduction: Many tools can be used for functional assessment following an Anterior Cruciate Ligament (ACL) injury or reconstruction. These include the assessment of stability, the assessment of neuromuscular factors such as strength, and the patient's perception of knee function. The manual dynamometer (MD) is a strength assessment tool that can be used in environments where isokinetic assessment is not feasible. The Lyshom questionnaire, Tegner scale, and the International Knee Documentation Committee (IKDC) scale are validated instruments for subjective functional assessment. Objective: To evaluate the correlation between muscle strength and reported knee function after ACL grafting, unrepaired ACL injury, and healthy knees. Methods: 95 male subjects were evaluated, 36 with ACL reconstruction, 23 with unrepaired ACL injury, and 36 without knee injuries. All were evaluated with the Lysholm questionnaire, Tegner, and IKDC scales. Muscle strength was assessed with the MD, and the limb symmetry index (LSI) was used to correlate with the reported function. Results: The lowest scores on the Lysholm questionnaires and Tegner and IKDC scales occurred in subjects with unrepaired injuries, with significance between groups (p=0.000–0.001). The association involving the ISL with the Lysholm questionnaire and IKDC scale was observed in the ISL of 10% and 15% only for the extension (p<0.01). Conclusion: The Lysholm questionnaire and the Tegner and IKDC scales indicated the level of function according to the clinical condition, and the association of LSI with reported function occurred only for extension. The association of strength tests, functional tests, and questionnaires should be considered for functional assessment of the knee. The MD should be a tool to be considered in the absence of an isokinetic dynamometer, and because it is superior to manual muscle strength testing (MMT).
Keywords: Muscle strength; Knee; Anterior cruciate ligament; Questionnaires.

Resumo

Introdução: Muitos instrumentos podem ser utilizados para a avaliação funcional após a lesão ou reconstrução do Ligamento cruzado anterior (LCA), e estes incluem a avaliação da estabilidade, avaliação de fatores neuromusculares como força e percepção do paciente em relação à função do seu joelho. O dinamômetro manual (DM) é um instrumento para avaliação da força que pode ser utilizado em ambientes onde a avaliação isocinética não é viável. O questionário Lyshom e escalas de Tegner e International Knee Documentation Committee (IKDC) são instrumentos validados para avaliação subjetiva da função. Objetivo: Avaliar a correlação da força muscular e função relatada do joelho após enxerto do LCA, lesão não reparada do LCA e joelhos saudáveis. Métodos: Foram avaliados 95 sujeitos do sexo masculino, 36 com reconstrução do LCA, 23 com lesão do LCA não reparada e 36 sem lesões no joelho. Todos foram avaliados com o questionário Lysholm, escalas de Tegner e IKDC. A força muscular foi avaliada com o DM, e utilizado o índice de simetria dos lados (ISL) para correlação com a função relatada. Resultados: As menores pontuações nos questionários Lysholm e escalas de Tegner e IKDC ocorreram nos sujeitos com lesão não reparada, com significância entre os grupos (p=0,000-0,001). A associação envolvendo o ISL com o questionário Lysholm e escala IKDC, foi observada no ISL de 10% e 15% somente para a extensão (p<0,01). Conclusão: Conclui-se o questionário Lysholm e escalas Tegner e IKDC demonstraram nível de função de acordo com a condição clínica, e que a associação do ISL com a função relatada ocorreu apenas para a extensão. A associação de testes de força, teste funcionais e questionários deve ser considerada para avaliação funcional do joelho. O DM deve ser uma ferramenta a ser considerada na ausência do dinamômetro isocinético, e por ser superior ao teste de força muscular manual (TMM).

Palavras-chave: Força muscular; Joelho; Ligamento cruzado anterior, Questionários.

Resumen

Introducción: Se pueden utilizar muchos instrumentos para la evaluación funcional después de una lesión o reconstrucción del LCA, y estos incluyen la evaluación de la estabilidad, la evaluación de factores neuromusculares como la fuerza y la percepción del paciente sobre la función de su rodilla. El dinamómetro manual (DM) es un instrumento de evaluación de la fuerza que puede utilizarse en entornos donde la evaluación isocinética no es viable. El cuestionario Lyshom y las escalas de Tegner y del Comité Internacional de Documentación de la Rodilla (CIDR) son instrumentos validados para la evaluación subjetiva de la función. Objetivo: Evaluar la correlación entre la fuerza muscular y la función informada de la rodilla después de un injerto de ligamento cruzado anterior (LCA), una lesión del LCA no reparada y rodillas sanas. Métodos: Se evaluaron 95 sujetos masculinos, 36 con reconstrucción del LCA, 23 con lesión del LCA no reparada y 36 sin lesiones de rodilla. Todos fueron evaluados con el cuestionario de Lysholm, las escalas de Tegner e IKDC. La fuerza muscular se evaluó con el DM y se utilizó el Índice de simetría lateral (ISL) para correlacionar con la función informada. Resultados: Las puntuaciones más bajas en los cuestionarios de Lysholm y en las escalas de Tegner e IKDC ocurrieron en sujetos con lesiones que no fueron operados, con significancia entre los grupos (p=0,000-0,001). La asociación del ISL con el cuestionario de Lysholm y la escala IKDC se observó en el ISL del 10% y del 15% solo para la extensión (p<0,01). Conclusión: El cuestionario de Lysholm y las escalas de Tegner e IKDC demostraron el nivel de función según la condición clínica, y que la asociación del ISL con la función reportada ocurrió solo para la extensión. Para la evaluación funcional de la rodilla se debe considerar la asociación de pruebas de fuerza, pruebas funcionales y cuestionarios. El DM debe ser una herramienta a considerar ante la ausencia del Dinamómetro Isocinético, y porque es superior al test de fuerza muscular manual (TMM).

Palabras clave: Fuerza muscular; Rodilla; Ligamento cruzado anterior; Cuestionarios.

1. Introduction

Functional assessment in patients with knee ligament insufficiency is a very important topic for professionals involved in the overall recovery process for Anterior Cruciate Ligament (ACL) injuries. Defining criteria to guide treatment decisions or even parameters for return to activities of daily living and sports facilitates communication with patients and between professionals (Shinzato et al., 1996; Davies et al., 2017).

Many standardized instruments in the literature allow for functional assessment after ACL injury or reconstruction. These include the assessment of passive stability, neuromuscular factors such as strength, power, proprioception, range of motion, and the patient's perception of their knee function (Jang et al., 2014; Malempati et al., 2015; Grindem et al., 2016; Davies et al., 2017; O'Malley et al., 2018).

Assessment of knee extensor and flexor strength has been documented in the literature as fundamental to the care of patients with ACL injuries and reconstructions and is generating much interest in improving performance and function. (Jang et al., 2014; Grindem et al., 2016; Luzo et al., 2016; Muff et al., 2016; Benfica et al., 2018; Nascimento et al., 2018; Florencio et al., 2019). Assessment with the isokinetic dynamometer (ID) is considered the gold standard but is quite expensive. Manual

muscle testing (MMT) is widely used in clinical settings but is subjective. (Mentiplay et al., 2015; Muff et al., 2016; Chamorro et al., 2017; Jackson et al., 2017; Almeida et al., 2018; Lesnak et al., 2019). An alternative technique is the manual dynamometer (MD), which is superior to the MMT when it comes to quantifying force (Muff et al., 2016; Florencio et al., 2019). The literature reports the use of MD in the assessment of muscle strength in many joints, including the knee, with demonstrated inter- and intra-rater reliability (Fulcher et al., 2010; Magalhães et al., 2010; Marcondes et al., 2011; Hansen et al., 2015; Mentiplay et al., 2015; Suzuki, 2015; Almeida et al., 2018).

The muscle strength test for knee pathologies is primarily aimed at comparing the strength of the affected side with that of the unaffected side by calculating the limb symmetry index (LSI). Studies report that an LSI of 10% to 15% for both knee extensors and flexors can be accepted to return to pre-injury activities. (Nunn & Mayhew, 1988; Noyes et al., 1991; Davies et al., 2017; O'Malley et al., 2018).

The correspondence between knee muscle strength and other subjective measures, such as self-assessment questionnaires, provides important information about function. Among the questionnaires utilized for the objective evaluation of the knee, the Lysholm questionnaire and International Knee Documentation Committee (IKDC) scale are the most commonly employed for individuals with ACL injury and/or reconstruction, along with the Tegner scale, which evaluates physical activity level (Fitzgerald et al., 2000; Irrgang et al., 2001; Kvist, 2004; Peccin et al., 2006; Plisky et al., 2006; Plisky et al., 2009; Metsavaht et al., 2010; Collins et al., 2011; Siqueira et al., 2012; Grindem et al., 2016; Luzo et al., 2016).

The objective of this study was to evaluate the correlation of knee extensor and flexor muscle strength performed with MD and the functional level reported in the Lysholm questionnaire, Tegner and IKDC scales in individuals with ACL reconstruction, individuals with unrepaired ACL injury, and individuals without knee injuries.

2. Methodology

This study was approved by the Research Ethics Committee of the Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo (HCFMRP-USP) and was conducted at the Movement Analysis Laboratory (MAL) of the Rehabilitation Center (RC) from HCFMRP-USP. A total of 95 male subjects were examined: 36 with ACL reconstruction, 36 without knee injuries, and 23 without knee injuries. The HCFMR-USP electronic database was consulted to select the operated and non-operated subjects, and the subjects without injuries were recruited through social networks with advertisements.

The general inclusion criteria were male, aged between 18 and 45 years, body mass index (BMI) $\leq$ 29.9 kg/m2, and being active according to the Tegner scale. The operated subjects were also considered to have undergone only ACL surgery performed with an ipsilateral autologous graft of the semitendinosus and gracilis tendons, with a postoperative period of minimum 1 and maximum 4 years, with surgery performed by the same team at the HCFMRP-USP assisted by arthroscopy, and with the rehabilitation process centralized at the RC of the HCFMRP-USP. In subjects with non-surgical injuries, the additional criteria were a single isolated ACL injury confirmed by magnetic resonance imaging (MRI).

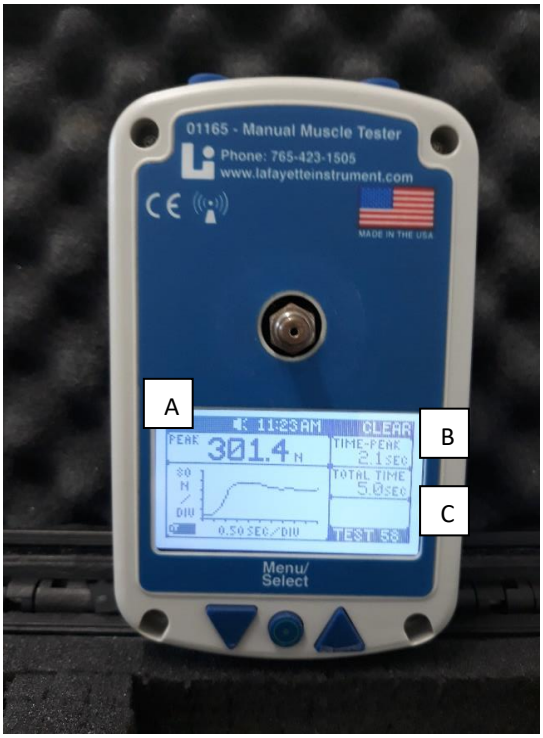
All participants received written instructions from the researcher on how to perform the tests and signed a consent form agreeing to participate in the study, and authorizing the disclosure of data and images of the tests performed. Subsequently, the subjects were asked to complete the questionnaire and the scales. The validated Portuguese versions of the Lysholm questionnaire, the IKDC scale, and the Tegner physical activity level scale were used.

In the Lysholm questionnaire, the scores obtained from the literature were used, with a total of 100 points, with the function score categorized as excellent (95-100 points), good (84-94 points), regular (65-83 points) and poor (<l64 points), and the variables limp, support, locking, instability, pain, swelling, stair climbing, and squatting were assessed. For the IKDC scale, scores set by the American Orthopedic Society for Sports Medicine committee (AOSSM) were used, ranging from 0 to 100, with higher scores representing better function. The examiner completed the Tegner scale based on the activity history obtained

during the examination. This scale rates the activity level from 0 (unable to perform due to knee problems) to 10 (participation in competitive sports) (Tegner & Lysholm, 1985).

The strength of the knee extensor and flexor muscles was assessed using the Lafayette Handheld Dynamometer Testing System Model-01165 (Lafayette Instrument Company, Lafayette IN, USA) (Figure 1), which measures peak torque, peak time, and total test time.

Figure 1 - Lafayette Handheld Dynamometer Testing System Model-01165 - The display shows A: Torque peak, B: Peak time, C: Total test time.



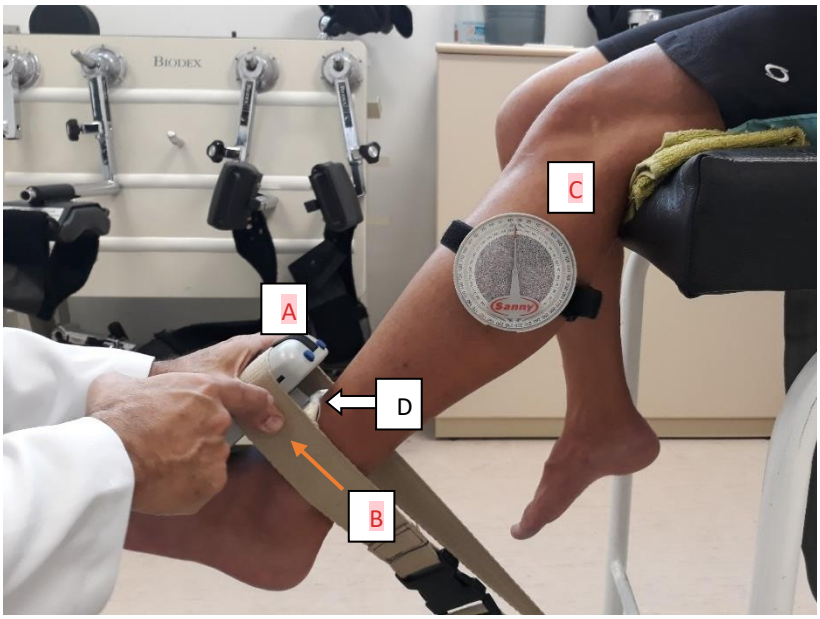
Source: Personal archive.

The extensor muscles were assessed in the 60º flexion position (with total extension considered 0º), with subjects seated on a couch, trunk erect, hips flexed to 90º, and knees off the couch. The hip was stabilized by a non-elastic strap and another non-elastic strap attached to the couch fixed the MD, which was positioned anterior and distal to the tibia at a demarcated point five centimeters proximal to the tip of the lateral malleolus. A Sanny® Pendulum Fleximeter, attached to the patient's leg proximal to the knee, was used to monitor a joint range of motion. To familiarize with the device, a submaximal contraction was always performed before the measurements.

For the measurements, subjects were instructed to "extend" the knee, make no explosive movement, exert maximal effort when the device beeped, and then verbally requested to perform the test as hard as possible until they were verbally instructed to relax after the beep indicating the end of the maximal voluntary isometric contraction (MVIC) (Figure 2).

The assessment consisted of three 5-second MVICs with a 30-second interval between them. After each measurement, the value displayed on the screen of the device was read and entered into a scoring form to calculate the reproducibility of the measurements, the average, and the deficits, i.e. the LSI. All measurements were performed by the same examiner. The strap used to attach the MD was always positioned perpendicular to the tibia to ensure adequate resistance and torque.

Figure 2 - Knee extensor assessment with MD - A: Lafayette Handheld Dynamometer Testing System Model-01165, B: Belt, C: Fleximeter, D: Sterile gauze.



Source: Personal archive.

The flexor muscles were assessed in the 30º flexion position (with full extension as 0º), in the prone position on a couch, and with the knee off the couch. The hip was stabilized by a non-elastic belt. A non-elastic belt attached to a backrest stabilized the MD, which was positioned posterior and distal to the tibia at a demarcated point five centimeters proximal to the tip of the lateral malleolus (Figure 3).

Figure 3 - Knee flexor assessment with MD- A: Handheld dynamometer - Lafayette Handheld Dynamometer Testing System Model-01165, B: Belt, C: Fleximeter.

Source: Personal archive.

To obtain the joint range of motion during the tests, a Sanny® pendulum fleximeter was used, which was attached to the patient's leg proximal to the knee. Once the patient assumed his position, he familiarized himself with the device by performing a submaximal contraction before taking the measurements.

For the measurements, subjects were instructed to "bend" the knee, make no explosive movement, exert maximal effort when the device beeped, and then verbally instructed to perform the test as hard as possible until they were verbally instructed to relax after the beep indicating the end of the MVIC. The MD fixation strap was always attached to the backrest and positioned perpendicular to the shin to ensure adequate resistance and torque.

The assessment consisted of 03 MVIC of 5 seconds with an interval of 30 seconds between them. After each measurement, the value displayed on the screen of the device was read and noted on the evaluation form to calculate the average and deficits. The examiner was a 1.73 cm tall, 80 kg f man who was familiar with the operation of the MD. In both operated and non-operated subjects, the unaffected knee was always tested first; in healthy subjects, the dominant knee was tested first.

As the MD does not have a computer interface, the LSI calculations for the extensor and flexor muscles were performed using the following equation.

$$LSI = \frac{\textit{Operated side or Injured side or Non-dominant side}}{\textit{Non-operated side or Non-injured side or Dominant side x (100)}} \textit{ - 100 = LSI\%}$$

To compare the LSI with the questionnaires, we considered comparing the best results in the questionnaires and scales with an LSI of 10% and 15%. Comparisons of the IKDC with the LSI were performed using the Mann-Whitney test. The comparison between the Lysholm questionnaires and the Tegner scale was performed using Fisher's exact test. All graphs presented were created using R software, version 3.4.1, and analyses were performed using SAS 9.2. A significance level of 5% was assumed for all comparisons.

3. Results

The groups evaluated were homogeneous for age and body mass index, with a significant difference only for the Tegner scale (p=0.002) (Table 1).

Table 1 - Characteristics of the subjects evaluated with mean and standard deviation – Significant difference only for the Tegner scale.

Variables	Reconstruction	No lesions	Lesion not operated	*p*
Sample	36	36	23	
Age (years)	27,94 (±5,54)	28,30 (±6,69)	29,00 (±6,88)	0.912
BMI (kg/m^2)	25,08 (±2,93)	24,1 (±2,32)	26,67 (±3,40)	0.07
Tegner	5,38 (±1,63)	6.0 (±1,26)	4,56 (±1,50)	0.002*

BMI = Body Mass Index; kg/m^2 = Kilograms per square meter, * = significant; p = significance level of 0.05. Source: Research data.

We observed the lowest scores on the Lysholm questionnaires, Tegner, and IKDC scales in subjects with a non-operated ACL injury, with significance between groups (p=0.000 - 0.001) (Tables 1, 2 and 3).

Table 2 - Results of the Tegner scale, Lysholm, and IKDC questionnaires in the three groups with mean and standard deviation.

Reconstruction					No lesions					Lesion not operated				
I	**Tegner**	**Lyshom**		**IKDC**	**I**	**Tegner**	**Lyshom**		**IKDC**	**I**	**Tegner**	**Lyshom**		**IKDC**
1	7	94	G	93,1	1	4	100	E	97.7	1	4	86	R	77
2	7	85	G	75,9	2	4	100	E	94,3	2	3	79	R	52,9
3	3	89	G	89,7	3	5	100	E	100	3	3	46	P	58,67
4	7	90	G	90,8	4	7	100	E	92	4	3	80	R	49,4
5	7	100	E	100	5	7	100	E	100	5	3	89	G	73,6
6	3	79	R	75,9	6	7	99	E	98,9	6	4	83	R	63,2
7	7	80	R	81,6	7	5	100	E	100	7	4	80	R	75,9
8	3	95	E	79,3	8	5	100	E	100	8	7	100	E	100
9	7	100	E	100	9	7	100	E	100	9	7	100	E	100
10	7	89	G	86,2	10	7	100	E	100	10	5	90	G	82,8
11	4	100	E	100	11	10	100	E	100	11	7	100	E	98,9
12	3	95	E	100	12	8	95	E	100	12	5	79	R	58,6
13	7	93	G	97,7	13	7	86	G	69	13	5	90	G	83,9
14	7	90	G	95,4	14	6	100	E	100	14	7	100	E	85,1
15	5	95	E	95,4	15	5	100	E	100	15	6	69	R	59,8
16	3	91	G	86,2	16	7	100	E	100	16	6	83	R	57,5
17	7	100	E	100	17	6	100	E	100	17	5	100	E	71,3
18	6	91	G	82,8	18	6	100	E	100	18	3	53	P	41,4
19	7	100	E	100	19	5	100	E	100	19	5	86	G	80,5
20	5	100	E	88,5	20	5	100	E	100	20	3	85	G	44,8
21	7	100	E	100	21	6	100	E	100	21	3	75	R	49.4
22	3	85	G	96,6	22	7	100	E	100	22	4	94	G	78,2
23	4	99	E	90,8	23	6	100	E	100	23	3	60	P	41,4
24	4	100	E	100	24	4	100	E	100					
25	5	100	E	97,7	25	6	98	E	96,6					
26	7	99	E	97,7	26	7	100	E	89,7					
27	3	70	R	78,2	27	6	100	E	100					
28	6	100	E	98,9	28	5	100	E	100					
29	4	93	G	74,7	29	5	95	E	100					
30	4	100	E	100	30	6	100	E	100					
31	4	100	E	66,7	31	6	90	G	78,2					
32	6	100	E	97,7	32	6	100	E	100					
33	7	99	E	74,7	33	5	100	E	100					
34	7	74	R	59,8	34	4	100	E	100					
35	6	100	E	100	35	5	91	G	97,7					
36	5	100	E	100	36	5	100	E	100					
	5,38	93,75		90,33		6.0	98,72		97,61		4,56	82,91		69,76
	(±1,63)	(±8,06)		(±11,02)		(±1,2)	(±3,26)		(±6,54)		(±1,50)	(±14,81)		(±18,31)

I = individual; E = Excellent; G = Good; R = Regular; P Poor; ± = Standard deviation; Source: Research data.

Table 3 - Comparison of the Lysholm and IKDC questionnaires.

Scale/Questionnaire	Group	Average	Deviation	p
IKDC	No lesion *n* = (36)	97,61	± 6,45	0,001*
	Reconstruction *n* = (36)	90,33	± 11,02	
IKDC	Reconstruction *n* = (36)	90,33	± 11,02	0,000*
	Not operated *n* = (23)	68,88	± 18,39	
IKDC	No lesion *n* = (36)	97,61	± 6,45	0,000*
	Not operated *n* = (23)	88,21	± 90,25	
Lysholm	No lesion *n* = (36)	98,72	± 3,26	0,001*
	Reconstrução *n* = (36)	93,75	± 8,06	
Lysholm	Reconstrução *n* = (36)	93,75	± 8,06	0,001*
	Not operated *n* = (23)	82,91	± 14,81	
Lysholm	No lesion *n* = (36)	98,72	± 3,26	0,000*
	Not operated *n* = (23)	82,91	± 14,81	

* = significant; p = significance level of 0.05. Source: Research data.

For the Lysholm questionnaire, the scores were 98.72 (±3.26), 93.75 (±8.06), and 82.91 (±14.81) for the subjects without injury, the subjects with ACL reconstruction, and the subjects with an injury who had not undergone surgery, respectively, i.e. it was excellent in the group without injury, good in the group with surgery and mediocre in the group with an injury who had not undergone surgery.

For the IKDC scale, the mean scores were 97.61 (±6.54), 90.33 (±11.02), and 69.76 (±18.31) for the subjects without injury, the subjects with ACL reconstruction, and the subjects with injury who had not undergone surgery, respectively.

When examining the associations between the LSI and the Lysholm and IKDC questionnaires, we only found associations between the LSI of 10% and 15% as assessed by the MD in the extension and the two questionnaires (p <0.01) (Tables 4 and 5) and (Figures 4 and 5).

Table 4 - Associations of the LSI of 10% and 15% obtained in the MD with the Lysholm questionnaire.

Questionnaire	LSI extension with MD				LSI Flexion with MD			
	LSI 10%		LSI 15%		LSI 10%		LSI 15%	
Lysholm	<10	>10	<15	>15	<10	>10	<15	>15
95-100	44	15	50	9	46	12	51	7
84-94	11	9	16	4	18	2	20	0
65-83	5	9	7		10	5	12	3
<64	0	2	0	2	1	1	1	1
	p <0,01		*p <0,01*		*p = 0,20*		*p = 0,06*	

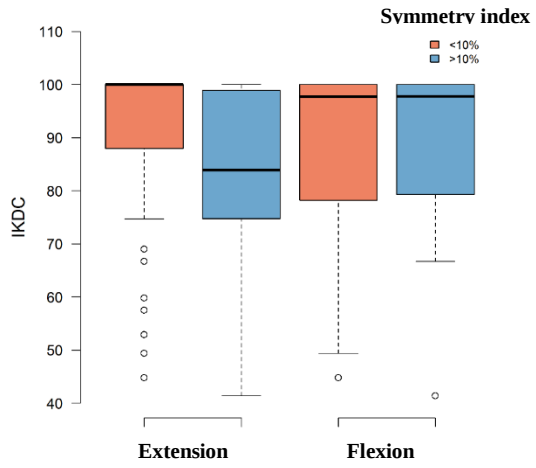
MD = Manual Dynamometer; LSI = Limb Symmetry Index; significance level 0.05. Source: Research data.

Table 5 - Associations of the LSI of 10% and 15% obtained in the MD with the IKDC scale.

Moviment	MD LSI	*n*	IKDC Minimum	1º quartile	Median	3º quartile	Maximum	*p*
Extension	<10	60	44,8	87,95	100	100	100	<0,01
	>10	35	41,4	73,6	83,9	98,9	100	
Flexion	<10	75	44,8	78,2	97,7	100	100	0,94
	>10	20	41,4	79,3	97,75	100	100	
Extension	<15	73	44,8	85,1	98,9	100	100	<0,01
	>15	22	41,4	63,2	79,9	97,7	100	
Flexion	<15	84	44,8	79,9	97,7	100	100	0,57
	>15	11	41,4	66,7	96,6	100	100	

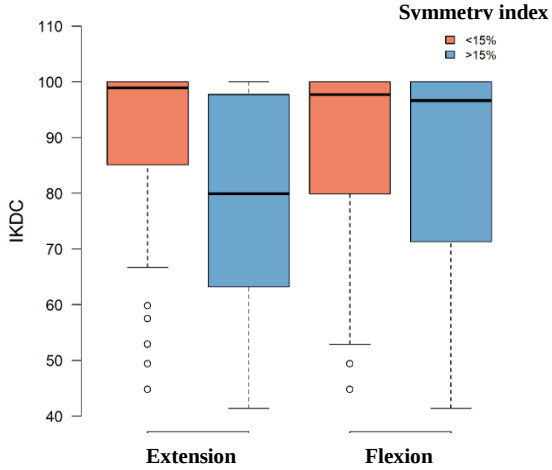
MD = Manual dynamometer; LSI = Limb symmetry index; n = sample; significance level = 0.05. Source: Research data.

Figure 4 - Box-plot of MD associations with IKDC - 10% LSI.



Source: Research data.

Figure 5 - Box-plot of MD associations with IKDC - 15% LSI.



Source: Research data.

4. Discussion

This work aimed to investigate the functional level in subjects with ACL reconstruction, subjects with non-operated ACL injury, and healthy subjects using the Lysholm questionnaire, the Tegner and IKDC scales, and to investigate the agreement

of the Lysholm questionnaire and KDC scale with muscle strength measurements, performed with MD using the limb symmetry index (LSI).

Associations between variables were performed using Fisher's exact test, a test for statistical significance used to analyze independent observations of two or more random variables (Pagano & Grauveau, 2004). Comparisons between the LSI and the IKDC were performed using the Mann-Whitney test, a non-parametric technique that allows two independent samples to be compared without making assumptions about the distribution of the data (Contador & Senne, 2016).

We observed the lowest scores on the Tegner scale, Lysholm, and IKDC questionnaires in the non-operated subjects, followed by the subjects with ACL reconstruction and the subjects without injuries, with significant differences between the groups. The Tegner scale assesses physical/functional characteristics and is reported in the literature for the assessment of knee ligament injuries and reconstructions It has been validated for use in both genders (Gonçalves et al., 2007; Collins et al., 2011). According to Tegner and Lysholm (1985), subjects with a scale below 3 may have low scores on functional assessments, which may imply an inability for some sports. Our patients with injuries without reconstruction had scores between 3 and 7.

The Lysholm questionnaire is also suitable for assessing function in individuals with knee ligament injuries and reconstructions (Gonçalves et al., 2007; Collins et al., 2011), and the IKDC scale, which according to Irrgang et al. (2001) is a scale that simplifies data collection and can be used for many conditions of the knee, including operated, unoperated and uninjured patients. Our results show lower scores for both the Lysholm and IKDC in non-operated individuals. For the Lysholm questionnaire, the results were excellent in the non-operated group, good in the operated group, and moderate in the non-operated injury group. This confirms what has been reported in the literature on knee dysfunction (Peccin et al., 2006; Gonçalves et al., 2007; Collins et al., 2011). For the IKDC scale, the best scores found in subjects without injuries also confirm the literature reporting that scores closer to 100 mean that the person has no limitations in activities of daily living (ADL) or sports in their knee (Irrgang et al.,2001; Metsavaht et al.,2010; Collins et al.,2011; Siqueira et al., 2012).

We used the LSI to capture the results of the tests performed at the MD. Thus, the values used in our study were not absolute, but the proportion of force between them. Nunn and Mayhew (1988) evaluated the relationship between isokinetic, isotonic, and isometric tests and reported that even if the absolute force values are different between the methods if the force ratio between the muscles is constant, the bilateral and ipsilateral muscle force ratios can be comparable.

We consider an LSI of 10% and 15% as normal, with the best scores in the questionnaires and scales. Studies report that deficits in the operated limb for both knee extensors and knee flexors of around 10% to 15% are acceptable, being classified as normal if the difference is less than or equal to 10%, minimal if the difference is up to 20% (Davies et al., 2017; O'Malley et al., 2018).

We found an LSI association of 10% and 15% only for the knee extensors with the Lysholm questionnaires and IKDC scales. Noyes et al., (1991) found no sustained significance in the association between questionnaires and quadriceps strength assessment, as did Vasconcelos et al. (2009) who found no significant correlation between the Lysholm questionnaire and peak touch deficit in patients with ACL reconstruction. However, in both studies, the authors assessed force using an isokinetic dynamometer and did not consider LSI but peak torque. Our findings may be an indicator of the importance of the quadriceps for knee stability, as mentioned by Imoto et al. (2012).

We studied subjects who had undergone ACL reconstruction, healthy subjects, and subjects with ACL injuries who had not undergone surgery to cover different clinical scenarios, as each scenario represents different changes in routine that may even have emotional implications, as noted by Abernethy et al (1995), Herrington et al. (2009), and Koblbauer et al. (2011). Like Dawson et al. (2014) and Hansen et al. (2015), we studied male patients between the ages of 18 and 45 years, as this age group has normal levels of muscle strength and greater engagement in sports activities, which is one of the main reasons for ACL

reconstruction surgery according to Jang et al. (2014). The inclusion of older men or women could promote differences in muscle strength and functional performance (Gaines &Talbot 1999; Jang et al., 2014).

Regarding the methodologies employed in our study to employ the MD, such as Suzuki (2015) and Florencio et al. (2019), we hold the belief that there is no consensus regarding the optimal methodology to employ. The methodology we used, i.e., a time of 5 seconds, repetition of 03 contractions with an interval of 30s between each, is an assessment model reported to be suitable for producing peak torque (Bittencourt et al., 2016; Almeida et al., 2018).

Although many studies on the assessment of knee muscles with MD have mostly used the 90º position to assess both knee flexors and extensors (Bohannon, 1986; Wang et al., 2002; Kelln et al., 2008; Katoh & Yamasaki, 2009; Katoh et al., 2011; Katoh & Isozaki, 2014; Koblbauer et al., 2011; Bohannon, 2012; Hansen et al., 2015; Muff et al., 2016; Jackson et al., 2017; Almeida et al., 2018; Florencio et al., 2019), we used the knee flexion position of 60º to assess the extensors and the 30º position for the flexors, following the example of Lienhard et al. (2013), who state that in these positions the muscles can generate greater isometric torque.

To assess the extensors, we used the sitting position, fixing the hip with a belt, like Mentiplay et al. (2015) and Almeida et al. (2018). The prone position, also with belt fixation on the hip, was used to assess the knee flexors because, as Trudelle-Jackson et al. (1994) and Hansen et al. (2015) mention, it is the common position in MMT.

We used a belt to fix the MD, taking into account the statement by Chamorro et al. (2017) that the reliability of the test can be influenced by the strength of the muscle group being assessed, i.e., the stronger the muscle group, the reliability can decrease if the test is carried out with manual support unless the assessor is stronger than the patient, and we also understood that the 60º and 30º positions we used would be difficult to maintain with manual support.

We encountered some difficulties and limitations in carrying out our study, and we feel that some considerations should be made in this regard:

Despite the large number of surgical procedures performed by the HCFMRP-USP team, due to the inclusion criteria that were determined in our work, the sample number was limited.

We had difficulty finding patients with ACL injuries who had not undergone surgical treatment within the same period and level of activity, which limited the number of samples in this group.

Although the patients who underwent surgery had all been operated on at HCFMR-USP by the same team and using the same procedure and had all received instructions for the rehabilitation program used at the RSC, not all of them did the program at the RSC, and some followed the protocol with other physiotherapists. Like Xergia et al. (2013), we intended to evaluate patients undergoing "typical" outpatient physiotherapy treatment. We believe that the results for comparison between the LSI and the questionnaires were not influenced by this factor, since each patient's condition was the same at the time of assessment.

Our sample population consisted only of young adult males; therefore, the results cannot be extrapolated to subjects beyond this age group, female subjects, or those with other knee pathologies;

We did not standardize the length of the lever arm and body mass in the MD measurements, considering, like Mentiplay et al. (2015); Mentiplay et al. (2018), that our analysis of the results was carried out only within the participants and that we considered the LSI and not the absolute strength.

5. Conclusion

It can be concluded that the level of function in subjects with ACL injuries who did not undergo surgery was worse than in subjects with ACL reconstruction and without knee injuries, and that the Lysholm questionnaire and the Tegner and IKDC scales demonstrated this level of function.

The agreement between the LSI determined by the MD occurred only for knee extensors for both, the Lysholm questionnaire and the IKDC scale, which demonstrates the importance of this muscle group for knee function.

Our results should not be extrapolated to other knee pathologies, and studies using MD and functional assessment can be conducted to evaluate this important tool that should be considered if it is impossible to use the gold standard for evaluating knee muscles.

The association of strength tests, functional tests, and self-report questionnaires should be considered by professionals when assessing subjects with knee ligament instability, and the MD may be a tool to consider in the absence of the ID for knee muscles assessment.

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