RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT: IMPACT OF MUSCULAR AND FUNCTIONAL PERFORMANCES AT THE RETURN TO PRE-INJURY ACTIVITY LEVEL

LYGIA PACCINI LUSTOSA[1], SÉRGIO TEIXEIRA DA FONSECA[2], MARCO ANTÔNIO PERCOPE DE ANDRADE[3]

SUMMARY

Introduction: ACL reconstruction targets the reestablishment of joint biomechanics and minimization of knee instability. Objective: to compare muscular and functional performances, and passive joint laxity between volunteers who, after ligament reconstruction, returned to the same pre-injury activity level and those who did not, Methods: 25 men who had their ACL ligament arthroscopically reconstructed (patellar ligament) by the same surgeon, at least two years previously were included in the study. The Cincinnati Knee Rating System was used in order to divide the volunteers into: Adapted Group - 15 individuals who returned to the same pre-injury activity level - and Non-adapted Group - 10 individuals who did not return to their pre-injury level. The assessment of functional performance was carried out by means of the hop and the figure-eight ratio tests. Muscular performance was evaluated by an isokinetic dynamometer and passive joint laxity was assessed by the KT-1000 arthrometer. Data analyses were performed by means of t-test and ANOVA. Results: No significant differences were found between the groups for tested variables. There were, also, no differences between legs (operated and not operated). Conclusion: Passive joint laxity or muscular and functional performances cannot explain the return of the individuals to their same pre-injury functional level.

Keywords: *Rehabilitation; Knee; Biomechanics.*

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INTRODUCTION

Knee ligament injuries are common in individuals practicing sports, with anterior cruciate ligament (ACL) injury being the most frequent one in contact sports[1]. This ligament rupture causes joint laxity, especially on rotational movements, and often causes disability to practice sports and joint wear-off[1-3]. Ligament reconstruction intends to reconstruct an injured ligament by replacing it by a structure that is similar to ligament tissue, so that it could be functionally effective[4].

Postoperative outcomes are assessed for the degree of residual ligament laxity, for functional level, for proprioceptive acuity change, for patient satisfaction, and for the presence of some complications such as pain, joint swelling, joint movement restraint, and thigh muscles' hypotrophy, especially the quadriceps[1-6]. As a result of those evaluations, some authors regard ligament reconstruction as the primary factor for joint stability and for returning to physical activity[1,7,8].

Tyler et al.[9] assessed ligament laxity in individuals submitted to surgery at least one year early and found a sample percentage (13%) with values consistent to injured ligament. However, those authors found no association of these values with functional level, with complaints of instability and presence of a positive Lachman's test[9]. They discussed the importance to differentiate passive laxity from dynamic measurements and functional performance. On the other hand, Brosky et al.[3], suggested that, after reconstruction, an effective joint stabilization occurs, and that surgery success rates should be assessed from the perspective of the return to physical activity. For those authors, the increased ligament laxity seen in some individuals, and occurring after some years of surgery, should be attributed to the viscoelastic properties of a tissue, and may have no correlation with function [3,6,9]. Still considering the presence of residual ligament laxity after ACL reconstruction, there are studies evidencing absence of correlation between patients' functional level as evaluated by objective clinical signs, such as positive Lachman's test and pivot shift test, and with subjective clinical signs, such as presence of pain, functional complaint, and instability complaint[4,6,10]. Those authors concluded that there is no direct correlation between functional level and degree of ligament laxity[4,6,10].

The importance of the mechanical function performed by a ligament is well discussed, but a large portion of the evidence bodies point out to a secondary role on joint stability. The sensorial function of a ligament and other structures composing a joint should also be considered in the dynamic joint stability[5].

Quadriceps muscle hypotrophy is another phenomenon frequently found in patients at the postoperative period of ACL reconstruction[11,12]. Some authors showed, from studies including quadriceps muscle force measurement, that the deficit found between limbs can still be seen for as long as two years after surgery[10,13,14]. Nevertheless, this strength deficit seems to have no correlation with other variables, such as functional level and residual ligament laxity, showing absence of evidences proving a direct dependence of muscle response due to a ligamentar structure[13,14].

Study conducted at the Federal University of Minas Gerais - UFMG
Correspondences to: Rua Álvares de Azevedo, 122 – Colégio Batista – Belo Horizonte – MG – Brasil – CEP.: 31110-290 – Email: lpaccini@horizontes.net

1. Master in Rehabilitation Sciences – Belo Horizonte University Center – UNI-BH
2. Post-Ph.D. in Sciences – Federal University of Minas Gerais – UFMG
3. Ph.D. in Surgery –Federal University of Minas Gerais – UFMG

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Thus, once the end goal in ligament reconstruction is the return to physical activity at the same pre-injury level, the assessment of neuromuscular and mechanical factors may help on clarifying how these influence and/ or determine joint stability. Furthermore, understanding these mechanisms may contribute to elucidate the reason why individuals, even after ACL reconstruction, are not able to perform physical activities back and to the same functional level anymore[11,15,16] .

Therefore, the objective of this study was to assess the degree of residual ligament laxity, muscular and functional performance in individuals submitted to anterior cruciate ligament reconstruction using patellar ligament, comparing a group of subjects who managed to get back to the same pre-injury level of physical activity (adapted) to a group of subjects who couldn't return to the same functional activity level (non-adapted).

METHODS

Twenty-five individuals were enrolled in the study, who had been submitted to knee's anterior cruciate ligament reconstruction via arthroscopy, using patellar ligament as a graft within the period comprehending July 1994 to June 2002. All subjects had been operated by the same surgeon. Inclusion criteria were the following: male subjects; unilateral injuries, and submitted to ACL reconstruction surgery at least two years earlier. Only subjects submitted to the same rehabilitation program have been included. This program was based on early intervention, targeting joint range gain, muscle strengthening prioritizing exercises in closed kinetic chain and functional drills. Those individuals remained for three months in average at the Physical Therapy service and were subsequently guided concerning muscle strengthening and functional drills continuation as off-service activities, but followed up by a physical therapist. All patients were allowed to practice sports only after the seventh postoperative month. All volunteers reported, at the moment of study evaluation, having tried hard to get back to the same level of activity they had previously to injury.

Mean age of the individuals in the adapted group (AD) was 34.5 years ($\pm$8.85) and, in the non-adapted group (NAD), it was 33.4 years ($\pm$7.53). Regarding affected side, 15 individuals had their right knee operated and 10 left knees. In the distribution by groups, in the adapted individuals group, 10 had their right knee operated and five left knees. In the non-adapted individuals group, we found five right knees and five left knees operated.

As for the presence of associated meniscal injury, six individuals did not have meniscal injuries, three from the AD group, and three from the NAD group. The remaining subjects showed meniscal injuries, with 12 being included on adapted group and seven in the non-adapted one. Surgical treatment for meniscal injuries, when prescribed, was performed at the same surgical time as ligament reconstruction or in procedures performed previously to ligament reconstruction.

This study was approved by the Committee of Ethics in Research of this Institution, and all volunteers signed a Free and Informed Consent Term before entering the study.

Initially, the volunteers answered to the functional scale named *Cincinnati Knee Rating System*[17] – CKRS, in order to be assigned to AD and NAD groups. A total score above 90 points was regarded as AD and, below 85, as NAD [17]. The individuals achieving a score between 86 and 89 were excluded in order to mitigate potential bias between groups due to their threshold status.

Then, all volunteers have been assessed by a performance test (hop test) and 8-run, by dynamometry and byKT-1000. As a way to control potential confusing variables, we decided to include a male population only, in order to eliminate any differences between genders. As the goal was to determine adapted and non-adapted individuals groups, excluding females seemed to be the best strategy to minimize the risks of having different groups, thus ruling out the influence of factors that could change results when tested variables were to be compared.

The examination started with an evaluation of the passive ligament laxity measurement made with the KT-1000 arthrometer (Medmetric Corporation, San Diego, California). Those measurements were taken by the same investigator, who was previously trained on the test. Volunteers remained at dorsal decubitus, the instrument being positioned on lower limb using the parameters described by the manufacturer [8]. Measurements were initially taken on the non-operated knee and then on the knee submitted to surgery. The instrument was calibrated, and good patient positioning and relaxation was achieved at the moment of tests. For each individual, three measurements were done, and the average was used for data reduction.

Following, volunteers were guided to perform warm-up exercises for five minutes on a bicycle and static stretching for muscle groups: ischiosural, quadriceps and sural triceps, as three 20-second series for each stretching exercise. The individuals were positioned on a built-in chair of the Byodex System 3 Pro dynamometer, keeping hip at 80° of flexion, with support to trunk, and fixated by instrument's straps. Then, the evaluation by isokinetic dynamometry was performed on knee flexor and extensor muscles, at concentric mode, at angle speeds of 60°/s and 300°/s. Volunteers were guided regarding the test and the need to make the strongest effort as possible. At each speed, a drill with three repetitions was performed in order to become familiar with the exercise, and the isokinetic measurement taken from five repetitions at maximum effort. The individuals were encouraged by claps and incentive words such as "Go! Come on! More... Don't stop!", etc.

The performance test – 8-run[18] and *hop test* were then performed. These tests were conducted at a gymnasium. The hop test was performed by means of a one-foot simple distance vault. The subjects were guided to remain at one-foot support, hands back or close to body, in order to avoid impulse with upper limbs. From a voice command of "Prepare...go!", volunteers vaulted as far as possible, landing at the same foot as they started with. The non-operated limb was always measured first. The vault distance in centimeters was noted, and the test was repeated three times on each lower limb.

Then, the straight run test was performed. A straight 10-meter distance was determined on the gymnasium. Photoelectric cells (*Multisprint, Leszek* – CENESP) were positioned at the start and finish lines of the path and linked to a laptop. The individual was asked to take position at the start line and, after a voice command of "Prepare...go!" they had to run the established distance as fast as possible. Between each run, a 1-minute rest interval was allowed, and the test was repeated three times. The time spent in each shift was noted. After a five-minute interval, the researcher guided the volunteer regarding the 8-shape run (Figure 1) sketched on the gymnasium floor. That figure was 14-meter long by 4-meter large. The start line was always established at two meters from one of the straight lines. The individuals started running from that point on, where the photocells were positioned. They were instructed to run as fast as possible, following the shape of the figure, and to stop only after exceeding the starting point. The voice command was the same as previously. Between each run session, a 1-minute rest interval was allowed, and the test was repeated three times. The time spent in each shift was noted.

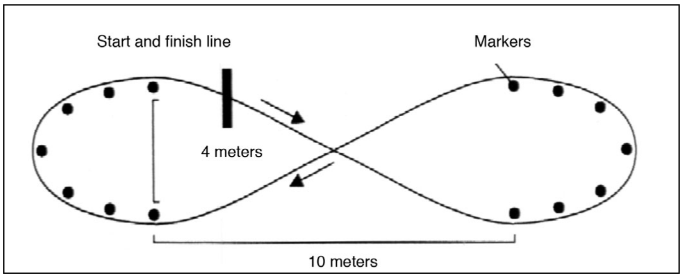

Figure 1 - *Performance test: "Eight"-run, adapted from Fonseca et al[18]*

DATA REDUCTION

Residual ligament laxity was measured by the averages of the measurements at 134N of each limb. From those values, the difference between limbs was calculated as millimeters.

Flexor and extensor muscles' effort was measured by built-in software of the isokinetic dynamometer, based on the calculation of the area under curve torque/ angle. Values found, as *joules,* were normalized, that is, divided by each individual's body weight.

The hop test was calculated from measurements averages, as a ratio of the measurements for an operated limb divided by a non-operated limb, and multiplied by 100. The ratio of the performance test was also calculated from the averages of the measurements noted, by dividing the time spent on the 8-shape run by the time spent on the straight run[18].

STATISTICAL ANALYSIS

The variables age, ligament laxity and the functional performance tests - functional scale, hop test and 8-run have been evaluated by the t-test for independent groups, which enabled comparison between groups. Muscular function data were submitted to statistical analysis by mixed ANOVA with an independent factor (group) and another with repeated measurements (limbs). The significance level adopted was alpha = 0.05.

RESULTS

The end score average on the Cincinnati's scale for group AD and NAD showed a significant difference between groups ($p< 0.0001$), where group AD showed an average of 96.87 (±2.75) and the NAD group, 77.30 (±6.14). No significant difference was found between groups regarding age ($p= 0.75$). The average time since ligament injury to surgery was 23.32 months, with the adapted individuals group reporting an average of 23 months and the non-adapted group 23.79 months.

The t-tests revealed no significant difference between the averages in the adapted and non-adapted groups for variables such as time of injury until surgery, residual ligament laxity, ratio of the 8-run test average divided by straight run and hop test. Averages and standard deviations, as well as p value for each variable are shown on Table 1.

Variable	Adapted group	Non-adapted group	Odds
Time since surgery (months)	67.31 (± 28.52)	52.20 (± 31.33)	p= 0.22
KT-1000 (millimeters)	2.60 (± 1.49)	2.28 (± 2.28)	p= 0.59
Ratio of the 8 figure	4.36 (± 0.27)	4.26 (± 0.25)	p= 0.37
Ratio of the Hop test	95.18 (± 4.70)	94.64 (± 3.37)	p= 0.76

Table 1 - *Average, standard deviations and odds ratio of the results of variables time since surgery, functional level, ligament laxity and functional performance compared for adapted and non-adapted groups.*

The statistical analysis of the variable extensor muscles' effort at angle speed of 60°/s showed no significant difference between groups ($F= 0.85$, $p= 0.37$), between limbs ($F= 2.38$, $p= 0.14$) e in group vs. limbs interaction ($F= 2.46$, $p= 0.13$). In the analysis of flexor muscles at angle speed of 60°/s, no significant difference was found between groups ($F= 0.60$, $p= 0.45$), between limbs ($F= 0.52$, $p= 0.48$), and group vs. limbs interaction ($F= 0.82$, $p= 0.37$) as well. Regarding the analysis of the variable extensor muscles' effort at angle speed of 300°/s, no significant difference was found between groups ($F= 1.01$, $p= 0.33$), between limbs ($F= 1.22$, $p= 0.28$) and in group vs. limbs interaction ($F= 1.83$, $p= 0.19$). In the analysis of flexor muscles at angle speed of 300°/s, no significant difference was found between groups ($F= 0.16$, $p= 0.68$), between limbs ($F= 0.03$, $p= 0.87$) and in group vs. limbs interaction ($F= 1.14$, $p= 0.29$) as well. The average and standard deviations of values found in relation to the muscular function analysis are found on Table 2.

	Adapted Group		Non-adapted group	
Variables	Involved limb	Non-involved limb	Involved limb	Non-involved limb
Ext. effort 60°/ s (as J/ Kg)	300.57 (± 42.51)	329.47 (± 51.74)	300.45 (± 68.75)	296.59 (± 38.37)
Flexors effort 60°/ s (as J/ Kg)	198.15 (± 42.27)	188.01 (± 30.13)	180.67 (± 50.36)	183.34 (± 32.82)
Ext. effort 300°/ s (as J/ Kg)	180.31 (± 25.20)	188.61 (± 28.15)	175.64 (± 29.28)	173.56 (± 18.14)
Flexors effort 300°/ s (as J/ Kg)	116.51 (± 29.47)	114.08 (± 29.39)	108.34 (± 22.78)	113.45 (± 23.52)

Table 2 - *Values for knee's extensor and flexor muscles effort and standard deviations at angle speed of 60°/s and 300°/s, considering the involved and the non-involved limb, and comparing adapted and non-adapted groups.*

DISCUSSION

This study intended to compare residual ligament laxity, muscle performance and functional performance among AD and NAD individuals aiming to identify variables that may impact knee functional stabilization in individuals submitted to ACL reconstruction using patellar ligament. The results showed no significant difference between limbs and between groups when the study variables were analyzed.

One of the criteria used for assessing success of interventions in individuals submitted to ACL reconstruction is the return to the same pre-injury activity level [16]. Functional scales developed for that purpose intend to determine objective and subjective parameters for measuring the level of activity of individuals presenting dysfunctions resulting from knee joint injuries[19]. Johnson et al.[19], after a systematic review, described 54 different scales, most of them associating clinical symptoms, functional and clinical abilities and patient satisfaction. Among the various scales available, the *Cincinnati Knee Rating System* has been one of the most commonly used ones[19]. The significant difference found in this study, when compared to the CKRS average score, provide assurance that the groups didn't present the same functional level.

Functional performance tests have been created intending to develop an activity that could be similar to physical activity, mimicking the movements performed in sports gesture[6,18]. In this study, functional performance tests - 8-run and hop test - showed no significant difference between both groups in the study. This result showed that, despite of individuals' complaints, the non-adapted group could not be considered as different from the adapted group concerning the ability to develop speed and perform movements such as turns. Despite complaints of instability and disability reported in physical activities, those individuals, in planned situations, probably used a mechanism of adaptation to perform the activity. Fonseca et al.[18] suggested a validated performance test for assessing knee function. The authors demonstrated that the 8-shape run test can distinguish a population of normal individuals from injured ones and suggested its combination with the hop test. On the other hand, there are some authors who recognize that functional tests show great sensitivity and validity, but question the fact of being performed in a laboratory environment, where the performance developed is not the same as when at actual sports practice[20]. The individuals assessed in the present study, regardless of groups, did not show differences in test situations. That allows us to state that non-adapted individuals - while showing a similar performance to adapted subjects at test situations - cannot be regarded as able to perform activities demanding greater functional performance. Those individuals may have presented an influence of the ankle joints, hip and trunk action, of the muscular strength and of neuromuscular mechanisms of joint stabilization[20]. That interaction between lower limbs' joints perhaps allows for the absorption of ground response forces and balance maintenance, resulting in the non-occurrence of differences between groups during test. However, this kind of compensation was not assessed in the present study, but should be addressed in further studies.

Ligament laxity has been attributed by some authors as a determinant factor for joint stability. However, the results found in this study for residual ligament laxity showed no significant difference in the average of measurements between adapted and non-adapted groups, with the adapted group showing a numerically higher average difference value between limbs than the non-adapted group, yet not significant. Thus, we cannot state that the presence of ligament laxity is a determinant factor for function or return to the same pre-injury activity level. Tyler et al.[9], also found the presence of residual ligament laxity after reconstruction, with a difference between limbs ranging from 3 to 5 mm in individuals reporting no functional complaints. Those authors concluded that the permanence of the anterior tibial translation can be attributed to the fact that ligament laxity tests are a passive measurement, while during functional activities, muscle action prevents this laxity to manifest itself as instability. The absence of significant differences between both study groups allows us to say that residual ligament laxity was not a determinant factor for individuals to return or not to the same pre-injury functional activity level. It is possible that the existence of a mechanism of adaptation enables functional activities to be performed, thus offsetting passive residual ligament laxity. This assumption corroborates with some results described in literature suggesting that neuromuscular mechanisms may play a role on joint stabilization[5,12].

Muscle strength has been frequently reported as a factor influencing joint stability. In the present study, the variable knee extensor and flexor muscles' effort, normalized by body mass, was used to check the impact of muscular performance over function. Our data show no significant difference between limbs, between groups, and in group vs. limbs interaction at any speed tested. Some authors suggested that the changes to muscle strength could impact an individual's functional performance, and could cause a reduced function level[10,15]. Nevertheless, the correlation of such changes with function is not clearly established[12]. Some authors showed that muscular strength changes did not evidence a linear correlation with functional disability, since some individuals with values below those regarded as normal for non-injured individuals could not return to sports activities[10,12,15]. Thus, the effort variable addressed in this study cannot be used for explaining the fact that non-adapted individuals are not able to get back to the same pre-injury activity level. This datum reinforces the idea that muscles' ability to generate effort is important, but not determinant for functional stability.

While this study has delivered certain contributions, some limitations must also be pointed out. The presence of meniscal injury associated to ligament rupture is a condition that may influence joint congruence and predispose to instability.[] The population in this study showed a homogeneous distribution for presence of meniscal injury. However, as those injuries had been repaired in some cases combined with ACL reconstruction, some other cases in previous surgeries, we could not control the extension of this injury, as well as the kind of specific meniscal injury and the type of repairing procedure employed. Nonetheless, although not investigated in the present study, the fact that both groups include individuals with variable meniscal injuries minimized any bias in the study results.

Thus, the need to better understand the mechanism of joint stabilization and new evidences addressing this mechanism remains. An assumption exists that individuals submitted to surgical procedures should behave as normal individuals, since the neoligament is seated on an appropriate isometric point, and the graft has already undergone maturation phase. However, we cannot yet explain why, even after reconstruction, there are some individuals that can't get back to the same pre-injury level of activity.

CONCLUSION

The results found here show that non-adapted male individuals' inability to return to the same pre-injury functional level cannot be explained by residual ligament laxity, by functional performance, and by knee's flexor and extensor muscles' ability to generate effort after ligament reconstruction.

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