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ACL deficient potential copers and non-copers reveal different isokinetic quadriceps strength profiles in the early stage after injury

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Abstract

Background—Isokinetic muscle strength tests using the peak torque value is the most frequently included quadriceps muscle strength measurement for anterior cruciate ligament (ACL) injured subjects.

Aims—The purpose of this study was to investigate quadriceps muscle performance during the whole isokinetic curve in ACL deficient subjects classified as potential copers or non-copers, and investigate whether these curve profiles were associated with single-leg hop performance. We hypothesized that quadriceps muscle torque at other knee flexion angles than peak torque would give more information about quadriceps muscle strength deficits. Furthermore, we hypothesized that there would be significant torque differences between potential copers and non-copers, and a significant relationship between angle specific torque values and single-leg hop performance.

Study Design—Cross-sectional study; Level of evidence, 2

Methods—Seventy-six individuals with a complete unilateral ACL rupture within the last 3 months were included. The subjects were classified into potential copers and non-copers according to the criteria from Fitzgerald et al[12]. Isokinetic quadriceps muscle tests were performed at 60°/sec (Biodex 6000). Mean torque values were calculated for peak torque as well as for specific knee flexion angles. The one-leg hop and the 6 meter timed hop tests were included and symmetry indices were used.

Results—The peak torque value did not identify the largest quadriceps muscle strength deficit. Rather, these were established at knee flexion angles of less than 40°. There were significant differences in angle specific torque values between potential copers and non-copers ($p<0.05$). Moderate to strong associations were disclosed between angle specific torque values and single-leg hop performance, but only for non-copers ($r \geq 0.32$– 0.58).

Conclusions—Angle specific quadriceps muscle torque values of less than 40° of knee flexion provide more information on the quadriceps strength deficits after ACL injury compared to the commonly used peak torque values.

Keywords

ACL injury; isokinetic evaluation; quadriceps strength; peak torque; angle specific torque

INTRODUCTION

Quadriceps weakness is one of the main dysfunctions following anterior cruciate ligament (ACL) injury[5, 31, 36, 55]. However, the characteristics of quadriceps insufficiency have not been well described[18, 53], for the group as a whole or specified for ACL deficient subjects classified as potential copers and non-copers[12]. Isokinetic dynamometry is the predominate method for quadriceps muscle strength evaluation both in healthy individuals and after ACL injury[1, 8, 22, 27, 31, 41, 58]. The majority of studies of quadriceps muscle strength after ACL injury have used peak torque as main outcome measure[22, 41, 49]. Quadriceps peak torque represents the value of the one point during knee extension from 90-0° where the individual is able to produce the highest force[53]. Peak torque may give limited information about the muscle performance during the full selected range of motion (ROM)[16, 54]. Another established isokonetic quadriceps muscle strength parameter is work per unit, which reflects the ability of the muscle to produce force throughout the ROM[11, 16, 21, 39]. However, assessments of work also does not identify where during the ROM eventual muscle performance insufficiencies are most prominent.

Isokinetic quadriceps curves from ACL injured knees may have inherent irregularities that could be clinically relevant. Tsepis et al[53] applied a frequency domain analysis to evaluate the isokinetic performance of ACL deficient subjects. They found significant frequency content asymmetry in that there was less steadiness in the curve of the injured knees compared to the uninjured. This decreased smoothness of the time-torque curve pattern was suggested to be indicative for the level of force control[53]. The application of frequency analysis in isokinetic dynamometry is, however, still unexplored, and the implications for clinical purposes are unclear[41]. Irregularities in isokinetic curves have in a limited number of studies also been evaluated with qualitative approaches, indicating that it may be possible to detect deviations in the curve by visual inspection[2, 3]. However, the associated time-torque values are not taken into consideration with only qualitative descriptions, and solely subjective inspection of an isokinetic curve should not guide clinical decisions.

Quadriceps muscle performance is important for knee joint protection throughout the whole movement cycle[53]. Thus, it may be reasonable to describe and evaluate quadriceps torque production in detail throughout the ROM[2]. Conventional isokinetic evaluation of peak torque and work may be inadequate for this purpose, and existing approaches for curve descriptions lack the required information on torque values. Given the evident differences in ability to functionally stabilize and control the knee between ACL deficient individuals classified as potential copers and non-copers, it would be of particular interest to explore whether these dissimilarities also are reflected in their isokinetic quadriceps strength profiles. To our knowledge, no study has performed an extensive angle specific analysis of isokinetic quadriceps curve characteristics and eventual associations between such curve profiles to knee function in ACL deficient subjetcs. In this study, we propose exploration of angle specific quadriceps torque values throughout the knee extension ROM as an alternative method for generating a complete isokinetic quadriceps strength profile.

The aim of this study was: 1) To provide a detailed description of the isokinetic quadriceps strength profile for ACL deficient individuals; in general and following the classification as potential copers or non-copers. 2) To investigate if these quadriceps strength profiles are associated to performance during single-leg hop tests in a way that may enhance our clinical interpretation of isokinetic quadriceps curve characteristics after ACL injury. We hypothesized that: 1) Quadriceps muscle torque at other knee flexion angles than peak torque would give more information about quadriceps muscle strength deficits, 2) There would be angle specific torque differences between potential copers and non-copers, and 3) The relationship between angle specific torque and single-leg hop performance would differ between potential copers and non-copers.

MATERIAL AND METHODS

Subjects

Seventy-six individuals with a recent ACL injury treated at our rehabilitation clinic (Hjelp24 NIMI Ullevaal) from January 2007 to December 2008 were included in the study. Patients were considered for enrolment if they were diagnosed with a unilateral complete rupture of the ACL within the last three months. Complete tear of the ligament was confirmed by magnetic resonance imaging (MRI) and an anterior side-to-side displacement of the tibia relative to the femur of at least 3 mm measured by an instrumented knee arthrometer[56] (KT1000, Med-Metric, San Diego, California, USA). Subjects had to be between the age of 13–55 years, with an activity level prior to the incident injury at level I or II according to the criteria described by Hefti et al[14]; equivalent to regular participation in pivoting sports. Subjects were included if they had asymptomatic meniscus injury. This was defined if MRI indicated meniscus injury but subjects had no ROM deficit, no swelling and were able to hop without pain and subsequent effusion of the knee joint. Exclusion criteria were concomitant ligamentous injury, bilateral involvement, symptomatic meniscal or cartilage injury and/or fracture. All subjects were examined and judged eligible for inclusion by the same single physical therapist.

All subjects signed a written informed consent. The rights of the subjects are protected by the principles outlined in the Declaration of Helsinki, and the study was ethically approved by The National Committees for Research Ethics in Norway.

Pre-inclusion rehabilitation

All subjects underwent rehabilitation to resolve impairments before inclusion. When the clinical milestones full passive ROM, no swelling, able to walk without a limp, full active knee extension and the ability to hop on one leg without pain were met, testing was scheduled. All subjects were clinically assessed by the same physical therapist (xx) to confirm that the prerequisites for testing were met.

DATA COLLECTION

All tests were supervised by one of three physical therapists (IE, HM, IS) performing all tests in the project. The test battery included an isokinetic quadriceps muscle strength test and two single-leg hop tests. All subjects performed a standardized ten minute warm up on a cycle ergometer. To minimize risk of giving way episodes during single-leg hop testing, a peak torque quadriceps strength index of >70% for the uninjured limb was acquired. After five minutes rest, single-leg hop test were performed.

Isokinetic strength

Isokinetic quadriceps strength measurements were performed with a Biodex 6000 dynamometer (Biodex Medical Systems Inc., Shirley, New York). ROM was set from 90° flexion to full extension (0°), which is the customary ROM used for isokinetic quadriceps strength assessment[42]. The angular velocity of 60° per second (60°/sec) was used. Isokinetic testing at 60°/sec is frequently referred to as a relevant and valid measurement for quadriceps muscle performance in ACL deficient individuals[9, 15, 23, 39, 40], and has also revealed typical curve shapes in healthy individuals[3]. Low velocities will further ensure that an adequate range of the selected ROM is covered at the set velocity[9, 26]. The reliability for isokinetic muscle testing of knee extension is previously reported to be adequate[19], and intraclass correlation coefficients (ICCs) for isokinetic testing of knee extensor muscle performance at 60° have been shown to be above 90, both for healthy subjects and for subjects with ACL deficiency[19, 44, 51].

Subjects were explained the principles of isokinetic strength testing prior to the test. The regulations of the depth and height of the test chair, the side-to-side placement of the dynamometer and the length of the attachment a rm were individually adjusted. Correct alignment of the anatomical axis of the knee joint and the rotation axis of the lever arm was assured in order to verify the validity of the joint angles[52], and effects of gravity were corrected. All tests were performed first on the uninjured side. Before the test subjects performed a standardized trial session of four repetitions with submaximal effort to familiarize themselves to the equipment. After the trial session there was a standardized one minute pause before the test, which consisted of five repetitions. The exact same procedure was thereafter performed on the injured side. No verbal cues were given to the subjects from the test leader during testing other than counting from one to five.

Single-leg hop tests

Different forms of single leg hop tests have been widely used and are shown to have high validity and reliability as performance measurement outcomes for ACL deficient individuals[10, 12, 43, 50]. In this study, the one-leg hop (OLH) test and the 6-meter timed hop (6MTH) test were included[32]. The OLH and 6MTH tests represent different aspects of knee function. The OLH test is established as the most commonly used hop test for ACL deficient subjects[10, 34, 45, 54] and entails the ability to control the knee when landing after a maximum performance, thus, an assessment of functional stability[33]. The 6MTH test reflects the ability to maintain velocity during repeated hops and is the only hop test incorporated in the classification algorithm for potential copers and non-copers[12]. Both tests have shown to be reliable for ACL deficient subjects, with ICCs for limb symmetry index (LSI) values from 0.82 to 0.92[43]. A metric measurement band was taped to the floor for the measurement of hop distance of the OLH test, and a stop watch was used to manually time the 6MTH test. In the OLH test, subjects had to manage a well-balanced landing on one foot. Subjects performed one practice trial and two test trials for each of the different hops. Testing for each hop test began on the uninjured side, followed by the injured side. No brace was used during the hop tests.

ANALYSES

Raw data from the isokinetic strength tests of the uninjured and injured leg was exported from the Biodex software in ASCII format and parsed into Microsoft Office Excel 2007 (Microsoft Corporation, Redmond, Washington) through a proprietary algorithm. Each trial consisted of five full movement cycles. The first and the last full cycle was removed in order to avoid possible warm-up or fatigue effects[3, 53]. In order to focus on the extension part of each relevant cycle, cutoff for each subcycle was done at the first occurrence of directional shift in force. Torque values for selected angles were calculated as the average of these three repetitions, whereas peak torque was the single point during one of these three cycles were the highest force was produced. A numerical integration in the time dimension was performed over the vector set in order to calculate the total extension work done within our cutoff limits. Work in cycle refers to the average work performed in one extension cycle.

Torque production at the outer positions of the isokinetic curve must be interpreted with caution because there may be inertial effects close to the acceleration (start) and deceleration (end) of the movement[26, 41]. In order to reduce such errors torque values between 90−80° and 15−0° flexion were be eliminated from the analyses. Thus, torque values were included in the final analyses for 80°, 70°, 60°, 50°, 40°, 30°, 20° and 15° flexion to represent strength development throughout the ROM. Torque values were normalized from the formula torque (nm)/bodyweight (kg).

Mean torque values at all specific angles, peak torque and work in cycle were tested for normal distribution and mean differences between the injured and uninjured side computed with a paired Student’s t-test. Relative differences in torque between the injured and uninjured leg were computed from the formula 100-(injured/uninjured)*100, and mean differences between potential copers and non-copers were calculated using an independent Student’s t-test. The LSI of the OLH test and the 6MTH test were calculated from the mean of the two trials, using the formula injured/uninjured*100 for the OLH test and uninjured/injured*100 for the 6MTH test, respectively.

Pearsons Product-Moment correlation coefficients were used to assess the association between mean relative differences of torque at specific angles, peak torque and work in cycle and mean LSI from the OLH and 6MTH tests. Correlations were regarded moderate if r=.30–.50, and strong if r>.50[7, 25]. Furthermore, in order to investigate explanatory power of torque at each specific angle, peak and work in cycle, the final step of the analysis included regression analyses. Due to inherent multicolinearity both between torque values and the single-leg hop tests, simple linear regression models were computed with each of the specific torque values, peak torque and work in cycle as the independent variable and the two single-leg hop tests as the dependent variable.

Statistical Package for Social Sciences 16.0 (SPSS Inc., Chicago, Illinois) was used for all mean comparisons, correlation and regression analyses.

RESULTS

Seventy-six individuals with a unilateral ACL-rupture, 44 women and 32 men, with the mean age of 24.5 years (range 14–45) and 28.3 years (range 18–47), were included in the study. Mean time between date of injury and data collection was 60.7 (range 23–96) days. Following the criteria of Fitzgerald et al.[12]; 44 subjects were classified as potential copers and 32 subjects as non-copers. Classification as a potential coper requires ≥80 % performance on the 6MTH, a visual analogue assesment of knee function of ≥ 60 %, a score on the Knee Outcome Survey Activities of Daily Living Scale (KOS-ADLS) of ≥80 %, and no more than one episode of giving way since the index injury[12].

Peak torque was reached at a mean angle of 61° for the injured leg and 60° for the uninjured leg. There were no difference in angle of peak torque between potential copers and non-copers. Significant differences (p<0.05) were found between the absolute strength values for the injured versus the uninjured leg for torque at all the specific angles, peak torque and work in cycle for all subjects, except for potential copers at 80° knee flexion (p=0.152) (Table 1).

Mean relative strength values for potential copers and non-copers throughout the ROM showed that there were significant differences (p<0.05) in strength between the groups for all torque conditions, except at 50° knee flexion (p=0.069). Peak torque mean relative differences between the injured and the uninjured leg were 12.0 % for the group as a whole, 9.5 % for potential copers and 15.1 % for non-copers; whereas the corresponding mean relative differences in work in cycle were 12.8 %, 9.2 % and 17.4 %. The largest mean relative differences between the injured and the uninjured leg were established at knee flexion angles less than 40°, with values ranging from 14.6% to 16.0% for the group as a whole, 8.8% to 11.8% for potential copers and 18.3% to 22.6% for non-copers. The mean relative strength differences at specific angles during the ROM from 80−15° knee flexion for all subjects, potential copers and non-copers are illustrated in Figure 1.

The mean LSI of the single-legged hop tests we re 91.1% (SD = 9.67) for OLH test and 92.5% for 6MTH test (SD = 8.49). There were no significant differences in LSI between potential copers and non-copers. No significant correlations were established between strength and LSI for the OLH test or the 6MTH test for potential copers (Table 2). The moderate correlations for the group as a whole, thus, stem from the non-copers. In order to evaluate the explanatory contribution of relative mean strength performance at different conditions for non-copers, single linear regression models were computed (Table 3).

Significant R^2-values were found at 60°, 50° and 40° knee flexion, peak torque and work in cycle for the OLH test ($p<0.05$). Explanatory power for the significant conditions ranged from 13.3% for peak torque to 19.7% for 50° knee flexion. For 6MTH test, highly significant R^2-values were established for all knee flexion angles, peak torque and work in cycle ($p<0.001$) except 70° ($p<0.05$) and 80° knee flexion (NS). Explanatory values were higher for the 6MTH test than the OLH test; ranging from 14.1% for 70° knee flexion to equal or above 30% for 40°, 30°, 20° knee flexion and work in cycle.

DISCUSSION

Our hypotheses were supported by the results. ACL deficient individuals reveal an isokinetic quadriceps strength profile with the largest strength deficits for the injured leg at knee flexion angles less than 40° knee flexion. This characteristic pattern is applicable for the whole patient group, but most evident in individuals classified as non-copers. There were angle specific torque differences between potential copers and non-copers. Non-copers exhibit an undoubtedly different quadriceps strength profile than potential copers, with significant differences for all strength assessments except at 50° knee flexion ($p<0.05$). The angles that discriminate between potential copers and non-copers are those greater than 60° and less than 40° knee flexion. Peak torque measurements typically occur in the range were differences were smallest. Associations between angle specific torque and single-leg hop performance were evident only in non-copers.

Comparing relative strength values between the injured and the uninjured leg, the largest deficits were established for knee angles less than 40° knee flexion. From the interpretation of these strength profiles, the validity of the extensive use of peak torque as the only outcome measurement when evaluating quadriceps strength in ACL deficient individuals may be questioned. The ACL is biomechanically exposed for most strain when the knee is in slight flexion or full extension, combined with internal rotation and/or valgus loading[29, 37, 57]. In a recent systematic review, Shimokochi et al.[46] concluded that most ACL-injuries occur when the knee is exposed to combined motions at or near full extension. Peak torque is in our study reached at 61° for the injured and 60° for the uninjured side; which is comparable to other studies[18, 47, 49, 53]. Our findings, with significantly larger deficits at knee flexion angles less than 40°, may suggest that the point during the ROM where peak torque is reached not necessarily is the most relevant outcome for quadriceps strength assessment in subjects with ACL deficiency. The interpreation of peak torque in our study would imply that the group as a whole and those classified as potential copers would be close to or within what is regarded as normal limb symmetry with no definite muscle imbalance. However, the quadriceps deficits found at 30° to 15° knee flexion in non-copers were above 20%. These findings are enhanced by the fact that non-copers compared to potential copers are significantly weaker in mean comparisons of strength at 15° and 20° knee flexion in the injured side, but have similar strength values at the uninjured side (except at 70° knee flexion). Hence, the side-to-side differences documented in this study are not caused by increased strength in the uninjured leg, but stem from evident weakness at the injured side. The subjects included in this study have relatively small deficits in quadriceps strength in that they at mean are close to the 90 % side-to-side cut-off considered to be within normal symmetry[48]. It may be hypothesized that the characteristic isokinetic quadriceps profile described in this study may manifest itself even more clearly in ACL deficient individuals with more prominent deficits.

Few previous studies have investigated quadriceps torque curve profiles in detail. Shirakura et al.[47] investigated quadriceps torque in 30 individuals classified as having chronic ACL deficiency at 60°/sec at 9° intervals throughout the extension curve from 81° to 9° knee flexion. They found significant differences in quadriceps torque values between the injured and uninjured side at angles less than 54° knee flexion. However, peak torque values in the injured knee were comparable both to the uninjured knee and a group of controls. This is in line with our results; since we found evident asymmetry at angles below 40° knee flexion but less asymmetry at peak torque. Bryant et al.[6] computed average quadriceps torque at 10° intervals from 80° to 10° knee flexion, and found that average torque values obtained between 70° and 20° flexion were significantly associated with The Cincinatti Knee Score (r-values 0.48–0.59). The authors argued that torque values in this area of the isokinetic curve should be emphasized in order to improve knee function. Our results suggested more specifically that it is the area between 40° and 15° knee flexion that is of particular importance, especially when addressing the subjects classified as non-copers. The curve profile characteristics established for the non-copers in our study were also in correspondence to Ikeda et al.[18]; who described a quadriceps curve pattern for about one fourth of ACL deficient subjects characterized by a sharp descending slope in the late phase of the curve towards full extension. They did, however, not classify their cohort to potential copers and non-copers, so the functional status of the subjects that were characterized by this drop in the curve is unknown.

Critique has been raised towards the use of isokinetic assessment because its lack of functionality[1, 41]. However, one argument in favor of isokinetic testing is that the open kinetic chain nature of the test allows isolation of the muscle of concern. Functional weight-bearing movements will always involve motion in adjacent joints as well as the target joint. Thus, functional assessments will reflect multi-level performance. It is, therefore, just the open chain kinetic feature of isokinetic testing that often is being criticized for non-functionality that enables specific quantification of deficits in isolated muscles[41, 53].

In most existing studies on relationship between isokinetic strength and single-leg hop test performance, peak torque has been the outcome variable for the isokinetic assessments[13, 35, 38, 54]. Different angular velocities from isokinetic assessments have been investigated[23, 35, 38, 54], but correlations between exact torque values at different knee flexion angles throughout the isokinetic curve and single-leg hop performance has not been reported in the literature.

In this study, moderate associations (r=.30–.50)[7, 25] were established between strength and hop performance when looking at the subjects as one group of ACL deficient subjects. These results are compatible to previous studies that have reported significant, but moderate correlations[23, 33, 38, 39, 54]. When the subjects are classified into potential copers and copers, however, no significant correlations were evident for those classified as potential copers. For non-copers, moderate correlations were established for knee flexion angles 80°−40°, peak torque and work in cycle for the OLH test, whereas the 6MTH test was strongly correlated (r>.50)[7, 25] to knee flexion angles from 50°−20°, peak torque and total work, and moderately correlated to knee flexion angles 70°, 60° and 15°. The subsequent regression analysis for non-copers showed that quadriceps torque from 40°−20° and work in cycle had the highest explanatory power for the 6MTH test. Values for each of these conditions exceeded 30%. For the OLH test, significant, but lower explanatory power was found for 60°− 40° knee flexion and peak torque. Hence, the characteristic iskonetic quadriceps profile characterizing strength deficits in non-copers was best reflected in the 6MTH test.

The ability to perform a single-leg hop is dependent on quadriceps strength, since a consequence of strength loss is a reduced ability to both absorb and generate force during activity[30]. However, single-leg hop tests also reflect neuromuscular control, power, joint function and ROM, as well as the self-esteem and confidence of the subjects[28, 43]. Providing a detailed description of the quadriceps strength profile in our subjects revealed information on functionality in the OLH and 6MTH tests that would have been disclosed if only peak torque had been included; especially for the 6MTH test. Our results further suggest that classification into potential copers and non-copers may divulge clinically important differences both in the isokinetic quadriceps strength profiles and their association to knee function that would be unapparent if the individuals had been regarded as one homogeneous group of ACL deficient individuals.

The classification algorithm for identifying potential copers and non-copers include several functional and clinical variables that combined indicate the leven of neuromuscular function and ability to stabilize the knee during activity[17]. Isokinetic quadriceps strength is not incorporated in the classification algorithm[12]. Still, our results signify that the isokinetic quadriceps strength profile of ACL deficient subjects reflects the classification; in that those revealing a curve with ascending side-to-side differences between the injured and uninjured leg from 40° knee flexion towards full extension are more likely to be non-copers. Our study may contribute to disclose more specifically the nature of these quadriceps muscle performance deficits. In addition, previous studies considering the classification algorithm for ACL deficient individuals have been limited in explaining the underlying factors that may contribute to the differences in dynamic knee stability observed between potential copers and non-copers[17]. The deviant characteristics of the isokinetic quadriceps strength profiles in potential copers and non-copers may add to our understanding of differences in stabilization strategies. From our results we suggest that angle specific torque values should be incorporated in evaluation of isokinetic quadriceps strength assesments in addition to peak torque and work, and also be considered as a supplement to single-leg hop tests in order to better characterize potential copers and non-copers. Future studies should outline how the identified quadriceps curve profiles are adjusting as a response to specific rehabilitation, or whether they are persistent over time. If the latter is the case, advising non-copers to return to high-level activity based on assessments of peak torque alone could be imprudent.

Limitations

The inclusion criteria for this study entail that only individuals with an isolated ACL injury, who were able to perform both isokinetic dynamometry and single-legged hop tests without pain, are represented. Hence, the results can not be generalized to ACL deficient subjects with concomitant knee injuries that involve the symptoms pain or reduced ROM.

No control group of uninjured subjects was included in this study. Even though the of the uninjured leg as control is an established approach when evaluating deficits after ACL injury[4, 15, 38], recent studies have suggested that neuromuscular dysfunction and quadriceps strength loss after ACL injury also affects the uninjured side[20, 24, 36]. Including a control group of uninjured subjects could therefore enhanced our interpretation of the isokinetic quadriceps strength profiles of the ACL deficient knees.

CONCLUSIONS

Isokinetic curve profiles based on angle specific torque values provide more information on quadriceps muscle performance after ACL injury than the established use of peak torque values alone. Quadriceps deficits are in general more severe at knee flexion angles less than 40°, and this characteristic pattern is even more evident for individuals classified as non-copers. The curve profiles are also reflected in single-hop performance, in particular when associated to the 6 meter timed hop test. Implementing isokinetic curve profiles in the assessment of ACL deficient patients i n addition to established measurements may enhance understanding of quadriceps deficits, and be an important tool for more adequate evaluation of isokinetic quadriceps strength development during the rehabilitation process.

Clinical relevance

Interpretation of the isokinetic curve profiles seem to be of clinical importance for the evaluation of quadriceps muscle performance after ACL injury.

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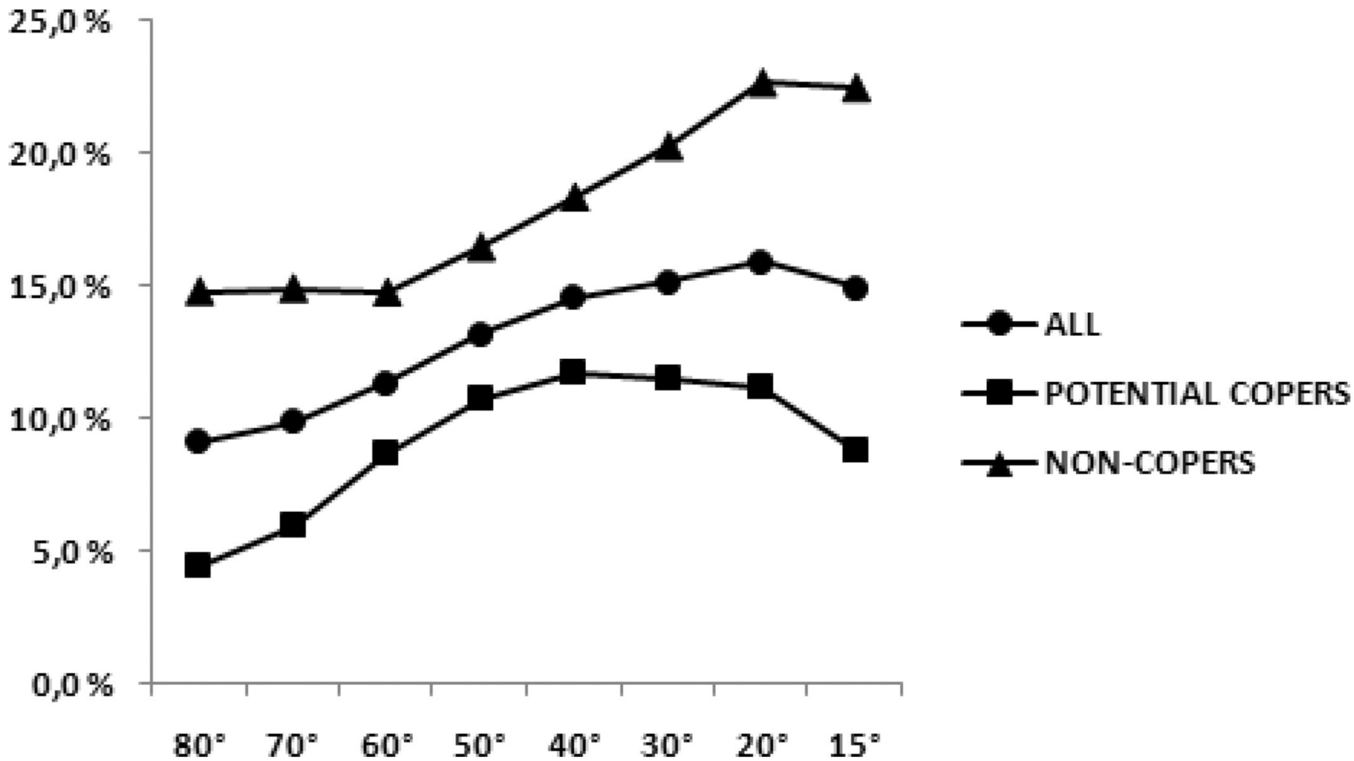

Figure 1. Relative mean strength differences between the injured and the uninjured leg throughout the knee extension ROM (80-15° knee flexion angle)
Legend x-axis: KNEE FLEXION ANGLE (°)
Legend y-axis: RELATIVE STRENGTH DIFFERENCES (%)

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Table 1

Mean absolute strength differences between the injured and the uninjured leg at specific angles, peak torque and work in cycle

KNEE FLEXION ANGLE	TORQUE INJ (N-M/BW)	TORQUE UNINJ (N-M/BW)	REL DIFF (%)	MEAN DIFF/SD	P-VALUE MEAN DIFF
ALL SUBJECTS (N=76)					
80° knee flexion	155.3	170.9	9.1	15.5 (34.5)	<.001
70° knee flexion	202.4	224.7	9.9	22.3 (36.5)	<.001
60° knee flexion	212.4	239.6	11.4	27.2 (35.3)	<.001
50° knee flexion	196.8	226.8	13.2	29.9 (33.9)	<.001
40° knee flexion	165.8	194.1	14.6	28.3 (28.3)	<.001
30° knee flexion	131.8	155.4	15.2	23.6 (24.6)	<.001
20° knee flexion	95.9	114.1	16.0	18.2 (21.4)	<.001
15° knee flexion	78.5	92.3	15.0	13.8 (19.2)	<.001
Peak torque	228.4	259.4	12.0	31.0 (31.6)	<.001
Work in cycle	209.1	239.7	12.8	30.6 (32.3)	<.001
POTENTIAL COPERS (N=44)					
80° knee flexion	155.3	162.5	4.4	7.2 (32.5)	.152
70° knee flexion	202.5	215.3	5.9	12.8 (35.1)	.020
60° knee flexion	211.4	231.5	8.7	20.1 (34.5)	<.001
50° knee flexion	197.4	221.1	10.7	23.8 (33.8)	<.001
40° knee flexion	168.9	191.4	11.8	22.5 (27.6)	<.001
30° knee flexion	136.9	154.7	11.5	17.8 (22.9)	<.001
20° knee flexion	101.8	114.6	11.2	12.8 (19.6)	<.001
15° knee flexion	84.1	92.2	8.8	8.9 (18.1)	.002
Peak torque	228.1	252.1	9.5	24.0 (31.4)	<.001
Work in cycle	213.3	234.8	9.2	21.6 (29.8)	<.001
NON-COPERS (N=32)					
80° knee flexion	155.4	182.4	14.8	27.0 (34.2)	<.001
70° knee flexion	202.2	237.6	14.9	35.4 (34.8)	<.001
60° knee flexion	213.8	250.8	14.8	36.9 (34.6)	<.001

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KNEE FLEXION ANGLE	TORQUE INJ (N-M/BW)	TORQUE UNINJ (N-M/BW)	REL DIFF (%)	MEAN DIFF/SD	P-VALUE MEAN DIFF
50° knee flexion	195.9	234.5	16.5	38.5 (32.4)	<.001
40° knee flexion	161.6	197.9	18.3	36.3 (27.7)	<.001
30° knee flexion	124.8	156.5	20.3	31.6 (24.9)	<.001
20° knee flexion	87.8	113.5	22.6	25.7 (21.8)	<.001
15° knee flexion	70.8	91.3	22.5	20.6 (18.8)	<.001
Peak torque	228.6	269.3	15.1	40.6 (29.8)	<.001
Work in cycle	203.4	246.3	17.4	42.9 (32.3)	<.001

INJ = Injured leg
UNINJ= Uninjured leg
N-M= Newton meter
BW = Body weight
REL DIFF = Percentage mean differences
MEAN DIFF = Mean difference absolute values
SD = Standard deviation

Table 2

Correlation coefficients between mean relative strength differences and leg symmetry index from the one-leg hop test and the 6-meter timed hop test

ALL SUBJECTS (N=76)

	DIFF 80°	**DIFF 70°**	**DIFF 60°**	**DIFF 50°**	**DIFF 40°**	**DIFF 30°**	**DIFF 20°**	**DIFF 15°**	**DIFF PEAK**	**DIFF WORK**
OLH	−.268*	−.282*	−.315**	−.326**	−.265*	−.205	−.156	−.164	−.287*	−.335**
6MTH	−.129	−.193	−.304**	−.354**	−.393**	−.442**	−.448**	−.409**	−.297**	−.386**

POTENTIAL COPERS (N=44)

	DIFF 80°	DIFF 70°	DIFF 60°	DIFF 50°	DIFF 40°	DIFF 30°	DIFF 20°	DIFF 15°	DIFF PEAK	DIFF WORK
OLH	−.233	−.209	−.222	−.178	−.063	−.016	.069	.074	−.194	−.165
6MTH	.042	.088	−.024	−.125	−.092	−.146	−.191	−.206	.021	−.065

NON-COPERS (N = 32)

	DIFF 80°	DIFF 70°	DIFF 60°	DIFF 50°	DIFF 40°	DIFF 30°	DIFF 20°	DIFF 15°	DIFF PEAK	DIFF WORK
OLH	−.325	−.348	−.379*	−.444*	−.393*	−.275	−.238	−.269	−.365*	−.430*
6MTH	−.231	−.375*	−.476**	−.511**	−.580**	−.574**	−.552**	−.496**	−.537**	−.548**

* p<.05,

** p<.001

DIFF = Relative difference between injured/uninjured
NUMBER° = Torque at specific knee flexion angles
PEAK = Peak torque
WORK = Work in cycle
OLH = One-leg hop test
6MTH = 6-meter timed hop test

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Table 3

Single linear regression models for mean relative strength differences for non-copers with the one-leg hop test and the 6-meter timed hop test leg symmetry index as dependent variables

NON-COPERS (N = 32)

		DIFF 80°	DIFF 70°	DIFF 60°	DIFF 50°	DIFF 40°	DIFF 30°	DIFF 20°	DIFF 15°	DIFF PEAK	DIFF WORK
OLH	**R^2**	.106	.121	.143*	.197*	.155*	.076	.056	.073	.133*	.185*
	B	−.325	−.348	−.379	−.444	−.393	−.300	−.238	−.260	−.365	−.430
6MTH	**R^2**	.053	.141*	.227**	.261**	.336**	.329**	.305**	.246**	.288**	.300**
	B	−.231	−.375	−.476	−.511	−.580	−.574	−.552	−.496	−.537	−.548

* p<.05,

** p<.001

DIFF = Relative difference between injured/uninjured
NUMBER° = Torque at specific knee flexion angles
PEAK = Peak torque
WORK = Work in cycle
OLH = One-leg hop test
6MTH =6-meter timed hop test
R^2 = R square of the regression
B = Beta