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PROJECT TITLE: Long-term follow-up of ACL reconstruction: Insight into the natural history of altered biomechanics of the knee joint.

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SUMMARY:

The goal of ACL reconstruction is to restore stability to the knee joint and prevent the onset of osteoarthritis. Little is known of the long-term natural history of a knee joint that has undergone ACL reconstruction. Our study set out to investigate changes in the knee joint following ACL reconstruction. This retrospective study examined 68 participants who had received a semitendinosus/gracilis autograft ACL reconstruction a mean 14.6 years prior. Clinical evaluation involved radiographic analysis, IKDC knee examination form, instrumented laxity testing with the KT-1000 arthrometer, Tegner Activity Scale, Lysholm Knee Score, ACL QOL outcome questionnaire, and knee flexor/extensor strength testing using the Biodex III dynamometer. We observed increased incidence of OA in the reconstructed knee compared to the contralateral knee, especially in the medial compartment. Tegner Activity Score was reduced from the pre-injury level. We also report a significant decrease in knee extensor strength in the reconstructed knee compared to the contralateral knee. In conclusion, the semitendinosus/gracilis hamstring autograft showed an increased incidence of OA compared to contralateral knee, but a very good clinical outcome in the majority of patients.

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Introduction:

The anterior cruciate ligament (ACL) is one of the primary stabilizing structures of the knee joint.[1] An intact ACL is critical for resisting anterior translation of the tibia on the femur and conferring pivotal stability while engaged in sport.[2] Contact and pivoting sports such as soccer, football, and hockey have high rates of knee injury, thus the ACL has become the most frequently ruptured ligament in the knee.[3] It is estimated that 100,000 ACL reconstructions done annually in the United States [4] or about 10, 000 in Canada. Young women are 3-5 times more likely to sustain an ACL rupture, however, since young males tend to participate in more high risk sports, the absolute number of ACL reconstructions in males is greater than females.[3,5,6]

A detailed natural history of the knee joint following ACL rupture has not been characterized by a well-designed prospective cohort study.[2] The immediate problems (functional instability) and long term complications of uncorrected ACL rupture are however well understood.[1,2]

Rupture of the ACL changes the kinematics of the knee joint and may cause associated injuries such as damage to menisci, articular cartilage, or other ligaments.[7] If an ACL deficient knee remains untreated, the joint is more likely to suffer secondary meniscal injury that may ultimately require a menisectomy.[8] Conservative treatment of ACL rupture such as early modification of activity, and neuromuscular rehabilitation can result in good knee function and an acceptable activity level in a large number of patients.[8] However, despite the reasonable success with conservative treatment, some studies suggest that upwards of 2/3 of patients will require surgical treatment in the long term.[8] The risk for developing degenerative joint disease post ACL rupture has been described as 40-80% higher than unaffected individuals. Thus surgical intervention to restore proper kinematics of the knee joint sets out to prevent joint instability, and reduce the likelihood of developing osteoarthritis.[7]

Review of Literature:

Anatomy of the Knee Joint:

The knee joint allows for flexion and extension, but is more than a simple hinge joint demonstrating a rotational component.[2] Three bones articulate at the knee joint, the femur, tibia, and patella. Both the tibiofemoral (TF) and patellofemoral (PF) joints are contained within a common capsule. Articular cartilage covers both the medial and lateral condyles of the femur, the medial and lateral condyles of the tibia, and the inner surface of the patella. The medial and lateral sides of the knee are primarily stabilized by the medial and lateral collateral ligaments respectively. The medial collateral ligament (MCL) is the broader of the two ligaments and is continuous with a semilunar cartilaginous cushion separating the medial condyle of the femur from the medial condyle of the tibia. This structure is known as the medial meniscus. The lateral collateral ligament (LCL) is not attached to the lateral meniscus; it instead spans from the lateral femoral epicondyle to the head of the fibula. The MCL provides valgus stability to the knee whereas the LCL provides the knee with varus stability.[9]

The cruciate ligaments are the primary stabilizers of the knee in the anterior and posterior directions. These ligaments are important in keeping the articular surfaces of the femur and tibia in contact, and stabilizing the knee in the sagittal plane. The PCL restricts posterior translation of the tibia on the femur while the ACL restricts anterior translation of the tibia on the femur.[9]

Mechanism of Injury

ACL rupture has been reported as frequently as 1:3500 annually amongst the general population.[3] This incidence increases greatly when the population is in their second or third decade and heavily involved in sport.[3] Although athletes are very likely to sustain an ACL rupture while playing contact sports, a considerable number occur in non-contact sports. Some studies report that up to 72% of ACL ruptures occur by a non-contact mechanism.[10] Most non-contact injuries are sustained at foot strike with the knee is close to full extension.[10]

Clinical Tests and Diagnosis of ACL Injury

Since the ACL is the most common repairable structure injured in the knee, there is a need for health care providers to recognize the signs and symptoms of ACL rupture in the clinical setting.[1] There are several clinical exams that have been validated in the literature, but three exams are used most often because of the ease of administration and high sensitivity and specificity: the Lachman test, Pivot Shift test, and Anterior Drawer test.[1,11]

Benjaminse and colleagues describe the Lachman test as the most valid test to determine ACL tears, with a pooled sensitivity of 85% and a pooled specificity of 94%.[1] The pivot shift test is very specific at 98%, but has a poor sensitivity of 24%.[1] The anterior drawer test shows good sensitivity and specificity in chronic conditions, respectively 92% and 91%, but not in acute conditions.[1] The authors conclude by recommending that the Lachman Test is performed first when suspecting ACL injury.[1] The pivot shift test has a low sensitivity; however, due to the high specificity of the test; the authors still recommend this assessment.[1]

Definitive diagnosis of an ACL rupture often comes from a combination of clinical exam and imaging.[12] Conventional radiographs are somewhat limited in the diagnosis of ACL injury as the ACL itself does not appear on film. An ACL rupture however can be inferred by anterior tibial spinal avulsion, and exaggeration of the normal indentation in the middle third of the lateral femoral condyle.[12] The advent of MRI has greatly expanded the role of radiology in the diagnosis of acute knee injuries.[13,14] The MRI has now become the gold standard for non-invasive diagnosis of ACL injury, with reported accuracy rates of 90-100%.[15] MRI, however, remains an expensive diagnostic test and should be utilized for more complicated or confusing cases.[15]

Treatment Options:

There are two major options for patients with an ACL deficient knee. Several factors guide the decision on whether to undergo surgical reconstruction or conservative treatment; activity level, high risk lifestyle, and overall function of the deficient knee.[2] Typically surgical reconstruction is reserved for those at high risk including the following; athletes, heavy laborers, those with associated meniscal tears, or patients with repeated giving way episodes.[2] A conservative approach on the other hand assumes that the ACL deficient knee functions reasonably well under certain circumstances.[2]

Though the best technique and graft type are still yet to be determined, the quadrupled hamstring autograft is popular in Canada due to high rates of satisfaction on subjective results, thigh strength, and significantly lower anterior knee pain than the Bone-Patellar Tendon-Bone graft (BPTB).[16] More specifically, the majority of Canadian surgeons prefer using a single incision, with a trans-tibial approach to a single femoral tunnel, and a doubled semitendinosus/gracilis autograft.[16]

Subjective Knee Assessment:

There are several methods to assess outcomes after an ACL reconstruction that include questionnaires that focus on the patient's quality of life, activity level pre and post reconstruction, and symptomatic quantification.

The subjective outcome measure for chronic anterior cruciate ligament deficiency measures quality of life (QOL) in patients with chronic anterior cruciate ligament deficiency. This disease-specific quality of life measure is a 32-item questionnaire using a 100-mm visual analog scale. Scores range from 0 to a maximum score of 100. The questionnaire was designed to be able to distinguish between patients who require surgery from those who can be treated non-operatively.[17]

The Tegner activity score is a simple questionnaire used to assess the individual's activity level at baseline and at the long-term follow-up.[18] A grade of 10 represents participation in high demanding knee-activities like professional soccer or American football, while a 0 represents sick-leave or disability pension.[18]

The patient-administered Lysholm score is used to document subjective knee symptoms.[19] In the Lysholm score, the highest obtainable score is 100. If the patient has impaired knee function with locking, instability, pain, swelling, limp, walking aid, decreased ability to climb stairs and squat, the score ranges from 0-100.[19]

Strength Testing:

Isokinetic strength testing of hamstring and quadriceps muscle groups has traditionally been accomplished with hand-held dynamometers or automated strength testing apparatuses such as the Biodex or Cybex.[20,21] Several studies have reported varying results with regards to mechanism of hamstring regeneration following ACL reconstruction, and associated muscle flexion strength; therefore, this is an ongoing field of research.[20-22]

Hypothesis and Aims

The objectives of this retrospective long-term follow-up study are as follows: (1) to determine if ACL reconstructed knees with hamstring tendons have a greater incidence of degenerative changes compared to the control knee, (2) to determine if there is an association between patient quality of life and the incidence and severity of degenerative changes in the ACL reconstructed knee, (3) to determine any strength deficits with the flexor/extensors of the knee, and (4) to identify risk factors that may predispose individuals to long-term degenerative changes of the knee joint including age, gender, BMI, time to surgery, secondary pathology, activity level, smoking status, WCB status, and medical history.

We hypothesized that there will not be a greater incidence of degenerative changes in the reconstructed knee compared to the control knee. We also hypothesized that there will be no correlation between patient quality of life and severity of degenerative knee changes, and no significant differences in the flexor or extensor strength between the reconstructed knee and contralateral knee.

Methods:

Between 1992 and 1998, 334 patients received an ACL reconstruction with a quadrupled semitendinosus/gracilis (hamstring) tendon autograft and were screened for this study. Of the sample pool, patients were excluded only if there was no current contact information or they had received previous knee surgeries to either the index or control knee other than arthroscopy. After eligibility was met participants were contacted by telephone to request participation. Informed consent for this study was obtained from all participants and was approved by the University of Manitoba Biomedical Research Ethics Board.

Radiographic Assessment:

Radiographic assessment of the knee joint was undertaken to assess the incidence of degenerative changes in the joint. Bilateral antero-posterior lateral notch films of both knees of the participants were reviewed by a radiology resident, and confirmed by an experienced radiologist blinded to the clinical details. The presence of joint space narrowing and osteophytes in the TF and PF joint were graded on a 4-point Kellgren-Lawrence scale (range 0–4, 0 for no evidence of JSN or bony change).

Clinical and Subjective Assessment:

Height and weight were recorded for each participant before an IKDC exam (International Knee Documentation Committee) was performed. Sagittal knee laxity was examined with the Lachman Test, Anterior Drawer Test, and Pivot Shift Test. The Lachman test was performed both with and without the use of the KT-1000 arthrometer and graded according to the IKDC ligament evaluation form with Lachman grade 0 as <3mm, grade 1 as 3-5mm, grade 2 as 6-10mm and grade 3 as >10mm in comparison to the uninjured side. The Pivot Shift Test was graded as 0 (negative), 1 (glide), 2 (clunk) and 3 (gross). The instrumented knee testing was accomplished with the KT-1000 arthrometer (MED metric Corp., San Diego, California, USA) using the manual maximum (MM) test difference between the injured and non-injured knee. The IKDC examination also assessed the knees of the participant for alignment, patella position, a thorough ligament and compartment exam, a functional test consisting of a one leg hop measured as a percentage of the opposite side, and deficits in range of motion (both active and passive). Range of motion of the index and the contralateral knee was measured with a goniometer.

The participants completed a demographic form. Knee pain and overall perceived knee function was categorized on a 100-mm visual analog scale. Information was also collected with regards to age, gender, BMI, sports played, occupation, WCB status, medical history, and smoking status. The Tegner score, Lysholm Score and ACL QOL questionnaire were administered to participants prior to clinical examination and strength testing.[17-19]

Strength Testing:

To evaluate any strength differences between reconstructed and control limb, a Biodex III Isokinetic Dynamometer was used (Biodex Medical Systems, Shirley, NY) to perform knee concentric flexion and extension movements. Maximum peak torque for both hamstrings and quadriceps muscle groups were assessed. Measurements were taken at 60, 150, and $240°\cdot s^{-1}$.

Participants were seated and secured in the chair. The knee-attachment device was secured to the leg so that the inferior border of the pad was placed on the superior border of the medial malleolus. The limb to be tested first was randomized and the range-of-motion limits were then determined and set. The starting position was 90° of knee flexion, and the endpoint was 0° of full knee extension. Once the subject was seated and secured, instructions were given on the testing process. The first trial was a warm-up trial and the participant was instructed to use approximately 75% of their total power. The trial consisted of 3 repetitions at $60°\cdot s^{-1}$, 3 repetitions at $150°\cdot s^{-1}$, and 3 repetitions at $240°\cdot s^{-1}$, with a 20 second rest period between velocities. After a 2 minute rest period, the participant was instructed to use 100% effort for the actual test. There was then a 2-minute rest period while the machine was set up for the contralateral leg, at which point testing was identical to the previous limb.

Data analysis

A set of descriptive statistics was organized for the demographical information. Chi-squared analyses were performed to evaluate the differences between participants' reconstructed and non-reconstructed knees with regards to the Kellgren-Lawrence rating, as well as for medial and lateral joint line narrowing. Repeated measures t-tests were used to compare knee laxity as measured using the KT-1000, and before and current Tegner scores. A repeated measures ANOVA was performed to compare reconstructed and non-reconstructed knee flexion and extension strength at the three velocities measured. Linear regression was performed to determine the contribution of potentially relevant variables in predicting Kellgren-Lawrence grade in the reconstructed knee: present age, age at time of surgery, height, weight, BMI, gender, and medial and lateral meniscal damage at the time of surgery. A correlation was also conducted to identify the association between the presence or absence of ACL reconstruction and OA grade. All statistical tests were considered significant at alpha equal to 0.05. Analyses were performed using SPSS 16.0 (IBM SPSS, Atlanta GA).

Results

Demographics

Of 334 consecutive patients who underwent ACL reconstruction between 1992 and 1998, 173 were considered eligible of which 68 consented to the study (Figure 1). Demographic information is presented in Table 2. The mean age (SD) of participants at the time of their initial surgery was 31.2 (9.1) years and at the time of follow-up was 45.8 (9.2) years with a mean number of years since surgery of 14.6 (1.9). Sixty-three percent of participants were male, 37% female. The average BMI at the time of recent follow-up was 28.5 (4.7).

Forty-six percent (31/68) of participants underwent reconstruction on their right knee and 54% on the left. Seven percent (5/68) of participants had to undergo a subsequent reconstruction of the same knee while an additional six percent (4/68) had their ACL reconstructed on the leg opposite to their initial injury.

Radiological findings

The frequency distribution of Kellgren-Lawrence grades for reconstructed and non-reconstructed knees of participants is presented in Figure 2. Comparing side-to-side, a significant difference was found with reconstructed knees presenting with more prevalent and severe arthritic changes than the contralateral side ($p<0.01$). With respect to joint narrowing, patients' reconstructed knees had significantly greater incidence and severity of medial joint line narrowing than on their non-reconstructed side ($p<0.045$; Figure 3). There was no significant difference between sides with respect to lateral joint narrowing ($p=0.2443$; Figure 3). On the reconstructed side, medial joint space narrowing was significantly more prevalent than lateral ($p=0.008$); however, on the non-reconstructed side, there was no difference in the rate of medial versus lateral joint space narrowing.

Clinical and Subjective Assessment:

IKDC clinical assessment scores are presented in Figure 4. Sixty-five percent (44/68) of participants attained a Grade B or nearly normal knee function. Mean ligament laxity was 7.18 mm (2.7) for the reconstructed side and 6.16 mm (1.8) for the non-reconstructed side. On paired comparisons, laxity was found to be statistically greater on the ACL reconstructed side than the non-reconstructed side ($p=0.016$).

Mean (SD) Lysholm and ACL-QOL scores were 75.8% (16.4) and 67.4% (24.0), respectively. Participants reported a significant drop in activity level based on the Tegner Activity Scale ($p<0.001$; Figure 6). The median score before the injury was 7 (min-max = 3-10) and the median current score was 5 (min-max = 1-9). Patients were also asked to indicate their type of sporting activity. Twenty-three percent (15/64) of participants are involved in light sports, 19% (12/64) in moderate, 1% (1/64) in moderate and light, and 5% (3/64) in moderate and contact sports. Fifty-two percent (33/64) were not involved in any sports.

Knee flexor and extensor strength

Mean (SD) side-to-side knee flexion and extension strength is presented in Figure 5. A significant difference was found in extension strength between the reconstructed and non-reconstructed knees across all velocities ($p=0.008$). Strength was consistently higher in the knee that was not reconstructed. Conversely, there were no differences between participants' reconstructed and non-reconstructed knees with respect to knee flexion strength ($p=0.139$). There was a significant relationship between both knee flexion and extension strength and velocity, with strength decreasing with increasing contraction velocity ($p<0.001$ for both comparisons). No side-velocity interaction effects were identified for either flexion or extension ($p=0.275$ and $p=0.098$, respectively).

Factors related to degenerative changes

Of all the potentially relevant variables included in the regression analysis to predict Kellgren-Lawrence grade in the reconstructed knee, medial meniscal surgery (repair or partial menisectomy) was the only variable found to be statistically significant ($p=0.011$). The presence or absence of ACL reconstruction was found to be significantly correlated with Kellgren-Lawrence grade of the knee ($r=0.253$; $p=0.005$).

Discussion

A long-term ACL follow-up study by Mihelic and colleagues showed that there were significantly higher rates of osteoarthritis (OA) in conservatively treated patients over reconstructed patients.[24] Whether OA is more prominent in the reconstructed knee compared to the non-reconstructed knee has so far been unclear. The population in our study provided insight into the long-term development of osteoarthritis following ACL reconstruction. When comparing side-to-side we found that the reconstructed knee presented with a greater incidence and more severe degenerative changes than the contralateral side.

An ultra-long-term follow-up using BPTB autografts by Pernin and colleagues described an increasing trend towards severe OA in the reconstructed knee from 11.5 years post reconstruction to 24.5 years post reconstruction.[25] BPTB autografts however, have shown higher rates of OA development than hamstring autografts.[26] Whether degeneration of the reconstructed knee in our patients will continue is still unclear. Interestingly, when looking at what aspect of the knee joint is most severely affected we noted that there was a significantly greater incidence and severity of medial joint space narrowing in the reconstructed knee compared to the non-reconstructed knee. This side-to-side difference was not seen with respect to the lateral compartment. This was investigated further noting that medial joint space narrowing was significantly more prevalent than lateral narrowing within the same knee. One hypothesis explaining a high incidence of medial joint space narrowing is partial medial menisectomy or repair at time of surgery. Medial menisectomy has been demonstrated several times in the literature as a risk factor for developing knee OA.[24-28] A regression analysis in our study of all the possible variables that may affect the Kellgren-Lawrence score in our study demonstrated that medial meniscal repair or partial menisectomy at time of surgery was indeed significant.

The IKDC assessment of the participants in this study showed excellent clinical outcomes. Seventy-six percent of participants attained an IKDC Grade B or better which correlates with a normal or nearly normal knee. Several studies have performed the IKDC ligament exam at long-term follow-up. For the most part these studies have also presented good clinical outcomes and similar results for laxity.[24-27,29-33] With instrumented laxity testing, however, there was greater laxity on the reconstructed knee than the non-reconstructed knee. This side-to-side difference in laxity is in agreement with previous studies using BPTB autografts, fresh frozen allografts and hamstring autografts.[31,32] It is important to note though that the mean (SD) difference in KT-1000 measured laxity between sides was only 1.0 mm (3.2). The recommended lower limitation for the instrument is 2-3 mm, thus the increased laxity noted in the reconstructed leg should not be considered clinically significant.[23]

The mean scores for the Lysholm and ACL-QOL subjective knee scores indicated that patients were doing well. The Lysholm scores in this study (75.8%) mirror similar long-term follow-up studies, however, are somewhat lower than other reports in the literature. Mean Lysholm scores of 84.3 have been reported by Mihelic and colleagues, in a 17-20 year follow-up study after BPTB autograft reconstruction.[24] A study by Almqvist and colleagues reported relatively high Lysholm scores (median = 95) for 55 participants that had undergone an allograft reconstruction 10 years earlier.[30] Another study, by Moller and colleagues, reported high Lysholm scores {mean = 90 (40-100)} at an 11.5 year follow-up of BPTB reconstruction.[34] The higher scores reported by these studies may be related to many factors. Lysholm scores may have been related to the shorter follow-up time seen in these two studies, or the subjective nature of the test itself. To the best of our knowledge ACL-QOL scores have not been included in the literature for any long-term ACL follow-up studies. The results we reported may be the first of their kind for such a study.

The results of our study reported a significant drop in activity level based on the Tegner Activity Scale. Several studies with similar populations and time to follow-up have also reported a drop of 1-2 levels on the Tegner Activity Scale.[7,24,30,35] It was noted that only 5% of our population continued to engage in moderate or contact sports, while 43% of participants engaged in light or moderate activities, and 52 % did not participate in any sport. Whether the decrease in Tegner score is related to a decrease in knee function or just a factor of age and change in lifestyle is yet to be determined.[36]

Knee flexor/extensor strength testing in this study provided some interesting results. As semitendinosus and gracilis are harvested to use as a graft, one would expect to see a deficit in hamstring strength in the reconstructed knee. This was not evident. A possible explanation for this is the ability of the hamstring tendons to grow back into their original configuration which is an ongoing field of research.[37] Traditionally, strength testing studies have taken place only a couple of years post reconstruction. Knee flexor/extensor strength data from long-term follow-up studies are limited. A study by Heimstra and colleagues from 2007 demonstrates a recovery of 90% of knee extensor strength compared to the uninjured limb after at least one year post surgery. The knee flexor strength did not recover to a normal level.[38] Interestingly, Heimstra also pointed out that when compared to a control group, the ACL reconstructed group demonstrated strength deficits in both reconstructed and uninjured limb.[38] However, results from that study were approximately one year after surgery and a full recovery may not have been achieved. As for what is to be expected in the long-term, Nakata and colleagues found that extension and flexion were 90% and 92% of the opposite side, respectively, at 60/sec using the Biodex II system. Interestingly, Nakata and colleagues used Tibialis Anterior allografts and demonstrated flexor deficits while our study was based on hamstring autografts and showed no strength loss in knee flexion. The mechanism behind this phenomenon remains unclear.

By nature, retrospective studies have inherent biases due to study design. Selection bias caused by examining only participants that are willing to return, and/or that our study team was able to contact may have skewed results. If we had been able to retrieve contact information for more of the study population and had consented them it would have strengthened the study as well. A properly designed prospective study would have achieved stronger outcomes; however this study type was not a possibility.

Conclusion:

This long-term follow-up of patients that had undergone ACL reconstruction a mean of 14.6 years ago, demonstrated that there is increasing incidence of medial compartment OA in the reconstructed knee in comparison to the contralateral knee. Activity levels and subjective evaluation were decreased but IKDC scores for the majority of patients were in the normal or nearly normal category. An unexpected finding was that extensor strength was significantly decreased in the reconstructed knee when compared the contralateral knee. Despite the increasing incidence of OA and lower than reported subjective scores, patients have very good clinical results. Semitendinosus / Gracilis autograft ACL reconstruction should be a highly recommended procedure for those looking for excellent long-term outcomes.

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Robert Gourlay

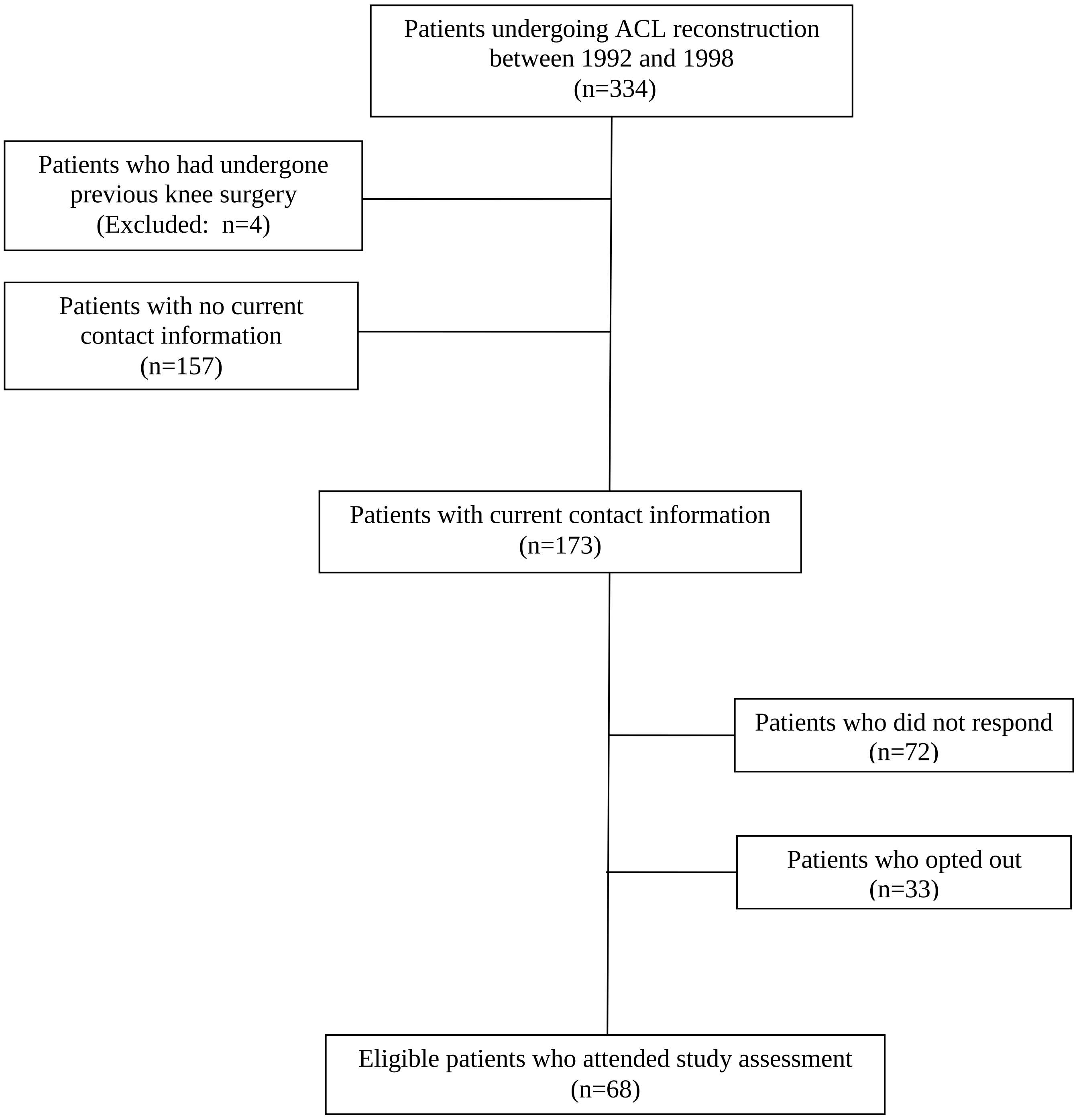

Table 1. Summary of demographic informations and subjective outcomes.

	N	Mean	SD	Min	Max
Age at sx (yrs)	68	31.2	9.1	15	58
Present age (yrs)	68	45.8	9.2	29	71
Yrs since sx (yrs)	68	14.6	1.9	12	19
Height (m)	66	1.73	0.09	1.55	1.92
Weight (kg)	66	86.4	18.5	45.0	129.5
BMI	66	28.5	4.7	18.7	40.6

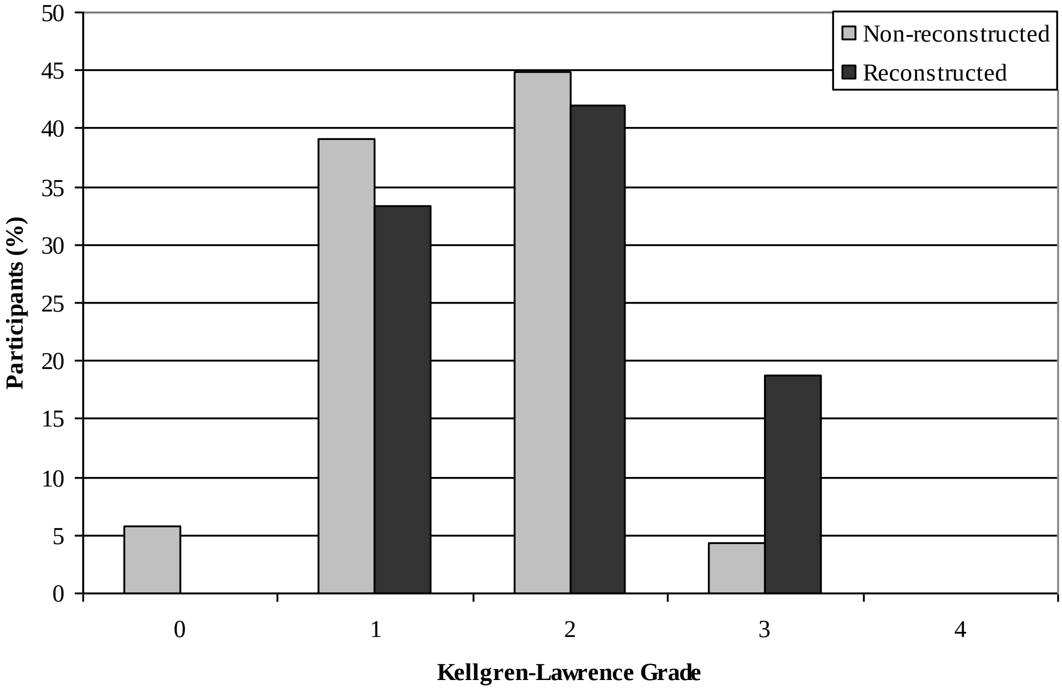

Figure 2. Classification of knee OA for participants' non-reconstructed and reconstructed knees.

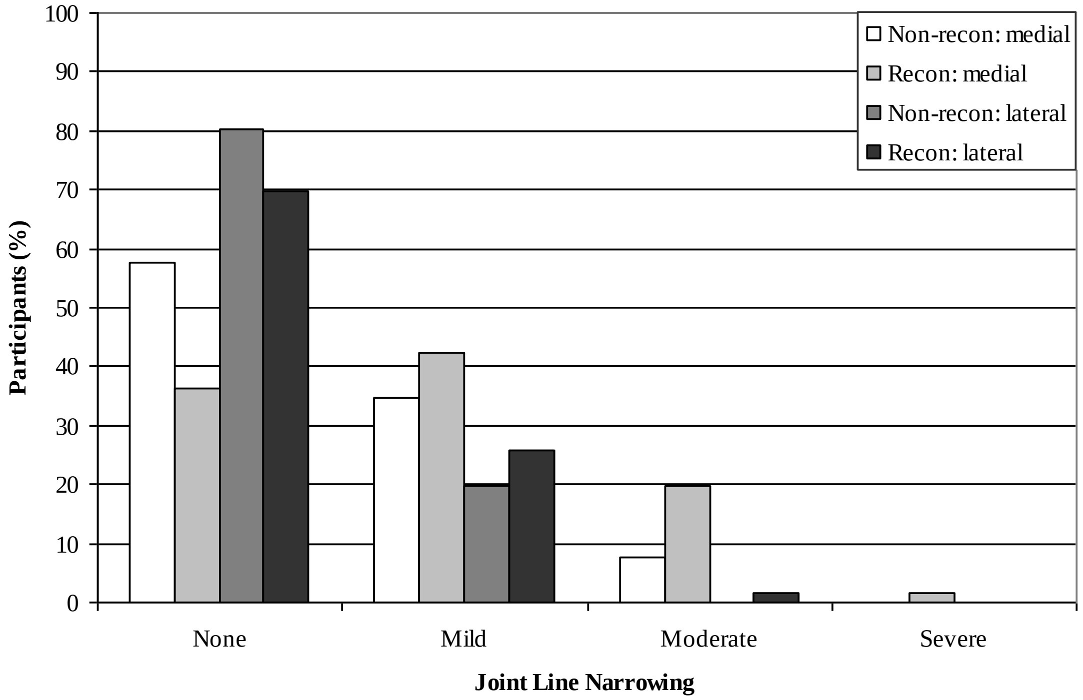

Figure 3. Knee joint narrowing for participants' non-reconstructed and reconstructed knees.

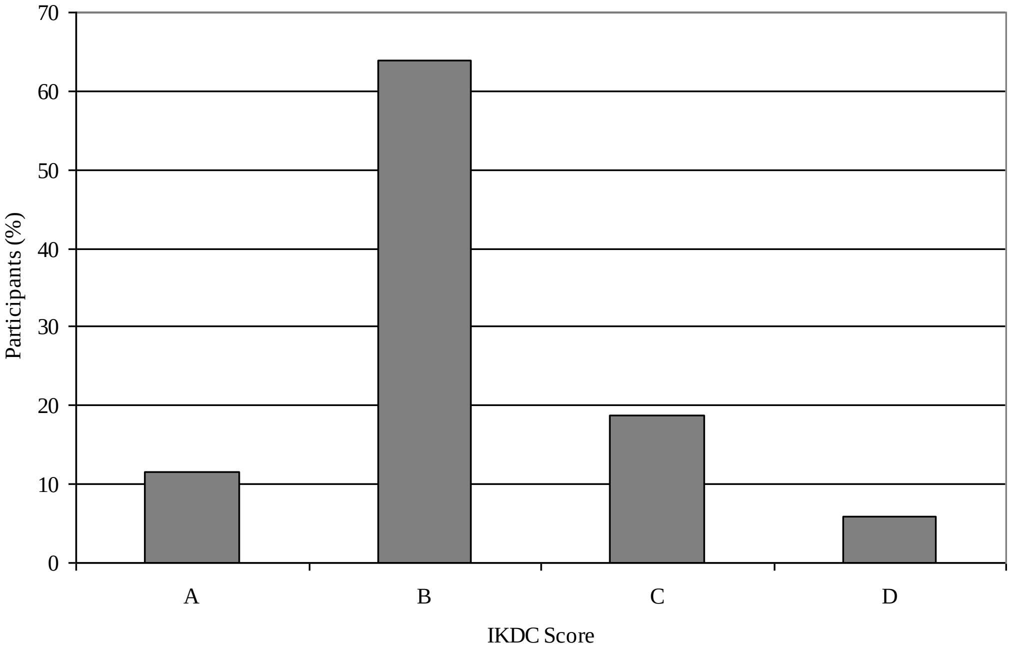

Figure 4. Frequency distribution of participants with respect to IKDC knee assessment cores.

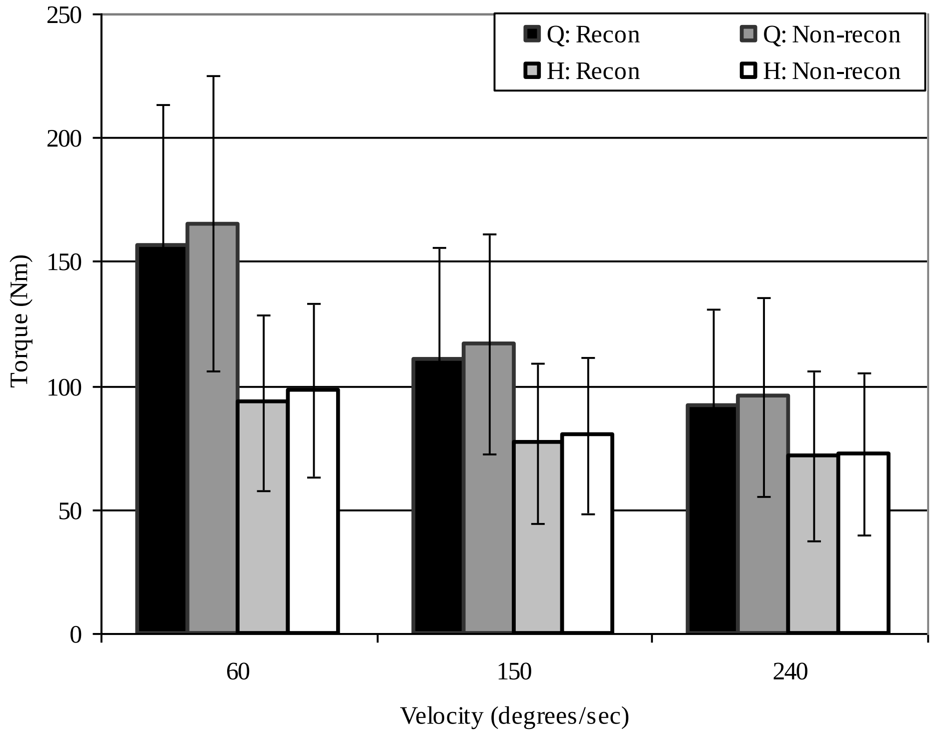

Figure 5. Knee flexion and extension strength for participants' reconstructed and non-reconstructed knees across three velocities.

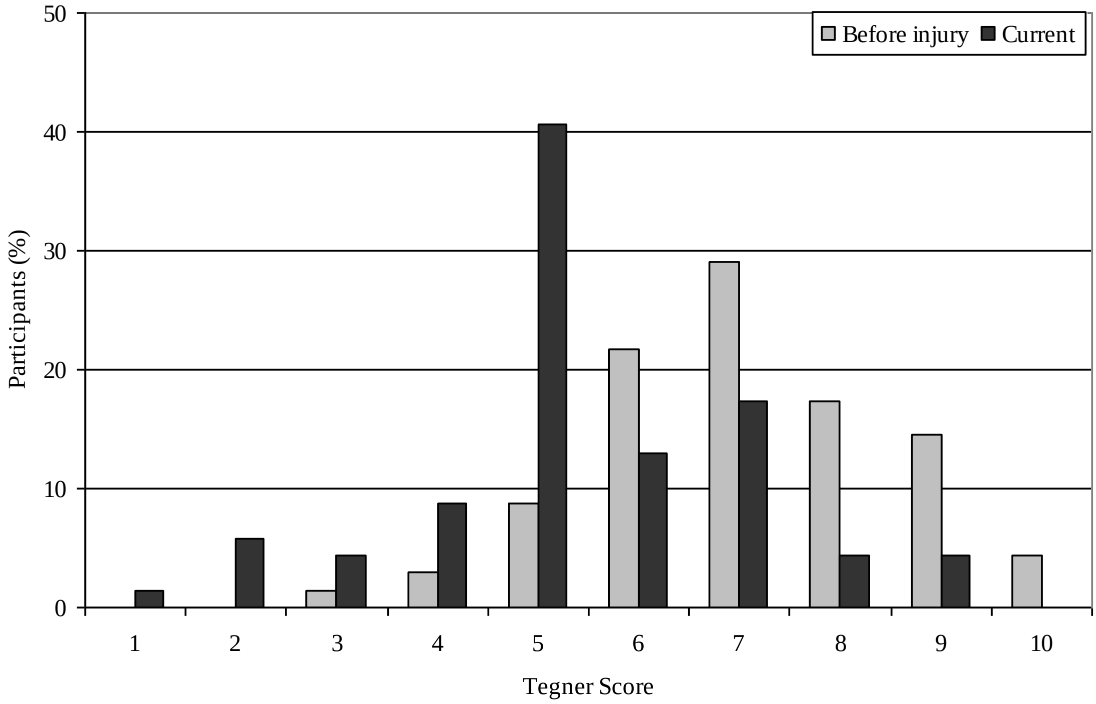

Figure 6. Frequency distribution of participants with respect to 'Before Injury' and 'Current' Tegner scores.