Association between knee muscle strength, kinesiophobia and functional outcomes after ACL reconstruction in young non-athlete adults

Bacso C[1], Arimaa A[1,2], Oksanen A [1,2], Karppi P[1,2], Perasto L[3], Knifsund J[1,2], Lankinen P[1,4], Laaksonen I[1,2]

[1] Department of Medicine, University of Turku, Turku, Finland

[2] Department of Orthopaedics and Traumatology, Turku University Hospital, Turku, Finland

[3] Department of Biostatistics, University of Turku, Turku, Finland

[4] Satasairaala Central Hospital, Satakunta Hospital District, Pori, Finland.

Corresponding author:

Cristofer Bacso, BA

Address: Luolavuorentie 2, 20700 Turku, Finland

Email: cristofer.bacso@gmail.com

ABSTRACT

Background. Anterior cruciate ligament (ACL) is the most commonly injured ligament requiring surgical reconstruction. The relationship between functional outcomes and kinesiophobia after ACL injury rehabilitation remain unclear.

Objective. To assess whether results from self-administered questionnaires such as Tampa Scale of Kinesiophobia (TSK) and Knee Injury and Osteoarthritis score (KOOS) at different time points after reconstruction are associated with functional strength testing.

Materials and methods. 56 patients (36 male, 20 female) who underwent an ACL reconstruction and subsequent rehabilitation according to our exercise laboratory protocol. This included multiple plyometric tests, isometric knee strength testing (angular momentum of 60°/s) and a 10-m walking speed measurement. In addition, all patients were asked to fill out TSK during their testing visit and KOOS at three, six and twelve months from reconstruction.

Results. The mean TSK-FIN score was 34 (range 21-51) (male 35 (SD 6), female 32 (SD 7)). TSK-FIN scores did not correlate with any physical function tests. The mean KOOS scores at 1 year were 98 points for female and 95 points for male. When age, sex, single leg hop for distance, and potential meniscal repair were included into the linear model, female sex was associated with higher 1 year KOOS scores ($p<0.001$).

Conclusion. No clinically significant correlation was found between TSK and KOOS scores and functional outcomes. Further research is needed on optimizing the patient-reported outcome measure (PROM) best suitable for ACL rehabilitation.

Keywords: anterior cruciate ligament reconstructions, exercise laboratory, rehabilitations, patient reported outcome measure, functional test

INTRODUCTION

The anterior cruciate ligament (ACL) is the most commonly injured ligament of the knee requiring surgical treatment.[1] In the US alone over 200 000 ACL injuries are recorded annually.[2] Based on current scientific evidence, the first-line treatment of ACL rupture is conservative and surgical treatment is considered if instability remains after rehabilitation.[3] Surgical treatment is considered the first-line treatment for patients with high functional demands such as professional athletes and patients with concomitant injuries requiring immediate surgical treatment. However, the choice of treatment method is always made through shared decision-making with the patient and after adequate rehabilitation approximately half of all patients require later ACL reconstruction.[3,4]

Despite 90 % of surgically treated ACL rupture patients achieving acceptable outcome, only 40% to 55% return to sport to the same or higher level although the numbers are likely higher for professional athletes.[3,5–7] There are several different return-to-sport (RTS) criteria and testing methods that can be utilized when evaluating rehabilitation to avoid too early RTS and re-injury.[8] These tests include qualitative and quantitative measurements in both muscle strength and plyometric testing and limb symmetry in addition to clinical exams.[1] Recently, psychological self-evaluations and patients' kinesiophobia have also become a common tool to evaluate recovery besides the physical function measurements in ACL injury patients.[9] These self-evaluations are low-cost and accessible, easy to implement and suitable in different environments compared to physical testing. Fear of re-injury or lack of confidence have been identified as possible factors in reduced functional outcome in patients after surgical treatment of ACL rupture.[10]

Although, various methods of physical function testing have been extensively studied in professional or semi-professional athletes with ACL injures, more knowledge is needed especially in young non-athlete adults with ACL reconstruction on the relationship between isokinetic knee muscle strength, psychological factors and objective functional tests commonly used in clinical practice. It is also unclear whether perceived kinesiophobia can predict the recovery of knee function and performance after ACL reconstruction.

The purpose of this study was to examine the association between patient reported kinesiophobia scores, patient reported knee specific outcome measures scores and knee physical function in young non-

athlete adults after ACL reconstruction. Our hypothesis was that these variables are associated with each other and poor patient reported kinesiophobia scores and knee specific outcome measures could predict poor coping with isokinetic knee muscle strength and functional tests after ACL reconstruction in young non-athlete adults.

MATERIAL AND METHODS

Participants

A total of 56 patients (36 male, 20 female) with primary ACL reconstruction. The data for this study was collected retrospectively from electronic medical records of Turku University Hospital between January 1st 2019 and May 31st 2021. All patients with a unilateral ACL reconstruction who completed all self-reported questionnaires and participated in all physical function tests at Exercise Laboratory of Turku University Hospital were included in the study. Participants were excluded if they were treated conservatively or suffered from multi-ligament injuries.

Baseline characteristics of the study population are presented in Table 1. The data included demographic data (age, sex, injured side, smoking status (no smoking, currently smoking or previous smoker), body mass index, nationality (Finnish or other), injury type), initial and postoperative visits to outpatient clinic for pre-operative assessment, and surgical data (meniscal injury and treatment, autograft type and thickness). Too few ligament injuries were recorded for statistical analysis. In addition, records from rehabilitative physiotherapy, number of physiotherapy visits, and data from the exercise laboratory visit, including Tampa Scale of Kinesiophobia (TSK-FIN), were analyzed. All patients filled out the knee-specific and self-reported Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire[11] at three time points as a part of the standard treatment protocol of the orthopedics clinic: at the preoperative outpatient visit and at three and 12 months post-operatively. The KOOS holds five scored subscales: pain, other symptoms, function in daily living (ADL), function in sports and recreation and knee-related quality of life (QOL). The score is measured as a percentage from 0 to 100 with 0 representing extreme problems and 100 representing no problems.[12]

All patients underwent arthroscopic ACL reconstruction (code NGE35 by the NOMESCO Classification of Surgical Procedures version 1.14 by the Nordic Medico-Statistical Committee) with either hamstring or patellar tendon autograft (Table 1).

The study design was approved by the Joint Ethics Review Committee of the University of Turku Medical School and Turku University Hospital.

Exercise laboratory measurements

Self-administered questionnaire concerning perceived kinesiophobia, active range of movement of operated knee extension and flexion and physical function tests in this order were executed as part of normal clinical practice by experienced physical therapists at the Exercise Laboratory. Knee range of movement was measured with a goniometer patient lying on a plinth. Patients used sport shoes, shorts and t-shirts in all physical measurements. Complete measurements were performed on average at six months postoperatively.

Kinesiophobia

The patients were asked to fill out the Finnish version of Tampa Scale of Kinesiophobia (TSK-FIN).[13,14] The aim of TSK-FIN is to assess pain-related fear (fear of motion or physical activity) among patients with persistent musculoskeletal pain. TSK-FIN consists of 17 items with each item having a four-point Likert scale with the following alternatives: strongly disagree, disagree, agree and strongly agree. After inverting items 4, 8, 12 and 16, a sum score is calculated. The range of the score is from 17 to 68 with a higher number indicating a greater fear of movement.

Functional tests

The functional tests were carried out in the same order: Walking speed (km/h) with a digital stopwatch was assessed over a 10-m walkway on the floor surface with flying start at one's usual brisk pace (running was not allowed). Patients were requested to walk and warm up before other subsequent activities by walking ten minutes on the Zebris treadmill (FDM-THP 3i Measurement platform, Medical GmbH, Germany) with the same walking speed as measured on the floor surface. The Zebris system consists of the treadmill ergometer (H/P Cosmos) with an integrated, calibrated measuring pressure platform embedded beneath the belt. Before finishing walking on the treadmill, gait data was captured over the last 30 second period and the software was subsequently used to calculate mean spatiotemporal gait

parameters. In this study the parameter of foot rotation of both sides in degrees (inward, outward, neutral) was recorded for analysis.

After walking on the treadmill, the patients performed four single-legged hop tests of both legs[15–18] in the following order: Single hop for distance (single hop), crossover hop for distance (crossover hop), triple hop for distance (triple hop) and 6-meter timed hop (6-m timed hop). Extended measurement scale with length of 6 meters and width of 15 centimeters was firmly taped on the floor and was used to record the results. For the hop tests for distance the aim was to hop as far as possible (cm) and for 6-meter timed hop as fast as possible (s) over marked distance of 6 meters. The tests were started with the uninjured leg with the toes behind a marked starting line. Standing on one leg was the starting position of all tests. All controlled hop tests were performed at least three times with each leg separately with the first performance being a practice effort. Hop tests for distance were considered successful if the landing on one limb was stable (stay in place for two seconds) and under complete control of the patient. If the landing with one leg was not valid, the test was repeated. The average of two accepted results from all hop performances was used to calculate limb symmetry. The limb symmetry index (LSI) was expressed as a percentage of the averaged involved limb hop distances divided by the averaged uninvolved limb hop distances for each hop distance test. Respectively for the 6-m timed hop, LSI was expressed as the percentage of the averaged uninvolved limb hop time divided by the averaged involved limb hop time.[16,19] A limb symmetry score of less than 85 % has been considered abnormal.[15]

Isokinetic muscle force

After single-legged hop tests isokinetic knee extension and flexion muscle forces were measured by using an isokinetic dynamometer (Con-Trex MJ, sampling rate 100 Hz, Switzerland). Patients were seated on the dynamometer chair with the hip joint at about 85°. The distal shin pad of the dynamometer was attached 2-3 cm proximal to the lateral malleolus by a strap. To stabilize the body during force measurement, straps were also applied across the chest, pelvis and mid-thigh. The alignment between the dynamometer rotational axis and knee joint rotation was checked at the beginning of each trial. The range of motion of the knee was 75°, from 90° to 15° of knee flexion (0° corresponding to knee fully extended) and the preset constant angular velocity was 60°/s (slow). Two or three submaximal concentric practice repetitions were completed prior to each test series. Concentric isokinetic measurements involved three maximal, continuous and reciprocal knee extensions and flexions. Patients were exhorted to push as hard and as fast as possible and complete the full range of motion. The force result of the knee extensors and flexors was expressed as a relative peak torque (Nm/body weight, kg). Knee flexion-extension force ratio of both

sides were expressed as the percentage of maximal flexion torque (Nm) divided by the maximal extension torque (Nm).

Statistics

Percentages and mean values with standard deviations were used in the description of the data. Associations between variables of patient reported TSK-FIN scores, KOOS and knee physical function tests were evaluated with Pearson correlation coefficient. If the assumptions of Pearson correlation did not hold the Spearman correlation coefficient was used.

Association between dependent variables (KOOS at 3 months and 1 year, knee flexion and extension forces of operated side, knee flexion and extension forces of operated side compared to the healthy side, knee flexion-extension force ratio of both sides) and explanatory variables were examined with a linear model. The explanatory variables in the model were the following: age, sex, meniscus repair and single hop for distance on the operated side. First, the linear model included only age and sex. Secondly, meniscus repair was added to the model. Finally, single hop for distance on the operated side was added to the model. Model-based means and estimates for continuous explanatory variables are presented from these linear models.

P-value (two-tailed) less than 0.05 were interpreted as statistically significant. Computing was performed with SAS System version 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS

A total of 62 patients had an exercise laboratory visit due to ACL reconstruction during our study time (36% female) (Table 1). The median time to the exercise laboratory visit was 6 months (range 6-14 months). More detailed data on exercise laboratory testing are presented in Table 2.

Table 1. Baseline characteristics of the study population

Characteristic	**Male (n=36, 64.3%)**	**Female (n=20, 35.7%)**	**All (n=56, 100%)**
Age, mean (range)	28 (14 - 46)	29 (16 - 56)	29 (14 - 56)
Injured ACL, right side, n (%)	21 (72)	8 (28)	29 (52)
Current or previous smoker[1], n (%)	6 (75)	2 (25)	8 (25)
Body mass index, mean (SD)	26 (4)	25 (3)	26 (3)

Nationality, Finnish, n (%)	26 (59)	18 (41)	44 (79)
Injury type, n (%)			
Sport event, pivot injury	31 (66)	16 (34)	47 (84)
Sport event, non-pivot injury	3 (50)	3 (50)	6 (11)
Miscellaneous event	2 (67)	1 (33)	3 (5)
Concomitant meniscus injury, n (%)	18 (72)	7 (28)	25 (45)
Meniscus procedure, n (%)			
0=none	6 (100)	0 (0)	6 (11)
1= partial meniscectomy	7 (78)	2 (22)	9 (16)
2= suturation	5 (50)	5 (50)	10 (18)
Used autograft[2], n (%)			
Hamstring autograft	35 (71)	14 (29)	49 (89)
BTB autograft	1 (17)	5 (83)	6 (11)
Autograft thickness femoral side[3] (mm), mean (SD)	8 (1)	9 (1)	8 (1)
Number of rehabilitative physiotherapy sessions, mean (SD)	7 (1)	8 (2)	8 (2)
[1]Missing 24, [2]Missing 1, [3]Missing 1			
ACL = Anterior cruciate ligament, BTB = Bone-tendon-bone			

184 Data presented as number of participants or mean + range, percentage or standard deviation (SD)

185 depending on the characteristic.

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187 **Table 2** Characteristics of KOOS, TSK-FIN score and physical function tests

Characteristic	**Male**	**Female**	**All (n=56)**
Time from surgery to exercise laboratory visit (months), median (range)	6 (6 - 14)	7 (6 - 14)	6 (6 - 14)
KOOS, mean (range)			
Preoperative[1]	73 (33 - 97)	75 (15 - 100)	73 (15 - 100)
3 months[2]	92 (80 - 99)	87 (73 - 97)	89 (73 - 99)
12 months[3]	95 (77 - 100)	98 (96 - 100)	96 (77 - 100)
TSK-FIN score[4], mean (SD)	35 (6)	32 (7)	34 (6)
Operated knee flexion force (Nm)	125 (37)	76 (26)	107 (41)
Comparison to healthy side, %	98 (32)	87 (23)	94 (29)
Operated knee extension force (Nm)	181 (64)	110 (34)	156 (65)
Comparison to healthy side, %	84 (13)	79 (22)	82 (17)
Flexion/extension force ratio, operated side, %	72 (17)	75 (31)	73 (23)
Flexion/extension force ratio, healthy side, %	63 (14)	63 (15)	63 (14)

AROM knee hyperextension[5]	1 (2)	1 (2)	1 (2)
AROM knee flexion[6] (°)	138 (5)	139 (8)	139 (6)
10m walking speed (km/h)[7]	6 (1)	6 (1)	6 (1)
Operated foot rotation (°)			
Internal rotation[8]	3 (2)	1 (0)	2 (2)
External rotation[9]	8 (3)	6 (3)	7 (3)
Healthy side foot rotation (°)			
Internal rotation[10]	2 (2)	3 (0)	2 (2)
External rotation[11]	8 (4)	5 (3)	7 (4)
Operated leg long hop (cm)[12]	137 (35)	115 (25)	129 (33)
Comparison to healthy side, %	84 (17)	82 (15)	83 (14)
Operated leg triple hop (cm)[13]	411 (110)	334 (66)	382 (103)
Comparison to healthy side, %	86 (17)	85 (14)	86 (16)
Operated leg crossover hop (cm)[14]	365 (113)	292 (71)	340 (106)
Comparison to healthy side, %	86 (16)	83 (18)	85 (17)
Operated leg 6m hop time (s)[15]	3 (1)	3 (0)	3 (1)
Comparison to healthy side, %	119 (33)	122 (26)	120 (31)
[1] Missing 21, [2]Missing 37, [3]Missing 29, [4]Missing 1, [5]Missing 3, [6]Missing 3, [7]Missing 1, [8]Missing 52, [9]Missing 5, [10]Missing 52, [11]Missing 5, [12]Missing 1, [13]Missing 2, [14]Missing 4, [15]Missing 5			
KOOS = The Knee injury and Osteoarthritis Outcome Score, TSK-FIN = Finnish version of the Tampa Scale of Kinesiophobia, Nm = Newton-metre, AROM = Active range of motion			

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189 **Table 3** Linear regression analysis to examine the association between KOOS, TSK-FIN score and physical

190 function tests. Data presented as correlation coefficient (p-value)

Characteristic	**TSK-FIN**	**KOOS 3 months**	**KOOS 1 year**
Operated knee flexion force, comparison to healthy side	0.23 (0.0867)	0.24 (0.3171)	-0.17 (0.3917)
Operated knee extension force, comparison to healthy side	0.03 (0.8541)	0.29 (0.2252)	0.21 (0.2968)
Flexion/extension force ratio, operated side	0.06 (0.6744)	-0.10 (0.6978)	**-0.54 (0.0038)**
10m walking speed	0.08 (0.5716)	-0.17 (0.4862)	-0.09 (0.6491)
Operated leg long hop	0.05 (0.6983)	**0.67 (0.0017)**	0.24 (0.2288)
Operated leg long hop, comparison to healthy side	0.10 (0.4902)	**0.67 (0.0017)**	0.06 (0.7649)
Operated leg triple hop	0.11 (0.4332)	0.44 (0.0690)	0.12 (0.5512)
Operated leg triple hop, comparison to healthy side	0.08 (0.5651)	**0.48 (0.0417)**	0.03 (0.9247)
Operated leg 6m hop time	-0.22 (0.1197)	-0.05 (0.8469)	0.02 (0.9247)
Operated leg 6m hop time, comparison to healthy side	0.01 (0.9617)	0.22 (0.3718)	0.06 (0.7600)

191 TSK-FIN = Finnish version of the Tampa Scale of Kinesiophobia; KOOS = the Knee Injury and Osteoarthritis

192 Outcome Score

Bold indicates statistical significance (p > 0.05).

TSK-FIN

The mean TSK-FIN score was 34 (range 21-51) (male 35 (SD 6), female 32 (SD 7)). TSK-FIN scores did not correlate with any physical function tests (Table 3).

KOOS

At 3 months postoperatively female patients reported lower KOOS scores than male (86 points vs. 92 points, respectively, est= -6.4, 95% CI -0.7 - -0-2, p=0.008). Also, higher age was associated with lower KOOS score in the univariate model (est= -0.47, 95% CI -10.7 - -1.9, p=0.0004). When association between physical function test results and 3 months KOOS score were evaluated, lower KOOS scores were associated with shorter single hop for distance and poorer outcome in single hop for distance and triple hop for distance for the operated leg compared to the non-operated leg (p=0.002, p=0.002, and 0=0.04, respectively). However, when age and sex were added to multivariate model the correlation between physical function tests and 3 months KOOS diminished (Table 3). Triple hop for distance, flexion/extension force ratio of operated side, flexion and extension forces of operated leg compared to the non-operated side, and meniscal repair did not correlate with KOOS scores at 3 months.

The mean KOOS scores at 1 year were higher for both sexes than at 3 months, 98 points for female and 95 points for male. When age, sex, single leg hop for distance, and potential meniscal repair were included into the linear model, only sex were associated with 1 year KOOS scores (p<0.001).

Muscle strength tests

The only factor associated with knee flexion or extension force was sex. Knee flexion and extension force of operated side or knee flexion and extension forces of operated side compared to the non-operated leg had no correlation for KOOS or TSK results at either 3 months or 1 year postoperatively. In the univariate model flexion and extension forces correlated with single leg hop distance, however, when adjusted for age, sex, and meniscal repair in the multivariate model sex was the only explaining factor

DISCUSSION

In our data TSK-FIN results did not have an association with physical function test results which was opposite of our hypothesis. Also, KOOS scores at 3 months and at 1 year postoperatively did not correlate with physical function tests. Further, the only explaining factor for extension and flexion force result was sex. Overall, patients' functional outcome scores were good.

TSK-FIN is a widely used and validated tool to assess kinesiophobia.[23,24] It has been reported to reliably present patients' kinesiophobia and scores improve over time after ACL reconstruction. Fear of re-injury or lack of confidence have been identified as possible factors in reduced functional outcome in patients after surgical treatment of ACL rupture in earlier literature.[10,25] Our hypothesis in this study was that high kinesiophobia would be associated with impaired performance in exercise laboratory testing. The lack of this association in our results was somewhat surprising. The earlier literature has mainly reported association between RTS and kinesiophobia. Also, there is also data that higher kinesiophobia is associated with poorer limb symmetry, stiffened jump-landing biomechanics, and re-injury.[26–28] Especially RTS might be more associated than physical performance testing as psychological factors are strongly associated with it. In our study, we assessed association between perceived kinesiophobia and physiological test results which might explain the lack of association. Our findings are in line with some earlier studies assessing the association of knee functional tests and limb symmetries with knee related quality of life.[20–22] Tavares et al. found that knee related quality of life was associated with higher knee functional status and psychological factors. Comparably to our results, they did not find association between one leg hop and knee force tests, and quality of life in ACL operated patients, which supports our assumption.[20] As in our data, this study consisted of recreational athletes.

Further, Tavares et al. found no correlation between knee limb symmetry index and KOOS subscales. In our material KOOS results at 3 months or at 1 year did not correlate with exercise laboratory test results. In the univariate model there seemed to be an association between single leg hop distance and KOOS results, however, this difference diminished when age and sex were added to the model. In

earlier literature on ACL operated patients 4 months patient reported outcome measures (PROM) have been associated with more symmetrical muscle strength at 1 year.[29] As our material is retrospective there were some missing information and the number of patients that had filled KOOS questionnaires was unfortunately low which might weaken the interpretations and lead to bias. Also, even though KOOS is well validated among patients with ACL rupture, catching instability related problems with a PROM is difficult.

Current consensus is that rehabilitation after ACL reconstruction should be evaluated by the patient's individual needs and progress and not solely based on time from the surgery.[9] However, RTS earlier than 9 months postoperatively is associated with a 7-fold risk of re-rupture despite the rehabilitation progress compared to later RTS in patients participating in pivoting sports.[30] The risk of re-injury and the current rehabilitation progress of the patient should be evaluated prior to physical function testing by a physical therapist in order ensure sufficient control of the operated knee. Athletes returning to sports prior to reaching adequate muscle strength and knee movement are even 4 times as likely to suffer a re-injury than athletes whose muscle strength is at the required level.[31]

The best test to assess patients' readiness to RTS is still under discussion. According to a recent consensus for youth and young adults single leg hop and crossover hops might be promising tests in this regard.[32] However, in our material including age and sex into the model diminished the association between single leg hop and KOOS. Also, for TSK-FIN there was no association to these variables.

Even though, we found no associations between the questionnaires and physical function tests our physiotherapists found the test results valuable in their clinical work. Also, patients who were re-tested during their rehabilitation process were surprised with their ability to cope with the tests. Many patients had more unrealistic and optimistic perceptions of their muscle strength and balance compared to reality. In addition to numeric data, careful qualitative assessment of performed physical tests are important factors when setting goals of physical therapy with ACL operated patients.

In the future, it would be interesting to compare the recovery and the rehabilitation of the knee function between ACL reconstruction patients assessed with objective functional measurements and those without functional measurements with a prospective randomized control study design. It would also be valuable to know the meaning of the recurrent and regularly executed knee functional testing on the rehabilitation motivation of ACL reconstruction patients. Currently reliable and exact qualitative measurement methods involving the body and lower extremities movement control and alignment

assessments during the functional testing are further spare. In addition, more exact assessment methods involving motion analysis with vertical ground reaction force measurements are needed.

We acknowledge that this study has several limitations. Firstly, the study design was retrospective and therefore there is a risk of selection bias. Even though our study subjects were non-athletes, they likely represent a highly active population as physical therapists have selected them to participate in exercise laboratory testing. Secondly, the number of study subjects who had filled out the KOOS questionnaire was limited and it is possible that all potential associations were not revealed. Further, the postoperative rehabilitation protocol was not controlled and there was some variation in time between the surgery and exerciser laboratory testing. The strength of our study is a fairly large sample size and that the study population likely better represents a general population compared to a select group of professional athletes. Even though the research according to the subject is highly focused on professional athletes, the majority of ACL rupture reconstructions are performed in the general population.

CONCLUSION

Self-reported kinesiophobia and functional ability at 3 months and 1 year after primary ACL reconstruction did not have an association with physical function tests in non-athlete adults.

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