Which patient reported outcomes to collect after anterior cruciate ligament reconstruction

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Abstract: While objective clinical data—such as range of motion, strength, and stability—is necessary to monitor for patients recovering from anterior cruciate ligament (ACL) reconstruction, patient reported outcomes (PROs) provide additional helpful data points regarding clinical recovery from the perspective of the patient. Ideally, clinical data in these high-demand patients incorporates objective and subjective data both pre-operatively and throughout the post-operative recovery course. A number of different PRO measures have been created and validated for patients with ACL injury. However, this same variety can create challenges when attempting to determine which PRO measure is most useful—and practical—to collect on a routine basis. The goal of this review is to provide an overview of the numerous types of patient-reported and subjective clinical outcome tools that are available to practitioners. When successfully incorporated into daily practice, these tools can serve as integral data points for both clinical and research applications.

Keywords: ACL reconstruction; patient reported outcomes (PROs); outcomes collection

Introduction

In recent years, increasing emphasis has been placed on collecting patient reported outcomes (PROs) in the field of sports medicine in order to assess functional recovery following injury from the perspective of the patient (1-3). In the context of anterior cruciate ligament (ACL) injury, several different PRO measures have been developed and validated for use. Practitioners should be aware of the strengths and limitations of each of these PRO measures in order to determine which score is most relevant and practical to implement into daily clinical practice.

Ideally, an outcome measure for patients with ACL injury would measure post-operative pain, mobility, quality of life, and return to functional activity (4,5). These outcome measures must be validated and responsive, with the ability to detect meaningful, clinically relevant change in patients with different functional capacities (6,7). A balance must be met, however, with survey comprehensiveness and ease of administration; surveys that ask an abundance of questions may be impractical or difficult to administer to patients in a routine fashion.

The goal of this review is to provide an overview of the numerous different available PRO measures for patients with ACL injury. Currently, there is no "gold standard" with regards to which specific measure is "best" to use in these high-demand patients. Unfortunately, this lack of consensus creates inefficiencies when attempting to compare results of different clinical studies that use disparate scores. In the future, consolidation of outcome reporting may be necessary.

Objective outcome measures

Objective measures, which quantitatively assess aspects of

recovery independent of patient input, are often used to supplement PROs and can even contribute to final scores, such as in the case of the International Knee Documentation Committee Forms (IKDC) or the Cincinnati Knee Rating System (CKRS) (8,9). The most common objective scores include tests that quantify strength (using a dynamometer), range of motion (using a goniometer), stability (using a knee translation device, such as the KT-1000), and pain medication requirement diaries (10-12).

The primary advantage in measuring objective outcomes is the consistency and reliability of their measurements; that is, the impact of human error or subjective interpretation is largely minimized. Unfortunately, these measures do not incorporate patient perspective and return to functional capabilities. For example, two patients with the same objective knee measurements post-operatively could have different abilities to return to work or athletic participation. While both may "score" similarly according to objective metrics, the patient who cannot regain functional capacity will still be considered a "failed outcome" compared to the patient who returns successfully. This shortcoming forms the compelling foundation for incorporation of PROs into clinical outcomes reporting in patients with ACL injury.

Subjective outcome measures

The use of the visual analog scale (VAS) and single assessment numeric evaluation (SANE) scores can provide a quick and versatile manner in which to assess broad subjective outcomes. With these assessment tools, patients can quickly mark pain levels, functional status, or even satisfaction. The VAS is widely used in research and clinical settings and can be found as a component in numerous outcome measures, or stand as a PRO measure on its own (13). With verbal or pictorial descriptions of the extremes, patients indicate their status on a line of uniform distance. Often this is used for pain evaluation, but this can unfortunately limit a multidimensional subjective feeling of pain to one dimension (e.g., magnitude). Another limitation becomes apparent when quantifying VAS scores, as it is important for all patients to receive a VAS that is uniform in length, which is hard to maintain digitally, or after numerous photocopies of paper versions as well (14).

Similarly, SANE scores are also versatile and brief in nature. Usually on a scale of 0 to 100, the patient can report overall sentiments about function and satisfaction. Shelbourne and colleagues have shown that SANE scores have moderate to strong positive correlations with longer

PRO surveys such as the IKDC and CKRS following ACL reconstruction and knee arthroscopy. Thus, in limited fashion, SANE scores may provide a quick alternative to lengthy questionnaires (15). Although caution should be exercised as a SANE score may lack the ability to specify what portion of knee function impacts the overall rating (15). Overall, the VAS and SANE have valuable utility for assessing satisfaction in addition to other aspects of the patient experience. These tools can also gauge satisfaction with regards to care and outcomes, as well as whether the patient would undergo the surgery again and/or recommend the treatment to another patient.

PRO measures

PRO measures are traditionally classified into generic health questionnaires, anatomically-specific or disease-specific (6). The organization of this review mirrors these categorizations.

Generic health questionnaires and other quality of life assessment measures

The most common general health assessments used to report on patients recovering from ACL reconstruction include: The Medical Outcomes Study (MOS) derived Short Form-36 and Short Form-12 (SF-36, SF-12), and European Quality of Life (EQ-5D) (*Table 1*). It is useful to measure these scores pre- and post-operatively, as patients with higher pre-operative general health scores have been shown to be more satisfied and more likely to return to pre-injury physical activity following ACL reconstruction (31,32). These questionnaires can also form the foundation for cost-utility analysis scores used in cost-effectiveness research. Some studies do this using the SF-6D, a six-dimensional measure derived from SF-36 responses (23,24). One significant weakness in using general health assessments in patients with ACL injury is that the forms may not be sensitive or specific enough to appropriately capture this high-demand patient population, which is often younger and more active than the patients used to establish generic health assessments (33,34). Despite this, quality of life is still important to monitor as it demonstrates the global impact of the injury to the patient.

Short form-36 and -12

The SF-36 is one of the most widely used and established

Table 1 Overview of generic health and quality of life PROMs

Generic health and qoL PROMs	Background	# of items	Domains/dimensions	Scoring Aspects	Ref.
MOS SF-36	Short Form (SF) derived from the Medical Outcomes Study (MOS) by RAND Corp, modified over the years. Version 2 (v2) is most recent and commercially available from Optum Inc.	36	Subscales: vitality (V), physical functioning (PF), bodily pain (BP), general health perceptions (GH), physical role functioning (PR), emotional role functioning (ER), social role functioning (SR), mental health (MH). Two component summary scores: physical component summary (PCS) and mental component summary (MCS)	*Commercial scoring software: Ware scoring: orthogonal model, uncorrelated PCS and MCS scores (e.g., subscales pertinent to PCS are positive to PCS, but apply negative weights to MCS, and vice versa); Hays scoring: item response theory model. PCS and MCS scores are correlated and all subscales contribute to a summary score; Overall scale: population norm-based. Standardized 0–100 scale with population mean of 50 and SD of 10	(16-20)
MOS SF-12	Subset of MOS SF-36, also commercially available from Optum Inc. (version 2)	12	Subscales: same 8 subscales found in SF-36. Two component summary scores: physical component summary (PCS) and mental component summary (MCS)	*Commercial scoring software: same scoring principles as in SF-36.	(21,22)
MOS SF-6D	Six-dimensional preference-based utility index calculated from SF-36 data. Commonly used to calculate quality adjusted life-years (QALY) for economic analyses.	N/A	Subscales: 6 subscales included in calculation. physical role functioning and emotional role functioning combined together (ER + PR), and general health (GH) not included. V, PF, BP, and MH also included in calculation of SF-6D	Conversion calculation formulas available	(23,24)
RAND VR-36	Original set of 36 short form (SF) questions derived from MOS by the RAND Corp. Available for free	36	Subscales: same 8 as commercial version of SF-36. (V, PF, BP, GH, ER, PR, SR, MH)	Scoring outlined in RAND Corp. website (www.rand.org)	(6,20)
EQ-5D	European quality of Life developed by EuroQol Group	6	5 dimensions: mobility, self-care, usual activities, pain, and anxiety/depression. 1 vertical VAS question; rating overall health 0–100, 100 being best imaginable health. EQ-5D-5L is five answer version (5L) that has been shown to distinguish greater health states and more sensitive than 3 answer version	Summary index scores range from 1 to –0.594 (best health to worst imaginable health) and are derived from preference weights based off general population numbers	(25-27)
KOOS-QoL	Knee Injury and Osteoarthritis Outcome Score (KOOS)-Quality of Life (QoL)	4	KOOS-QoL is a single domain within KOOS questionnaire	Each question scored from 0–4 and then total is scaled to 100	(28)
ACL-QoL	ACL quality of Life (QoL) developed by Mohtadi *et al.*	32	Domains: symptoms and physical complaints, work-related concerns, recreational activity, sport participation, lifestyle, social/emotional. All VAS questions	Each VAS question is scored 0–100, and then an overall score is summed and converted to a 0–100 scale with each question having equal weight	(29,30)

generic health surveys and has been validated and psychometrically analyzed extensively in various disease states (16-19,35), including orthopedics (36-38). It contains eight subscales that comprise two summary scores for a total of 36 questions (*Table 1*). Numerous studies have used it to assess quality of life and cost-effectiveness following ACL reconstruction (39-42). Average time to completion has been reported to be around 5 to 10 minutes (34).

Early studies of the SF-36 have demonstrated strong correlation with traditional ACL PRO scores, such as the IKDC and the Lysholm Knee Score (43). However recent reports have indicated that the SF-36 may not be a relevant score for assessing many musculoskeletal conditions, citing issues of sensitivity, relatively large floor and ceiling effects, and one scoring method that creates a lack of correlation between the two summary scores (20,34,44). Therefore, while useful as a general health assessment tool, its ability to predict function and satisfaction after ACL reconstruction may be limited, and supplementation using knee-specific PRO measures should be considered (33,34).

In light of the challenge in administering a 36-item survey, a 12-item shortened version of the form was created. It has been validated, and psychometrically analyzed in orthopedic populations (21,45). Named the SF-12, it has been shown to be a suitable alternative, displaying strong correlations to its lengthier counterpart, the SF-36 (22). It is our recommendation that the SF-12 be implemented into daily practice when considering a general health assessment form.

EuroQol-5D (EQ-5D)

Another common assessment for general health is the EQ-5D (*Table 1*). Despite European origin, U.S. normative index scores have been studied across different ages (46). Five questions and a vertically oriented VAS allow the patient to report overall health status in a simplified manner (25). It has been shown in total hip arthroplasty patients that the newer five answer choice version (EQ-5D-5L) can distinguish mores health states than the three-answer variety (EQ-5D-3L), making it a more sensitive instrument with reduced floor and ceiling effects (26,27). Advantages of the EQ-5D include its brief nature (5 questions + a VAS) and standardized population norm based scoring. Furthermore, these scores can be converted to health utility states, thereby facilitating health utility research.

Few of its validation studies focus on orthopedic use (26,47). Of those that do, none has assessed validity on ACL injury or reconstructed patients. Despite this void, the EQ-5D is commonly accepted as a good measure of general health overall, and has nonetheless been used to assess quality of life after ACL reconstruction (48). Use of the EQ-5D over the SF-36 seems to be mostly preference-based, with availability and cost being key factors (*Table 1*). This questionnaire has been the more preferred choice in European studies, but its brevity, and free access make it a viable option for assessment of ACL quality of life in North America as well.

Knee-specific quality of life assessments

Outside of generic health surveys, there are a handful of other knee-specific quality of life assessments. The ACL-QoL (*Table 1*) was originally validated and developed by Mohtadi *et al.* in chronic ACL deficient patients, but has recently been further validated in a broader sample of ACL tears (29,30). The original study showed excellent test-retest reliability with no significant difference between administrations of survey, with average error of the total score around 6%. Additionally, 84% of the survey takers displayed appropriate responsiveness alongside clinical change (29). The more recent investigation revealed adequate internal consistency, as evaluated by Cronbach's alpha, among meeting other metrics demonstrated by high-quality instruments (30). It is a 32-item, all VAS questionnaire, which may be a substantial addition to the other forms and surveys filled out by patients in the office. Other limitations outlined by some maintain that the VAS style questions do not allow for analysis of symptoms based off of functional limitations (8). Nevertheless, a study comparing knee quality of life questionnaires found that the ACL-QoL (Mohtadi QoL) had the highest percentage of questions endorsed by ACL deficient patients as being important in comparison to other knee specific questionnaires (49). Some propose that the ACL-QoL is the most relevant quality of life assessment and thus most truly "valid" and appropriate to collect for ACL patients (50). Perhaps further scientific investigation might help solidify the role of this undervalued PRO measure.

The Knee Injury and Osteoarthritis Outcome Score (KOOS—discussed more in depth below) has a quality of life component (KOOS-QoL) (*Table 1*). This subsection consists of four questions and has been used as PRO measure on its own in the literature (33). It has been shown to distinguish patients with an increased risk of ACL reconstruction failure, with a reported clinical failure

score of <44, and every 10-point reduction in KOOS-QoL score resulting in 33.6% higher risk for a later revision (51). The KOOS validation study showed that the QoL section showed the largest effect size at 6 months post-op, indicating a highly practical significance as score differences during administration are readily apparent (28). The brevity of this questionnaire may be an enticing choice for the busy provider looking to assess quality of life in his/her ACL patient population.

Few cost-effectiveness studies use knee-specific questionnaires to assess quality of life (52). This is an interesting point since it is known that knee-specific measures produce lower health related quality of life scores than more generic surveys such as the SF-36 (33). Researchers looking to fill this gap could offer an alternative economic analysis using knee specific quality of life measures that is perhaps more accurate and applicable to the decision-making of an ACL/sports surgeon.

Knee and disease-specific PRO measures

The following are well-established and the most commonly used PRO measures for ACL reconstruction reported in recent literature (53): the International Knee Documentation Committee Subjective Knee Form (IKDC-SKF), Lysholm Knee Score, Tegner activity scale, KOOS, and the CKRS (*Table 2*).

International Knee Documentation Committee (IKDC) Subjective Knee Form (SKF)

The IKDC (*Table 2*) is the most widely used PRO measure in high impact literature to evaluate patient outcomes following ACL reconstruction, appearing in 71% of studies from 2010 through 2014 (53). Furthermore, normative data has been established and easily available for comparison purposes (54). Higgins *et al.* determined validity with statistically significant correlations to the SF-12 in 534 ACL patients, although higher correlation was expectedly seen with the PCS score rather than the MCS (55). This corroborates the original findings of the validation study by Irrgang *et al.* done in relation to the SF-36 (9). Furthermore, Higgins *et al.* found internal consistency coefficients were notably high at 0.87 and 0.88, above the acceptable standard of 0.70 (55). The original validation paper commented on high test-retest reliability coefficients (0.94) although only a small sample size was studied, on average 50 days apart in survey administration (n=33) (9).

Responsiveness of the IKDC-SKF was assessed by Irrgang's group in 207 patients and displayed adequate responsiveness to clinical change, even in the ACL injury sub-cohort (n=50). However, only 22 of those subjects underwent reconstruction, with no comment on the responsiveness post-operatively (56). Other investigations reveal that the IKDC-SKF outperforms the KOOS in a head to head comparison when monitoring ACL injuries and reconstruction with regards to measurement properties (62) and patient perception (63). The IKDC-SKF is the preferred choice to track PROs in ACL reconstructed patients, with well-established measurement properties and patient relevance.

Lysholm knee score and Tegner activity scale

The Lysholm Knee Score (*Table 2*) is one of the oldest knee-specific PRO measures (57). It was first described in 1982 in ACL patients and later modified in 1985 to capture meniscal injury outcomes (58). Population norms across several age ranges are available in individuals with normal knees for reference (64,65). In 2009, Briggs *et al.* studied the Lysholm knee score in over 1,000 ACL reconstructed patients and showed acceptable validity, test-retest reliability, and responsiveness. Although satisfactory, the mentioned Lysholm studies report lower values of internal consistency (Cronbach's alpha =0.72) than IKDC and CKRS studies outlined in this review. Additionally, there was an inherent and noteworthy lack of correlation to the mental component score of the SF-12 likely due to its anatomic/region-specific design, as expected (58). Interestingly, an ACL reconstruction study found that the Lysholm Knee Score can be accurately administered over the phone with comparable results to a face-to-face interview (66). The brief nature and convenience of administration of this score affords it to be one of the more commonly used validated knee-specific scores (53).

The Tegner activity scale (*Table 2*) was designed to be a complementary measure to the Lysholm in order to allow clinicians to detect whether decreased activity levels influence the functional scores of the Lysholm. As such, the Tegner Activity Scale was not meant to be used on its own (57). Although not specific to ACL injuries, it is the third most commonly used PRO in ACL studies from 2010 through 2014, behind the Lysholm (53). Average scores in normal knees have been reported for reference (65). The Tegner's recent and confirmatory validation study in ACL reconstructed patients was intuitively conducted

Table 2 Overview of knee-specific PROMs

Knee-specific PROMs	Background	# of items	Domains	Scoring aspects	Ref.
IKDC-SKF	International Knee Documentation Committee (IKDC) Subjective Knee Form (SKF)	18	IKDC SKF is one of 6 forms (demographics, health assessment, knee history, surgical documentation, and knee examination). The IKDC SKF components: symptoms, sports/activities, function	IKDC SKF: items are scored 0 to 4 or 0 to 10 depending on number of possible answers in each question. Total SKF Score: response values are summed and divided by maximum possible score, and multiplied by 100.	(54-56)
Lysholm	Designed for ligament injury in 1982, and modified in 1985 to include meniscal injury	8	8 components: pain, instability, locking, swelling, stair climbing, cane/crutch use, squatting, limping	Total of 100 points: 25 points for pain, 25 to instability, 15 to locking, 10 to swelling, 10 to stair climbing and 5 points each to cane or crutch use, squatting, and limping	(57,58)
Tegner	Patients are asked to assess activity level before and after injury	1	11 level activity scale: activities of daily living, work-related activity, and recreational/competitive sports	Total: 0–10 depending on activity level. Ability to participate in competitive sports set as the maximum score of 10 and inability to work because of knee problems as the minimum score of 0	(57,58)
KOOS	Knee Injury and Osteoarthritis Outcome Score (KOOS). 3 of 5 subscales taken from Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)	42	WOMAC derived: pain, other symptoms, activities of daily living. Remaining 2 subscales: sports/recreation, quality of life	Each question scored from 0–4 and then total of each domain is scaled to 100. Each domain score is to be interpreted separately	(28)
CKRS	Cincinnati Knee Rating System (CKRS). Contains objectively reported forms: examination, instability, radiographs, and functional testing. Subjective, patient reported form is more of the focus in modified CKRS	13	13 multi-part scales focused on symptoms, patient perception of knee function, activities of daily living function, sports activities function, sports activity scale and occupational rating scale	Point maximums of 20 given to symptoms, 15 to daily life and sports functionality, 25 to physical exam, 20 to stability, 10 to radiographic findings, and 10 for functional testing. Total sums to 100. Higher scores denote better outcomes	(8)
KNEES-ACL	Knee Numeric Entity Evaluation Score (KNEES)-ACL. Designed to be psychometrically adequate with Rasch Analysis and patient focus group endorsements	41	7 Domains: activities of daily living, psychosocial, looseness, slackness symptoms, sport behavior, and sport physical	Seven summary scores, compared separately. Each question has 5 response categories, from "none at all" to "yes, a lot"—Response categories and scoring not explicitly clear	(59,60)
JACL-25	Japanese Anterior Cruciate Ligament Injury Questionnaire-25 item (JACL-25). Developed using focus group pilot studies and relevance assessments	25	3 Domains: based on kinetic properties of knee motion: (I) middle-to-high speed flexion and extension of the knee; (II) low-speed flexion and extension of the knee; and (III) abduction and adduction of the knee	5 point scale, responses range from "not at all" to "extremely". Higher score, associated with worse condition. Total 100 points	(61)

by the same group that studied the Lysholm Knee Score, Briggs *et al*. In 505 patients, they found similar results with acceptable psychometric parameters such as test-retest reliability, internal consistency, validity, and responsiveness (58). The authors of this recent validation study recommend to use the two scales at 6, 9, and 12 months, in addition to longer follow-up following ACL reconstruction (58). With continued validity in ACL reconstructed patients, these long-standing PRO measures remain appropriate for use in these patients.

KOOS

In three of its five total subscales, the fully patient-reported KOOS (*Table 2*) includes all questions in original format from the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) to maintain validity and comprehensiveness in a variety of knee conditions. As it pertains to ACL reconstruction, the questionnaire has been shown to be valid, responsive, and reliable since 1998 (28). Largely, this is likely a result of the addition of two subscales to the WOMAC domains, Sport/Recreation and Quality of Life, which allow the instrument to measure function after acute knee injuries in more active and youthful patients and better assess magnitude of change (67). It is recommended that the subscale scores not be aggregated into a total, rather each subscore interpreted separately (28). An updated study of population norms was recently conducted, providing important reference values (68). A recent KOOS systematic review and meta-analysis verifies the original findings of adequate measurement properties, however only a few of the pooled studies were conducted in ACL injured patients (69). The KOOS in its entirety is considered by some as an invalid PRO measure for the ACL reconstructed patient (50). Others agree, with the caveat that only the QoL and Sports/Rec subsections display ACL appropriate unidimensionality, and psychometrics using a Rasch model analysis (67). Overall, it is freely available and is the fourth most commonly used PRO measure in ACL literature in recent years (53). Though, the number of questions and unrelated subscales make it a weaker choice for ACL reconstruction reporting.

CKRS

The CKRS was first referenced in the literature in 1983. Like the IKDC, it contains subjective and objective portions (*Table 2*). A modified version exists that focuses on the

patient-reported input only and is known as the modified CKRS (70). The CKRS in its entirety has shown to be valid, responsive, and statistically reliable in ACL injured and reconstructed patients (8,71). Similarly, adequate measurement properties have been shown in the modified CKRS in a variety of knee disorders (70,72).

In recent years, the CKRS is used less often in ACL reconstruction literature compared to the other measures mentioned in this review (53). Additionally, there has been no statistical evaluation of the internal consistency of the CKRS in any knee condition, to our knowledge. Although it has been evaluated to be a high-quality instrument, the inconsistencies of the various survey versions in the literature, make the CKRS a suboptimal choice for use in ACL reconstructed patients. Furthermore, the briefer and patient-reported modified version has not been psychometrically tested in ACL patients, even though these properties have been shown to be acceptable in other knee disorders. The CKRS strengths rely on its objective outcome components, and therefore better options are available for patient reported input.

Newer ACL-specific PRO measures

In the last three years, other PRO assessments that have been developed for ACL specific use; these include the KNEES-ACL and the JACL-25 (*Table 2*). The KNEES-ACL is a 41 item PRO measure that was created using a Rasch analysis of a larger pilot questionnaire developed by literature reviews and patient interviews. Specifically designed for ACL deficient and reconstructed patients, it contains seven constructs, including a psychosocial domain, that have been psychometrically satisfactory in 242 patients (59,60).

The JACL-25 is one of the newest ACL-specific PRO measure developed by a group out of Japan. It consists of 25 questions scored on a 5-point scale, totaling 100 points. Strong correlations to the IKDC, Lysholm, and Tegner have been shown along with reliability and responsiveness (61). For both questionnaires, weaknesses are based off its limited use. Use of these newer questionnaires may lead to innovative reports, but further evaluation in large diverse sample populations are needed to solidify their position in ACL reconstruction outcomes reporting.

Milestone PRO measures: return to activity

It is our opinion that, among patients with acute ACL injury and subsequent treatment or reconstruction, the most

important clinical outcome is the time required to return to pre-injury level of function, as opposed to a more arbitrary score on any given PRO measure. However, studies rarely report this important statistic (53). Therefore, we propose that clinicians consider a "milestone PRO" when evaluating these high-demand patients.

Milestone reporting would allow clinicians to report metrics that are most important to patients: return to activity. For example, for an athlete, the milestone reporting would include the time needed to return to full competition following ACL reconstruction. For a laborer, that data point would report time to return to full work capacity. One advantage of this outcome is that it is extremely quick and easy to report, thereby providing a potentially significant advantage over traditional PRO.

Evolving role of NIH PROMIS questionnaires

Recently, the NIH developed the Patient-Reported Outcome Measure Information System (PROMIS) in an effort to standardize outcome collection using valid and reliable PRO measures. This system offers many questionnaires, but the one most relevant to ACL reconstruction—the one gaining the most traction in the orthopedic community—is PROMIS Physical Function (PF) (*Table 3*). This form, which measures a patient's self-reported physical capability, is available as either a static short form (SF) with a fixed number of questions, or as a dynamic computerized adaptive test (CAT) that uses patient responses to determine subsequent questions.

Currently, the data on PROMIS PF for use in ACL reconstruction is very limited. A study by Papuga *et al.* compared IKDC and PROMIS PF CAT score for 106 patients undergoing ACL reconstruction and found a significant relationship between these PROs with a correlation coefficient of 0.8954. Furthermore, PROMIS PF CAT was more sensitive than the IKDC in detecting a decrease in physical function at 3 weeks post-operative and an increase in physical function at 10 weeks post-operative, while also taking significantly less time to complete (77).

Other studies have demonstrated similar findings for PROMIS PF CAT against the SF-36 general health questionnaire for foot and ankle surgery, revealing these measures to be strongly correlated at 0.79 with PROMIS PF CAT having less unexplained variance, floor effects, and ceiling effects (80,81). However, to date, no studies have directly compared these outcome measures in the setting of ACL reconstruction. It is assumed that these CAT versions require electronic administration with computers, which can be an obstacle for some clinics, but advancements in tablet computers are making this obstacle easier and cheaper to hurdle.

Patient reported psychological assessment: important for ACL recovery?

Numerous studies have shown that psychological factors affect the outcomes of ACL reconstruction (82-84). For example, Christino *et al.* demonstrated significant relationships of self-esteem levels to functional test performance and measures such as the IKDC, SF-36 and the KOOS-QOL (84). Motivation level during rehabilitation is another important psychological factor for ACL reconstruction success and return to pre-injury level (85). With respect to knee injuries, an overarching concept in this field is self-efficacy, which describes thought processes in regards to judgement of capabilities, as it influences efforts expended when facing the difficulties of recovery (73). This summarizes the need for a psychological assessment tool to track and predict recovery from ACL reconstruction.

The Knee Self-Efficacy Scale (K-SES) (*Table 3*) has been validated in a sample of 104 ACL injured and reconstructed patients with acceptable test-retest reliability as well (73). The K-SES has been proven to be a great predictor of a patient's return to intensity and frequency of physical activity at 1 year follow-up (86). The established validity and reliability in ACL reconstructed patients make the K-SES one of the strongest choices for assessing psychological factors before surgery and during recovery.

Another option is the ACL return to sport after injury questionnaire (ACL-RSI) (*Table 3*). It has demonstrated promising preliminary validation data (74), but further psychometric analyses have not been conducted. Some have used the ACL-RSI with success and have displayed that athletes who returned to sport pre-injury level had significantly greater psychological readiness (83). These findings suggest strong links between psychological factors and recovery, and even utility to gauging a patient's mental state during ACL injury and recovery. While useful, the ACL-RSI needs further analysis of reliability and responsiveness, and thus is a secondary option to the more well-tested K-SES.

The TSK-11 (*Table 3*) is an 11-item short form designed to measure kinesophobia, or fear of movement. This survey has been validated, and shown appropriate internal

Table 3 Psychological assessments and NIH PROMIS questionnaires

Questionnaires	Background	# of items	Domains	Scoring aspects	Ref.
Psychological assessments					
K-SES	Knee Self Efficacy Score (K-SES) designed to measure perceived self-efficacy	22	4 domains: daily activities, sports and leisure activities, physical activities, knee function in the future	Responses: 0–10 with 0 being "not at all certain" and 10 being "very certain"	(73)
ACL-RSI	ACL Return to Sport after Injury (ACL-RSI) measures the psychological impact of returning to sport after reconstruction	12	3 domains: emotions, performance confidence, risk appraisal	All items are VAS-based with "not at all" and "extremely" as verbal descriptors of extremes	(74)
TSK-11	Tampa Scale of Kinesophobia-11 item (TSK-11). Psychometric properties assessed in patients with low back pain	11	No explicit domains	Each item is scored from 1 to 4 on a Likert scale (from strongly disagree to strongly agree). Total scores range from 11–44; minimal detectable change level of 4 points. Higher scores reflect greater fear of movement	(75,76)
NIH PROMIS					
Physical function	Static short forms and computer adaptive testing (CAT) versions available. CAT question choices determined by Item Response Theory (IRT)	Varies	Physical health	Scoring available via assessmentcenter.net; operated by Northwestern University	(77)
Depression	Similar short form and CAT availability. CAT item bank contains 28 items	Varies	Emotional distress	Scoring available via assessmentcenter.net; operated by Northwestern University	(78)
PI	PROMIS Pain Interference (PI) also has similar short form and dynamic CAT versions. CAT item bank contains 40 items	Varies	Physical health	Scoring available via assessmentcenter.net; operated by Northwestern University	(79)

consistency, reliability and responsiveness in chronic low back pain patients (75). Unfortunately, no studies have measured the psychometrics of this form in ACL injured and reconstructed patients. Nevertheless, a pertinent study in ACL reconstruction recovery revealed that the TSK-11 was able to exhibit a significant correlation of high levels of kinesophobia to difficulties experienced in daily activities and poorer knee related quality of life (76). Lack of rigorous psychometric evaluation in the ACL injured/reconstructed population supports a smaller role for the TSK-11 in this setting.

PROMIS also aims to standardize reporting of psychological factors with relevant forms for depression, and pain interference (PI) with day-to-day activities. These forms are also available in static short form or dynamic CAT versions. The depression CAT form pulls from a 28-item question bank and focuses on "the last seven days" time span (78). It has shown predictive value in patients undergoing orthopedic procedures (79). PROMIS PI CAT form also consists of an item bank, with 41 questions total to pull from. These questions were studied in patients with acute and chronic knee disorders, and were deemed to be

acceptable for use in this population (87). These forms provide a medium for innovation in psychological outcomes reporting with regards to ACL reconstruction and an opportunity for expansion of research in this realm.

Summary

Clinical outcomes reporting serves two vital roles: helping monitor recovery following treatment as well as forming the foundation for patient-centered clinical research. As seen in this review, there are numerous ways by which outcomes can be measured following ACL treatment. These include objective outcomes, subjective outcomes, and PROs. Advantages of objective outcome reporting include the ability to compare outcomes across disparate patients and patient groups. However, this type of reporting may not adequately represent outcomes from the patient's perspective. As a result, PROs have increased in usage in order to provide more patient-centered input. A number of different PRO scores exist and are available for use, all with respective advantages and disadvantages. Non-traditional types of reporting, such as assessment of patient psychological state and "milestone based reporting" should also be considered for consistent use when monitoring ACL reconstruction recovery.

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