Tracking Patient Outcomes after Anterior Cruciate Ligament Reconstruction

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ABSTRACT

Purpose: To model how patients' knee range of motion (ROM), pain, and self-reported lower-extremity (LE) functional status change over the first 26 weeks following anterior cruciate ligament (ACL) reconstruction and to estimate the test-retest reliability of these measurements. **Methods:** Patients were assessed weekly over 26 weeks following ACL reconstruction. Outcomes were knee ROM, LE functional status measured by the Lower Extremity Functional Scale (LEFS), and pain measured by the 4-item pain intensity measure (P4). A nonlinear model was applied to describe change for each outcome. Intra-class correlation coefficients and standard errors of measurement were applied to estimate test-retest reliability and minimal detectable change. **Results:** A nonlinear model provided the following model fit values (R^2): P4 = 0.71, extension ROM = 0.51, flexion ROM = 0.99, LEFS = 0.97. For pain and ROM, the limit values were reached by approximately 12 weeks after reconstruction; LEFS values continued to increase up to 26 weeks. Test-retest reliability coefficients varied from 0.85 to 0.95. **Conclusions:** The greatest improvement occurred in the first 8 weeks after surgery. Recovery was nearly complete by 12 weeks with respect to pain and ROM, although LE functional status continued to improve throughout the study period. Scores on all measures demonstrated reliability, which supports their use with individual patients.

Key Words: knee; outcome assessment; prognosis; reproducibility of results.

RÉSUMÉ

Objet: Modéliser comment l'amplitude du mouvement (ADM) du genou des patients, la douleur et l'état fonctionnel autodéclaré des membres inférieurs (MI) changent au cours des 26 premières semaines suivant la reconstruction du ligament croisé antérieur (LCA) et estimer la fiabilité de test-retest de ces mesures. **Méthodes:** On a évalué les patients une fois par semaine pendant les 26 semaines qui ont suivi une reconstruction du LCA. L'ADM du genou, l'état fonctionnel des MI mesuré en fonction de l'échelle fonctionnelle des membres inférieurs (EFMI) et la douleur mesurée par le questionnaire sur l'intensité de la douleur à quatre questions (P4) ont constitué les résultats. Nous avons appliqué un modèle non linéaire pour décrire le changement de chaque résultat. Nous avons aussi appliqué des coefficients de corrélation intra-classe et les erreurs de mesure types pour estimer la fiabilité de test-retest et le changement détectable minimal. **Résultats:** Un modèle non linéaire a produit les valeurs suivantes d'adaptation du modèle (R^2): P4 = 0,71, ADM extension = 0,51, ADM flexion = 0,99, EFMI = 0,97. Dans le cas de la douleur et de l'ADM, les valeurs maximales ont été atteintes vers la 12^e semaine suivant la reconstruction et les valeurs EFMI ont continué d'augmenter jusqu'à 26 semaines. Les coefficients de fiabilité de test-retest ont varié de 0,85 à 0,95. **Conclusions:** L'amélioration la plus importante s'est produite au cours des huit semaines suivant l'intervention chirurgicale. Le rétablissement était presque complet à 12 semaines en ce qui a trait à la douleur et à l'ADM, même si l'état fonctionnel des membres inférieurs a continué de s'améliorer durant toute la période d'étude. Les résultats de toutes les mesures ont démontré de la fiabilité, ce qui appuie leur utilisation avec des patients particuliers.

Understanding patients' clinical course following anterior cruciate ligament (ACL) reconstruction is of interest to physical therapists working in orthopaedics in general and with athletic injuries specifically.¹ The term *clinical*

course refers to how patients change over the course of treatment with respect to outcomes that are of interest to both patients and physical therapists. Obtaining an evidence-based impression of the clinical course requires

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applying standardized outcome measures and having knowledge of how the typical or average patient with the characteristics of interest changes over time with respect to the outcomes of interest.² Armed with this information, physical therapists can set measurable goals and provide informed answers to patients' questions about their prognosis. A significant deviation from the predicted clinical course may prompt a clinician to reevaluate a patient's management. Our goal in this paper is to describe how patients' pain, knee range of motion (ROM), and lower-extremity (LE) functional status change following ACL reconstruction.

Standardized outcome measures have received considerable interest over the past three decades.^{3–6} Characteristics of standardized measures include descriptions of their conceptual framework as well as documentation concerning their development, application, and scoring. Furthermore, standardized outcome measures can be defended to the extent that their measurement properties within a specified context (e.g., patients attending a physical therapy clinic after ACL reconstruction) have been reported, critiqued and substantiated in peer-reviewed forums.

Writing an evidence-based measurable treatment goal requires knowledge of the expected outcome and the time interval for meeting it.^{1,2} The expected outcome can be expressed as a change score or a target value. Short-term goals often specify a change in score for example, 'To increase knee flexion by 9° or more in 2 weeks.' Long term goals typically reference a target value, for example, 'To increase knee flexion to 142° or more in 4 weeks.' The information required to write a measurable goal can be obtained from a growth curve displaying the change trajectory for the outcome of interest coupled with knowledge of the magnitude of a detectable change, as there is no point in setting a goal change value that is smaller than the detectable change.

Although ACL reconstruction and subsequent rehabilitation have received considerable attention in the literature, we are aware of only one published attempt to formally describe longitudinal change by modelling post-reconstruction recovery. Alcock and colleagues applied a nonlinear model to describe the functional recovery of 49 patients during the first 16 weeks following ACL reconstruction.¹ They reported a rapid increase in functional status as measured by the Lower Extremity Functional Scale (LEFS) over the first 8 weeks; change in functional status then slowed from 8 to 16 weeks after reconstruction. At 16 weeks, the modelled LEFS score was 65/80, suggesting that complete recovery had not been attained.

The purposes of our study, therefore, were as follows: (1) To model how patients' knee ROM, pain, and self-reported LE functional status change over the first 26 weeks following ACL reconstruction; (2) to estimate the test-retest reliability of these measurements and apply

this information to estimate minimal detectable change (MDC); and (3) to illustrate how the information obtained can be applied to the clinical decision-making process and the writing of measurable goals for patients after ACL reconstruction.

METHODS

Study design

This observational study applied a fixed-occasion repeated-measures design. Patients were assessed at weekly intervals from week 1 to week 26 following ACL reconstruction.

Participants and setting

Patients were eligible for this study if they had undergone ACL reconstruction, with or without either meniscal or articular cartilage debridement, and presented for rehabilitation within 1 week of surgery. Patients were excluded if they had undergone a meniscal repair in addition to ACL reconstruction or revision surgery, had required additional procedures such as microfracturing, had medical conditions that would significantly compromise their functional status (e.g., neurological, respiratory, or cardiac conditions), or were unable to read English. Our sample size was one of convenience, and participants were consecutive patients fulfilling the eligibility criteria between January and June 2012. The study was conducted at the David Braley Sports Injury Clinic at McMaster University in Hamilton, Ontario. The Hamilton Health Sciences/McMaster Health Sciences Research Ethics Board approved this study, and all participants provided written informed consent.

Rehabilitation programme

The rehabilitation programme was based on the Fowler Kennedy Sport Medicine Clinic ACL protocol.¹ Treatment was provided by two physiotherapists, and exercises were supervised by a certified kinesiologist. Beyond basing treatment on this protocol and working in a collegial environment, no additional steps were taken to ensure the uniform delivery of treatment. In the early post-operative phase, the initial goals of rehabilitation were to reduce pain and swelling, progress weight-bearing status and improve gait, increase knee ROM and flexibility, improve muscle strength, and improve proprioception. In the middle stages of rehabilitation, the goals progressed to improving functional quadriceps strength and LE muscle endurance, with special emphasis on high- and low-velocity training, concentric- and eccentric-specific strengthening, and advancing proprioception exercises. Also included during this stage were more advanced functional retraining exercises and exercises to increase cardiovascular fitness. The goals of rehabilitation in the later stage consisted of sport-specific proprioceptive and functional training, speed, and agility and sport-specific cardiovascular fitness.

Outcome measures

P4

Developed by Spadoni, the P4 is a four-item self-report pain questionnaire.^{7,8} The four items ask about pain in the morning, in the afternoon, in the evening, and with activity. Each item is scored on an 11-point numeric rating scale (0 = no pain, 10 = pain as bad as it can be). Total P4 scores can vary from 0 to 40; higher scores represent higher levels of pain.

Range of motion

Knee flexion and extension were measured using a universal goniometer. With the patient supine and the foot on the bed, the axis of the goniometer was placed on the lateral epicondyle at the knee, and the arms were aligned with the greater trochanter at the hip and the lateral malleolus at the ankle.

Lower Extremity Functional Scale (LEFS)

Developed by Binkley, the LEFS is a 20-item self-report questionnaire that inquires about activities involving the lower extremity.⁹ Each item is scored on a 5-point scale from 0 to 4 point scale (0 = extreme difficulty or unable to perform activity, 4 = no difficulty). Total LEFS scores can vary from 0 to 80; higher scores represent higher levels of LE function.

Measurement protocol

The measurement protocol we applied took advantage of averaging measurements to minimize error and enhance reliability. For ROM measurements, the average of three trials performed on the same occasion represented the occasion-specific value. In addition to this, and for P4 and LEFS measurements, the average of measurements taken on 2 days within the same week represented the value analyzed for the growth and reliability analyses. Thus, week-specific ROM values for extension and flexion were the average of six measured values (three trials on each of two occasions); for the P4 and LEFS, week-specific values were the average of two measured values (one measurement per measure on each of two occasions).

Statistical analysis

To gain a general impression of the change trajectories for our outcome measures, we first plotted the values for each outcome measure on the y-axis and number of weeks on the x-axis. Based on these plots, we selected a nonlinear growth model. To give the y-intercept value meaning, and because patients were first assessed 1 week after reconstruction, we centred the Week variable by subtracting 1 from the number of weeks after reconstruction. The general growth model for each outcome measure (pain, ROM, functional status) was as follows:

$$\text{outcome measure value} = b_0 + (b_1 - b_0) \times (\exp(-\exp(b_2) \times (\text{week} - 1)))$$

where b_0 is the limit (i.e., predicted outcome measure value at 26 weeks after reconstruction), b_1 is the y-intercept value representing the outcome measure score centred at 1 week after reconstruction, and b_2 is the growth coefficient. Because each patient contributed multiple values for each outcome measure (i.e., the within-patient data were not independent), we applied a robust error estimate for clustered data. Clusters were the 29 patients. In addition, we calculated the week-specific scores for each outcome measure by surgical procedure (i.e., ACL reconstruction with or without debridement).

To estimate test-retest reliability, we calculated Type 2,1 intra-class correlation coefficients (ICC)¹⁰ and standard errors of measurement (SEM) for outcome measure scores at weeks 20, 21, and 22. The SEM conveys the within-patient error (variability) among occasions in the same units as the original measurement. We chose these weeks because the growth trajectories had essentially plateaued by week 20. We also calculated the minimal detectable change at a 90% confidence level (MDC₉₀) by multiplying the point estimate for the SEM by 1.65 (the z-value associated with a 90% CI) and $\sqrt{2}$ (which acknowledges that error is associated with two values when assessing change). The value of MDC₉₀ is the limit within which 90% of truly unchanged patients will display random fluctuations. MDC is often used as a guide for labelling a patient as truly changed.^{11(p84–86)}

All analyses were conducted using STATA version 12.1 (STATACorp, College Station, TX) and included point and 95% CI estimates for the parameters of interest.

RESULTS

The study sample consisted of 29 patients (14 women) with a mean age of 23.1 (SD 8.1, range 13–46) years. Of these 29 participants, 10 underwent ACL reconstruction; 11 underwent ACL reconstruction and meniscal debridement; 3 underwent ACL reconstruction and articular cartilage debridement; and 5 underwent ACL reconstruction and meniscal and articular cartilage debridement. Complete data were obtained from all 29 participants for weeks 1–12; 28 for week 13; 27 for week 14; 26 for weeks 15–17; 24 for weeks 18–19; 23 for weeks 20–21; 22 for week 22; 21 for weeks 23–24; and 20 for weeks 25–26.

Table 1 summarizes the nonlinear growth analyses, showing regression coefficients, root mean square (RMS) error values, and model fit coefficients (R^2). Figures 1–4 depict the modelled change trajectory and the actual change trajectories for each procedure-specific group over the 26 weeks following reconstruction for P4 (Figure 1), knee extension ROM (Figure 2), knee flexion ROM (Figure 3), and LEFS (Figure 4). Using Figure 1 as an example, the thick bold line depicts the modelled P4 change trajectory and the four thin lines represent the surgical procedure specific group means. For example, at 1-week post-reconstruction the P4 value is 21.9; the limit value is 3.5 P4 points. At 10-weeks the ACL only reconstruction group mean (circle) is approximately 4

Table 1 Growth Curve Results and Model Fit Indicators

	Outcome Measures (95% CI) Knee ROM			
	P4	Ext	Flex	LEFS
Limit coefficient (b_0)	3.50 (1.84–5.16)	−0.24 (−0.88 to 0.41)	139.11 (135.93–142.29)	70.17 (65.78–74.55)
y-intercept coefficient (b_1)	21.87 (18.49–25.06)	10.88 (8.09–13.66)	70.94 (64.04–77.83)	15.41 (11.68–19.14)
Growth coefficient (b_2)	−1.06 (−1.35 to −0.78)	−1.02 (−1.26 to −0.77)	−0.93 (−1.09 to −0.77)	−1.67 (−1.83 to −1.51)
RMS error	5.20	3.12	10.05	9.87
Model fit (R^2)	0.71	0.51	0.99	0.97

ROM = range of motion; Ext = extension; Flex = flexion; LEFS = Lower Extremity Functional Scale; RMS = root mean square.

Figure 1 Change trajectory of P4 pain scores from 0 to 26 weeks following anterior cruciate ligament (ACL) reconstruction. Fitted values-thick smoothed line; ACL reconstruction-circles; ACL reconstruction and meniscal debridement-squares; ACL reconstruction and cartilage debridement-triangles; ACL reconstruction and meniscal and cartilage debridement-diamond. © 2012, C. Cupido, reprinted with permission

Figure 3 Change trajectory of knee flexion values from 0 to 26 weeks following anterior cruciate ligament (ACL) reconstruction. Fitted values-thick smoothed line; ACL reconstruction-circles; ACL reconstruction and meniscal debridement-squares; ACL reconstruction and cartilage debridement-triangles; ACL reconstruction and meniscal and cartilage debridement-diamond. © 2012, C. Cupido, reprinted with permission

Figure 2 Change trajectory of knee extension values from 0 to 26 weeks following anterior cruciate ligament (ACL) reconstruction. Fitted values-thick smoothed line; ACL reconstruction-circles; ACL reconstruction and meniscal debridement-squares; ACL reconstruction and cartilage debridement-triangles; ACL reconstruction and meniscal and cartilage debridement-diamond. © 2012, C. Cupido, reprinted with permission

Figure 4 Change trajectory of Lower Extremity Functional Scale (LEFS) scores from 0 to 26 weeks following anterior cruciate ligament (ACL) reconstruction. Fitted values-thick smoothed line; ACL reconstruction-circles; ACL reconstruction and meniscal debridement-squares; ACL reconstruction and cartilage debridement-triangles; ACL reconstruction and meniscal and cartilage debridement-diamond. © 2012, C. Cupido, reprinted with permission

Table 2 Reliability Study Results

	Mean (SD)			ICC (95% CI)	SEM (95% CI)	MDC ₉₀
	Week 20	Week 21	Week 22			
P4	5.1 (6.4)	5.3 (7.2)	5.4 (7.3)	0.95 (0.90–0.98)	1.51 (1.21–2.00)	3.52
Ext	−0.8 (1.7)	−0.6 (1.4)	−0.6 (1.7)	0.85 (0.71–0.94)	0.62 (0.49–0.81)	1.45
Flex	138.4 (9.2)	138.7 (7.7)	139.3 (8.7)	0.85 (0.72–0.94)	3.25 (2.61–4.30)	7.58
LEFS	67.5 (9.3)	67.9 (9.8)	69.3 (9.4)	0.89 (0.77–0.95)	3.02 (2.43–4.00)	7.05

MDC₉₀ = minimal detectable change at 90% confidence level; Ext = knee extension ROM; Flex = knee flexion ROM; LEFS = Lower Extremity Functional Scale.

P4 points. Inspection of the growth curves for the four outcome measures reveals that the limit value is approximately reached by 12- to 14-weeks for the impairment outcomes of pain and ROM, whereas the lower extremity functional status of patients as measured by the LEFS continues to improve out to 26-weeks post-ACL reconstruction.

Table 2 summarizes the results of our test-retest reliability study. The mean values within outcome measures among the 3 weeks were similar, which suggests that no meaningful change occurred over the reassessment interval. Point estimates of the ICCs varied from 0.85 to 0.95. Table 2 also shows MDC₉₀ values.

DISCUSSION

The primary goals of our study were (1) to model change in pain, ROM, and LE function, and (2) to estimate the reliability of these measures in the context of patients following ACL reconstruction. We found that a nonlinear growth model provided a good fit for all four outcome measures and that improvements in pain and ROM were more rapid than improvements in functional status. For pain and ROM, participants approximated their limit value by 12 weeks after reconstruction; in contrast, their functional status continued to improve up to 26 weeks. Test-retest reliability coefficients for all four measures exceeded 0.85, and 95% CIs were reasonably tight for both ICCs and SEMs.

Although our eligibility criteria excluded patients with more extensive procedures, such as meniscal repair and microfracturing, differences in surgical procedures did exist in our sample, in that some patients also underwent meniscal or cartilage debridement. However, as Figures 1–4 show, the change trajectories for the different procedure groups are similar, with the possible exception of pain in the ACL and cartilage debridement group. In contrast, the ACL and meniscal and cartilage debridement group displayed a change trajectory quite similar to the modelled trajectory; a possible explanation for the apparent difference between the ACL and cartilage debridement group and the modelled value, therefore, is that this group consisted of only three patients.

To our knowledge, only one other study has modelled the recovery of patients following ACL reconstruction. Alcock and colleagues modelled the recovery of LE functional status as measured by the LEFS for 47 patients over the first 16 weeks after ACL reconstruction.¹ The mean age of their sample was 29 (range 15–55) years, slightly older than our sample. The growth coefficients for their model were as follows: limit 64.9, y -intercept (centred at 0.43 weeks post-reconstruction) 12.6, growth coefficient −1.51. To allow a more direct comparison between our estimates and those of Alcock and colleagues, we performed a post-hoc analysis for the LEFS data that limited the time frame to 16 weeks after reconstruction. Our revised coefficients (limit 66.1, y -intercept 13.8, growth coefficient −1.46) were remarkably similar to those reported by Alcock and colleagues. In another study examining the measurement properties of a hop test, Reid and colleagues reported mean LEFS scores of 66.0 for 23 men and 64.2 for 19 women at 16 weeks, and of 69.3 for men and 68.8 for women at 22 weeks, after ACL reconstruction.¹² The mean age of Reid and colleagues' sample was 25.6 (range 15–45) years. Their reported values are also similar to the modelled values obtained in our study. We interpret the results of Alcock and colleagues and Reid and colleagues as support for the validity of our LEFS recovery model.

We were unable to identify any studies that modelled ROM or pain as measured by the P4 following ACL reconstruction. However, in a retrospective study that compared the outcomes of patients receiving different amounts and frequencies of physical therapy, De Carlo and Sell reported average knee hyperextension ROM values of approximately 3° and 4° at 1 and 6 months respectively, and knee flexion values of approximately 125° and 139° at 1 and 6 months respectively.¹³ The former represent slightly greater range at 1 and 6 months post-reconstruction than our data for extension ROM, whereas De Carlo and Sell's flexion values are comparable to those modelled from our data.

Although the literature often characterizes reliability and validity as properties of measures, reliability and

validity coefficients actually pertain to measures' scores, which exist in a context¹⁴ that includes, but is not restricted to, the sample's characteristics, the setting, the condition of interest, and the measurement protocol. Of the measures applied in our study, only the LEFS has test-retest reliability estimates available in a similar context. Alcock and colleagues reported an ICC of 0.90 and a SEM of 3.7 LEFS points for test-retest measurements obtained within a 4-day interval for patients 7–9 weeks after ACL reconstruction,¹ similar to our ICC and SEM estimates of 0.89 and 3.0 LEFS points respectively. Reliability estimates for LEFS scores obtained in our study were similar to or marginally greater than those reported by others in different clinical contexts: Binkley and colleagues for people with a spectrum of LE problems (ICC = 0.86, SEM = 3.9 LEFS points)⁹; Pua and colleagues for people with osteoarthritis of the hip (ICC = 0.92, SEM = 3.6 LEFS points)¹⁵; and Yeung and colleagues for patients on a hospital's rehabilitation ward (ICC = 0.88, SEM = 3.5 LEFS points).¹⁶

Because of an absence of reliability estimates for the P4 and ROM measures in a comparable patient sample, our reliability estimates for these measures will be compared to those obtained for people with other orthopaedic conditions. Our study produced test-retest reliability estimates of ICC = 0.95 and SEM = 3.9 P4 points for the P4, representing higher levels of reliability than those reported by Spadoni and colleagues (ICC = 0.78, SEM = 3.9 P4 points) for a sample of 183 people with a variety of orthopaedic conditions.⁸ Similarly, reliability estimates of ROM obtained in our study are greater than those reported for people with osteoarthritis of the knee and patients following total knee arthroplasty (TKA).^{17,18} For example, a previous study on people with TKA estimated the test-retest reliability of knee extension measures at ICC = 0.60 and SEM = 2.7°.¹⁴ Flexion reliability was estimated to be ICC = 0.84 and SEM = 4.1°.¹⁸ In addition to our participants' condition being different from those reported in other reliability studies, it is likely that our reliability estimates were higher in most instances because we applied a measurement protocol that averaged measurements, thus reducing measurement error.

Clinical application of results

Studies that provide information on change trajectories and reliability of outcome measures can be applied to help clinicians form and evaluate evidence-based measurable goals. Below, using the LEFS as an example, in the context of a patient who presents 2 weeks after ACL reconstruction with a LEFS score of 25, we will illustrate how information from the current study can be applied to answer important clinical questions.

How confident can I be in this patient's measured value of 25 LEFS points?

Confidence in a measured value is directly related to the reliability of that value. It can be calculated by

multiplying the SEM by the *z*-value (standardized normal deviate) associated with the confidence level of interest. For example, to obtain a 90% confidence level, the SEM of 3.0 is multiplied by 1.65, producing a CI of ± 5.0 points. Accordingly, rather than thinking that the patient's true LEFS score is 25, we would think of it as being somewhere between 20 and 30. A previous study has reported that patients with LEFS scores in this range have quite a bit of difficulty with light activities around the house, going up and down stairs, walking two blocks, and getting into and out of the bath.¹⁹

How much change is required to be reasonably certain this patient has changed?

The answer to this question is based on the MDC. Applying the value of 7 obtained for MDC₉₀, our patient would have to change at least 7 LEFS points.

What is the target value for our patient?

The answer to this question is obtained by combining information from the growth curve with the number of weeks since the ACL reconstruction of interest. For example, if the number of weeks since reconstruction is 12, the target value will be 65; if the number of weeks is 26, the target value will be the model's limit value of 70 LEFS points. People with LEFS scores in this range have a "little bit of difficulty" "running on uneven ground" and "making sharp turns while running fast."^{19(p.157)}

What is the ideal reassessment interval?

This question can be answered by combining information from MDC₉₀ and the growth curve, which forms the basis for structuring a measurable goal. MDC₉₀ identifies the amount of change required, while the growth curve shows when a change equal to MDC₉₀ is likely to be achieved for the typical patient. Because the slope of the growth curve is nonlinear, the interval over which MDC₉₀ is likely to be achieved will vary. For a patient 2 weeks after reconstruction with a LEFS score of 25, the goal might be to increase the patient's LEFS score by 7 or more points in 1 week. However, for a patient at 6 weeks with a LEFS score of 50, the goal might be to increase the LEFS score by 7 or more points in 3 weeks.

LIMITATIONS

Our study has certain limitations. First, because prior information on how patients change over 26 weeks following ACL reconstruction was not available, our sample size was one of convenience and was not based on a formal calculation. A second limitation is that we did not assess participants' compliance with the rehabilitation programme, and therefore we do not know whether the observed change was a result of intervention. However, our modelled LEFS curve is supported to the extent that its estimated values are similar to the results reported by Alcock and colleagues¹ and Reid and colleagues.¹² A third limitation is that for reasons of feasibility, we modelled recovery to 26 weeks after reconstruction and

not beyond. We therefore cannot comment on what happens after 26 weeks, but our models suggest that while pain and ROM have essentially plateaued by this point, functional status appears to be still increasing.

Finally, we remind readers that the reliability values reported here are specific to the applied measurement protocol, which produced a criterion value based on averaging.

CONCLUSION

Our study showed that the greatest improvement on all measures occurred in the first 8 weeks after ACL reconstruction and that recovery was nearly complete by 12 weeks with respect to measures of pain and ROM. Lower-extremity functional status, however, continued to improve throughout the study period. Within the context of this study, scores on all measures demonstrated reliability coefficients consistent with individual patient use.

Modelling recovery after ACL reconstruction is clearly in its infancy, and there are many areas where subsequent inquiry could build on existing work. One topic for further investigation would be to examine potential prognostic indicators of recovery post-ACL reconstruction. Another topic for future study would be to extend the follow-up to 1 year or beyond. A third topic would be to expand our impairment, and self-reported activity outcomes to performance measures. It is our hope that the results from this study will benefit those planning subsequent studies in this area.

KEY MESSAGES

What is already known on this topic

Previous work has modelled recovery as measured by the LEFS up to 16 weeks after anterior cruciate ligament (ACL) reconstruction. This work applied a nonlinear growth model that demonstrated a rapid improvement in the first 8-weeks followed by slowing in improvement thereafter. At 16 weeks, a LEFS score of approximately 64 points was reached.

What this study adds

Our study adds to previous knowledge in two ways: first, by providing estimates of LEFS, pain, and ROM values out to 26 weeks after ACL reconstruction. This study also provides estimates of reliability for pain and ROM for patients after ACL reconstruction. At 26 weeks, the following outcomes were estimated: LEFS 70 points; knee flexion 139°; knee hyperextension 0.24°; pain 3.5 P4 points. The modeled LEFS score of 70 points suggests that full recovery has not yet occurred by 26 weeks post reconstruction.

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