ILL Request

1079668.

Item 1 of 1

ILL no 5097370
Status Change Date 03 Sep 2007
Title Journal of Sport Rehabilitation
ISSN 1056-6716
Call Number PERIODICAL SECTION A.C.T
Volume/Issue 14 (3)
Volume/Issue date of publication 2005
Author of Paper Pizzari, Taylor, McBurney, Feller
Title of Paper Adherence to rehabilitation after Anterior Cruciate Ligament ...
Pagination 201-214

Requester Symbol AULAT:IVLU
Requester Name La Trobe University Borchardt/Bundoora
Material Type Serial
Service Level Core
Service Type 1 Copy non returnable
Media Type 1 Photocopy
Status In Process
Authorisation Status To be Acknowledged
Copyright Text S49; This copy is required for the purpose of research or study, will not be used for any other purpose, and has not previously been supplied to me by an officer of the library
Service Level Core
Expiry Type Calc From Expiry Days
Expiry Date 15 Sep 2007
Requested Delivery Method Electronic Mail
Req. Payment Status Payments
Place on Hold No
Retry No
Max Cost 22.00
Currency Australian Dollars
Recip Agree No
Will Pay Fee No
Payment Provided No

Delivery Address

Addressee ARIEL: 131.172.180.37 or ariel@latrobe.edu.au EMAIL: docds@latrobe.edu.au
Org, Dept, Bldg, etc. ILDDS, La Trobe University Library, La Trobe University
City Bundoora
Region Victoria
Country Australia
Post Code 3086
DocStore No-Reply@clic.edu.au

Current Responder

Responder National Sports Information Centre -
Name National Sports

J Sport Rehabil. 2005;14:201-214. © 2005 Human Kinetics, Inc.

Adherence to Rehabilitation After Anterior Cruciate Ligament Reconstructive Surgery: Implications for Outcome

Tania Pizzari, Nicholas F. Taylor, Helen McBurney, and Julian A. Feller

Objective: To investigate the relationship between adherence to rehabilitation and outcome after reconstructive surgery of the anterior cruciate ligament (ACL). ***Design:*** A prospective cohort study with adherence to rehabilitation evaluated over 8 weeks correlated with outcomes at 9 and 12 months postsurgery. ***Participants:*** 68 patients who had undergone ACL-reconstructive surgery. ***Main Outcome Measures:*** Adherence was measured to and during appointments and by a self-report diary of home exercise. Outcomes were measured by 6 knee-function scales and 2 hop tests. ***Results:*** There was a significant relationship between home-exercise adherence and many outcomes for participants under 30 years of age (r_s = .33–.44). For participants age 30 and over there was a negative relationship between home-exercise adherence and outcome. There were no significant relationships between adherence to and during physical therapy appointments and outcome after ACL-reconstructive surgery. ***Conclusion:*** Participants under 30 years of age who adhered to their home-exercise regimen had better functional outcome, whereas adherent participants age 30 and over experienced worse outcome with better home-exercise adherence. ***Key Words:*** treatment compliance, knee injury, physical therapy

Rupture of the anterior cruciate ligament (ACL) is a common and debilitating injury that is considered the most costly injury in sport.[1,2] Surgical reconstruction of the ACL is generally indicated in patients involved in sports that require cutting and pivoting. Patients with very active lifestyles or physical occupations also tend to opt for surgical intervention over conservative management.[3]

Rehabilitation after ACL reconstruction has in recent years changed from a traditional, conservative approach with greater restrictions on activity to a more accelerated approach promoting early mobilization and return to activity.[4] The change from a traditional to an accelerated approach appears to be based on anecdotal evidence that nonadherent patients were returning to function sooner than patients adhering to the traditional regime. Shelbourne and Nitz[5] observed that patients who started weight bearing earlier or increased their range of knee motion

The authors are with the Musculoskeletal Research Centre, School of Physiotherapy, La Trobe University, Bundoora, Victoria 3086 Australia.

faster than advised had stronger and more functional knees at the completion of rehabilitation without compromising knee stability. It was argued that these outcomes occurred as a consequence of the lack of efficacy of the traditional protocol, and thus an accelerated protocol was developed.

In theory, if current accelerated protocols of ACL rehabilitation are efficacious, adherence to rehabilitation will render improved outcomes,[4,6] but investigators to date have presented limited evidence that such a positive relationship exists.[7-9] The aim of this investigation was to examine the relationship between adherence to rehabilitation and outcome after ACL reconstruction using both correlation and regression techniques. It was hypothesized that there would be a positive relationship between adherence and outcome.

Methods

Research Design

This prospective cohort study evaluated adherence to rehabilitation over the first 8 weeks after ACL-reconstructive surgery and correlated the findings with outcomes at 9 and 12 months. Three measures of adherence were correlated with 9 dependent variables of outcome. In the event of a nonsignificant relationship between adherence and outcome, data were further examined taking account of any confounding variables affecting outcome.

Participants

Ethical approval was sought and granted by the Faculty Human Ethics Committee, La Trobe University. Participants were recruited and provided informed consent before or just after ACL-reconstructive surgery. Surgeons provided the primary investigator with information regarding potential participants on a weekly basis. Patients meeting selection criteria were invited to participate. Participants included in the study were 68 patients (42 men, 26 women) of 4 orthopedic surgeons. All patients had undergone ACL-reconstructive surgery using either an autogenous hamstring tendon or an autogenous bone–patellar tendon–bone graft within 12 months of their ACL injury. Participants were included if they were attending one of the 7 physical therapy clinics involved in the study for follow-up rehabilitation. The age of participants ranged from 16 to 52 years, with a mean of 28.8 ± 8.3 years. The mean time between the injury and surgery was 4.1 ± 4.5 months. Most participants were not married (68%), were involved in competitive sport before injury (63%), and had injured their ACL while participating in sport (97%). Participants were about equally likely to have a manual (53%) or sedentary occupation (47%) and to have a patellar-tendon (46%) or hamstring-tendon graft (54%).

To reduce the likelihood of a poor outcome for reasons other than those related to rehabilitation adherence, patients were excluded if they (1) displayed collateral ligamentous laxity greater than grade II, as judged by the orthopedic surgeon at the time of surgery; (2) required surgery for repair of the posterior cruciate ligament; (3) displayed chondral lesions with exposed subchondral bone or radiographic or arthroscopic evidence of osteoarthritis; or (4) had a prior ACL injury to either knee.

Of 76 potential participants, 8 people were excluded, 5 because they did not attend a participating physical therapy clinic for rehabilitation, 1 because chondral lesions were discovered during surgery, 1 who was unable to attend assessment sessions, and 1 who declined the invitation to participate, citing lack of desire to be in the study, leaving 68 participants in the study.

Adherence

Three facets of adherence were measured: adherence to appointments, adherence during appointments, and adherence to home-exercise prescription. Adherence to appointments was measured by calculating the percentage of appointments attended of those scheduled. This method of adherence measurement is simple and objective.[10]

Participant adherence during each appointment was rated by the treating physiotherapists using the Sport Injury Rehabilitation Adherence Scale (SIRAS).[11] The SIRAS is a 5-point scale comprising 3 indicators of in-clinic adherence: the intensity with which the partipicant completed exercises during treatment (1 = *minimum effort*, 5 = *maximum effort*), the frequency with which the participant followed instructions (1 = *never*, 5 = *always*), and the degree to which the participant was receptive to progressions or changes in the rehabilitation program (1 = *very unreceptive*, 5 = *very receptive*). The 3 items were summed to give a score out of 15. The SIRAS has been reported to possess adequate levels of test–retest reliability, interrater reliability, internal consistency,[12] construct validity, and interrater agreement.[13]

Adherence to home-based exercise was assessed using a self-report (diary) method. Participants were required to record the number of exercise sessions and the number of different exercises prescribed by their physiotherapist and the number of sessions and exercises performed each day. The percentage adherence to the prescribed exercise regimen was calculated by dividing the number of exercises performed by the number of exercises prescribed and multiplying by 100. Prescribed exercises as recorded by the participants were cross-checked with the physiotherapist's record of exercise prescription.

To reduce possible inaccuracy resulting from reliance on memory, participants were instructed to complete the diary daily and return the relevant section of it on a weekly basis. Similar methods have been used in a number of investigations to measure home-exercise adherence.[14-17] In an attempt to reduce any bias in reporting in this investigation, participants were advised that accurate completion of the log would add to the worth of the investigation and were assured that their physiotherapist and surgeon would not be privy to their home-exercise-completion information.

Outcome Measures

Clinical Evaluation. The International Knee Documentation Committee (IKDC) Clinical Examination Form was used to evaluate knee outcome in terms of impairment. The IKDC system has recently been divided into a subjective section and a clinical-examination section.[18] The clinical-examination section evaluates knee-ligament injuries by measuring effusion, range of motion, and ligament laxity and categorizing each impairment into 1 of 4 categories: normal, nearly normal, abnormal, and severely abnormal. The worst rating of any impairment serves as the final overall evaluation of knee outcome. To date, all psychometric evaluations of the IKDC have been performed on the original IKDC system.[19,20]

Questionnaires. Although there are a variety of knee-rating scales reported throughout the literature to examine the results of ACL-reconstructive surgery, there appears to be no single optimal method of reporting ACL-surgery outcomes.[19,21] Different scales are proposed to be weighted toward different outcome features and produce quite different ratings for the same person.[22] The absence of a gold standard led to 3 questionnaires being used in this research project to examine outcome. First, the new subjective section of the IKDC was used. This scale examines symptoms of pain, swelling, "giving way" during activity, and the impact of the knee's condition on the functional capacity of the respondent.[18] Second, 4 scales from the Cincinnati Knee Rating System (CKRS) were used to examine various aspects of knee outcome: the symptom-rating scale, the change-in-sports-activity scale, the activities-of-daily-living (ADL) scale, and the function-sports scale. These scales allow assessment and scoring of symptoms at different levels of activity, changes in sporting activity since injury, and difficulties with ADL and sport participation.[19] Third, the Knee-Injury and Osteoarthritis Outcome Score (KOOS) was also used to assess subjective knee outcome.[23] This 42-item self-administered questionnaire is made up of 5 sections labeled pain, symptoms, ADL, sport and recreation function, and knee-related quality of life.[23]

Activity. The 6-m timed hop test[24] was one of the 2 hop tests used to examine functional outcome. Participants were timed hopping over a distance of 6 m. A limb-symmetry index was calculated by dividing the mean time (2 trials) in seconds of the uninvolved limb by the mean time of the involved limb and multiplying by 100.

The triple-cross-over hop test[25] was also used to examine knee function. Participants were instructed to hop 3 consecutive times on 1 foot, crossing over a 15-cm-wide strip on each hop. The total distance hopped was measured. A limb-symmetry index was calculated by dividing the mean distance (2 trials) in centimeters of the involved limb by the mean distance of the uninvolved limb and multiplying by 100. Both the 6-m hop test and triple-cross-over hop test have been shown to be reliable and have demonstrated evidence of construct validity.[24]

Procedure

At the time of recruitment participants were provided with a folder containing details of the study, 12 postage-paid reply envelopes, and a 12-week exercise logbook. Participants were instructed to keep a daily log of home-based exercise completion and return the appropriate home-exercise sheet on a weekly basis for 12 weeks after surgery.

All participants undertook a standardized rehabilitation program based on the similar protocols of the 4 participating orthopedic surgeons. The protocols emphasized some of the key principles of an accelerated program, such as immediate weight bearing as tolerated, early restoration of full knee extension, and early closed kinetic chain exercises, with the overall aim of returning to activities such as sport after 6–9 months. Although the key principles of the accelerated program were followed, specific details of each program were left to the clinical judgment of the treating physical therapist. Table 1 presents a summary of the goals of the rehabilitation protocols used.

Adherence to appointments and therapist ratings of adherence during appointments were measured at every appointment for 12 weeks after surgery. At 9 and 12 months after surgery participants were reviewed and all outcome measurements taken.

Statistical Analysis

Adherence Calculations. Home-exercise adherence was the average home-exercise completion over the first 8 weeks of rehabilitation. The decision to use the first 8 weeks of diary entries, rather than the first 12 weeks as planned, was based

Table 1 Summary of the Accelerated Rehabilitation Program Based on Protocols of the 4 Participating Surgeons

Time after surgery	Goals of rehabilitation
0–2 wk	Control swelling Full knee extension Range of motion: knee flexion Quadriceps strength: supine drills Hamstring stretching Calf raises Weight bearing as tolerated
2–6 wk	Eliminate swelling Maintain extension Knee flexion to 120° Equal hamstring length 4/5 hamstring strength Strengthening: squats, step-ups/-downs, calf raises, hip exercises Bicycling, proprioception Full weight bearing
6–12 wk	Full range of motion Full squat Full strength Continue strengthening Dynamic proprioception Return to jogging/running Bicycling, swimming, plyometrics
3–6 months	Full strength, range of motion, endurance Sport-specific drills
6–12 months	Return to sport with surgeon approval

on the higher return rate of diaries at the 8-week mark (96%) than at the 12-week mark (59%). It appeared that many participants only attended regular physical therapy and followed a prescribed program for the first 8 weeks after surgery and began sport-specific training after that time, making the exercise diaries difficult to complete after 8 weeks.

Relationships Between Adherence and Outcome. To address the primary aim of exploring the relationship between adherence and outcome, Spearman correlation coefficients were applied to explore trends in the data. After checking for assumptions of ratio of cases to variables, multicollinearity, singularity, normality, linearity, homoscedasticity, and independence of residuals,[26] we performed multivariate analyses to examine the contribution of the 3 adherence variables (attendance, SIRAS, home exercise) to the outcome measures (KOOS, 4 Cincinnati scales, IKDC subjective, IKDC objective, 6-m hop, triple-cross-over hop). The standardized regression coefficients calculated using multiple regression were used to interpret how much weight each variable contributed to the dependent variable,[27] and the significance of each coefficient was analyzed using a t test. The proportion of the total variance in each dependent variable that could be explained by the combined independent variable was also analyzed in terms of the squared multiple correlation coefficient (R^2). The individual importance of each of the adherence variables was examined by calculating the squared semipartial correlations (Sr^2). This represents the decrement in R^2 that would result from the elimination of each adherence variable from the regression model.

Relationships Between Other Factors and Outcome. In the event of a nonsignificant relationship between adherence and outcome, the data were explored to identify potentially important variables influencing outcome. The following factors were investigated for their influence on outcome: age, gender, number of physiotherapy appointments, surgeon, physical therapy clinic, graft type, job type (manual or sedentary), marital status (married/de facto or single), preinjury sporting level, and meniscal damage. Univariate analysis was used for dichotomous variables, and bivariate analysis was used for continuous variables. Any variables found to influence outcome were used to partition the data, and the relationship between adherence and outcome was reexamined using correlation and multiple regression.

Results

Attendance, SIRAS scores, and home-exercise data can be viewed in Table 2. No significant relationships with Spearman correlation coefficient were found between the outcome measures and adherence at 9 months, and only 1 weak and inverse relationship emerged between attendance scores and IKDC clinical examination at 12 months ($r_s = -.31$). In addition, none of the multiple-regression equations predicting outcome were significant at 9 and 12 months for the combined cohort of 68 participants, with all R^2 values equal to or less than .10 (Table 3). This suggests that prediction of outcome based on the values of the 3 measures of adherence was no better than prediction based on chance. The Spearman correlation coefficient and multiple-regression examination of the influence of adherence on outcome did not demonstrate a relationship until the participants were separated into 2 groups

Table 2 Measures of Adherence, Mean and Range

Adherence variable	Median (25th–75th percentile)
Attendance, % of scheduled appointments	100 (91.1–100)
SIRAS scores, 3–15	13.8 (12.9–14.7)
Home exercise, % of prescribed exercises	75 (60.9–86.5)

Table 3 Standard Multiple Regression of Adherence and Outcome at 9 and 12 Months for all Participants*

Outcome measure	R^2	Home exercise, β	Attendance, β	SIRAS score, β
9 months				
KOOS scores	.02	–.03	.02	.15
Cincinnati symptoms	.02	.11	–.09	.00
Cincinnati ADL	.05	–.08	–.09	.22
Cincinnati sport	.03	–.12	–.09	.12
IKDC subjective	.02	–.08	.02	.13
6-m hop	.10	–.20	.13	.26
triple-cross-over hop	.04	–.01	.13	.15
12 months				
KOOS scores	.02	.13	.00	–.04
Cincinnati symptoms	.03	.01	.10	.12
Cincinnati ADL	.01	.06	–.04	.04
Cincinnati sport	.01	.10	–.03	–.08
IKDC subjective	.01	.04	.04	.03
6-m hop	.02	–.05	.06	.12
triple-cross-over hop	.02	.03	.13	.04

*R^2 indicates multiple correlation squared; β, standardized beta coefficient; SIRAS, Sport Injury Rehabilitation Adherence Scale; KOOS, Knee-Injury and Osteoarthritis Outcome Score; ADL, activities of daily living; and IKDC, International Knee Documentation Committee.

based on age. Even so, this relationship was present only between home-exercise adherence and outcome. There were no significant associations between adherence to and during appointments and outcome when the sample was separated by age.

The age partition was performed because there was a significant difference in outcomes in participants age 30 years and over and those under age 30. Participants under 30 scored better on all outcome measures at 9 and 12 months. This was significant for KOOS scores, Cincinnati symptoms, IKDC subjective scores, 6-m hop test, and the triple-cross-over hop test at 9 months and Cincinnati symptoms scores and the 6-m hop-test scores at 12 months (Table 4). For other factors explored

Table 4 Significant Group Differences on Outcome Using Independent Groups *t* Test*

Outcome measure	Age Group: <30 y, n = 43, mean (SD)	Age Group: ≥30 y, n = 25, mean (SD)	*t*	*P*
9 months				
KOOS scores	89.0 (7.3)	84.7 (8.7)	–2.14	.036
Cincinnati symptoms	8.9 (1.0)	7.8 (1.3)	–3.56	.001
IKDC subjective	82.8 (13.2)	75.9 (12.4)	–2.06	.044
6-m hop	95.9 (8.5)	85.9 (15.3)	–2.82	.009
triple-cross-over hop	94.3 (11.1)	86.1 (14.5)	–2.51	.015
12 months				
Cincinnati symptoms	9.3 (.96)	8.2 (1.7)	–2.63	.013
6-m hop	96.4 (6.6)	92.1 (9.4)	–2.08	.042

*KOOS indicates Knee-Injury and Osteoarthritis Outcome Score, and IKDC, International Knee Documentation Committee.

there was either no relationship with outcome (gender, graft type, surgeon, physical therapy clinic) or there were very few relationships and they were inconsistent in direction at the 12-month follow-up (job type, marital status, preinjury sporting level, meniscal damage).

Adherence to home exercise was negatively correlated with all outcome measures except 1 in participants age 30 years and over at 9 and 12 months. For participants under age 30 home-exercise adherence was positively correlated with most outcomes at both 9 and 12 months (Table 5). When participants under and over age 30 were combined, there were no apparent or significant relationships between adherence and outcome (Table 5).

Multiple regression further supported home-exercise adherence as a positive predictor of outcome in participants under 30 years of age and a negative predictor of outcome in those over 30. Separate multiple-regression equations were calculated using the 3 adherence measures as independent variables and each continuous outcome measure at 9 and 12 months as the dependent variable. Three equations were significant in the under-30 group at 12 months. The equations predicting Cincinnati symptoms scores ($F_{3,32} = 4.67$, $P < .01$), Cincinnati ADL scores ($F_{3,32} = 2.92$, $P < .05$), and Cincinnati sport scores ($F_{3,32} = 4.08$, $P < .05$) were significant, and home exercise was the sole significant predictor of outcome scores in each equation (Table 6). Altogether, 30% ($R^2 = .30$) of the variance in Cincinnati symptom scores, 22% of the variance in Cincinnati ADL scores, and 28% of the variance in Cincinnati sport scores could be predicted by knowing scores on the 3 adherence measures. The squared semipartial correlation (Sr^2) shows that if home-exercise adherence were removed from the equation the predicted variance would be decreased by 15% for symptom scores, 19% for ADL scores, and 21% for sport scores.

Table 5 Correlation (r_s) Between Home-Exercise Adherence and Outcome*

Outcome measure	Age Group: <30 y (n = 43)	≥30 y (n = 25)	All ages (n = 68)
9 months			
KOOS score	.27	–.43†	.03
Cincinnati symptoms	.37†	–.19	.17
Cincinnati ADL	.05	–.21	–.02
Cincinnati sport	.38†	–.62†	.01
Cincinnati return to sport	.23	–.11	.12
IKDC subjective	.15	–.32	.03
IKDC clinical	.21	–.15	.08
6-m hop	.12	–.26	.03
triple-cross-over hop	.15	–.03	.12
12 months			
KOOS score	.33†	–.29	.10
Cincinnati symptoms	.44†	–.15	.23
Cincinnati ADL	.21	–.24	.07
Cincinnati sport	.44†	–.28	.18
Cincinnati sport activity	.13	–.03	.10
IKDC subjective	.23	–.27	.09
IKDC clinical	–.08	–.24	–.17
6-m hop	.13	–.11	.04
triple-cross-over hop	.18	.03	.13

*KOOS indicates Knee-Injury and Osteoarthritis Outcome Score; ADL, activities of daily living; and IKDC, International Knee Documentation Committee.
†$P < .05$.

Table 6 Standard Multiple Regression of Adherence on Outcome at 12 Months (for subjects ≤30 years old)*

		Home Exercise		Attendance		SIRAS Scores	
Outcome measure	R^2	β	Sr^2	β	Sr^2	β	Sr^2
Cincinnati symptoms	.30†	.39†	.15	.22	.05	.19	.04
Cincinnati ADL	.22†	.45†	.19	–.12	.01	.14	.02
Cincinnati sport	.28†	.47†	.21	.16	.02	–.08	.01

*R^2 indicates multiple correlation squared; β, standardized beta coefficient; Sr^2, squared semipartial correlation; and ADL, activities of daily living.
†$P < .05$ (2-tailed).

In the 30-years-and-over group there was only 1 significant equation when adherence was regressed onto outcome. The equation predicting Cincinnati sport scores at 9 months ($F_{3,19} = 4.06$, $P < .05$) was significant. Home-exercise adherence was the only significant predictor of Cincinnati sport scores ($\beta = -0.60$) and was a negative predictor, suggesting that greater home-exercise adherence was predictive of poorer scores on the scale.

Comments

The findings of the present investigation suggest that for participants under 30 years of age, adhering to a home-exercise program in the first 8 weeks after ACL reconstruction was correlated with improved outcome at 9 and 12 months postsurgery. Conversely, for participants age 30 years and over, adhering to a home-exercise program after ACL-reconstructive surgery was somewhat detrimental to outcome. Adherence in terms of attendance at rehabilitation and adherence during appointments (as measured by the SIRAS) did not predict outcome scores.

The finding that age had a significant impact on outcome is contrary to 4 recent investigations comparing outcomes in young and middle-aged patients after ACL reconstruction.[28-31] These 4 investigations noted no significant difference in outcomes between participants over age 40 and those under age 40. The contrasting findings between these studies and the present investigation can potentially be explained by the differing methods of measuring outcome. The outcome measures of choice in the 4 projects referenced included the Lysholm knee score (a subjective evaluation of impairment and activity), the IKDC clinical examination (effusion, range of motion, laxity, single hop for distance), and radiographic outcome. Such measures might not adequately discriminate outcomes to identify differences between age groups.

The Lysholm knee score has been identified in the literature as being more specific to activities of daily living than sporting activities[22] and therefore might not identify problems during more strenuous activities, resulting in most participants scoring high on the measure despite significant problems. Measures of impairment (IKDC clinical) did not demonstrate differences between age groups in the present investigation, so this finding is consistent with the lack of any significant difference found between age groups using the IKDC clinical examination in the other investigations. The significance of radiographic outcome after ACL reconstruction is not known. It is plausible that previous investigations have not identified a difference in outcomes between age groups because of the use of outcome measures that cannot discriminate at this stage of rehabilitation.

Although previous investigations[28-31] have not identified a difference in outcome after ACL-reconstructive surgery in older and younger participants, the findings of the present investigation are consistent with age-related changes in tissue and lifestyle. These age-related changes could negatively influence the recovery of older participants and could also have influenced the initial baseline level of such participants. Although it is feasible that older participants might not fare quite as well as their younger counterparts after ACL-reconstructive surgery, it does not explain why older patients who adhere to rehabilitation experience a worse outcome than older patients who do not adhere.

The findings of the current investigation agree with some of the findings of a similar investigation reported by Brewer et al,[7] who examined the adherence and outcome of 95 patients (mean age = 27 ± 8.2) attending rehabilitation after ACL reconstruction. Similar indices of adherence were used, although the method of measuring home-exercise completion was different, and adherence to home cryotherapy (ice) was also measured. Outcome measures differed from the present investigation, with 3 outcome measures being used: the KT1000 (laxity measure), the 1-leg hop test, and the Lysholm scale. Results showed no association between home-exercise adherence and any of the outcome measures. This finding is comparable to the findings of the present investigation with the sample combined (ie, all ages included in the calculations).

Rehabilitation protocols place a high demand on patients, with particular focus on the knee joint. The high exercise demands coupled with the limited recovery time evident in current ACL-rehabilitation protocols could be detrimental to patients over 30 years old. For example, the American College of Sports Medicine (ACSM)[32] guidelines for exercise prescription suggest a recovery time of 48 hours between strengthening-exercise sessions. For strengthening the quadriceps muscle, exercising 3 days per week is recommended.[33] Current ACL protocols exceed these recommendations for optimal muscle fitness and do not take into account the reduced ability of tissues such as cartilage, tendon, and bone to respond to normal loading or sustained exercise with age.[34] Based on home-exercise diaries used in this study, adherent participants typically completed knee exercises for more than 10 hours per week over 6 days of every week.

Older athletes might require even more recovery time based on evidence of soft-tissue changes with age.[35] A number of age-related changes in soft tissue have been reported in the literature and have been hypothesized to influence the recovery capacity of older athletes.[34] Different healing rates have been reported in the literature for patients under and over 30 when looking at meniscus healing after ACL reconstruction.[36] Tenuta and Arciero[36] found that on arthroscopy, patients over 30 who had previously undergone ACL reconstruction demonstrated decreased meniscal healing rates compared with patients under 30 years of age. Furthermore, the investigators found that patients undertaking a "conservative" rehabilitation program consisting of limited weight bearing and range of motion for the first 6 weeks after surgery demonstrated a higher rate of completely healed meniscal repairs than did participants undertaking an "accelerated" program. The authors concluded that accelerated programs might not be appropriate after ACL reconstruction with simultaneous meniscal repair. Although only 2 participants (3%) in the present study underwent meniscal repair, the findings of the Tenuta and Arciero[36] investigation lend weight to 2 explanations for the findings of the present investigation. First, that there is a difference in the tissue of participants age under and over 30 years that influences healing and recovery rates and, second, that the current method of ACL rehabilitation might not be appropriate for all participants.

Although it is important to acknowledge that correlation does not equal causation, the clinical implications of these findings are that rehabilitation after ACL reconstruction for older athletes should be decreased in intensity and spread out over a longer period. In addition, the promotion of home-exercise adherence among younger patients by physical therapists could help improve outcomes in this population. The findings of this study highlight the need for research on the efficacy of the accelerated rehabilitation approach after ACL reconstruction, particularly for older patients. A randomized study comparing the accelerated protocol with a less intense protocol based on ACSM guidelines in a sample of ACL-reconstructed patients over 30 years would be ideal. This would allow hypothesized changes in outcome to be attributed to the protocol.

A possible limitation of the current investigation was the method of data exploration. Unstructured searching through the data in an attempt to identify confounding variables could be considered a poor analysis technique. Considering the exploratory nature of the study, however, this method allowed the identification of an important confounding variable that could be further examined in future research.

The use of self-report diaries to monitor home-exercise adherence could also be considered a potential limitation of this study. The notion that self-reported adherence is subject to bias in a socially desirable direction[37] was addressed by informing participants that only the researchers would be privy to diary information, and even then information would be coded. To reduce the likelihood of inaccuracy because of poor recall,[37] participants were asked to complete the diary daily and send in the completed section at weekly intervals. This method ensured that at the very worst, diaries would have been completed weekly, a time frame that still depends on short-term recall. Because a wide range of home-exercise adherence was reported (31–107%) and the distribution was within normal limits, this was not regarded as a confounding problem.

Conclusion

The introduction of an accelerated approach to ACL rehabilitation promoting earlier weight bearing and movement and faster progression through rehabilitation milestones has been based on anecdotal evidence, with limited investigation of its effects. One explanation for the results of this study is that current rehabilitation might be too vigorous for older athletes. Current regimens might need to be reviewed and revised using accepted recommendations for exercise prescription.

References

1. Orchard J, Seward H, McGivern J, Hood S. Rainfall, evaporation and the risk of non-contact anterior cruciate ligament injury in the Australian Football League. *Med J Aust.* 1999;170(7):304-306.
2. DeLoes M, Dahlstedt LJ, Thomee R. A 7-year study on risks and costs of knee injuries in male and female youth participants in 12 sports. *Scand J Med Sci Sports.* 2000;10(2): 90-97.
3. Mirzayan R. Case Q&A: ACL injuries, part 1. *Medscape Orthop Sports Med* [serial online]. 2001;5(2).
4. Brukner P, Khan K. *Clinical Sports Medicine.* 2nd ed. Sydney, New South Wales: McGraw-Hill Book Co Australia Pty Ltd; 2001.
5. Shelbourne KD, Nitz P. Accelerated rehabilitation after anterior cruciate ligament reconstruction. *Am J Sports Med.* 1990;18(3):292-299.
6. Lai ETS, Ng GYF. A survey on the rehabilitative management of anterior cruciate ligament injuries in Hong Kong. *Hong Kong Physiother J.* 1997;15:15-21.
7. Brewer BW, Van Raalte JL, Cornelius AE, et al. Psychological factors, rehabilitation adherence, and rehabilitation outcome after anterior cruciate ligament reconstruction. *Rehabil Psychol.* 2000;45(1):20-37.
8. Schenck RC, Blaschak MJ, Lance ED, Turturro TC, Holmes CF. A prospective outcome study of rehabilitation programs and anterior cruciate ligament reconstruction. *Arthroscopy.* 1997;13(3):285-290.
9. Treacy SH, Barron OA, Brunet ME, Barrack RL. Assessing the need for extensive supervised rehabilitation following arthroscopic ACL reconstruction. *Am J Orthop.* 1997;26(1):25-29.
10. Brewer BW. Adherence to sport injury rehabilitation programs. *J Appl Sport Psychol.* 1998;10(1):70-82.
11. Brewer BW, Van Raalte JL, Petitpas AJ, Sklar JH, Ditmar TD. A brief measure of adherence during sport injury rehabilitation sessions. *J Appl Sport Psychol.* 1995;7: S44.
12. Brewer BW, Van Raalte JL, Petitpas AJ, et al. Preliminary psychometric evaluation of a measure of adherence to clinic-based sport injury rehabilitation. *Phys Ther Sport J.* 2000;1(3):68-74.
13. Brewer BW, Avondoglio JB, Cornelius AE, et al. Construct validity and interrater agreement of the Sport Injury Rehabilitation Adherence Scale. *J Sport Rehabil.* 2002;11(3): 170-178.
14. Chen CY, Neufeld PS, Feely CA, Skinner CS. Factors influencing compliance with home exercise programs among patients with upper-extremity impairment. *Am J Occup Ther.* 1999;53(2):171-180.
15. Henry KD, Rosemond C, Eckert LB. Effect of number of home exercises on compliance and performance in adults over 65 years of age. *Phys Ther.* 1999;79(3):270-277.
16. Friedrich M, Gittler G, Halberstadt Y, Cermak T, Heiller I. Combined exercise and motivation program: effect on the compliance and level of disability of patients with chronic low back pain: a randomized controlled trial. *Arch Phys Med Rehabil.* 1998;79(5):475-487.
17. Schneiders AG, Zusman M, Singer KP. Exercise therapy compliance in acute low back pain patients. *Man Ther.* 1998;3(3):147-152.
18. International Knee Documentation Committee. IKDC Knee Form 1999. Available at: http://www.aclstudygroup.com/IKDC%20form.htm. Accessed January 2000.
19. Risberg MA, Holm I, Steen H, Beynnon BD. Sensitivity to changes over time for the IKDC form, the Lysholm score, and the Cincinnati knee score. a prospective study of 120 ACL reconstructed patients with a 2-year follow-up. *Knee Surg Sports Traumatol Arthrosc.* 1999;7(3):152-159.
20. Irrgang JJ, Ho H, Harner CD, Fu FH. Use of the International Knee Documentation Committee guidelines to assess outcome following anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 1998;6(2):107-114.
21. Sgaglione NA, Del Pizzo W, Fox JM, Friedman MJ. Critical analysis of knee ligament rating systems. *Am J Sports Med.* 1995;23(6):660-667.
22. Borsa PA, Lephart SM, Irrgang JJ. Sport-specificity of knee scoring systems to assess disability in anterior cruciate ligament-deficient athletes. *J Sport Rehabil.* 1998;7(1): 44-60.
23. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee injury and osteoarthritis outcome score (KOOS): development of a self-administered outcome measure. *J Orthop Sports Phys Ther.* 1998;28(2):88-96.
24. Goh S, Boyle J. Self evaluation and functional testing two to four years post ACL reconstruction. *Aust J Physiother.* 1997;43(4):255-262.

25. Noyes FR, Barber SD, Mangine RE. Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *Am J Sports Med.* 1991;19(5): 513-518.
26. Tabachnick BG, Fidell LS. *Using Multivariate Statistics*. 3rd ed. New York, NY: HarperCollins College Publishers; 1996.
27. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice*. 2nd ed. Upper Saddle River, NJ: Prentice-Hall, Inc; 2000.
28. Barber FA, Elrod BF, McGuire DA, Paulos LE. Is an anterior cruciate ligament reconstruction outcome age dependent? *Arthroscopy*. 1996;12(6):720-725.
29. Brandsson S, Kartus J, Larsson J, Eriksson BI, Karlsson J. A comparison of results in middle-aged and young patients after anterior cruciate ligament reconstruction. *Arthroscopy*. 2000;16(2):178-182.
30. Heier KA, Mack DR, Moseley JB, Pain R, Bocell JR. An analysis of anterior cruciate ligament reconstruction in middle-aged patients. *Am J Sports Med.* 1997;25(4):527-532.
31. Viola R, Vianello R. Intra-articular ACL reconstruction in the over-40-year-old patient. *Knee Surg Sports Traumatol Arthrosc.* 1999;7(1):25-28.
32. American College of Sports Medicine. *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription*. 4th ed. Baltimore, Md: Lippincott Williams & Wilkins; 2001.
33. Feigenbaum MS, Pollock ML. Prescription of resistance training for health and disease. *Med Sci Sports Exerc.* 1999;31(1):38-45.
34. Buckwalter JA, Woo SLY, Goldberg VM, et al. Current concepts review: soft-tissue aging and musculoskeletal function. *J Bone Joint Surg Am.* 1993;75(10):1533-1548.
35. Brown M. The older athlete with tennis elbow: rehabilitation considerations. *Clin Sports Med.* 1995;14(1):267-275.
36. Tenuta JJ, Arciero RA. Arthroscopic evaluation of meniscal repairs: factors that effect healing. *Am J Sports Med.* 1994;22(6):797-802.
37. Meichenbaum D, Turk DC. *Facilitating Treatment Adherence*. New York, NY: Plenum Press; 1987.

J Sport Rehabil. 2005;14:215-233. © 2005 Human Kinetics, Inc.

Patterns of Dynamic Malalignment, Muscle Activation, Joint Motion, and Patellofemoral-Pain Syndrome

Jennifer E. Earl, Jay Hertel, and Craig R. Denegar

Context: Dynamic malalignment (DM), abnormal muscle activation, and static malalignments all might lead to patellofemoral pain (PFP) but have not been examined using a multifactorial approach. ***Objective:*** To determine which measures of static malalignment, DM, and muscle-onset times best predict PFP. ***Design and Setting:*** Between-subjects, laboratory. ***Subjects:*** 2 groups (PFP and uninjured) of 16 subjects each. ***Interventions:*** EMG and 3-D kinematic data were recorded during a step-down. Five static-alignment assessments were performed. ***Measurements:*** Three discriminant analyses using injury as the grouping variable and static measures, joint angles, and EMG onsets as the predictor variables. A final combined discriminant analysis using the most predictive variables from each set. ***Results:*** The static-alignment discriminant function was most predictive (81.3% correct), followed by the kinematic (69%) and the EMG (67%) functions. The final discriminant function included iliotibial-band flexibility, navicular drop, pronation, knee flexion, hip adduction, gluteus medius, and vastus medialis obliquus onset time and correctly classified 92.3% of PFP subjects. ***Conclusions:*** PFP can most accurately be predicted when multiple measures of lower extremity function are considered together. ***Key Words:*** alignment, knee, biomechanics

Patellofemoral-pain syndrome (PFP) is an overuse injury characterized by chronic, aching pain around the patella that is exacerbated by climbing stairs, squatting, or sitting with the knees flexed for prolonged periods of time. The multifactorial etiology of PFP makes it challenging to determine the cause or causes that are correctable with rehabilitation. Studies that have investigated individual factors contributing to PFP have produced inconsistent and sometimes contradictory results. The literature suggests that there are 3 areas in which dysfunction might lead to PFP: dynamic malalignment, abnormal muscle activation, and clinically measured static alignments.

Dynamic malalignment (DM) is defined as malalignment that occurs during movement as a result of poor neuromuscular control of the trunk and lower extremity. Several authors have made a clinical connection between DM and PFP.[1-4] There

Earl is with the Dept of Human Movement Sciences, University of Wisconsin–Milwaukee, WI 53201. Hertel is with the Dept of Human Services, University of Virginia, Charlottesville, VA 22904-1389. Denegar is with the Dept of Kinesiology, University Park, PA 16801.