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Assessing implementation, limited efficacy, and acceptability of the BEAST tool: A rehabilitation and return-to-sport decision tool for nonprofessional athletes with anterior cruciate ligament reconstruction

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A R T I C L E I N F O

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A B S T R A C T

Objectives: To assess the implementation, limited efficacy, and acceptability of the BEAST (better and safer return to sport) tool – a rehabilitation and return-to-sport (RTS) decision tool after anterior cruciate ligament reconstruction (ACLR) in nonprofessional athletes.
Design: Prospective cohort.
Participants: 43 nonprofessional pivoting sport athletes with ACLR.
Main outcome: Clinician- and athlete-experienced implementation challenges (implementation), changes in quadriceps power, side hop and triple hop performance from 6 to 8 months after ACLR (limited efficacy), athletes' beliefs about the individual rehabilitation and RTS plans produced by the BEAST tool (acceptability).
Results: The BEAST tool was developed and then implemented as planned for 39/43 (91%) athletes. Hop and quadriceps power performance improved significantly, with the largest improvement in involved quadriceps power (standardised response mean 1.4, 95% CI:1.1–1.8). Athletes believed the rehabilitation and RTS plan would facilitate RTS (8.2 [SD: 2.0]) and reduce injury risk (8.3 [SD: 1.2]; 0 = not likely at all, 10 = extremely likely).
Conclusion: The BEAST tool was implemented with few challenges and adjustments were rarely necessary. Athletes had large improvements in quadriceps power and hop performance on the involved leg. Athletes believed that the individual rehabilitation and RTS plans produced by the tool would facilitate RTS and reduce injury risk.

1. Introduction

Current rehabilitation guidelines for anterior cruciate ligament reconstruction (ACLR) underscore the need for an individual, multidisciplinary and sport-specific approach (Filbay & Grindem, 2019; Musahl & Karlsson, 2019). Unfortunately, guidelines for the late-phase rehabilitation and the transition to return to sport (RTS)

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are mainly based on expert opinion (van Melick et al., 2016).

Professional athletes, who often have high internal motivation and close follow-up from specialist health teams, have 5–8 times higher odds of RTS compared to nonprofessional athletes (Ardern et al., 2014). Furthermore, a higher proportion of nonprofessional athletes with ACLR who receive progressive rehabilitation at a sports medicine clinic report normal 2-year function in sport (80–94%) compared with those who receive usual care (55–59%) (Grindem et al., 2015). However, it is not sustainable nor possible for all athletes to be supervised by specialist sports rehabilitation professionals from the time of the injury to RTS. From 3 months after ACLR, more than 40% of Australian physical therapists recommend a transition to home/gym-based independent rehabilitation with only episodic reviews (Ebert et al., 2019). In Europe (Dingenen et al., 2021) and North America (Greenberg et al., 2018), the rehabilitation follow-up is also often discontinued before the athlete returns to sport. Most nonprofessional and youth athletes therefore self-manage the last phase of rehabilitation and RTS.

To bridge the gap between the demands of sport and high intensity workouts in a gym, approaches to late-phase rehabilitation and RTS transition have been proposed (Buckthorpe, 2019; Taberner et al., 2019). However, these approaches require access to a sports rehabilitation professional (e.g. for supervised on-field rehabilitation) and sophisticated equipment (e.g. GPS units and movement analysis systems). In other words, they require resources unavailable to most nonprofessional athletes. Further, both athletes and generalist rehabilitation professionals may lack the advanced knowledge required to turn approaches to late-phase rehabilitation and RTS transition into concrete plans. A decision tool that devises individual rehabilitation and RTS plans may therefore be more relevant for nonprofessional athletes – the largest group of athletes with ACLR who also have the lowest RTS rates.

We have therefore designed a rehabilitation and RTS decision tool for nonprofessional athletes: the BEtter And Safer reTurn to sport (BEAST) tool. To provide an individual plan for each athlete, the BEAST tool is based on a knee assessment and can trigger different protocols (e.g. for sport-specific training or effusion management). The protocols comprise the athlete's rehabilitation and RTS plan—the decision tool thereby provides a roadmap that the generalist rehabilitation professional can use to guide the athlete back to sport. To ensure relevance for our target group, the BEAST tool was designed in collaboration with athletes with experience of ACLR, primary care and expert sports physical therapists, and coaches in nonprofessional sport.

Due to the novelty of this decision tool, there is a need to assess whether it can be implemented as planned (implementation (Bowen et al., 2009)), whether it shows promise in being successful (limited efficacy (Bowen et al., 2009)), and whether athletes believe it to be helpful (acceptability (Bowen et al., 2009)). The objective of this study is to assess the implementation, limited efficacy, and acceptability of the BEAST tool – a novel rehabilitation and RTS decision tool for nonprofessional athletes with ACLR.

2. Methods

The first 43 athletes of the BEtter and Safer Return to sporT (BEAST) study participated in this study (clinicaltrials.gov #NCT04049292). The athletes were included from March 2019 to August 2020 at the Norwegian Sports Medicine Clinic (Nimi) and the Norwegian Sports Medicine Centre (Idrettens Helsesenter). Throughout postoperative ACL rehabilitation, athletes are often referred to these clinics via the sports insurance system and from local surgeons in the Oslo area. The reasons for referral are RTS assessments, and second opinions due to lack of appropriate testing equipment and requests for rehabilitation guidance. To be included in the BEAST study, athletes had to have had a primary ACLR in the last 6 months (+- 2 weeks) and have sustained their injury when they were 15–40 years old. The BEAST tool was designed for athletes in football, handball, basketball or floorball. Further inclusion criteria were therefore to have participated in either football, handball, basketball or floorball at least 2 times per week prior to injury and express a goal to return to this sport. We excluded athletes if they had ACL graft rupture, a grade 3 injury to any of the collateral ligaments or posterior cruciate ligament, had a contralateral ACL injury, did not understand Norwegian language, had other serious injury or illness that impaired function, or if they were professional athletes. A professional athlete was defined as someone who either had access to specialist sports medicine care (e.g. through the national team), derived their primary income from sports participation, or belonged to a team where a member of a sports health team was present at the majority of the training sessions.

2.1. BEAST tool development

An overview of the BEAST tool is depicted in Fig. 1 with terms explained in Table 1. In the initial development phase, we designed a preliminary version based on previous research (Grindem et al., 2016; Kyritsis et al., 2016) and clinical experience. The knee assessment was designed so that the necessary information to make rehabilitation and RTS progress decisions could be obtained in a single 60-min session that included a clinical knee examination, a quadriceps power test, and hop tests.

Feelings of isolation, lack of athletic identity, and insufficient social support are common barriers to RTS (Podlog et al., 2011). Therefore, we determined that sport-specific training should occur through progressive reintegration in team practice. Preliminary sport-specific protocols were drafted for football, handball, floorball, and basketball. Confidence and low fear facilitate RTS (Ardern et al., 2013), and injury-related fears are task-specific within each sporting context (Meierbachtol et al., 2018). We therefore determined that the sport-specific protocols should facilitate step-wise mastery of tasks of gradually higher athlete-perceived risk. The first steps (practice level 1–3 [PL1-3]) include sport-specific tasks in a safe and controlled environment. To progress, the athlete was required to complete a minimum of 4 sport-specific sessions over at least 2 weeks without experiencing effusion or pain. The final version of practice level 1–6 [PL1-6] for football is provided as an example in Table 2. Specific criteria for progression to restricted participation during team practice (practice level 4 [PL4]) and full participation in team practice (practice level 6 [PL6]) were set, representing biological healing (time from ACLR), sport-specific training status, knee joint effusion, integrity of the ACL graft, hop test results, and quadriceps power test results (Table 3). All criteria were devised as *minimum* requirements for progression. Athletes were advised to only progress if they passed the criteria; they were free to spend more time in each progression level even if they passed. Progression to match level 1 (ML1) was initiated following a minimum of 4 weeks at PL6; the earliest possible participation in match play was at 10 months after ACL reconstruction. Finally, we drafted protocols to be followed if athletes did not meet the PL6 criteria for effusion, quadriceps power, and hop tests. The first drafts of these protocols were based on clinical experience, previous research and a review of exercises in successful pivoting sports injury prevention programs.

A focus group of 4 pivoting sport athletes with experience of ACLR discussed the content and provided feedback on a draft version of the decision tool. The sport-specific protocols were revised to reflect a gradual increase in tasks with successively

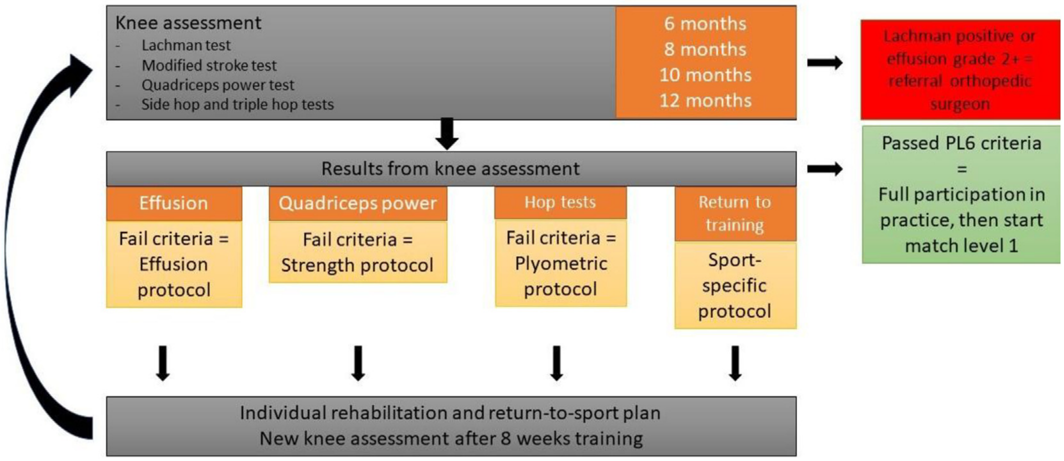

Fig. 1. Overview of the BEAST decision tool (PL = practice level).

Table 1
Description of terms.

Term	Description
Rehabilitation and RTS decision tool (BEAST tool)	The tool that determines what the athlete should do in terms of rehabilitation and RTS
Knee assessment	The 60-min session in the clinic that includes a clinical knee examination, quadriceps power test and hop tests, which produces the athlete's individual rehabilitation and RTS plan
Individual rehabilitation and RTS plan	The product of the decision tool and knee assessment. The plan is made up of one or multiple protocols
Sport-specific protocol	The detailed progression in sports participation. The protocol specifies which sport-specific skills the athlete should work on and limits what the athlete can do at team practice and matches
Effusion protocol	Actions to undertake when there is knee effusion grade 0 to 3
Strength protocol	The exercises the athlete performs if his or her quadriceps power test results are <90% limb symmetry index
Plyometric protocol	The exercises the athlete performs if his or her hop test results are <90% limb symmetry index

Table 2
Practice level 1–6 in the final football protocol.

Practice level	Activities on the field
1	Simple passing drills, running/dribbling without rapid change of directions
2	Passing drills with movement before/after passing, shooting/finishing, running/dribbling with change of direction but no opponent
3	All technical drills with the team, 1-on-1 drills, stand on the outside in square possession and similar drills (do not chase the ball)
4	All drills with the team, participate as back or wing in full-sided play
5	All drills with the team, full participation in full-sided play
6	Full participation, including small-sided play

Table 3
Criteria in the BEAST tool to progress to restricted participation during team practice (PL4) and full participation during team practice (PL6) in the sport-specific protocol.

	Time from ACLR	Sport-specific training	Modified stroke	Lachman	Side hop	Triple hop	Quadriceps power
Cutoff for PL4	≥8 months	PL3 completed	Grade 0	Negative	LSI ≥80%	LSI ≥80%	LSI ≥80%
Cutoff for PL6	≥9 months	PL5 completed	Grade 0	Negative	LSI ≥90%	LSI ≥90%	LSI ≥90%

PL: Practice level in the sport-specific protocol, LSI: Limb symmetry index.

higher athlete-perceived risk of injury and multiple other revisions were performed to facilitate athlete use (e.g. rest periods between sets in the quadriceps strength training protocol were reduced to 90 s and specific exercises were changed). The protocols were then reviewed by 8 primary care physical therapists with experience of rehabilitation after ACLR and minor changes were made. Finally, a nonprofessional coach in each of the 4 sports reviewed the sport-specific protocols to ensure clarity of language and that it would be possible to include an athlete with ACLR partially in team practice by following the instructions. The coach feedback led to minor clarifications and wording changes.

2.2. Final BEAST tool

Starting 6 months after ACLR, athletes underwent a knee assessment consisting of a clinical knee examination, quadriceps power test, a triple hop test, and a side hop test (see Appendix A for test procedures). The assessment was repeated 8, 10, and 12 months after ACL reconstruction, unless all criteria for full participation in practice (PL6, Table 3) were passed, in which case the athlete did not undergo further assessments. Athletes who passed all criteria except time from ACLR and/or sport-specific training also did not undergo further assessment. We routinely asked for the athlete's RTS goal during each knee assessment.

After the knee assessment, the athlete received an individual rehabilitation and RTS plan. The content of the plan was determined by the decision tool and reflected one or the combination of multiple protocols. Multisports athletes were advised to select and initially return to one of their sports through the RTS process. For sport-specific training (Table 2, full protocols for all sports in Appendix B), the athlete was responsible for sharing the plan and coordinating his or her restricted participation in team practice with the coach. The exercises in the strength and plyometric protocols (Appendix C) could be performed unsupervised in a gym, a rehabilitation clinic or on the sports field/court. If an athlete received rehabilitation support from a clinician, the athlete was responsible for sharing the rehabilitation and RTS plan and coordinating exercise selection with the clinician. No restrictions were imposed on other training (e.g. exercises for other muscle groups and cardiovascular fitness).

2.3. Implementation, limited efficacy, and acceptability

Implementation (Bowen et al., 2009) was assessed by investigating the degree to which athletes completed the knee assessments, any adjustments performed by the physical therapists, and challenges experienced by athletes or physical therapists during the assessments. To assess limited efficacy (Bowen et al., 2009), we assessed the change from 6 to 8 months in the key intermediary variables knee effusion, hop performance, and quadriceps power. Finally, acceptability (Bowen et al., 2009) was assessed by investigating the athletes' belief that the rehabilitation and RTS plan would facilitate RTS and/or reduce the risk of injury.

2.4. Data collection

Three physical therapists, with 9–21 years clinical experience, conducted the knee assessments as part of their regular clinical practice. The physical therapist used a standard form to record clinical stability, knee effusion, quadriceps power, and hop performance (see Appendix A for test procedures). The physical therapist also recorded the current level of sport-specific training, the content of the individual rehabilitation and RTS plan, if any adjustments were necessary, and challenges experienced by the athlete or physical therapist during the assessment. At 8 months, the athletes received a standard text message with a unique link to a survey through an online survey platform (Briteback AB, Norrköping, Sweden). The survey included two questions about athlete belief in the rehabilitation and RTS plan: "how likely do you believe it is that the plan will help you return to sport?" and "how likely do you believe it is that the plan will help you avoid new injury?" Both questions were rated from 0 (not likely at all) to 10 (extremely likely). A reminder was automatically sent to athletes who had not responded after 1 week.

2.5. Data management and analysis

For quadriceps power and both hop tests, the limb symmetry index (LSI) was calculated as the performance on the involved leg in percentage of the uninvolved leg performance. The peak of two trials was used to calculate LSI for the triple hop (see also Appendix A). Changes from 6 to 8 months were expressed as standardised response means (SRM) and classified as small (<0.5), moderate (0.5–0.8), and large (>0.8) (Cohen, 1988). We used paired t-tests to analyse changes in continuous variables. Effusion was treated as an ordinal variable and analysed with Wilcoxon signed rank test. Confidence intervals were calculated with Wald intervals for continuous variables and Wilson score intervals for categorical variables.

3. Results

Out of 44 eligible athletes, 43 (98%) accepted the invitation to participate. One athlete declined because he thought the intervention was too comprehensive. All 43 athletes attended the 6-month knee assessment. Nine athletes were included fewer than 2 months before a nation-wide shut-down of rehabilitation clinics and gyms in response to the coronavirus pandemic, and 1 athlete could not attend the 8-month follow-up due to Covid-19-related quarantine. These 10 athletes were excluded from the 8-month follow-up data. All 33 included athletes whose participation in the study was not disrupted by coronavirus were scheduled for and attended an 8-month knee assessment at a mean 1.9 (SD 0.3) months after the 6-month assessment. All 33 athletes also responded to the survey 8 months after ACLR.

The 43 athletes were aged 15–31 years, 30 (67%) were women, and they predominantly participated in football and handball (Table 4).

BPTB: bone-patellar-tendon-bone. Fifteen athletes (35%) had one concomitant injury, 9 athletes (21%) had two concomitant injuries, and 1 athlete (2%) had three concomitant injuries. In addition to the injuries listed in the table, 1 athlete had a grade 1 lateral collateral ligament injury and 1 athlete had a cartilage injury in the medial tibiofemoral compartment.

3.1. Implementation: challenges during the knee assessment and adjustments to the rehabilitation and RTS plan

Of the 43 athletes who attended the 6-month assessment, 42 (98%) completed quadriceps power testing, and 41 (95%) completed hop testing. The reasons for not completing quadriceps power and hop testing, respectively, were equipment malfunction (1 athlete) and grade 2+ knee effusion (2 athletes). Adjustment to the rehabilitation and RTS plan was performed in one case, as the physical therapist who assessed the athlete deemed it necessary to prescribe less challenging exercises than those in the plyometric protocol. The BEAST tool was therefore implemented as planned for 39 of 43 (91%) athletes. Of all 43 athletes, 9 (21%) reported some discomfort or pain during testing. One of these athletes had donor-site pain after quadriceps tendon graft harvest and 8 had donor-site pain after BPTB graft harvest.

Of the 33 athletes who attended the 8-month assessment, 33 (100%) completed quadriceps power and hop testing. Adjustment to the rehabilitation and RTS plan was necessary for one athlete who had medical exercise restrictions due to recently-contracted mononucleosis. The BEAST tool was therefore implemented as planned for 32 of 33 (97%) athletes. Discomfort or pain during testing was reported by 7 (21%) athletes. One of these athletes had donor-site pain after quadriceps tendon graft harvest and 6 had donor-site pain after BPTB graft harvest.

3.2. Limited efficacy: improvements in knee assessment variables

The results of the 6- and 8-month knee assessments are described in Table 5. At 6 months, the most common rehabilitation and RTS plan was the combination of the strength, plyometric, and sport-specific protocol (24/43, 56%). Three athletes (7%) received sport-specific training alone. Due to grade 2+ knee effusion, 2 athletes (5%) were referred to the surgeon. One of these athletes had a failed meniscal repair and subsequently underwent partial meniscectomy. For the other athlete, no additional injury was detected, and the effusion subsided with load adjustment as prescribed in the effusion protocol.

From 6 to 8 months after ACLR, there were statistically significant improvements in all measures of quadriceps power and hop

Table 4
Description of the 43 included athletes.

Athlete demographics (n = 43)	
Age (years), median (Q1-Q3)	19 (17–23)
Gender, n women (%)	29 (67)
Sport, n (%)	
Football	21 (49)
Handball	19 (44)
Floorball	2 (5)
Basketball	1 (2)
Height (cm), mean (SD)	173 (9)
Weight (kg), mean (SD)	71 (11)
BMI (kg/m^2), mean (SD)	23 (2)
ACL graft type, n (%)	
BPTB	31 (72)
Hamstrings	5 (12)
Quadriceps	7 (16)
Medial meniscus, n (%)	
No tear	30 (70)
Repair	10 (23)
Partial resection	2 (5)
Tear left in situ	1 (2)
Repaired root tear	0 (0)
Lateral meniscus, n (%)	
No tear	25 (58)
Repair	9 (21)
Partial resection	5 (12)
Tear left in situ	2 (5)
Repaired root tear	2 (5)
Medial collateral injury, n (%)	
No injury	40 (93)
Grade 1	0 (0)
Grade 2	3 (7)

performance for both the involved and uninvolved leg (Table 5, Fig. 2). The athletes had large improvements in quadriceps power for the involved and uninvolved leg, and for involved leg side hop and triple hop performance.

At 8 months, the most common rehabilitation and RTS plan was the combination of the strength, plyometric, and sport-specific protocol (14/33, 42%). Seven athletes (21%) received sport-specific training alone and none were referred to the surgeon. The percentage of athletes who passed individual criteria for PL4 and PL6 generally increased from 6 to 8 months after ACLR (Fig. 3a–d). Of the criteria that were possible to pass/fail at any timepoint, the quadriceps power criteria were consistently the criteria most athletes failed, while the criteria for knee effusion and clinical stability were passed with high frequency. Eight months after ACLR, 16 of 33 (48%) athletes passed all criteria for PL4.

Acceptability: athlete belief in the rehabilitation and RTS plan.

The mean (SD) athlete-reported belief that the rehabilitation and RTS plan would facilitate RTS was 8.2 (2.0). The mean (SD) athlete-reported belief that the plan would reduce injury risk was 8.3 (1.2).

4. Discussion

For 91% (39/43) of athletes, the BEAST tool was implemented as planned and no adjustments were necessary. The athletes had large improvements in involved side quadriceps power and hop performance from 6 to 8 months after ACLR. After following the rehabilitation and RTS plan for 2 months, athletes believed that the plan would facilitate RTS and reduce the risk of injury.

4.1. Implementation in practice

Although the decision tool was implemented with very few challenges, it is noteworthy that 21% of athletes, all with BPTB or quadriceps tendon grafts, had some discomfort or pain at the graft harvest site during the 6-month knee assessment. For several athletes in this study, the 6-month knee assessment was the first time since the injury that they exerted maximum effort with the involved leg. Rehabilitation prior to inclusion in this study was not controlled, and the tests may have provoked pain because the athletes were exposed to higher loads than what they were used to. At the 8-month assessment, quadriceps power on the involved side was substantially improved, yet a comparable proportion of athletes experienced discomfort or pain during the tests. We suggest clinicians inform athletes about the chance of donor-site discomfort or pain during the knee assessment. Other options, e.g. a progressive loading program, could also be explored to ease the transition from the postoperative rehabilitation to the maximum effort tests of the 6-month knee assessment. This may, however, not be appropriate for all athletes, especially athletes with an extended early postoperative period due to meniscal repair or meniscal root repair. To adapt to the athletes' individual progression in rehabilitation, a more flexible approach to the timing and commencement of knee assessments may be preferable in practice.

Table 5
Clinical stability, knee effusion, hop test performance, and quadriceps power performance 6 and 8 months after ACLR.

	N	6 months	N	8 months	n	Change (SD)	p-value
Lachman, positive (%)	43	0 (0)	33	0 (0)			-
Modified stroke test, n (%)	43		33				0.084
0		36 (84)		31 (94)			
Trace		3 (7)		2 (6)			
+1		2 (5)		0 (0)			
+2		2 (5)		0 (0)			
+3		0 (0)		0 (0)			
Side hop (hops), mean (SD)							
Involved	41	48 (17)	33	60 (13)	32	13 (11)	<0.001
Uninvolved	41	59 (12)	33	65 (12)	32	7 (9)	<0.001
Limb symmetry index (%)	41	82 (24)	33	92 (13)	32	12 (22)	0.003
Triple hop (cm), mean (SD)							
Involved	41	451 (77)	33	487 (76)	32	44 (40)	<0.001
Uninvolved	41	514 (72)	33	527 (70)	32	14 (36)	0.032
Limb symmetry index (%)	41	88 (8)	33	92 (8)	32	6 (8)	<0.001
Quadriceps power (w), mean (SD)							
Involved	42	151 (52)	33	176 (55)	32	29 (21)	<0.001
Uninvolved	42	206 (52)	33	224 (65)	32	15 (17)	<0.001
Limb symmetry index (%)	42	73 (15)	33	79 (14)	32	8 (9)	<0.001

Change scores are calculated for athletes who performed the tests during the 6- and 8-month knee assessment.

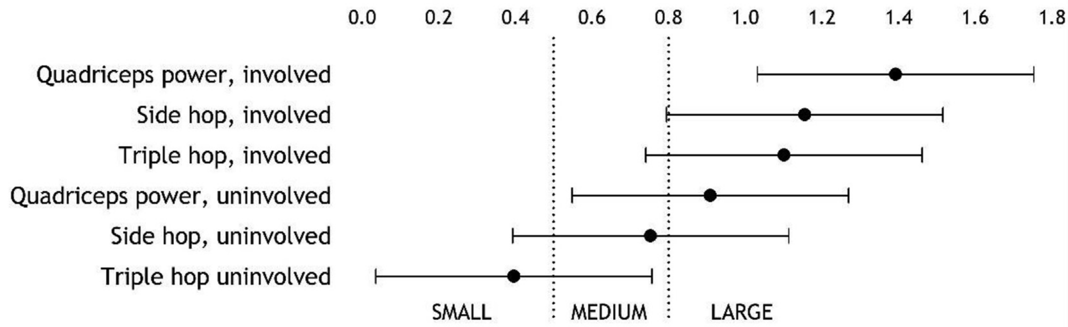

Fig. 2. Changes in quadriceps power and hop performance from 6 to 8 months after anterior cruciate ligament reconstruction (n = 32, dots represent standardised response means, whiskers 95% confidence intervals, and the dotted lines standardised response means size categories).

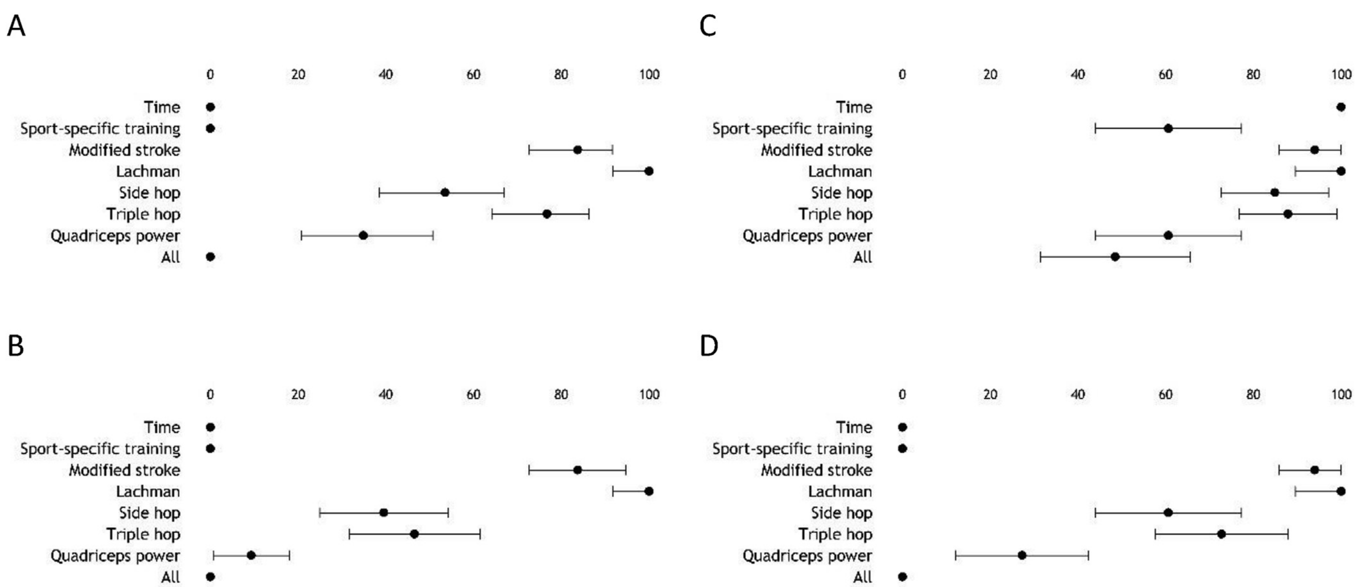

Fig. 3. Percentage of athletes passing individual criteria for practice level 4 (panel A) and 6 (panel B) sports progression 6 months after surgery (n = 43) and the percentage who passed criteria for practice level 4 (panel C) and 6 (panel D) sports progression 8 months after surgery (n = 33). Dots represent standardised response means and whiskers 95% confidence intervals. Confidence intervals are not presented for criteria that are impossible to fail/pass at the respective timepoints.

4.2. Improvements in knee assessment variables

Our results support previous literature (Beischer et al., 2017; Cristiani et al., 2019; Gokeler et al., 2017) and show that very few patients achieve symmetrical performance on hop tests and measures of quadriceps performance 6–8 months after ACLR. Even in young athletes recently cleared to RTS, the proportion meeting symmetry cutoffs of 90% for strength and hop tests is low (Toole et al., 2017). Undergoing concomitant medial meniscal repair or resection and having ACLR with a BPTB graft may further predispose an athlete to asymmetrical quadriceps strength and function 6 months after ACLR (Cristiani et al., 2019). In our sample, BPTB was the dominant graft choice and a third of athletes had medial meniscal surgery. The results of the 6-month knee assessment were therefore as expected. The decision tool was designed for use in a phase where formal rehabilitation follow-up is often infrequent or finished (Dingenen et al., 2021; Ebert et al., 2019; Greenberg et al., 2018). The substantial improvements in involved leg quadriceps power and hop test performance from 6 to 8 months are a promising indication that the rehabilitation and RTS plan improve quadriceps muscle power and functional performance. Despite the short training period of 8 weeks, the involved side change for all 3 tests was comparable with or larger than previously reported values for smallest detectable change (%) (Dingenen et al., 2019; Kockum & Heijne, 2015). The SRMs for both involved and uninvolved side quadriceps power are also higher than the SRMs for quadriceps peak torque from 4 to 6 months after ACLR following usual care (calculated from information in article) (Bodkin et al., 2021).

4.3. Athlete belief in the rehabilitation and RTS plan

The athletes believed that the rehabilitation and RTS plan would facilitate RTS and reduce injury risk. Although athletes believe compliance to rehabilitation is important for RTS (Sonesson et al., 2017), no previous study has, to our knowledge, quantified athlete belief in specific ACLR rehabilitation programs. We therefore do not know how our results would differ from those of a different rehabilitation plan. Athletes with ACLR experience a need for guidance and explicit feedback on how they are progressing throughout the rehabilitation (Paterno et al., 2019). Graded exposure to full participation in sport has also been described as an important part of managing fear of reinjury after ACLR (Mahood et al., 2020). The BEAST tool was created with these aspects in mind, and with athlete design contributions to ensure the challenging sport-specific tasks were broken into calculated progressions.

4.4. User contributions to the BEAST tool design

A key feature of our study is the intervention design contributions of athletes with ACLR, primary care physical therapists, and coaches in nonprofessional sports. The main design priority was to create a decision tool that could be implemented broadly and that addressed these users' needs. Therefore, we incorporated user advice and preferred solutions to the maximum extent possible. Due to our approach, the added health care costs include only coverage of up to four 60-min sessions per athlete with ACLR. The resources required to implement the intervention are minor compared to e.g. isokinetic dynamometry or motion analysis. However, the decision tool still requires some resources – most notably sufficient clinic space, a seated leg extension machine, a computerized muscle testing system, and clinician training. While the BEAST tool was adapted for users in our specific context, users in other clinical and sport contexts may have different needs and even more limited resources. Our study also highlights that there is a demand for such an intervention among nonprofessional athletes with ACLR – 98% of eligible athletes accepted the invitation to take part in this study. The athlete who declined to participate in the study thought that the intervention was too comprehensive, i.e. that an even simpler and less resource-demanding version would be preferable. A main challenge for this field is therefore to find solutions to improve RTS rates and reduce rates of new injury that are also accessible to nonprofessional athletes.

4.5. Generalisability

The BEAST tool is specifically designed for nonprofessional athletes with a first-time ACLR who aim to return to pivoting sport. Our results should not be generalised beyond this population. The athletes in this study mainly played football and handball, and the median age was 19 years. Compared to other cohorts (Bodkin et al., 2021; Grindem et al., 2020) and the general population with ACLR (Granan et al., 2009), the athletes in our study were younger and more active in pivoting sports. The characteristics of the study athletes were, however, similar to athletes in another cohort where only participants who planned to return to pivoting sports were included (Toole et al., 2017).

4.6. Strengths and limitations

A strength of this study is the high follow-up rate of eligible athletes. We consider the loss to follow-up due to the coronavirus pandemic to be random and the sample size was sufficient to detect changes in knee assessment variables and common implementation challenges. Natural history and learning effects may have contributed to the large improvements in quadriceps power and hop performance, and future research is warranted to assess the effect on muscle power and hop performance. Although two previous studies have not found a systematic learning effect in these tests (Dingenen et al., 2019; Kockum & Heijne, 2015), a learning effect might be present in our study as athletes had little familiarisation with the tests before the 6-month assessment. We report the initial results of athletes who followed the rehabilitation and RTS plan for 2 months. Future studies are needed for longer term follow-up, and to assess patient-reported outcomes, RTS, and new knee injuries.

5. Conclusion

The BEAST tool was implemented with few challenges and necessary adjustments. From 6 to 8 months after ACLR, athletes had large improvements in quadriceps power and hop test performance on the involved leg. The athletes believed that the individual rehabilitation and RTS plans produced by the decision tool would facilitate RTS and reduce injury risk.

Declaration of competing interest

CLA has received research salary support for work in return to sport from the Australian National Health and Medical Research Council (Early Career Fellowship APP1109779) Swedish Research Council (2015-03687) and Swedish Research Council for Sport Science (Postdoctoral fellowship D2018-0041), has received honoraria from non-profit post-professional sports medicine education providers for workshops and webinars on return to sport decision-making, and is Editor-in-Chief for Journal of Orthopaedic & Sports Physical Therapy (*JOSPT*). LE receives honorarium for instrument development for Arthrex and fellowship support and lecture fees for Smith & Nephew. He is an editor for the Journal of Bone and Joint Surgery and the British Journal of Sports Medicine (BJSM). MAR declares grant #R37HD37985 by the National Institutes of Health (The Delaware-Oslo ACL Cohort study). HG has received research salary support for work in return to sport from the Swedish Research Council for Sport Science, the International Olympic Committee, and the Norwegian Fund for Post-Graduate Training in Physiotherapy, has received honoraria from post-professional physical therapy education providers for workshops and lectures on rehabilitation and return to sport, and serves on the editorial boards of BJSM and JOSPT. HM, JK, GM: None declared

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Appendix A-C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2021.08.011.

Ethical statement

Written informed consent was acquired prior to inclusion and approval from the Norwegian South-Eastern Regional Committee for Medical Research Ethics was obtained.

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