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Using an integrated motor imagery and physical training intervention after knee injury: an interim analysis of the MOTIFS randomised controlled trial

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ABSTRACT

Objectives Physical function is often a main focus of knee injury rehabilitation, but recent recommendations include increasing attention to psychological factors. We have developed the MOTor Imagery to Facilitate Sensorimotor re-learning (MOTIFS) training model which integrates dynamic motor imagery into physical rehabilitation. The objective is to report interim analysis results of an adaptive randomised controlled trial regarding the pre-defined continuation criteria.

Methods Following a 12-week intervention in which participants were randomised to either MOTIFS or Care-as-Usual training, n=42 people undergoing rehabilitation for a traumatic knee injury were assessed for change from baseline to follow-up in psychological readiness to return to activity, using the ACL Return to Sport after Injury Scale (ACL-RSI), and side hop limb symmetry index. Continuation criteria included differences of ≥5 points in ACL-RSI and ≥8 points in side hop limb symmetry index in favour of the MOTIFS group. If these were not met, ≥5 points change in enjoyment was acceptable.

Results Pre-defined continuation criteria were not met for ACL-RSI (mean difference −8.1 (SE 4.1)), side hop limb symmetry index (mean difference 4.4 (SE 7.8)), nor enjoyment (mean difference 3.9 (SE 4.5)), indicating that major modifications are required for continuation of the MOTIFS trial.

Conclusion While results of this interim analysis did not show differences in psychological readiness to return to activity or side hop performance, previous research shows that the MOTIFS model is positive and enjoyable. Further research is warranted to evaluate more appropriate outcomes related to the holistic nature of physical and psychological readiness to return to activity.

Trial registration number NCT03473821.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Physical factors related to return to activity after traumatic knee injury have been well-explored, but psychological factors shown to be important are under-represented in research despite current recommendations.

⇒ Despite having passed physical return to activity testing following knee rehabilitation, psychological readiness remains consistently low and few psychological interventions specifically target these factors.

WHAT THIS STUDY ADDS

⇒ This study explores the use of a structured psychological intervention integrated into physical rehabilitation training for traumatic knee injury to simultaneously train physical and psychological factors using meaningful and individualised exercises.

⇒ Results show that pre-defined criteria were not met for psychological readiness to return to activity, side hop limb symmetry index or enjoyment, indicating that modifications to the MOTIFS trial are necessary to fully capture the nuanced and dynamic nature of both physical and psychological readiness to return to activity.

⇒ Re-examination of commonly used measures of readiness to return to activity may be required to reflect the complexities of ensuring a safe return.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This interim analysis indicates that the complex nature of rehabilitation needs to be more thoroughly explored to fully understand how physical and psychological factors interact. Further research is therefore required to integrate psychological training that effectively addresses all relevant aspects of this holistic perspective.

⇒ Future research should focus on identifying factors important for readiness to return to sport and the ability to modify these factors in a manner that encourages adaptability to activity-specific demands.

INTRODUCTION

Treatment following a traumatic knee injury includes physical rehabilitation training with or without reconstructive surgery.[1] Despite best-evidence treatment, many knee-injured people do not reach successful rehabilitation outcomes in terms of muscle strength[2] and function[3] and have worse patient-reported outcomes such as perceived knee function and fear of re-injury.[4]

Current best-practice guidelines for knee injury rehabilitation emphasise including psychological aspects of rehabilitation.[5]

However, the focus is often on rehabilitating physical function using neuromuscular and strength training.[1] Structured interventions specifically targeting psychological aspects of rehabilitation are lacking.

Psychological readiness to return to activity following the knee injury is often measured by assessing emotions, confidence and risk appraisal using the ACL Return to Sport after Injury Scale (ACL-RSI),[6] factors shown to be important for return to activity. However, specific clarification of which 'emotions' are evaluated or what 'risk appraisal' includes is lacking, making defining a real-world measure of readiness difficult. Additionally, psychological factors may negatively impact outcomes related to rehabilitation success, such as fear being associated with poorer hop performance.[7] Psychological skills training targets performance, confidence and self-efficacy[8] in uninjured athletes. One strategy is dynamic motor imagery (DMI), which creates a simultaneous mental and physical simulation of a specific activity based on one's own memories and experiences.[9] We have developed the novel MOTor Imagery to Facilitate Sensorimotor re-learning (MOTIFS) model, which integrates DMI into physical rehabilitation to simultaneously address physical and psychological factors.[10] The MOTIFS model creates an external focus of attention on meaningful, experience-based and task-specific situations. This method of training is based, in part, on the OPTIMAL Theory of Motor Learning, in which externally focused and self-determined motivation can aid in motor learning.[11] In creating meaningful exercises, it may be possible to modify perceptions of readiness to return to activity and physical function during rehabilitation training. The MOTIFS model has previously been shown to be associated with greater enjoyment, autonomy and positive psychological states, and movement quality can be maintained with the integration of DMI.[12] Additionally, physical therapists (PTs) and people with knee injuries perceive that the MOTIFS model provides structured psychological training to reduce fear and create meaningful, activity-relevant rehabilitation exercises.[13 14]

Given that the intervention is novel and has not been tested before, an adaptive randomised controlled trial (RCT) was designed and described in a study protocol,[10] including an interim analysis of predetermined continuation criteria to assess whether the trial can continue or whether modifications are necessary to ensure the constructs of interest are targeted. The aim of this study is to report the results of this interim analysis evaluating the MOTIFS model in reference to pre-defined psychological readiness to return to sport and physical hop function criteria and inform continuation of the trial.

METHODS

Study design and participants

This is an interim analysis of a 1:1 single assessor-blinded cumulative adaptive cluster-randomised controlled trial, conforming to the Consolidated Standards of Reporting Trials (CONSORT) statement extension for pragmatic trials.[15] clinicaltrials.gov registration: NCT03473821.

Experimental condition was assigned to n=6 participating clinics using a randomised number generator and third-party-administered sealed opaque envelopes (n=3 MOTIFS clinics, n=3 Care-as-Usual (CaU) clinics). Forty-two participants were randomised to the MOTIFS (n=21) or CaU (n=21) groups based on the clinic at which they were receiving treatment prior to inclusion (figure 1). People 16 years or older undergoing rehabilitation supervised by a PT for traumatic knee injury with a goal of returning to physical activity, had begun single leg hop training and understood a Scandinavian language or English were eligible. Participants were pre-screened by acting PTs in collaboration with the study coordinator (SC); those meeting preliminary criteria were contacted by the SC for further screening. Eligibility criteria, fully described previously,[10] were designed to recruit a sample representative of the target population.

Participant and public involvement

The MOTIFS model was developed in collaboration between clinically active PTs, and physical therapy and psychology researchers. Prior to model finalisation, participating PTs and knee-injured patients provided feedback. PTs were responsible for intervention administration and received education from the research team in the application of MOTIFS principles.

Interventions

The PT-administered MOTIFS model uses the principles of patient-centred (1) discussion and (2) creation of meaningful exercises, (3) execution of physically and psychologically realistic situations and (4) evaluation of realism and relevance, as described in detail in a study protocol.[10] For example, a soccer player performing a toe raise physically and mentally simulates a header using a hanging ball, imaging where to aim at a specific goalkeeper while simultaneously executing rehabilitation movements (see Cederström *et al*[12] for an explanatory film). MOTIFS clinics were provided equipment to aid in imagery realism.

MOTIFS included approximately 20 min of a standard 60 min session three times per week for 12 weeks, with six PT-supervised sessions, of which three included face-to-face SC visits to ensure correct execution. The remaining 30 sessions were performed at home (ie, unsupervised by the PT), and patients were instructed to apply MOTIFS principles to the PT-recommended programme. As data was collected partly during the COVID-19 pandemic, the number of required PT-supervised and SC-supervised sessions was flexible (ie, at-home or digital). CaU training, performed in the patient's clinic three times per week for 12 weeks with six PT-supervised sessions, consisted of commonly used knee rehabilitation practices, including neuromuscular training to improve muscular control and dynamic stability.[5] Participants were encouraged to perform at-home or on-field rehabilitation according

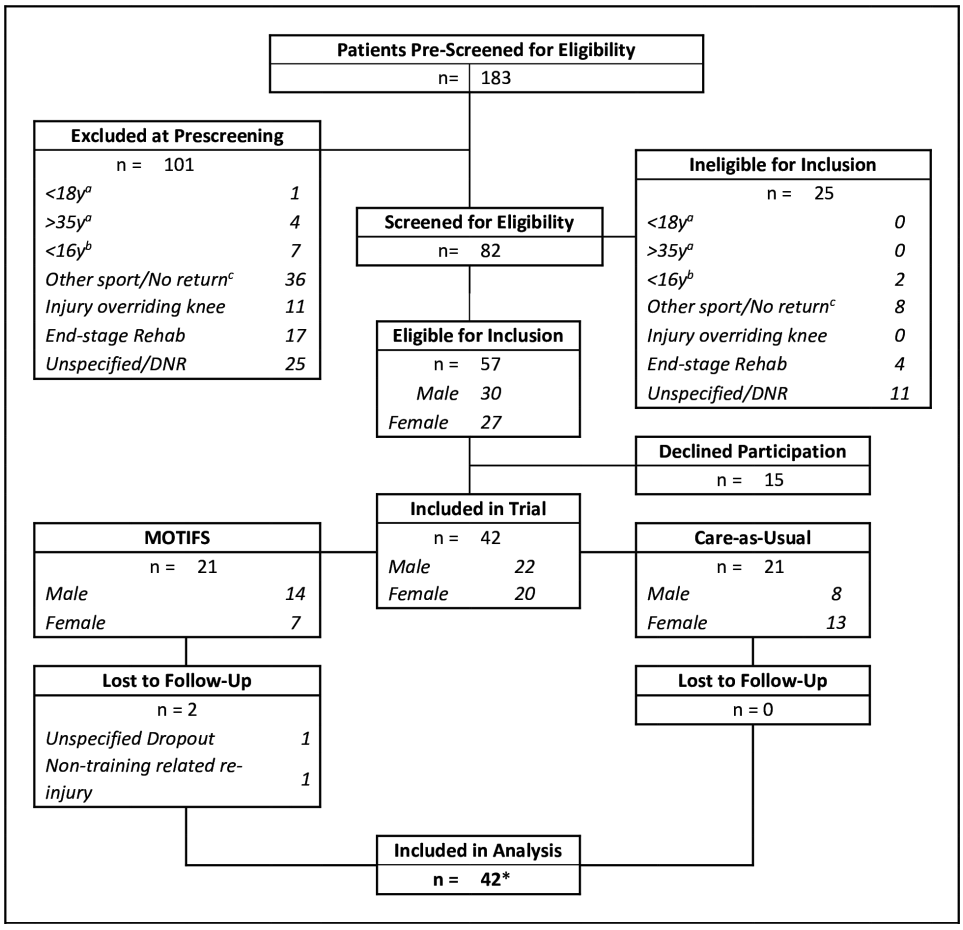

Figure 1 Participant flow diagram. [a]Inclusion criteria changed to include participants aged 16 years and older—November 2018. [b]Inclusion criteria changed to include sports other than soccer, handball, basketball, floorball—July 2019. [c]Inclusion criteria changed to include all traumatic knee injuries (ie, not only ACL injuries)—January 2020. *All data included in the final analysis as total missing does not exceed 5%, as specified in the study protocol. Data collection occurred between March 2018 and August 2022. DNR, did not respond; end-stage rehab, end-stage rehabilitation (ie, will return or be released from rehabilitation before intervention is completed); MOTIFS, MOTor Imagery to Facilitate Sensorimotor re-learning; no return, will not return to sport; y, years old.

to the PT-recommended programme. The SC had telephone contact with participants three times during the intervention.

Outcomes

Outcomes were assessed at baseline and 12-week follow-up, along with weekly adherence questionnaires, distributed to participants via email using the REDCap electronic data capture tool,[16] hosted by Lund University. An experienced test leader collected informed consent and demographic and functional data at the participants' treating clinic or the university laboratory.

Main outcomes were pre-defined continuation criteria, including mean between-group differences from baseline to 12-week follow-up in two patient-reported outcome measures and one hop test.[10] Psychological readiness to return to sport was evaluated using the ACL-RSI, encompassing emotional response, confidence and risk appraisal.[6 17] Physical function limb symmetry index (LSI) was evaluated using a 40 cm single leg side hop.[18] The Physical Activity Enjoyment Scale (PACES) evaluates enjoyment following physical activity,[19] translated to Swedish by the authors (moderate test–retest reliability; intra-cluster correlation coefficient=0.60; SEM=6.50). Secondary outcomes included previously described hop performance and participant-reported outcomes (table 1).[10] Continuation criteria were defined as: ≥5 points in ACL-RSI[6] and/or ≥8% in side hop LSI in favour of the MOTIFS group. If this was not fulfilled, ≥5 points in the PACES score was acceptable.

Data analysis

Continuation criteria were analysed using independent samples t-tests using the SPSS statistical software package (IBM, Armonk, New York, USA). To account for two main outcomes, p values were adjusted to p=0.025 (97.5% CI) to take into account the risk of introducing type I errors. Complete case analyses were performed by a blinded third-party data management committee (DMC), including a statistician and a physical therapy researcher with clinical experience, using a pre-defined

Table 1 Outcome measures

	Outcome measure	
Main outcomes (continuation criteria)	ACL-RSI[6]	12-item scale from 0 (worst) to 100 (best)
	Side hop LSI[18]	$\frac{\text{Number of side hops injured leg}}{\text{Number ofside hops uninjured leg}}$ X 100 (expressed as per cent)
	PACES[19]	18-item scale from 18 (worst) to 126 (best)
Secondary patient-reported outcomes	Knee Osteoarthritis Outcome Score[31]	42-item scale from 0 (worst) to 100 (best) on subscales pain, symptoms, sport and recreational activity, activities of daily life, quality of life
	Perceived Stress Scale[32]	10-item scale from 0 (best) to 40 (worst)
	Patient Enablement Instrument[33]	6-item scale from 0 (worst) to 12 (best)
	Rehabilitation Satisfaction[34]	1-item scale from –3 (dissatisfied) to 3 (satisfied)
	Rehabilitation Motivation[35]	3-item scale from 0 (worst) to 10 (best)
	Tegner Activity Scale[36]	3-item (pre-injury, current and future) scale from 1 (low activity) to 10 (very high activity)
Secondary physical outcomes	Hop Battery LSI[37]	Number of side hops (40 cm) Distance in a single leg hop for distance $\frac{\text{Side hop LSI+SLHD LSI}}{2}$
Adherence		Self-reported number of PT-supervised and at-home sessions (36 recommended; 6 of which PT-supervised) and session duration
AEs		Self-reported number and type of AEs, if any
		Serious AE: giving way episodes and/or new injury
		Training-related AE: giving-way episodes, swelling and pain

ACL-RSI, ACL Return to Sport after Injury Scale; AE, adverse events; LSI, limb symmetry index; PACES, Physical Activity Enjoyment Scale; PT, physical therapist; SLHD, Single Leg Hop for Distance.

checklist (online supplemental file 1). The DMC was then unblinded to draw conclusions about criteria fulfilment and subsequent modifications, discussed in an expert group, comprised of the DMC and authors (NC, expertise in motor imagery; SG, expertise in sport psychology; EA, primary investigator, expertise in physical therapy).[10] Fulfilled criteria result in continuation with no modifications; minor changes result in continuation with a new sample size calculation; major alterations result in modifications to optimise the model with a new sample.

Secondary analyses used independent samples t-tests. In addition to planned secondary analyses, ACL-RSI subscales (confidence, emotion and risk appraisal) were analysed separately. A multiple regression model using age, body mass index, time from injury to baseline testing, pre-injury sport, clinic (ie, cluster), gender and concomitant injuries as covariates analysed sensitivity; linear regression examined potential cluster effects. Activity level, stress and enablement were analysed using χ^2 testing. Motivation and rehabilitation satisfaction were presented as descriptives. Adherence was presented as a percentage of total sessions (out of 36 prescribed) and a mean number of PT-supervised and at-home sessions, and median range of self-reported at-home training minutes. Total adherence includes the summed total number of PT-supervised and at-home sessions out of a possible 36 (ie, 6 PT-supervised and 30 at-home sessions possible).

RESULTS

The sample included n=42 participants with a median pre-injury activity level of 9 (table 2). There were statistically significant between-group differences in number of ACL injuries (p=0.015), treatment type (p=0.006), injury mechanism (p=0.009) and pre-injury sport (p=<0.001).

Main outcomes

There were no significant changes in ACL-RSI, side hop LSI or PACES from baseline to 12-week follow-up. Continuation criteria were not reached, leading to a DMC recommendation of major modifications.

Secondary analyses

No significant between-group differences were observed in ACL-RSI subscales. The CaU group had a significantly greater change in number of side hops on the uninjured leg from baseline to 12 weeks (table 3). Motivation data is available in table 4. For rehabilitation outcome satisfaction, n=9 (47%) in the MOTIFS group and n=11 (53%) in the CaU group were dissatisfied with 12-week rehabilitation outcomes. There were no between-group differences in perceived stress, enablement or current or future activity level (table 5).

Table 2 Demographic information of the MOTIFS and Care-as-Usual (CaU) groups

Demographic variable	MOTIFS (n=21)	CaU (n=21)
Age (years; mean (SD))	20.9 (3.5)	23.6 (5.3)
BMI (mean (SD))	24.17 (2.71)	24.17 (3.45)
Pre-injury activity level (median (IQR))*	9 (8–9)	9 (7–9)
Time from injury to baseline testing (weeks; mean (SD))	54.19 (20.26)	61.10 (47.02)
Gender # (%)	7 (33) female	13 (62) female
Pre-injury sport # (%)		
Soccer	12 (57.1)	10 (47.6)
Handball	5 (23.8)	1 (4.8)
Basketball	0 (0.0)	1 (4.8)
Floorball	4 (19.0)	0 (0.0)
Other†	0 (0.0)	9 (42.9)
Injury # (%)		
Anterior cruciate ligament	21 (100)	17 (81)
Meniscus	8 (38)	9 (43)
Previous knee injury	2 (9.5)	1 (4.8)
Mechanism (contact)	8 (38.1)	1 (4.8)
Treatment type # (%)		
Rehabilitation only	1 (4.8)	8 (38.1)
ACLR+rehabilitation	20 (95.2)	13 (61.9)

*Pre-injury activity level based on patient-reported responses to Tegner activity scale at baseline testing.
†'Other' sports: general fitness (ie, gym; n=4), American football (n=1), roller derby (n=1), wakeboard (n=1), Thai boxing (n=1), taekwondo (n=1).
ACLR, ACL Reconstruction; BMI, body mass index (kg/m^2); MOTIFS, MOTor Imagery to Facilitate Sensorimotor re-learning.

Sensitivity and cluster analyses

Sensitivity analyses indicated that the model does not predict ACL-RSI change (F[7, 32]=1.446, p=0.222, R^2=0.240) or side hop LSI change (F[7, 27]=0.704, p=0.669, R^2=0.154). No significant cluster effects for ACL-RSI change (F[1, 38]=2.059, p=0.160, R^2=0.051]) or side hop change (F[1, 33]=0.670, p=0.419, R^2=0.02) were indicated.

Adherence

The MOTIFS group had 49% total adherence to the required three sessions per week; mean 8 (SD 8.6) out of 6 PT-supervised sessions and mean 10.3 (SD 11.3) out of 30 at-home sessions, reporting median 152–210 at-home training minutes. The CaU group reported 91% total adherence; mean 13.5 (SD 8.6) of 6 PT-supervised sessions, mean 19.4 (SD 15.1) of 30 at-home sessions and median 292–329 at-home training minutes. The MOTIFS group used imagery median 16–20 min per week, reporting median 'moderate' vividness.

Adverse events

Adverse events for the whole sample were reported by n=27 (64.3%; n=10 MOTIFS, n=17 CaU) participants, of which n=6 (14.3%; n=2 MOTIFS, n=4 CaU) were serious. Twelve training-related adverse events were reported in the MOTIFS group, and 21 in the CaU group.

DISCUSSION

Results of the interim analysis of 12 weeks of MOTIFS training do not meet pre-defined criteria for the outcomes chosen for this study. The aim of this analysis was to provide data to inform continuation or modification of this trial and is not a final result of the effect of MOTIFS training in general.

Psychological readiness to return to activity

The ACL-RSI was chosen as a main outcome because it is a commonly used measure of psychological readiness to return to activity in relation to the subscales of confidence, emotions and risk appraisal. In the RCT, we reasoned that training according to the MOTIFS principles would provide motivating and meaningful training. This was based on previous research indicating that person-centred shared decision-making can increase intrinsic motivation,[20] which could allow for increased movement-relevant confidence and greater enjoyment, thereby influencing psychological readiness.

Contrary to our hypothesis, results did not meet pre-defined criteria of ≥5 points difference in psychological readiness to return to activity. Interviews with patients[14] and PTs[13] indicate that MOTIFS training provides structured psychological training that prepares for return to activity. Therefore, the outcomes used in this study should be re-evaluated to address this inconsistency. Readiness to return decisions is often based on physical or psychological criteria,[21] but these tend to not consider activity-specific demands. If misunderstood, psychological readiness to return to activity may increase the risk of future injury.[22] MOTIFS training, perceived as a more meaningful and task-specific method of preparing for activity-relevant demands,[14] may increase understanding of physical and psychological limitations. Meaningful training can be positive for motivation and identity while simultaneously resulting in negative psychological states.[23] For example, motor imagery provides realistic predictions of potential task-specific outcomes, which may lead to decreased confidence.[24] A better understanding of limitations may be a facilitative adaptation, as readiness to return requires a holistic understanding of activity-specific demands and both physical and psychological patient-acceptable symptom states. The ACL-RSI provides an indication of global readiness but may not be an effective measure, as it is not sensitive to task-specific readiness and understanding of physical and psychological limitations.[6]

In the future, readiness to return to activity could be assessed by evaluating enhanced expectancies, important according to the OPTIMAL theory of motor learning,[11]

Table 3 Results of main analyses for between-group and within-group differences from baseline to 12-week follow-up

Outcomes	MOTIFS				CaU				Difference (MOTIFS – CaU)	
	Baseline (mean±SD)	12 weeks (mean±SD)	Change*		Baseline (mean±SD)	12 weeks (mean±SD)	Change*		Change (mean (SE))	P values (95% CI)
			n	Mean±SD			n	Mean±SD		
ACL-RSI†	52.9±21.1	50.0±21.4	19	−0.8±12.0	40.4±16.0	47.6±18.9	21	7.3±13.7	−8.1 (4.1)	0.056 (−17.6; 1.5)‡
Emotion	53.9±21.5	47.6±23.2	19	−4.1±18.9	40.0±16.2	47.3±18.6	21	7.3±19.3	−11.4 (6.0)	0.067 (−23.7; 0.82)
Confidence	49.4±23.9	48.4±23.4	19	1.3±14.1	39.8±17.6	45.5±20.8	21	5.7±11.7	−4.4 (4.1)	0.288 (−12.7; 3.9)
Risk appraisal	59.3±24.8	59.9±23.5	19	2.4±12.1	42.5±27.8	53.7±25.0	21	11.2±23.2	−8.7 (5.8)	0.142 (−20.5; 3.1)
Side hop LSI†	76.4±21.3	89.2±21.2	18	15.8±24.8	73.1±28.4	84.4±21.5	17	11.4±21.0	4.4 (7.8)	0.579 (−13.9; 22.7)‡
Side hop (injured; #)	37.2±14.5	42.8±13.3	18	7.6±12.2	29.4±16.3	35.9±17.5	17	9.1±9.7	−1.5 (3.8)	0.691 (−9.1; 6.1)
Side hop (uninjured; #)	48.6±11.9	47.9±10.9	18	−0.3±6.8	39.5±18.9	43.1±17.8	18	6.1±5.2	−6.4 (2.0)	0.003 (−10.5; −2.3)
PACES†	89.7±18.3	88.0±17.7	19	−1.5±14.1	90.3±11.8	84.9±14.8	21	−5.4±14.0	3.9 (4.5)	0.386 (−5.1;12.9)
KOOS pain	63.1±8.8	65.2±8.7	19	2.6±9.6	59.8±8.8	60.1±11.6	21	0.3±10.5	2.4 (3.2)	0.463 (−4.1; 8.8)
KOOS symptoms	31.3±10.4	33.6±10.9	19	2.8±10.9	33.3±9.3	35.5±11.3	21	2.2±9.3	0.6 (3.2)	0.850 (−5.9; 7.1)
KOOS ADL	71.3±4.7	72.6±3.7	19	1.3±4.6	70.1±6.9	70.1±8.2	21	0.0±5.6	1.3 (1.6)	0.425 (−2.0; 4.6)
KOOS sport/rec	47.1±18.7	53.4±17.3	19	5.8±15.3	40.0±19.3	46.7±18.4	21	6.7±16.5	−0.9 (5.1)	0.863 (−11.1; 9.4)
KOOS QoL	22.0±13.2	28.6±10.9	19	7.8±10.8	23.5±14.4	26.2±12.8	21	2.7±10.6	5.2 (3.4)	0.131 (−1.6; 12.1)
SLHD LSI	89.2±18.1	94.8±10.4	19	7.2±11.1	90.2±18.9	92.8±12.9	19	2.2±11.2	5.0 (3.6)	0.177 (−2.3; 12.3)
SLHD (injured; cm)	126.9±30.0	150.2±29.8	19	23.9±20.9	118.5±41.1	128.5±34.7	19	13.3±18.0	10.6 (6.3)	0.101 (−2.2 ;23.4)
SLHD (uninjured; cm)	144.1±27.3	158.9±28.1	19	13.3±15.9	132.3±37.8	139.5±34.6	18	11.6±15.1	1.7 (5.0)	0.736 (−8.5; 11.9)
Hop battery LSI	82.6±17.4	92.0±14.5	18	11.8±12.9	81.2±20.9	88.3±16.2	17	7.6±12.2	4.2 (4.3)	0.333 (−4.5; 12.8)

For secondary outcomes, two-tailed significance set at p=0.05.
*Change calculated as 12-week follow-up minus baseline for each participant.
†Main continuation criteria outcomes.
‡Due to two main outcomes, two-tailed significance set at p=0.025 (97.5% CI).
ACL-RSI, ACL Return to Sport After Injury Scale; ADL, activities of daily living; CaU, Care-as-Usual; KOOS, Knee Osteoarthritis Outcome Score; LSI, limb symmetry index; MOTIFS, MOTor Imagery to Facilitate Sensorimotor re-learning; PACES, Physical Activity Enjoyment Scale; QoL, Quality of Life; Side Hop (#), number of side hops; SLHD, Single Leg Hop for Distance; Sport/Rec, sport and recreation.

Table 4 Self-reported motivation at baseline and 12-week follow-up

	MOTIFS		CaU	
	Baseline	12 weeks	Baseline	12 weeks
	Median (IQR)	Median (IQR)	Median (IQR)	Median (IQR)
How important is it that you to return to your previous activity level?	9 (2)	8 (3)	9 (3)	8 (3)
Do you think it is possible for you to return to your previous activity level?	7 (6)	7 (5)	7 (4)	8 (3)
How much time and effort are you willing to invest to return to your previous activity level?	10 (2)	9 (3)	9 (3)	8 (4)

Results based on a scale from 1 (worst) to 10 (best).
CaU, Care-as-Usual; MOTIFS, Motor Imagery to Facilitate Sensorimotor re-learning.

in terms of task-specific self-efficacy. Readiness to return may depend on psychological factors suggested as important aspects of motor learning[11] such as intrinsic motivation and realistic expectations,[25] which the ACL-RSI subscales, including vague and undefined terms such as 'emotions', do not capture.[6] However, the current study only explores broad motivation, highlighting the need for future research to evaluate where on the motivational continuum participants fall (ie, intrinsic vs extrinsic). Given differences between the enjoyment and meaning constructs, future research may also evaluate eudaimonic motivation to determine whether training is perceived to align with personal values,[26] possibly providing insight into meaning related to athletic or activity identity. This would likely provide more nuanced data regarding psychological factors important for task-specific readiness.

Functional performance

The side hop is a commonly used test in rehabilitation following traumatic knee injury to assess physical readiness to return to activity. We hypothesised that side hop ability would improve following MOTIFS training based partly on the OPTIMAL theory of motor learning.[11] This theory suggests that external focus and intrinsic motivation during moderately challenging and meaningful movements can improve motor learning.[11] The MOTIFS model provides this opportunity when integrated into rehabilitation exercises.

Results show that side hop LSI did not fulfil pre-defined continuation criteria of ≥8% in favour of MOTIFS training. ACL-RSI and KOOS scores indicate that fear and anxiety may be persisting problems, which can in turn influence motor execution.[7] Physical deficiencies combined with negative psychological interpretation of knee limitations during the side hop may result in protecting the injured limb. Additionally, the physical and cognitive complexity of the side hop impairs performance,[27] indicating that it may not be sensitive enough to detect differences between similarly deficient knee-injured groups.

More appropriate outcomes could include neurocognitive challenges, which provide ecologically valid

Table 5 Results of Perceived Stress Scale, Patient Enablement Instrument and Tegner Current and Future Activity levels at baseline and 12W

	Baseline			12W			Change (12W minus BL)		
	MOTIFS	CaU	Difference	MOTIFS	CaU	Difference	MOTIFS	CaU	Difference
	Median (IQR)	Median (IQR)	(MOTIFS – CaU)	Median (IQR)	Median (IQR)	(MOTIFS – CaU)	Median (IQR)	Median (IQR)	(MOTIFS – CaU)
PSS*	27.0 (9.5)	24.0 (9.5)	p=0.27	25.5 (11.5)	22.0 (8.5)	p=0.57	–3.0 (4.5)	–2.0 (8.5)	p=0.62
PEI	6.0 (5.0)	10 (3.5)	p=0.08	9.0 (7.0)	8.0 (4.0)	p=0.44	1.0 (2.8)	–1.0 (5.0)	p=0.53
Tegner Current	3.0 (1.0)	3.0 (3.0)	p=0.73	N/A	N/A	N/A	N/A	N/A	N/A
Tegner Future	8.0 (2.0)	8.0 (4.0)	p=0.31	N/A	N/A	N/A	N/A	N/A	N/A

*Perceived Stress Scale categories: low stress=0–13; moderate stress=14–26; high stress=27–40.
BL, baseline; CaU, Care-as-Usual; MOTIFS, Motor Imagery to Facilitate Sensorimotor re-learning; N/A, not applicable, data not collected; PEI, Patient Enablement Instrument; PSS, Perceived Stress Scale; Tegner Current, current activity level; Tegner Future, future activity level; 12W, 12-week follow-up.

measures of preparation for return to activity demands, such as maintaining movement control in the face of external stimuli.[28] Imagery has been suggested to increase similarity to real situations, known as functional equivalence,[29] and MOTIFS training is designed to mimic meaningful and realistic situations, including external factors. MOTIFS may therefore increase the ability to withstand dual-task cognitive interference and thereby task-specific readiness.

Enjoyment

We also hypothesised that PACES scores would improve in the MOTIFS group, as discussions regarding training would be more intrinsically motivated[30] and activity-relevant, leading to greater enjoyment. However, pre-defined criteria of ≥5 points in enjoyment in favour of MOTIFS training were not met.

PACES was developed in reference to lack of boredom and willingness to repeat an activity,[19] but more realistic expectations regarding the ability to execute activity-specific movements may reduce willingness to repeat training and thereby perceived enjoyment. In an interview study, participants indicated that they performed MOTIFS exercises but classified them as training rather than rehabilitation.[14] This may be an indication of meaning, and not necessarily enjoyment, as it is more in line with athletic identity. Eudaimonic motivation[23] may therefore be a relevant future outcome measure.

Strengths and limitations

Strengths include that this is an interim analysis of a pragmatic adaptive RCT, allowing for preliminary analyses to determine continuation feasibility. This ensures trial progress and allows for modifications to target clinically important constructs in a pragmatic and easily implemented holistic intervention. Additionally, we present a novel method of integrating psychological skills training into physical rehabilitation to meet clinical recommendations.

The between-subject design may be a limitation. Participants are only exposed to one arm of the intervention; that is, those in the CaU group do not experience MOTIFS training. Results may therefore be misleading, as participants are not familiar with what is new and merely accept the training as it is, rather than critically appraising attitudes towards it. For example, if they are not aware that CaU training can be made activity-specific, ratings of enjoyment may be higher since they have nothing to which to compare.

The MOTIFS intervention is PT-led, so training fidelity control was limited, but interviews suggest that PTs followed the MOTIFS principles.[13 14] Data collection took place partly during the COVID-19 pandemic, during which reported adherence was markedly reduced (by approximately 20% in the MOTIFS group and 10% in the CaU group), which may have influenced results. Adherence results in the MOTIFS group may be misleading, as interviews with patients indicate they did not respond to adherence questionnaires despite having completed training, possibly indicating that they re-interpret at-home rehabilitation training as sport-specific training.[14] The sample size is low, making statistical comparisons difficult; however, continuation criteria were of greater importance, and statistical testing was merely a method of assessing trends. Additionally, results indicate significant differences in type of injury, treatment, mechanism, and sport, possibly influencing results.

Deviations from protocol

The protocol stated that interim analyses would be performed on the inclusion of n=50 participants. Analyses were performed earlier to ensure progress following slow inclusion during the COVID-19 pandemic. Low adherence due to COVID-19 restrictions rendered per protocol analyses based on adherence unnecessary. During data collection, age, injury, and physical activity inclusion criteria were changed.

Clinical implications

Previous interviews indicate that MOTIFS provides a structured method of addressing psychological aspects in rehabilitation, perceived as a valuable tool for patients and PTs.[13 14] As the MOTIFS model integrates a psychosocial intervention into physical rehabilitation training, it is necessary to re-evaluate the outcomes used to assess readiness to return to activity.

CONCLUSIONS

The results of this interim analysis did not reach pre-defined continuation criteria, indicating that major alterations are necessary. Common tests of physical performance that rely mainly on physical function and global psychological measures may not be sensitive to the changes brought about by MOTIFS training. We propose that measures of task-relevant self-efficacy and meaning are needed to assess readiness to return to activity. Additionally, physical measures that include neurocognitive challenges can assess the ability to maintain movement control when exposed to external stimuli rather than primarily physical tests. It may also be relevant to evaluate the MOTIFS model using within-subject comparisons, which can provide a better understanding of perceptions of the training given the individualised nature of the intervention. As previous results show that patients and clinicians find the MOTIFS intervention beneficial,[13 14] we propose further research to continue developing the holistic perspective necessary for effective and pragmatic rehabilitation training.

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Patient consent for publication Not applicable.

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