Motor Imagery to Facilitate Sensorimotor Re-Learning (MOTIFS): Integrating Dynamic Motor Imagery in Current Treatment of Knee Injury

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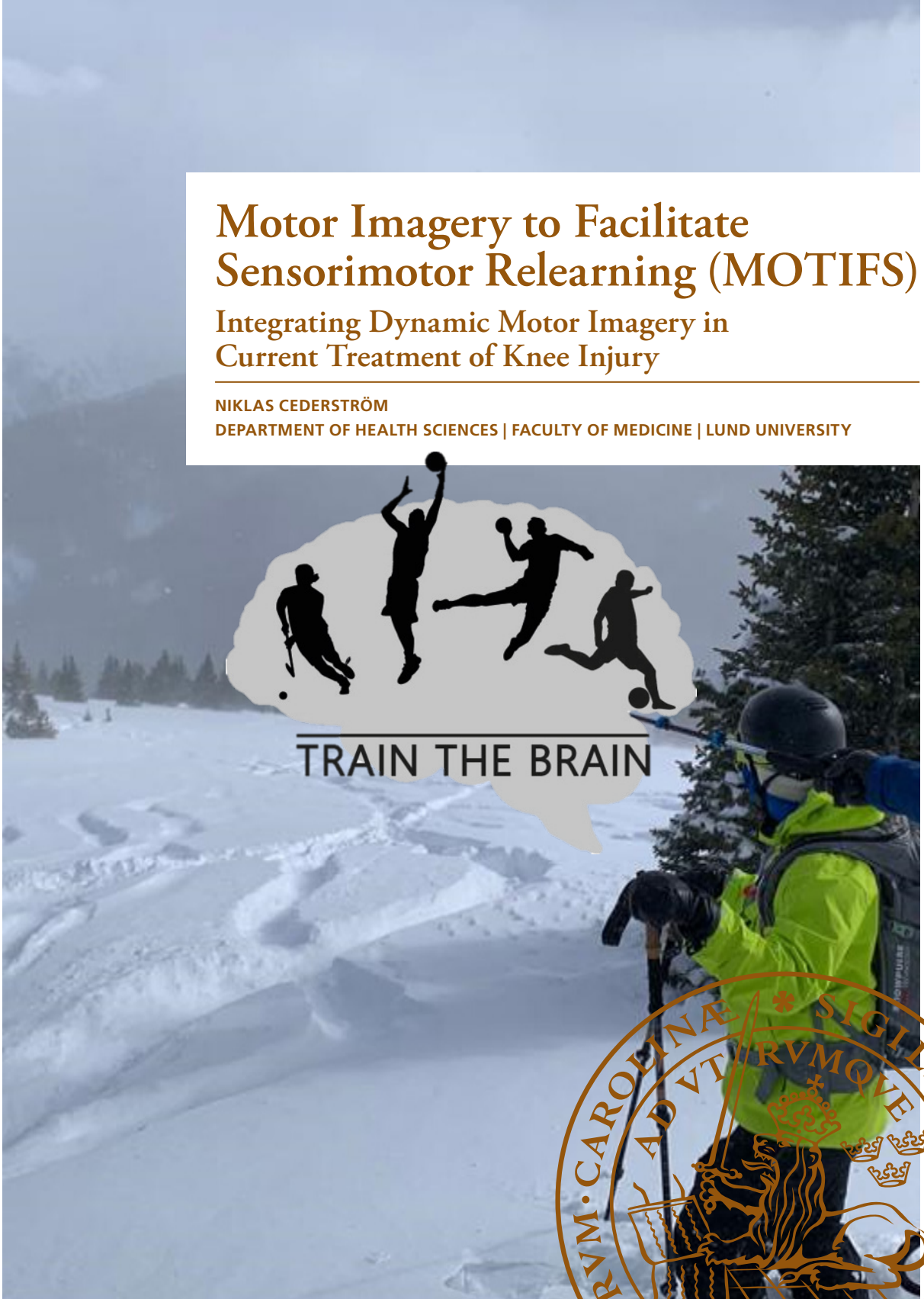
DEPARTMENT OF HEALTH SCIENCES | FACULTY OF MEDICINE | LUND UNIVERSITY



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About the Author

NIKLAS CEDERSTRÖM received bachelor's degrees in psychology and philosophy from the University of Colorado in 2012. In 2014, he completed a Master's degree in Sports Sciences with emphasis in Sport Psychology at Lund University. He started his PhD studies in 2018 at the Department of Health Sciences at Lund University in the research group Sport Sciences.

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DOCTORAL DISSERTATION

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Motor Imagery to Facilitate Sensorimotor Re-Learning (MOTIFS): Integrating Dynamic Motor Imagery in Current Treatment of Knee Injury

Traumatic knee injury is common in physical activity that includes jumping and cutting movements, and most commonly include anterior cruciate ligament (ACL) or meniscus injuries. Surgical or non-surgical intervention strategies may be chosen, but treatment will include a physical-therapist led physical training program. The aim of this training is to strengthen and stabilize the knee. Despite receiving best-practice treatment, many are unable to return to their pre-injury activity level. Recent research has suggested that this may be explained, in part, by psychological factors such as fear of re-injury or lack of confidence. In addition to physical treatment, guidelines include recommendations to address psychological factors. The detail of how this can be done is lacking, and the extent to which psychological variables are adequately addressed is questionable.

In response to this gap, we have developed the novel Motor Imagery to Facilitate Sensorimotor Re-Learning (MOTIFS) model, which integrates psychological training into physical rehabilitation protocols using a dynamic motor imagery intervention. MOTIFS increases realism and relevance while simultaneously physically and psychologically simulating activity-specific and individualized rehabilitation exercises. The aim of this thesis is therefore to develop and explore the efficacy of the MOTIFS model in physically and psychologically preparing knee-injured people for return to activity compared to care-as-usual rehabilitation.

In a first step, the effect of the MOTIFS model on enjoyment and other self-reported outcomes was evaluated in a cross-over study (Paper I) in which uninjured people underwent training according to both MOTIFS and care-as-usual training protocols. Next, a protocol details an ongoing randomized controlled trial (Paper II) which will compare 12 weeks of MOTIFS and care-as-usual training in terms of psychological readiness to return to activity and functional performance. Finally, two interview studies were conducted in which physical therapists (Paper III) and patients (Paper IV) in both MOTIFS and care-as-usual groups were interviewed about the experiences of rehabilitation training following traumatic knee injury.

Results of this thesis show that the MOTIFS model has the potential to increase enjoyment of knee injury prevention and treatment exercises. Other self-reported outcomes were also improved, and the MOTIFS model does not seem to sacrifice movement quality, indicating that it is possible to modify exercises by integrating a dynamic motor imagery intervention. Results of the interview study with physical therapists indicates that those in the MOTIFS group perceive a greater focus on psychological factors while using the new training model, and believe that it is an effective method of increasing patient readiness to return to activity. Those in the care-as-usual group describe their perceptions of rehabilitation training as having a mainly physical focus. They expressed a desire for more tools to address psychological factors, as they perceive patient reactions to be psychological in nature and feel they were ill equipped to handle these factors. Patients in the MOTIFS group perceive MOTIFS to be a meaningful and positive method of increasing their readiness to return to sport, owing to early exposure to activity, which helps them feel that they have longer to prepare for their return. Those in the care-as-usual group perceive a lack of psychological focus, and their success is measured in terms of their physical progress through rehabilitation.

Results indicate that the MOTIFS model may be a feasible and clinically implementable method of addressing psychological factors in rehabilitation training. As the randomized controlled trial is still ongoing, no conclusions can be drawn regarding the efficacy of the intervention on rehabilitation outcomes. However, given the results of Papers I, III and IV, it seems a promising start to bridge the gap between physical and psychological rehabilitation outcomes.

Key words Knee Injury, Rehabilitation, Sport and Exercise Psychology, Qualitative

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To my family

"Motif (noun):

1. : a usually recurring salient thematic element (as in the arts)

   especially: a dominant idea or central theme.
2. : a single repeated design or color"
   - *Merriam-Webster Dictionary*

Table of Contents

Abstract

Traumatic knee injury is common in physical activity that includes jumping and cutting movements, and most commonly include anterior cruciate ligament (ACL) or meniscus injuries. Surgical or non-surgical intervention strategies may be chosen, but treatment will include a physical-therapist led physical training program. The aim of this training is to strengthen and stabilize the knee. Despite receiving best-practice treatment, many are unable to return to their pre-injury activity level. Recent research has suggested that this may be explained, in part, by psychological factors such as fear of re-injury or lack of confidence. In addition to physical treatment, guidelines include recommendations to address psychological factors. The detail of how this can be done is lacking, and the extent to which psychological variables are adequately addressed is questionable.

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In a first step, the effect of the MOTIFS model on enjoyment and other self-reported outcomes was evaluated in a cross-over study (Paper I) in which uninjured people underwent training according to both MOTIFS and care-as-usual training protocols. Next, a protocol details an ongoing randomized controlled trial (Paper II) which will compare 12 weeks of MOTIFS and care-as-usual training in terms of psychological readiness to return to activity and functional performance. Finally, two interview studies were conducted in which physical therapists (Paper III) and patients (Paper IV) in both MOTIFS and care-as-usual groups were interviewed about the experiences of rehabilitation training following traumatic knee injury.

Results of this thesis show that the MOTIFS model has the potential to increase enjoyment of knee injury prevention and treatment exercises. Other self-reported outcomes were also improved, and the MOTIFS model does not seem to sacrifice movement quality, indicating that it is possible to modify exercises by integrating a dynamic motor imagery intervention. Results of the interview study with physical therapists indicates that those in the MOTIFS group perceive a greater focus on psychological factors while using the new training model, and believe that it is an effective method of increasing patient readiness to return to activity. Those in the care-as-usual group describe their perceptions of rehabilitation training as having a mainly physical focus. They expressed a desire for more tools to address psychological factors, as they perceive patient reactions to be psychological in

nature and feel they were ill equipped to handle these factors. Patients in the MOTIFS group perceive MOTIFS to be a meaningful and positive method of increasing their readiness to return to sport, owing to early exposure to activity, which helps them feel that they have longer to prepare for their return. Those in the care-as-usual group perceive a lack of psychological focus, and their success is measured in terms of their physical progress through rehabilitation.

Results indicate that the MOTIFS model may be a feasible and clinically implementable method of addressing psychological factors in rehabilitation training. As the randomized controlled trial is still ongoing, no conclusions can be drawn regarding the efficacy of the intervention on rehabilitation outcomes. However, given the results of Papers I, III and IV, it seems a promising start to bridge the gap between physical and psychological rehabilitation outcomes.

Populärvetenskaplig sammanfattning

Många fysiskt aktiva personer drabbas av traumatisk knäskada, så som främre korsbands- eller meniskskada, särskilt de som deltar i aktiviteter som innehåller snabba riktningsförändringar, inbromsningar eller hopp. Skadan innebär lidande och funktionsnedsättning för den drabbade, både inom idrotten och i vardagen. Förbättrade behandlingsmetoder skulle vara till nytta. Sedvanlig behandling av dessa skador innebär fysisk rehabiliteringsträning, med eller utan operation. Syftet med träningen är att nå god funktion och stabilitet i knät genom att träna styrka, koordination, balans, och rörlighet. Detta för att knäleden ska tåla den belastningen som personen kommer att utsättas för efter att rehabiliteringen är fullgjord. Målet är ofta att återgå till samma fysiska aktivitetsnivå som innan skadan uppstod. För att kunna uppnå detta mål behöver den knäskadade personen vara väl förberedd både fysiskt och psykologiskt.

Endast cirka 50 % av de knäskadade personerna återgår till sina respektive idrotter, detta trots behandling enligt sedvanliga principer. Ny forskning har visat att bakomliggande orsaker delvis kan förklaras med psykologiska faktorer såsom rädsla för att skadas igen och ett bristande tillit till sin förmåga att genomföra uppgifter hos den knäskadade. Sedvanliga rehabiliterings-principer syftar till att förbättra fysisk funktion i knät, men fokus på psykologiska aspekter saknas i stort sett. Anledningen kan vara otillräcklig kunskap hos kliniskt aktiva fysioterapeuter samt brist på tillämpningsbara träningsformer som syftar till att stärka även psykologiska faktorer i rehabilitering.

Vi har utvecklat en ny metod, Motor Imagery to Facilitate Sensorimotor Relearning (MOTIFS), även kallad Train the Brain. Detta för att kunna integrera psykologiska träningsprinciper i fysisk rehabiliteringsträning. MOTIFS-modellen använder en form av psykologisk träning som kallas för dynamisk motorsimulering. Det innebär att en knäskadad person simulerar meningsfulla och relevanta situationer både fysiskt och mentalt samtidigt som en rehabiliteringsövning utförs. Detta ska hjälpa den knäskadade personen att utföra en rörelse på ett mer effektivt och naturligt sätt genom att modifiera övningen så att den liknar verkliga idrotts- eller aktivitetssituationer både fysiskt och psykologiskt.

Syftet med avhandlingen är att utveckla och utvärdera en holistisk och klinisk relevant träningsmodell. Fysioterapeuter ska kunna använda den för att förbättra effekten av rehabilitering efter traumatisk knäskada avseende både självskattade psykologiska faktorer samt funktionell muskelfunktion.

För att utvärdera MOTIFS-modellen har vi gjort fyra delstudier. Inledningsvis har vi undersökt om denna nya träningsform upplevs som roligare och mer meningsfull än sedvanliga övningar som syftar till att förebygga och/eller behandla knäskador hos icke-skadade bollidrottare (studie I). I nästa steg beskrivs en randomiserad kontrollerad studie där patienter som genomgår behandling efter traumatisk

knäskada slumpmässigt fördelas till att antingen få rehabiliteringsträning enligt MOTIFS-modellen eller sedvanlig behandling under en 12-veckors period innan de återgår till sin idrott eller aktivitet (studie II). I denna studie undersöker vi om MOTIFS-träning kan leda till ökad känsla av att vara psykologiskt förberedd att återgå till träning, samt förbättrad knäfunktion i ett hopptest. Slutligen har två intervjustudier genomförts. Den första undersöker hur fysioterapeuter som behandlar personer med knäskada upplever rehabiliteringsträning med antingen MOTIFS-modellen eller sedvanlig behandling (studie III). Den andra intervjustudien undersöker hur patienter upplever rehabiliteringsträning med MOTIFS eller sedvanlig behandlingsträning (studie IV).

Denna avhandling visar att fysisk rehabiliteringsträning med integrerad psykologisk träning i form av MOTIFS-modellen, har förmåga att öka glädjen under träningen jämfört med sedvanlig behandling. Resultaten ifrån den randomiserade kontrollerade studien (studie II) är inte tillgängliga för att dra några slutsatser eftersom studien fortfarande är pågående. En preliminär analys kommer att göras, vilket kan ge viktig information för huruvida MOTIFS-träning kan påverka knäskadade personers psykologiska och fysiska tillstånd under och/eller efter rehabiliteringsträning.

Intervjustudierna visade att fysioterapeuter upplever ökad fokus på psykologiska aspekter i rehabiliteringsträning när MOTIFS-modellen används, och tror att det kan vara ett effektivt sätt att bättre förbereda personer med knäskada för återgång till fysisk aktivitet. Fysioterapeuter som använder sedvanlig behandling upplever fokus på fysiska aspekter trots att de är medvetna om vikten av psykologiska faktorer i rehabiliteringen. De efterfrågar mer fokus på dessa faktorer och önskar konkreta verktyg som kan tillämpas kliniskt. Patienterna i MOTIFS-gruppen upplever rehabiliteringen som ett bra sätt att träna inför återgång till sin idrott och tycker att den tidiga exponeringen av simulerad träning leder till att de känner sig mer redo för en återgång. Patienterna som får sedvanlig behandling upplever stor psykologisk påfrestning under sin skadeperiod, men upplever att de inte har verktygen för att kunna hantera dessa, och efterlyser mer psykologiskt fokus i sin rehabilitering. Patienterna upplever att framstegen mäts enbart i fysiska termer.

Resultaten tyder på att MOTIFS-träning kan vara ett sätt att kliniskt tillämpa träning som har större psykologisk fokus. Eftersom resultaten ifrån den randomiserade kontrollerade studien inte finns tillgängliga ännu kan vi inte dra några direkta slutsatser om effekten av MOTIFS-träning hos knäskadade individer. Resultaten ifrån studierna I, III och IV visar dock att denna träningsmodell kan vara ett sätt att förbättra rehabiliteringen efter traumatisk knäskada.

List of Papers

I. Cederström N, Granér S, Nilsson G, Ageberg E. Effect of motor imagery on enjoyment in knee-injury prevention and rehabilitation training: A randomized crossover study. *Journal of Science and Medicine in Sport*. 2021; 24(3):258-263. doi: https://doi.org/10.1016/j.jsams.2020.09.004

II. Cederström N, Granér S, Nilsson G, Dahan R, Ageberg E. Motor Imagery to Facilitate Sensorimotor Re-Learning (MOTIFS) after traumatic knee injury: study protocol for an adaptive randomized controlled trial. *Trials*. 2021; 22(1). doi: https://doi.org/10.1186/s13063-021-05713-8

III. Cederström N, Ageberg E, Granér S. Lived Experiences of Physical Therapists Treating Traumatic Knee Injuries Using Integrated Psychological Training (MOTIFS) in the Context of Care-as-Usual Training: A Qualitative Interview Study. Submitted 2022.

IV. Cederström N, Ageberg E, Granér S. Lived Experiences of Patients Undergoing Treatment for Traumatic Knee Injury Using Integrated Psychological Training (MOTIFS) in the Context of Care-as-Usual Training: A Qualitative Interview Study. Submitted 2022.

Thesis at a Glance

Aim/s	Main Results	Conclusions
Paper I		
To explore the effect of the MOTIFS intervention on enjoyment of knee-injury prevention and rehabilitation exercises, as well as other patient-reported outcomes.	Enjoyment was shown to be higher following training according to the MOTIFS model than in care-as-usual training.	MOTIFS training may be a plausible method of modifying physical exercises by integrating dynamic motor imagery in order to influence self-reported enjoyment and other psychological variables.
Paper II		
To compare the efficacy of rehabilitation with integrated dynamic motor imagery, and rehabilitation alone (care-as-usual) in terms of improving both readiness to return to activity and muscle function in physically active males and females with a traumatic knee injury and with a goal of returning to physical activity.	Results are not yet available; an interim analysis will be completed, after which a more accurate sample size can be calculated and the model can be evaluated for potential modification based on pre-defined criteria.	Given that results of the interim analysis are positive, this will provide an indication that the MOTIFS model has the potential to be implemented in clinical settings in order to influence psychological factors in rehabilitation following traumatic knee injury. If results do not show significant differences, this may indicate that the model does not adequalely address psychological factors, or that there are implementation difficulties. Following completion, results will be analyzed and interpreted to draw conclusions for future directions.
Paper III		
To gain deep and nuanced understanding of how clinically active physical therapists perceive and make sense of their reality in relation to using MOTIFS training to rehabilitate traumatic knee injury.	Physical therapists in the MOTIFS group percieve a greater focus on psychological factors in rehabilitation, and believe that it provides patients preparation for return to activity. Those in the Care-as-Usual group perceive training to have a mainly physical focus, despite percieving a need and desire for more psychological focus in rehabilitation	Results indicate that MOTIFS training may be an effective method of shifting rehabilitation paradigms from a mainly physical focus towards one which also includes more psychologically focused training methods. Further research is needed to confirm the efficacy of the MOTIFS model.
Paper IV		
To explore and gain insight into how knee-injured participants experience and make sense of rehabilitation following traumatic knee injury using the MOTIFS training model.	Patients in the MOTIFS group percieve rehabilitation as an effective method of preparing for return to activity both physically and psychologically. Those in the Care-as-Usual group perceive a focus on physical aspects of rehabilitation, and a lack of tools to address important psychological factors.	Implementing MOTIFS training in rehabilitation may be a plausible and pragmatic intervention to adress both physical and psychological factors in knee injury rehabilitation. Further research is needed to confirm the efficacy of MOTIFS training.

Definitions

Functional Equivalence	The similarity between a mentally represented image and the overt execution of that action in terms of shared neural substrate (1)
Imagery	The internal psychological recall and rehearsal of sensory experiences in the absence of external stimuli (2)
Motor Imagery	A psychological representation of an action based on memory and experience without overt motor output, used as a method of learning and planning movement (3, 4)
Dynamic Motor Imagery	Motor imagery coupled with movement in order to increase vividness of the imagery situation and similarity to the action being imaged, used as a method of improving learning effects of motor imagery (5)
Motor Learning	Processes which encourage long-term changes in the capability of performing physical action through experience and practice (6)
Patient-Reported Outcomes	Measures of outcomes based on responses coming directly from the patient, often in terms of health, quality of life, or perceived function, with no interpretation from others (7)
PETTLEP	A model of motor imagery which incorporates Physical, Environmental, Task, Timing, Learning, Emotion, and Perspective into an imagery task in an attempt to increase functional equivalence (8)

Abbreviations

ACL	Anterior Cruciate Ligament
ACL-RSI	Anterior Cruciate Ligament Return to Sport after Injury Scale
CaU	Care-as-Usual
DMI	Dynamic Motor Imagery
MOTIFS	Motor Imagery to Facilitate Sensorimotor Re-Learning
OPTIMAL	Optimizing Performance Through Intrinsic Motivation and Attention for Learning
PACES	Physical Activity Enjoyment Scale
PETTLEP	Physical, Environment, Task, Timing, Learning, Emotion, Perspective
PT	Physical Therapist
RCT	Randomized Controlled Trial
RPE	Rate of Perceived Exertion
SAM	Self-Assessment Manikin
SDT	Self-Determination Theory

Introduction

Knee Injury

Physical Factors in Injury

Injury Mechanism

Knee injury is common in jumping and cutting sports such as soccer and handball, and physical activities like jogging.(9, 10) Most commonly, this includes anterior cruciate ligament (ACL) and/or meniscus injury.(11) Traumatic injuries may be sustained in combination with a cutting movement, or landing following a jump.(12) The mechanism of ACL and meniscus injuries has been suggested to be the knee being in a valgus position (that is, the knee medial to the midline in reference to the upper and lower leg) and near full extension, in combination with knee rotation when exposed to an external force such as landing or cutting.(12-14)

Epidemiology

In the general population, ACL-injuries have been found to be sustained by approximately 0.81/1000 people, with 75% of these injuries occurring during participation in sport or physical activity.(9) In ACL-injured people, approximately half may also have a concomitant meniscal injury.(15) Risk-factors for ACL-injury are thought to include intrinsic, or anatomical, factors such as female sex, knee-related asymmetry and laxity, suboptimal hamstrings-quadriceps strength ratio, and a history of previous knee injury.(16) External factors, that is, those outside the body, can include the surface on which activity is performed and weather conditions.(16)

Traumatic meniscus injuries have been shown to have a prevalence of 0.5-0.7/1000 people.(17) Males suffer meniscus injuries at a rate over twice that of females,(11, 17) and up to 3 times as often.(18) Risk-factors can be anatomical,(19) or related to higher physical activity levels, knee joint laxity, and body mass index.(20)

Symptoms and Consequences

Symptoms of ACL injury often include functional instability as a combined result of strength, range of motion, and proprioceptive deficits, along with increased knee

laxity.(21) Short-term effects of ACL injury include reduced range of motion, strength, hop ability and increased joint instability.(22) Quadriceps and hamstrings strength deficits have also been observed long-term.(23) Sustaining an injury has been shown to lead to alterations in movement patterns following ACL treatment. One systematic review and meta-analysis showed persistent changes in knee flexion angles up to 1 year, and knee flexion moment up to 3 years after an ACL reconstruction.(24) Long-term, osteoarthritis is common among those that have sustained an ACL injury or reconstruction.(25, 26) This may be connected to the shorter-term consequences, in that risk factors for development of osteoarthritis include altered kinetic and kinematic movement patterns and lower physical activity, as well as the fact that having sustained an ACL injury previously is itself a risk factor.(27) History of ACL injury is also related to increased risk of contra-lateral injury (28) and ipsilateral re-injury.(29)

Symptoms of traumatic meniscus injuries include localized pain and swelling, especially in connection with bending or twisting,(30) as well as clicking, locking, and giving way episodes.(13) Symptoms may also include instability and knee laxity.(17) Up to a year following surgical meniscal repair, quadriceps and hamstrings strength may also be reduced.(23) In non-operated meniscus-injured people, reduced strength, hop ability, and range of motion have been observed.(31) In the long-term, meniscus injury also increases the risk of developing osteoarthritis.(17)

When ACL injuries are sustained in combination with meniscus injuries, long-term consequences have been shown to include worse patient-reported outcomes.(32) This can include the Knee Osteoarthritis Outcome Score, measuring perceived knee function, symptoms, and quality of life,(33) and the International Knee Documenting Committee questionnaire, measuring symptoms, function, and sports activity.(34) While movement patterns may return to preinjury levels of function following a meniscal repair,(35) kinematics and kinetics can still change in ACL-deficient knees.(36) Suffering concomitant ACL and meniscus injuries may further increase the risk of developing osteoarthritis.(17, 37)

Treatment of Traumatic Knee Injuries

Treatment for ACL injuries according to best-practice guidelines includes rehabilitation with a physical therapist (PT) as the first line of treatment. Other options may include a surgical intervention to reconstruct the ACL.(21, 38) Surgical intervention may be more likely depending on geographical location, with a rate of 0.746 per 1000 person-years in the United States in 2014, and may be up to approximately half that in Scandinavia.(39) Surgery may lead to higher adherence and more positive views on rehabilitation.(40) However, given the invasive nature of surgery and associated risks, physical rehabilitation has been suggested to be considered as a first-line of treatment,(21) as it has been shown that outcomes

following surgical interventions are not significantly better than non-surgical treatment.(41, 42)

Similarly, treating meniscus injury includes physical training to reduce swelling, increase quadriceps and hamstrings strength, and eventually dynamic training.(30) Non-operative treatment is preferred unless mechanical symptoms are severe, and physical rehabilitation fails to reduce these, (30) though surgical intervention to repair or replace the meniscus may also be necessary.(17)

Whether PT-led rehabilitation training or surgical treatment is chosen, physical training is used to rehabilitate physical function to prepare an injured person for return to daily life or recreational physical activities. Physical rehabilitation treatment for knee injuries has been described as aiming initially to reduce load on the injured structure while building strength in activity-relevant musculature (e.g. both bi- and unilateral training) using both weight-bearing and non-weight-bearing exercises, progressively increasing loading to provide joint stability, range of motion, and strength.(14, 21, 30, 43, 44) The strategy is not necessarily to treat the injured structure itself, rather to focus on the surrounding musculature in order to provide optimal conditions for stability and healing, thereby reducing potential negative loading on the ACL or meniscus, for example.

Best-practice guidelines suggest that these goals can be achieved by following a phase-based progression, in which each phase aims to achieve a particular set of goals.(21, 38) For example, the acute phase aims to reduce knee effusion and improve range of motion, followed by a phase intended to encourage weight bearing and improved strength.(21, 38) Subsequent phases build upon these, with the addition of encouraging sport-relevant skills training.(21, 38) Despite these guidelines, there does seem to be some inconsistency in whether they are consistently used by clinicians,(45-47) and evidence for the effects of rehabilitation strategies is relatively low.(48) Programs including open and closed kinetic chain exercises and electrical stimulation have moderate evidence to support their effectiveness in improving strength, function, and laxity.(48)

Treatment strategies for traumatic knee injury (i.e. ACL and meniscus) are based on similar principles in terms of using physical rehabilitation training to restore function. Therefore, in this thesis, principles supplied by best-practice guidelines for treatment of ACL injury will be used as a model. These recommendations include phases through which a patient progresses based on fulfilment of criteria-based testing.(21, 38) An illustration of this is provided in Figure 1. Focus of rehabilitation training is restoration of function by building stability, mobility, and strength, which progresses in complexity and difficulty in order to be able to handle the load to which the person will be exposed.

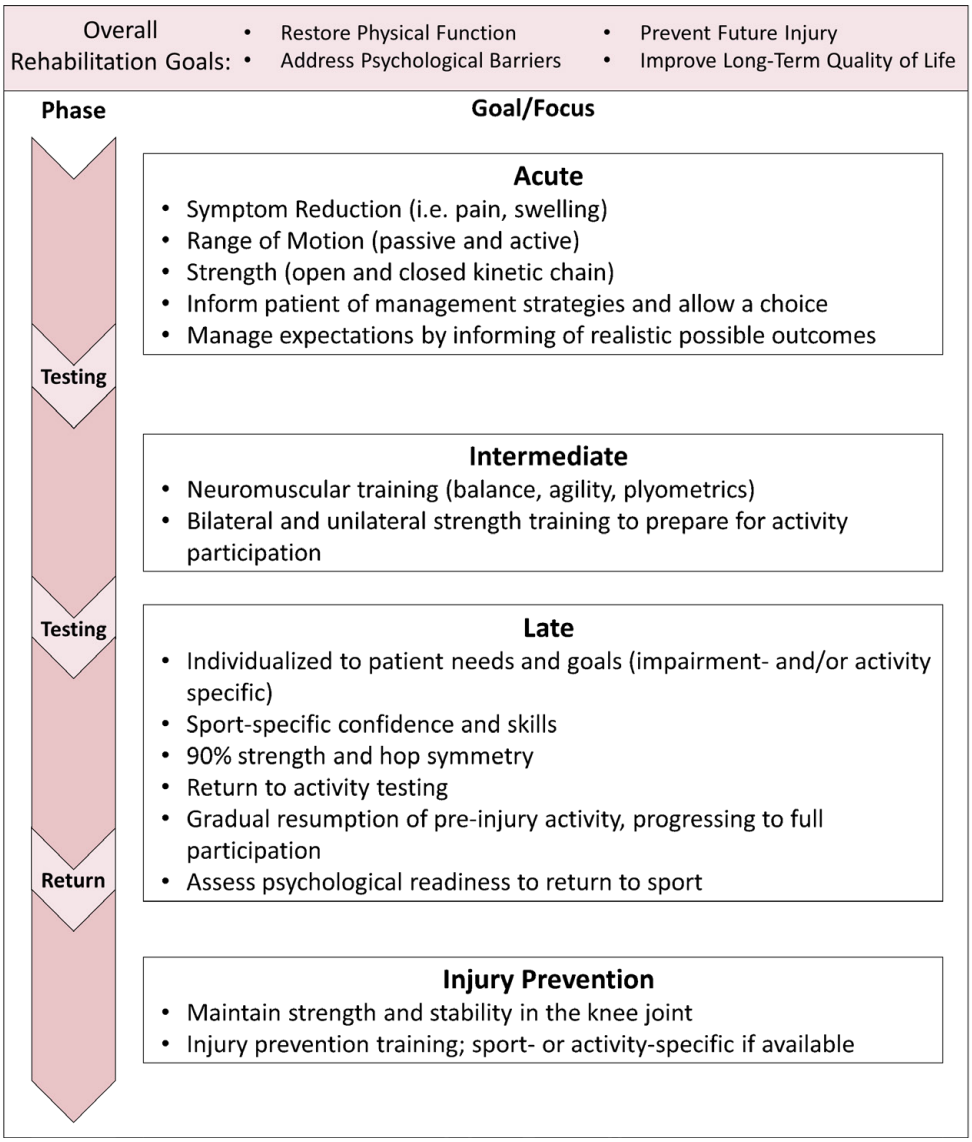

Figure 1. Evidence-based guidelines for rehabilitation following anterior cruciate ligament injury. Adapted from Filbay and Grindem (2019)(21).

Rehabilitation Goals and Return to Activity

A main goal of rehabilitation is often to return to pre-injury or modified activity levels. In order to achieve 'successful' rehabilitation outcomes, PT-led rehabilitation training aims to reduce physical symptoms such as joint effusion and giving way episodes. Strategies for this may include using strength training to improve side-to-side strength differences in the quadriceps and hamstrings. Patient-reported outcomes are also evaluated to determine subjective feelings of trust in the knee, symptoms, and knee function. This is often done using tools such as KOOS,(33) Lysholm Scale,(49) and IKDC questionnaire.(34) Additionally, success in rehabilitation includes whether or not the patient is able to return to their desired sport or activity level.(50)

Despite best-practice treatment, many people still exhibit functional impairments such as reduced strength and hop performance.(51, 52) In terms of return to activity, approximately 65% of ACL-injured people are unable to return to their pre-injury activity levels.(53) It is important to note that many athletes report fear of re-injury as a reason for not returning to their activity.(44) Meeting return to sport criteria is not necessarily a predictor of sustaining a second injury,(54) but there may be an association between passing return to sports criteria and lower risk of re-injury.(44) Previous studies have shown, however, that risk of sustaining a second ACL injury is higher following rehabilitation for a first.(29, 55)

Along with fear, a large number of athletes also report not returning due to lack of confidence,(56) indicating that despite awareness and recommendations being used to ensure readiness, not enough is being done to prepare people psychologically for return to activity. Filbay and Grindem (21) encourage activity-specific training, described in terms of training load, which can be monitored using physical symptoms as markers. The tests used to determine physical readiness to return include movements traditionally seen as being 'sport-specific,' such as hop ability,(21) and include reaction and directional change evaluations.(57) The increase in focus on non-physical aspects is a positive step in the right direction, however, concrete strategies need to be put forward for PTs to use in the clinic. The aims of care-as-usual (CaU) training are in terms of neuromuscular control and movement performance during situations related to sport, but return to activity criteria may be lacking in sport-relevance in pivoting sports.(58) Suggestions for how to progress plyometric training have been put forth, though the focus of these is still physical, implying that strength, control, and loading are most important in these plyometric tasks.(59) This suggests that rehabilitation maintains a large focus on physical execution and maintenance of movement quality, indicating less focus on the actual demands of real-world sport or activity training until closer to the return phase. Recommendations include psychosocial aspects, but do not provide structured interventions which PTs can use to address these issues,(21, 38) which can result in maintaining only superficial knowledge that is not conducive to proper treatment of psychological issues.

Psychological Factors in Injury

Psychological Effects of Injury

Psychological factors have been shown to be related to successful rehabilitation outcomes, with more positive psychological responses being associated with higher rates of return to sport.(53) Athletes with higher self-efficacy and rehabilitation satisfaction, and lower levels of fear may be more likely to return to their pre-injury activity level.(60) Having lower knee confidence in specific tasks has been shown to negatively influence performance on a series of single-leg hop tasks.(61) Further, scoring lower on the ACL Return to Sport after Injury Scale (ACL-RSI), a scale which measures psychological readiness to return to sport in terms of emotions, confidence, and risk appraisal,(62) has been shown to result in greater limb asymmetry, suggesting a psychological influence on function.(63)

Influence of Psychological Factors on Physical Rehabilitation Outcomes

Results of previous research highlight the importance of being able to provide adequate psychological support during rehabilitation training.(21, 38, 64) In order to do this, however, it is important to understand the theoretical underpinnings of the interaction between physical and psychological outcomes. In examining models which attempt to explain this interaction, one can begin to see the importance of providing training which allows for the development of confidence, understanding, and support in order to develop coping skills.

When examining these aspects from a patient perspective, factors such as fear, physical ability, athletic identity, and social support have been suggested to be important.(65) The revised stress and injury model proposes an interactive mechanism which increases injury risk.(66, 67) This model suggests that, when presented with a stressful situation, a person will exhibit a stress response, in which a cognitive appraisal of the risk or ability to complete the task interacts with physiological and attentional factors. For example, a person may believe that a tackle is a high-risk maneuver, which may shift attention away from the relevant situational cues (i.e. the ball and opposing player), and can cause the muscles to stiffen, resulting in an inability to effectively absorb the forces applied during the tackle. This thereby increases injury risk. An important aspect of this model is the fact that both history of stressors, such as previous injury, and coping mechanisms are thought to mediate the cognitive-physiological stress response. A person that has proper coping mechanisms may be better able to monitor their stress and re-structure their cognitive responses, thereby reducing perceived stress and potentially reducing the injury risk. Once injured, this stress response is proposed to include cognitive, behavioral, and emotional responses which interact to influence physical and psychological recovery outcomes, according to the Integrated Model of Response to Sport Injury.(68) This model also includes the addition of coping resources and interventions as factors which can influence patient response to their injury.

One explanation for the effect of psychological factors on physical rehabilitation outcomes following an injury is presented in the Biopsychosocial Model of Sport Injury Rehabilitation, which proposes a mediating relationship between three facets of the rehabilitation process.(69) According to this model, physical (or biological) factors including the healing process and resulting circulation and neurochemical effects, as well as things like sleep and pain, can influence psychological factors. This may be in terms of cognitive responses, such as how the injury is interpreted, and behavioral responses like avoiding behaviors due to fear or pain. Likewise, the presence or absence of social factors can have an effect. Overall life stress, being away from teammates, and being in a new social environment at the clinic may also influence the cognitive responses, mood, and behavior of a knee-injured person. It is important to note, also, that these effects are postulated to be bidirectional. That is, physical factors cause a psychological response, but there is an equal effect of fear on the physical execution of a movement. For example, a person with high fear and low confidence may have altered physical function as a response. Other factors, such as financial stressors, are also important to take into account. An injured person may have a reduction in income due to inability to play at a professional level, or inability to work outside of their sport, increasing overall stress levels.

Psychological Readiness to Return to Activity

Literature has consistently indicated that injured people are not psychologically ready to return to activity. This seems to be true despite physical readiness to return according to commonly used return to sport criteria, include functional hop and strength measures, for example. Recently, psychological readiness to return to activity(62) has been used in evaluating readiness to return.(70) Lower psychological readiness has been shown to be associated with a higher risk of sustaining a second ACL injury in young people.(71) However, a recent study has shown that higher psychological readiness can also increase re-injury risk.(72) These conflicting results may indicate a limitation in the ACL-RSI, in that the questions may not be sensitive enough to evaluate the nuances associated with the emotions, confidence, and risk appraisal experienced during a rehabilitation and return to activity period. It may be argued that the questions reflect more global fear, evaluating overall anxiety regarding injury risk, as opposed to the risk inherent in specific situations, and the subsequent ability to physically and psychologically cope with that risk. By adopting this broad perspective towards fear, it is possible that it is not being addressed properly. The Fear Avoidance Model suggests that experiencing fear can result in a response in which one avoids the stressors causing that fear.(73) Inadequate handling of fear may be associated with negative rehabilitation outcomes in that fear reduces confidence,(74) which may result in avoiding rehabilitation as a potential source of pain.(75, 76) This is important in the rehabilitation context in that training needs to be completed, and should be of high quality, in order to provide the necessary tools for the patient to adapt to a potentially risky situation in a healthy way.(40)

Current Treatment Strategies for Psychological Factors in Rehabilitation

In current rehabilitation models, the focus tends to be primarily on restoration of physical function.(21, 38) It is important to note, however, that rehabilitation treatment necessarily includes a degree of psychosocial impact.(21, 38, 77) For example, simply by being a part of the process implies that social support is provided by the PT, and by encouraging higher intensity or pushing for progression, the interaction between physical and psychological is being taken into account.(78, 79) In order to do this in the correct way, however, rehabilitation training must also include methods of influencing these important factors in the correct manner to avoid negative outcomes.

Best-practice guidelines include recommendations to address psychological aspects in rehabilitation, using strategies including goal-setting and relaxation, and the use of questionnaires, as well as by encouraging self-determined and informed treatment strategies.(21, 38) How these measures may be used practically to develop psychological treatment strategies is unclear from the literature. Ardern et al. (57) include in their consensus statement the recommendation to take into account biopsychosocial factors in rehabilitation according to the biopsychosocial model. However, the recommendations do not expand on how a clinician might go about doing this. Recommendations for returning to sport include gradual introduction to sport-specific training,(21, 38) and on-field return-to-play evaluations involve sprint, endurance, and agility testing,(58) but the psychological component is missing. Increased focus on psychological factors is a step in the right direction, however, awareness alone does not do enough to provide effective strategies.

In order to properly address psychological factors, it is necessary to have a clear idea of how to influence these aspects in the rehabilitation environment. Calls have been made for a more activity-relevant approach to ensure that patients are prepared to handle the complexity of activity before being released.(80) This indicates a need for a rehabilitation paradigm which includes more sport-specificity in a way which provides the patient with tools to address psychological factors and develop individual coping mechanisms based on their individual needs. In order to do this, it is important to provide training which discourages avoidance, and instead allows a safe environment in which the person can train for their activity in such a way as to build confidence, self-efficacy, and create their own strategies for solving the riddle of return to sport. Based on this, an addition to best-practice guidelines may be necessary in order to specify more clearly how to address psychological aspects in rehabilitation. A proposal for this is presented in Figure 2, which provides more specific recommendations for introducing and integrating psychological factors in rehabilitation training.

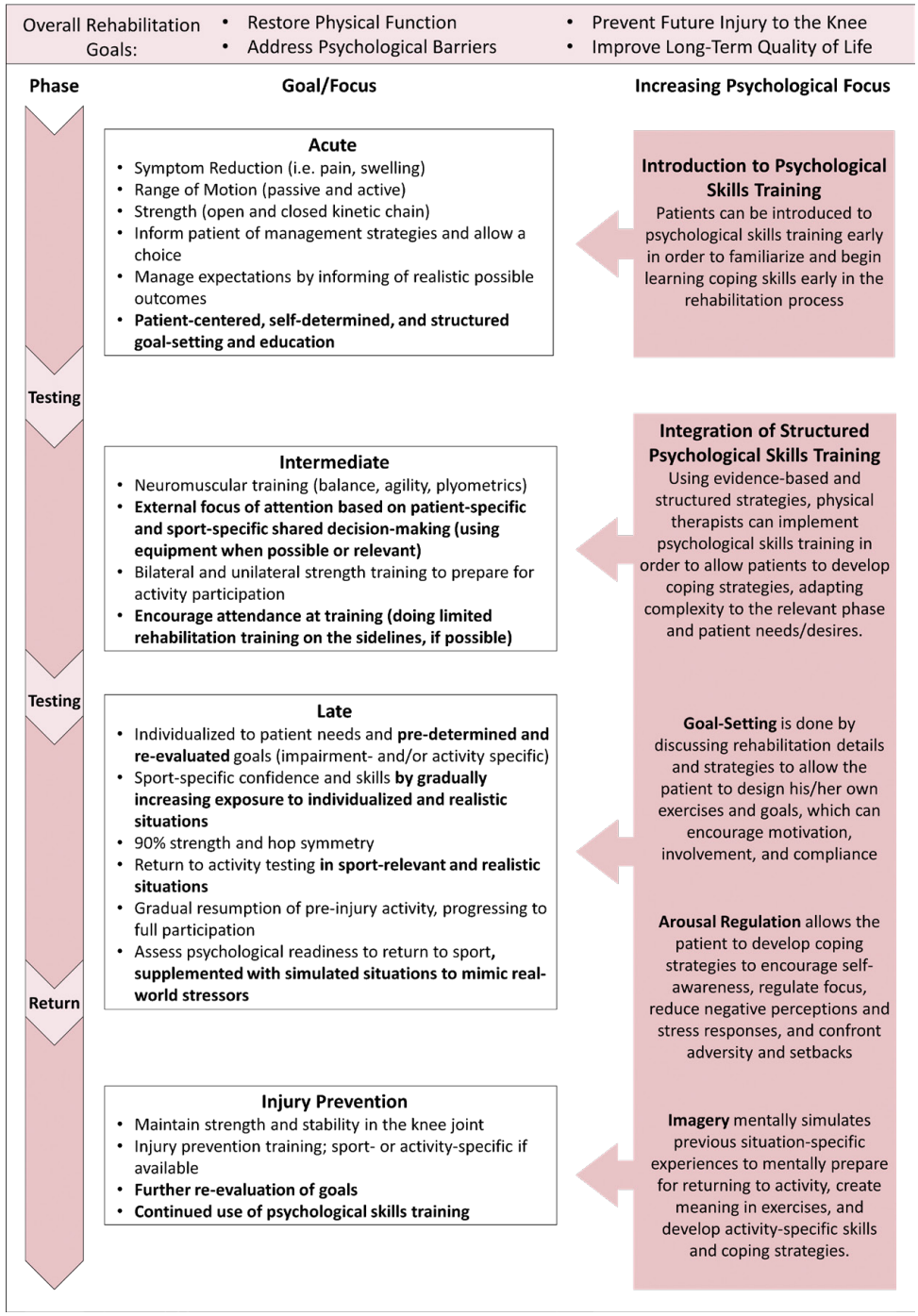

Figure 2. Proposed integration of psychological skills training into physical rehabilitation following anterior cruciate ligament. Figure adapted and modified from Filbay and Grindem (2019)(21).

Combining Physical and Psychological Rehabilitation Interventions

Current Implementation of Psychological Interventions in Rehabilitation

In order to identify how to best increase activity-specific focus to address both physical and psychological factors in rehabilitation, it is necessary to evaluate what is currently being done. Literature is sparse in regards to clinically feasible methods of effecting any change in the current rehabilitation paradigm to implement psychological interventions. Utilizing strategies such as goal-setting, relaxation training, and emotional and social support is recommended,(65) though in terms of execution, this may require a degree of education to ensure proper use of these interventions. Current recommendations include the option of referring patients to external sport psychology professionals.(21, 81, 82) While this can be a good option for some, it may be argued that a patient that has undergone treatment provided by many different people does not want to be sent away to another health professional, as it may be a stressful and time-consuming alternative. Further support for a lack of implementation knowledge is provided by a study examining PT experiences of rehabilitation, in which addressing psychological factors was identified as being vital, while also expressing a need for education in these methods.(83) As such, it is clear that PT education regarding which interventions are available and effective, and above all how to correctly implement them, is an important area of study.

Psychological Interventions Alongside Rehabilitation

There is, however, a lack of research on real-world implementation of directed psychosocial interventions,(81) further supporting the claim that awareness of how to use these is low. Separate interventions targeting a range of psychosocial aspects have been identified, however, they often consist of psychological training performed in addition to rehabilitation training and include goal-setting, positive self-talk, and relaxation imagery, for example.(84) Cognitive Behavioral Therapy is a strategy that has received widespread attention which aims to change patterns of thinking in order to alter behavioral patterns. The principles involved include that i) there are interacting emotional, physiological, and behavioral systems, ii) altering cognitive processing is essential for any positive change, iii) there are different types of cognitive processing, and iv) cognitive content and how this is acted upon plays a role in how to address issues.(85) These interventions have been used in rehabilitation, with varying degrees of success, and with focus on pain management.(86) Cognitive Functional Therapy is an offshoot of this, developed as a physical therapy intervention which has shown a degree of success in reducing disability in low back pain patients by addressing barriers to recovery.(87) The

principles of cognitive behavioral therapy include identifying and altering negative behaviors by restructuring one's way of thinking. The goal is to anchor thoughts more in reality by examining things rationally, which in turn allows one to face fears or relax, thereby preparing a person to be able to maintain a more desirable behavior during potentially problematic interactions.

A potential issue with this is the nature of the intervention as a separate session in which participants are discouraged from pain-avoidance techniques and provided with information on goal-setting and self-management strategies, for example.(86) One aspect which is included is the use of progressive exposure or stress inoculation training, in which a person is steadily introduced to stressors in order to encourage the development of coping strategies. However, Cognitive Behavioral Therapy-based training tends to focus on pain management, and not necessarily rehabilitation principles.(87). The principles are similar for pain management interventions, and focus on how to control cognitive processing in relation to reactions to pain.(88) These principles may be relevant for cognitive behavioral change in terms of avoidance behavior or self-efficacy on a broad level, but physically active people need preparation for specific stressors which are not always cognitive in nature. A further difficulty is that this separate training can include relaxation, which can be difficult to implement in a clinical setting. This is also potentially problematic for a physically active population, in that it may ignore other important aspects of return to activity such as confidence and fear connected to activity in an aroused state (that is, the opposite of relaxed). It has been shown that strategies aiming to address these other factors are effective in improving outcomes, however, the fact that they are separate indicates an extra step which may not always be feasible or pragmatic in a clinical setting.(84)

Physical Therapist-Led Psychological Interventions

Others have attempted to integrate physical and psychological training by implementing PT-led interventions. PTs have indicated that the training they received in integrating these psychosocial interventions is insufficient for some, while others experience it as a useful tool in the clinic.(89) This indicates that steps need to be taken to ensure that each PT is given what he or she needs in the form of a clinically relevant and feasible intervention. This is essential to ensure that psychosocial factors are actually addressed. A study examining cognitive behavioral therapy-based training principles compared with only exercise, and with a combination of the two, showed that a treatment strategy in which psychological training is combined with physical training is more beneficial.(90) This may suggest that equally targeting both physical and psychological outcomes is one which can be further developed. However, this form of training is only integrated in the sense that the PT delivers the intervention, and is not worked into the physical training itself, and so is still a separate session. The fact that this training is based on principles targeting behavioral change and pain management suggests that the

performance-related effects have the potential to be improved upon. In a population aiming to return to physical activity, it is important to also focus on being able to efficiently and safely execute the desired activity. A potential method of addressing this is to further develop the strategy of integration, but instead integrate psychological skills training which target aspects relevant to life after rehabilitation, including return to physical activity, into the exercises themselves. The benefits of doing this include a more time-efficient and pragmatic training which aims to provide coping strategies which influence real-world and relevant factors related to return to activity.

Integrating Psychological Interventions into Rehabilitation

The question of how to integrate psychological skills training into rehabilitation should therefore focus on which skills are available to train, and what these interventions target. Physically active people likely want to be able to return to their activity, and so it is necessary to instead examine what kinds of psychological interventions exist for more performance-based outcomes.

Psychological Skills Training

In terms of sport psychological interventions, several have historically been used to help athletes perform at their best. Traditionally, sport psychology uses a set of tools based on structured goal-setting, arousal regulation, self-talk, and imagery.

Goal-setting is done by defining specific and challenging goals based on individual ability, feedback from a qualified observer, commitment to the outcome, and available resources in relation to the activity itself, and should focus primarily on learning as opposed to only focusing on milestone process goals.(91) This may answer the call for autonomous and competence-based decision-making to improve performance in injured people, but does not explicitly address fear or provide opportunities for developing coping skills. Arousal regulation is a method by which a person can control their emotions and learn to handle things such as stress or fear, for example. Strategies can include using biofeedback from heart rate monitors, progressive relaxation, and cognitive behavioral training.(92) In terms of the injured person, these strategies can provide coping skills to deal with fear, but may not necessarily use the patients' activity-related competence to encourage motivation, and relaxation is not an effective method of training to return to activity-ready fitness. Self-talk is another method of psychological control, in which key words or phrases can be used to influence the way a person sees a situation, providing cues or having a calming effect.(93) Development of these strategies are often

autonomous, but on their own, they may not have the power to provide the support needed to encourage readiness to return to activity.

Imagery

Finally, a method of mental preparation has been described which can incorporate several of these interventions to improve performance(92) by engaging in an imagery, or visualization, session. The aim is to create a mental representation which simulates an action without any overt movement in order to be better physically prepared when it comes time to actually execute that action.(94, 95) Commonly, imagery is thought of as being done in a relaxed setting, perhaps lying on a couch and creating a mental image of a successful outcome, a method known as static imagery. Focus of imagery can include cognitive, motivation, visual, or kinesthetic, for example.(95, 96) This has developed over the years, and it has been shown that motor imagery, which focuses on context, tactics, technique, and kinesthetic aspects in order to simulate a situation which is as realistic as possible is more effective.(97) By including overt movement in this form of imagery, the realism can be further enhanced.(5) Including this movement results in Dynamic Motor Imagery (DMI), which attempts to simulate a realistic situation which has functional equivalence, defined as the neurological similarity between the imaged and the actual executed action.(1)

The PETTLEP Model of Motor Imagery

One theory of motor imagery has attempted to provide an outline for how to create this equivalence, known as the PETTLEP model of motor imagery.(8) This acronym stands for Physical, Environmental, Task, Timing, Learning, Emotion, and Perspective, and the model postulates that increasing realism in as many of these aspects as possible may increase the functional equivalence of an imagery situation.(8)

Including a **physical** aspect means that the movement should be dynamic and include aspects relevant to the actual execution. This does not need to be full execution, but can include standing still and imaging a jump, while including arm and head movements to make the imagery feel more realistic.

Being in the correct **environment** is thought to improve realism, as the sights, sounds, and smells will be more true to the spirit of what is being imaged and can remind a person more clearly of what is being done.

The imaged **task** should include a relevant situation, which could mean that a basketball player should image basketball (i.e. not soccer), or more specifically a free-throw or a shot from the side on which that player typically finds themselves during play.

The **timing** aspect means that the situation should be imaged as close as possible to the actual speed and time-frame of overt execution, meaning that a 1-second or 30-second approach may not be realistic for a javelin thrower, but five seconds is relevant for that individual and their approach style.

An important aspect is also that the imagery session should include **learning**. The imagery should be based in reality, and not in a perfect ideal, which means that mistakes are allowed, and corrections encouraged. In doing so, it is possible for the person to identify their mistakes and figure out how to best correct them, providing an opportunity to improve their actual execution.

Emotional aspects are also important, in that it is likely not realistic for a person to image a free-kick in soccer with no feelings of excitement or in a totally relaxed state. Encouraging an increase in heart rate, simulating happiness or butterflies in ones stomach, or the stress of having 30 seconds left in a game can help to prepare an athlete for the real situation.

Finally, **perspective** is something which should be taken into account. There are typically two perspectives which are taken: internal (first-person) and external (third-person). An internal perspective includes imaging a situation which is seen through one's own eyes, as though the imager is actually performing the movement. This perspective is often associated with more performance-based training, as it focuses on learning the physical feeling and how to get into specific positions.(95) An external perspective sees the person from outside the body, as though watching oneself on film, and is thought to be more related to learning in terms of providing visual cues of what the technique should look like.(95) Using this DMI training, which includes both physical and mental training, has been shown to be more effective in improving performance than physical training alone in athletes.(98, 99)

In a practical example, a study examined using a PETTLEP-based motor imagery training session to train high jumpers, resulting in improved performance in terms of success (jumping over the bar) and technical execution.(5) This may be related to the jumpers' performance of imagery based on a contextual understanding of the task, which includes a degree of action planning, in which the imagery scenario allows for predictions of the results of an action.(100) Imaging a familiar scenario and performing a physical movement with confidence may therefore make prediction more effective, resulting in a more realistic understanding of the real-world context.

Imagery in a Rehabilitation Context

Imagery may therefore be a good alternative for an injured population, because it has the potential to address many of the psychosocial factors important for rehabilitation. Much of the research has been done in uninjured people, but the psychological effects may be relevant for those with injuries, as well, though

systematic reviews have shown conflicting results.(101, 102) Results of research in ACL-injured people has shown that DMI can reduce fear and improve confidence,(103) and in uninjured people to have a positive effect on motivation, affective, and psychological skills outcomes.(98) Studies have also suggested a cognitive influence, promoting adaptations to structures relevant for physical practice.(104, 105) The plastic changes in the brain that occurs with motor imagery training may result in positive long-term changes.(106) Motor imagery interventions may also be effective in reducing pain and increasing strength in knee arthroplasty(107) and osteoarthritis patients.(108) Results of these studies are interesting, because they suggest that DMI has the potential to address the aspects identified as important, including fear, coping skills, motivation, and neurophysiological changes, as well as physical outcomes such as strength in both uninjured and injured populations. The method by which DMI is implemented may also have the ability to address identity, environment, and social aspects, as the PETTLEP principles aim to focus on these factors as well.

Performance Enhancement Effects of Imagery

As the aims of physical rehabilitation include preparing patients for return to physical activity, it is important to examine the performance enhancement and learning effects of a DMI intervention. PETTLEP-based motor imagery utilizes individualized meaning to aid in performance and learning of physical movement. This is important, because psychological factors shown to be important to rehabilitation can be interpreted as relating to their competence, relatedness, and autonomy. These three factors constitute the main pillars of the Self-Determination Theory (SDT) of motivation, which states that intrinsic motivation can be increased by making decisions which are based on one's own competence, are directly related to activity or people, and which are self-generated.(109, 110) Feelings of fear and physical ability suggest that patient's sense of competence is lacking. Being injured and performing rehabilitation away from the team, and not being able to participate, suggests that athletic identity and social support are missing, as well. Autonomy is taken away as patients are unable to make their own decisions and control their own fate, and those that have a goal of returning to sport are especially vulnerable to this. Motivation is seen as being on a scale, according to this model, from intrinsic to extrinsic.(110) Extrinsic motivation implies that the reason for doing something is for some external gain, or potential avoidance of negative consequences. This could be, for example, to avoid getting in trouble, or to acquire money. Intrinsic motivation, on the other hand, is doing something for the simple pleasure of having engaged in that particular activity.

By engaging in imagery, a person is undergoing a process in which he or she will be looking back on their own experiences and actions in order to decide what is meaningful, realistic, and possible for them to image. This relates to the autonomy and competence categories of SDT, and by discussing with someone to determine a

possible imagery 'script' and by imaging teammates, friends, or opponents, a degree of relatedness can also be achieved. This may contribute to the fact that motor imagery has been shown to positively influence intrinsic motivation.(97) As such, the effect of a DMI session may help in the acquisition, practice, and correction of sport-specific skills for a knee-injured person.

Motor Learning Effects of Imagery

Motor learning, which includes practice intended to learn or relearn how to execute a physical skill or movement,(6) can be an important factor in performance enhancement, especially in a rehabilitation context. The OPTIMAL (Optimizing Performance Through Intrinsic Motivation and Attention for Learning) Theory of Motor Learning suggests that practicing realistic and relevant skills with an external focus, intrinsic motivation, and positive support is more likely to create confidence, resulting in success and satisfaction.(111) The external focus of attention is important, as focusing on something outside of the body has a positive effect on motor learning, and increasing the distance of focus away from the body improves the effects.(112) An internal focus of attention includes attempting to control actions by focusing on the body and muscles themselves, shown to result in less control than external focus.(113) This is in line with the theory of re-investment, which postulates that increased focus on consciously controlling movement based on working knowledge disrupts the pathway, resulting in suboptimal movement.(114) Similarly, the Constrained-Action Hypothesis claims that focus on internal aspects of movement imposes constraints on the motor system, resulting in inefficient movement patterns.(112) In knee rehabilitation literature, clinicians have shifted from internal to external focus, and strategies have been suggested for encouraging this in clinical environments during execution of rehabilitation training.(115)

Intrinsic motivation, external focus, and success are thought to encourage learning by releasing dopamine, which helps a learner remember the movement and develop the correct neural pathways. This latter aspect is presented in a proposed extension to the OPTIMAL Theory, which claims that Prevention, Rehabilitation, Exercise, and Play (OPTIMAL - PREP) encourage dopamine release and shift attentional focus to more efficiently recruit brain regions in sensorimotor integration.(116)

In using imagery, one is able to re-create contextual factors based on previous experiences and interests to foster intrinsic motivation, which is considered a necessary aspect for motor learning.(111) Combining motivation with confidence and external focus has been shown to further increase these learning effects compared to individually.(111, 117) Experience-based individualized context for an injured person can allow an imagery session which is motivated and externally focused, and confidence can be built by adapting to their individual needs. This can include modifying the imagery situation to reflect the new reality which the injured person now faces. One theory of motor learning, the Constraints-Led Approach, states that constraining actions can allow for greater resilience and problem-

solving.(118) Constraints are individual, task-specific, and environmental factors,(119) including changes in the body, varying equipment size, and situational factors such as lighting or temperature.(120) Following an injury, patients are constrained due to the changes in physical abilities in the form of functional deficits. Dynamical systems theory postulates that the presence of variability in movement is positive, providing the learner with important feedback to achieve a functional goal, rather than restricting to fixed movement patterns.(121) For example, a study examining postural control in ACL-deficient people showed that the most important feedback in maintaining balance during dynamic tasks may be visual, as closing one's eyes during testing reduced control.(122) This can be important for clinicians in that introducing constraints may be an effective method of improving proprioceptive control, for example training balance using destabilizing shoes.(123)

Cognitive Effects of Imagery

In addition to performance and motor learning effects, evidence also suggests cognitive effects of motor imagery. The mechanisms dictating the cognitive and neurological effects of imagery are not well understood, but theoretical explanations have been presented. The psychoneuromuscular theory postulates that creating vivid images produces low magnitude neuromuscular impulses,(124) that is, a low degree of muscle activity below the threshold for explicit movement. The symbolic learning theory takes a cognitive approach, in which one creates a mental 'map' of the movement pattern to prime the body for execution.(125) This is said to be better for cognitive aspects of tasks as opposed to purely motor tasks, for example decision-making in soccer rather than weightlifting. Two theories have also emerged regarding neurological mechanisms. The bioinformational theory states that when a person is exposed to a scenario-specific stimulus, the information is organized into functionally relevant codes, which in turn increases the relevant physiological response.(126) In this theory, imaging soccer-specific stimuli like sounds, smells, or the ball rolling towards ones feet, is coded into soccer-relevant categories for which there is an appropriate response, such as passing or shooting. An extension of this is the triple code model, which creates a realistic image of the environment and scenario, leading to psychophysiological change based on the individualized meaning of the image.(127) Crucial to functional equivalence is the inclusion of meaning, in which the example of the soccer player may be altered if imaging the last minutes of a championship game, rather than a generic situation.

Regardless of the mechanism, motor imagery may lead to cortical reorganization to develop movement pathways and improve psychophysiological performance, the effects of which may be greater when combined with physical training.(128) Studies suggest that simple tasks can reflect neural activation changes in motor and visual brain regions.(129, 130) Studies examining fMRI results have also shown that task performance can be improved to a greater degree using motor imagery than with standard training protocols in which participants merely repeated the task.(129, 131)

Rationale for Thesis

In order to simultaneously address both physical and psychological aspects of rehabilitation, we have developed the novel Motor Imagery to Facilitate Sensorimotor Re-Learning (MOTIFS) training model for rehabilitation following traumatic knee injury. The MOTIFS Model provides an approach which departs from the typical dualistic nature of rehabilitation, which sees rehabilitation as including separate psychological and physical treatment strategies. Instead, the integration of motor imagery training into existing rehabilitation protocols allows for a more holistic approach to treating knee injuries. By providing care which encourages PTs and patients to work together to create meaningful and intrinsically motivated training sessions, it is possible to make rehabilitation more enjoyable, more autonomous, and allow the patient to feel more control while re-learning and/or improving motor skills following a traumatic knee injury.

By teaching PTs a method of providing individualized, autonomous and meaningful care, the MOTIFS model may increase patient motivation. Allowing a patient to decide their own path through rehabilitation, guided (not led) by their care-provider, self-determined and intrinsic motivation may be achieved. This will likely lead to better compliance with training, which implies more engaged and efficient training. Imaging a sport- or activity-specific situation necessarily shifts the focus externally, thus fulfilling the requirements of the OPTIMAL Theory of Motor Learning,(111) which can be used to learn and automatize motor skills.(98, 132, 133) As rehabilitation following knee injury includes re-learning and re-gaining functional movement patterns, motor learning is an important factor in achieving successful rehabilitation outcomes.

The contextual aspects of DMI also provide an opportunity for patients to be exposed to their activity prior to being released, allowing for a period in which they are preparing for return both physically and psychologically. MOTIFS simulates the real-world environment, and gradually introduces a person to the stressors to which he or she will eventually be exposed, allowing for development of coping skills in a safe environment.

If this is possible, it may be feasible for the MOTIFS model to encourage greater psychological and physical readiness to return to activity through having imaged sport-specific situations prior to return.

Overall Aims and Goals of the Thesis

The goal of this thesis is to propose a holistic and clinically relevant training model which provides a pragmatic method for PTs to address psychological factors of knee injury in rehabilitation following traumatic knee injury.

The aim is to develop and test a novel knee injury prevention and rehabilitation training program that will provide greater effects on patient-relevant and muscle function outcomes than currently available programs.

Specific Aims

1. To explore the effect of a MOTIFS intervention on enjoyment of physical activity, as well as other patient-reported outcomes. The hypothesis was that athletes would report higher self-reported enjoyment of physical activity following MOTIFS training compared with a training session using established knee injury prevention and rehabilitation training principles.
2. To compare the efficacy of rehabilitation with integrated dynamic motor imagery, and rehabilitation alone (care-as-usual) in terms of improving both readiness to return to activity and muscle function in physically active males and females with a traumatic knee injury and with a goal of returning to physical activity. The hypothesis of the randomized controlled trial is that 12 weeks of rehabilitation with integrated dynamic motor imagery will improve patient-reported psychological readiness to return to physical activity and objective muscle function to a greater extent than care-as-usual rehabilitation.
3. To gain deep and nuanced understanding of how clinically active PTs perceive and make sense of their reality in relation to using MOTIFS training to rehabilitate traumatic knee injury.
4. To explore and gain insight into how knee-injured participants experience and make sense of rehabilitation following traumatic knee injury using the MOTIFS training model.

Methods

Overview of Included Studies

Table 1. Overview of the studies included in this thesis

Study I	
Study Design	Randomized Cross-Over Study
Participants	Uninjured athletes (n=30) previously or currently active in team ball sports
Methods	Participants performed commonly used knee injury prevention and rehabilitation exercises according to MOTIFS and Care-as-Usual in a randomized order with a 10-minute wash-out period.
Data Analysis	Mixed Models analysis; non-parametric data analyzed using Wilcoxon signed-rank testing, followed by Fisher's Exact
Study II	
Study Design	Adaptive Randomized Controlled Trial Protocol
Participants	Patients receiving treatment for traumatic knee injury with a goal of returning to physical activity
Methods	Participants randomized to 12 weeks of rehabilitation training, using either the MOTIFS Model or Care-as-Usual.
Study III	
Study Design	Qualitative Interview Study
Participants	Physical therapists treating patients using MOTIFS (n=6) or Care-as-Usual (n=8) for traumatic knee injury; Sub-group from Study II along with external participants
Methods	Semi-structured interviews
Data Analysis	Interpretative Phenomenological Analysis
Study IV	
Study Design	Qualitative Interview Study
Participants	Patients that have undergone treatment for a traumatic knee injury using either MOTIFS (n=5) or Care-as-Usual (n= 7) treatment; Sub-group from Study II
Methods	Semi-structured interviews
Data Analysis	Interpretative Phenomenological Analysis

Ethical approval was granted by the regional ethical review board of southern Sweden (Etikprövningsnämnden [Etikprövningsmyndigheten as of 2019]) for all studies included in this thesis (Study I: DNR 2018/161, 2019/03154; Studies II, III, and IV: DNR 2016/413, DNR 2018/927). The trial was registered on clinicaltrials.gov (NCT03473821).

Motor Imagery to Facilitate Sensorimotor Re-Learning (MOTIFS)

In order to provide holistic training which prepares people both physically and psychologically for return to sport, mental training can be integrated into CaU physical training exercises using the novel Motor Imagery to Facilitate Sensorimotor Re-Learning (MOTIFS) model. This is based on a model of DMI which attempts to create a functionally equivalent imagery situation by attempting to physically and/or psychologically recreate as many physical, environmental, task, timing, learning, emotion, and perspective aspects as possible.(8) Development of the MOTIFS model was a long process which involved discussions between researchers with expertise in physical therapy and sport psychology, and clinically active PTs. In order to achieve the goals of improving both physical and psychological outcomes, careful planning was required in order to ensure that both sides of this interdisciplinary model were integrated in a plausible and feasible way. In addition to planning meetings, the model was also pilot tested with injured athletes to receive their feedback, and discussed with PTs. These end-user discussions were invaluable in ensuring development of a model which maintained the theoretical underpinnings of both physical rehabilitation and psychological skills training interventions.

The MOTIFS model is integrated into rehabilitation training following traumatic knee injury requiring long-term (i.e. longer than 12 weeks) treatment. The model is applied to exercises in the intermediate phase,(21) the goal of which is to restore dynamic knee stability, and increase muscle strength and power using strength, perturbation, and plyometric training.(21) This gradually progresses to increase task-specific focus(21, 57, 59) on reaction and perturbation training to improve quality and re-learning of sport-specific movements.(59) It is important to note that the MOTIFS model does not aim to replace commonly used rehabilitation principles, rather it is a new dimension in which psychological skills training is integrated into appropriate exercises. This allows for pure strength training, for example, in which sport-specific imagery may not be appropriate.

PTs in the MOTIFS condition receive training in implementation of principles (Figure 3) which allow them to work together with the patient to integrate physically and psychologically relevant situations into existing exercises commonly used in rehabilitation practice.

Step 1: Discuss

In creating a MOTIFS exercise, the PT and patient first discuss the physical goals of the movement in order to create or increase understanding of the exercise itself to ensure proper execution. The movement is then discussed in terms of correct

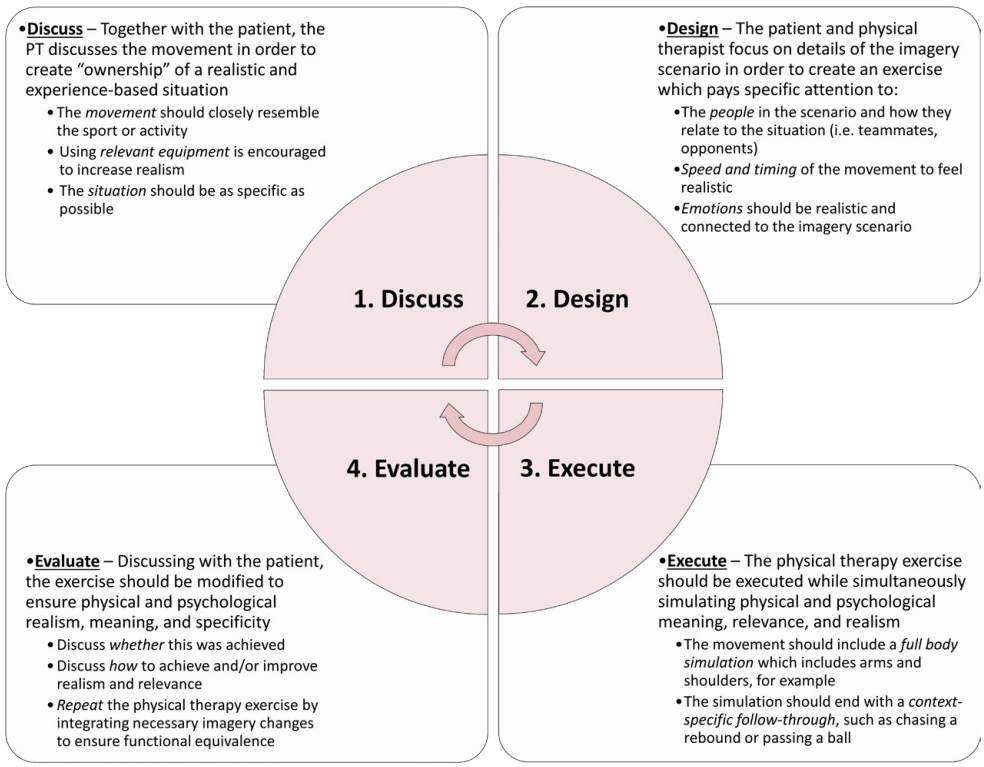

Figure 3. Principles of the MOTIFS model used to create individually relevant and context-specific rehabilitation exercises. Adapted from Cederström et al 2021 (134).

execution in the context of the patient's sport or activity in order to increase the patient's understanding of the meaning and relevance. Basing discussion on the needs and desires of the patient encourages autonomy, competence, and relatedness, which are important in developing intrinsic motivation according to SDT.(109) Importantly, this means that the discussion is not one in which the PT explains how the movement fits with a particular activity; instead the patient is encouraged to think of a relevant situation that is meaningful to his or her sport or activity, position, and style of play. By gaining greater understanding of the context through self-exploration, the patient is better able to create an imagery scenario which is a realistic physical and mental representation of a situation which bears meaning.

Step 2: Design

The PT and patient then design an exercise in a way that encourages individually meaningful and autonomous shared decision-making. Ensuring that the patient creates an individualized and relevant situation encourages autonomy, allowing the patient to do what he or she wants to do within the bounds of the rehabilitation exercise. Since it is the patient him- or herself deciding based on previous experience and an individual tactic or style of play, the MOTIFS exercise will be directly related to the individual's competence. Relatedness comes in two different forms: a connection with the PT during discussion and feeling a sense of involvement, and in simulating a connection with teammates and/or opponents during the situation (i.e. passing or shooting opportunities).

The exercise should be created according to a multi-faceted approach, in which the goals are to create meaning and relevance for the patient, and to fulfil the relevant rehabilitation requirements (e.g. strength, balance). Discussion therefore includes not only physical execution, but also technical aspects, such as where other players might be, who the opponent is, and a plan for the next step in the movement (i.e. where to shoot or pass). As many PETTLEP aspects as possible should also be included to ensure vivid imagery during execution. The PT can and should ensure that the movement is executed correctly, and may alter the physical or psychological aspects based on individual needs. For example, the PT may see that execution is negatively influenced by the patient's anxiety, prompting a lightening of focus on physical execution and encouraging more realism in order to build confidence. On the other hand, the PT may see that the patient is very confident in the sport-specific situation, but unable to maintain good movement quality, so a less intense focus on some PETTLEP aspects may be employed until movement is acceptable.

MOTIFS training provides a structured form of psychological skills training in which more active encouragement of individualization and patient involvement in exercise design details, and the degree of activity-specificity constitute a distinction from CaU training. The focus on movement is important in this regard, as the MOTIFS model shifts away from focusing primarily on performance and quality of movement and more towards patient perception of the activity itself. It is not simply an unexpected directional change; it is preceded by an approach, and finished with a follow-through of the movement in the context of the imagery situation which has been decided upon by the patient him- or herself. This should include imaging, as vividly as possible, the specific person to whom one is passing, what color the imaged opponent is wearing, and/or sights, sounds, and smells that are relevant to the situation being imaged. Self-determined shared decision-making in design of exercises allows the patient to adapt to his or her physical and psychological needs throughout rehabilitation. More sport-relevant movements are possible as rehabilitation progresses, allowing for the "Physical" PETTLEP aspect to become more functionally equivalent. Figure 4 illustrates this using a toe-off movement,

which the MOTIFS movement focuses on maintaining a quality physical rehabilitation movement according to the relevant principles. This builds into a physical simulation of a header situation, heading the ball, and using both upper and lower body movements. She simultaneously images where to aim the ball against a particular goalie with both teammates and opponents surrounding her.

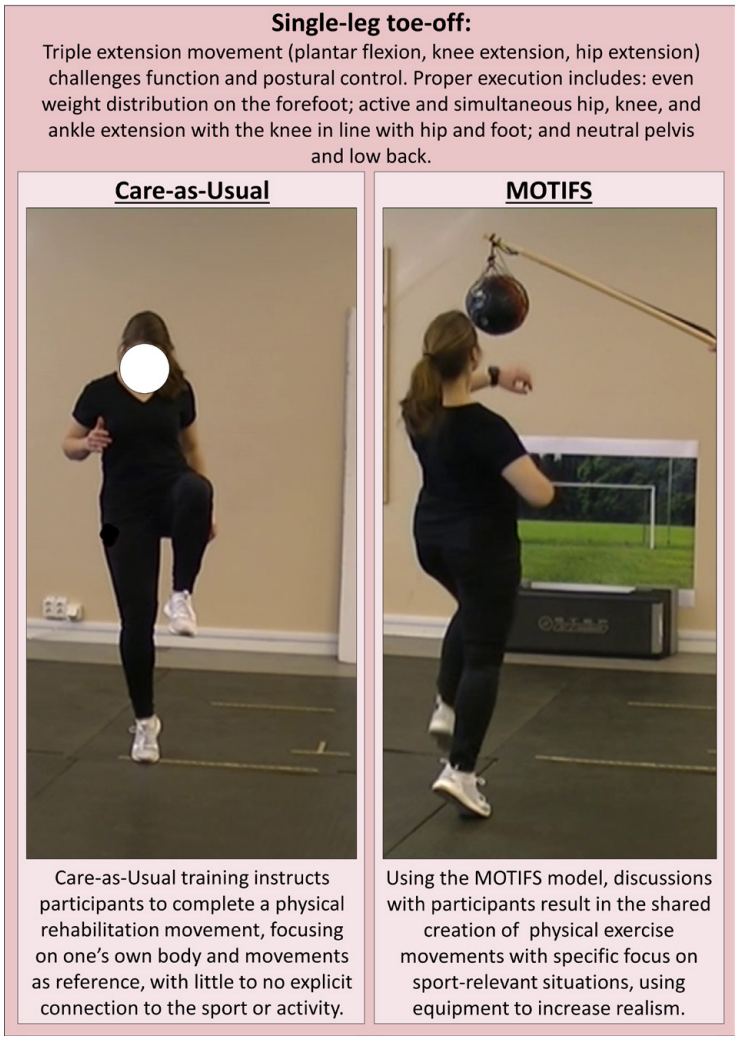

Figure 4. Example of performing a toe-off movement using care-as-usual training and the MOTIFS model to modify the movement to increase meaningful functional equivalence. The model in this figure is not a participant in any of the included studies in this thesis, and has provided consent for these photographs to be included here.

Step 3: Execute

The next step is to perform the movement, utilizing the externally focused PETTLEP-based DMI situation to encourage realism through physical and mental simulation, integration of equipment, using the whole body (i.e. not just the lower extremities), and by starting and ending the movement with a context-specific approach or follow-through. Meaningful focus on external factors related to the imagery situation takes advantage of the patient's familiarity with the movement to more readily plan an action. Action-planning may aid in cognitively preparing for execution of that action,(135) and by focusing on external factors, motor learning may be enhanced.(136) Planning action based on experience and relevant external focus allows for more natural and automatic execution of a meaningful activity-specific situation, and avoid the cognitive disruptions of re-investment.(114)

One current rehabilitation progression model suggests beginning with an internal focus to ensure proper execution, which can then progress to more external by adding a ball, for example.(137) However, while this model does include using activity-relevant movements, it does not describe preparation for the important external stimuli which will be encountered beyond taking a step-wise approach.

The MOTIFS model attempts to fill this gap, in which the patient uses an external focus and previous knowledge and experiences to create functionally equivalent situations which reflect meaningful experience more closely resembling training. Reaching for a point on the wall or adding a ball may increase external focus, but this is a reminder of the activity in which the patient was active prior to their injury, and does not incorporate situation-specific realism. This is analogous to attempting to improve soccer skills by kicking a ball against a wall. There are similarities, but it is not providing the stimuli necessary to learn and improve dynamic sport skills.

Step 4: Evaluate

Finally, the exercise is evaluated through a second discussion, in which the PT and patient discuss how realism and relevance can be optimized, and making appropriate changes based on this discussion. This encourages variation and adaptability in exercise prescription. Coupling motivated and reasonably challenging exercises has been shown to be beneficial for motor learning,(111) and the MOTIFS model encourages this by maintaining functional equivalence. Modulating the environment or equipment can also ensure that an imagery scenario is vivid to maintain both physical and psychological equivalence and meaning. In order to accomplish this, continual discussion and re-evaluation of exercises and imagery scenarios is necessary. An effect of this is also a patient-led discussion of increasing difficulty and context ensure that they are being challenged, relevance is maintained or updated given changes in ability, and can avoid repetitive exercises.

Enjoyment (Paper I)

Participants and Methods

Uninjured athletes (n=30) that were either active, or had been active in the past 5 years in sports including jumping and cutting movements were included, recruited from local sports clubs and university settings (Table 2). A cross-over design was used, which provides within-subjects data, as it allows each participant to act as his or her own control. This design can minimize confounders such as between-subjects variance, and including non-injured people reduces impact of factors resulting from injury, such as physical ability. This thereby allows for a more direct evaluation of the training model itself. Due to the nature of the training protocols, it was not possible to blind participants. However, during instructions, no specific references were made to the treatment arm, though it is likely they were able to differentiate between the two. The cross-over design also included a 10-minute wash-out period to ensure that effects of the first training session (e.g. heart rate, enjoyment, or boredom) did not carry over to the next.

Table 2. Participant Demographics Cross-Over Study, n=30

Demographics		n (%)
Gender	Male	15 (50%)
	Female	15 (50%)
Sport	Soccer	14 (47%)
	Handball	7 (23%)
	Basketball	3 (10%)
	Floorball	6 (20%)
Age (SD)		22 (3.2)
Active (#)		24
Years of experience (SD)		13.8 (4.0)
No longer active (#)		6
Years since active		2.8 (1.9)

SD = Standard Deviation

Main Outcome

The main outcome of this study was the Physical Activity Enjoyment Scale (PACES), a valid 18-item scale summed for a total score presented on a scale of 18 (worst) to 126 (best).(138) This questionnaire was not available in Swedish, so the authors translated according to guidelines established for translation and cross-cultural adaptation.(139) The Swedish version of PACES showed moderate test-retest reliability on a 10-minute cycling task performed by a separate sample of n=30 university students mean 17.6 (SD 0.7) days apart (intra-class correlation coefficient=0.70; standard error of measurement=6.5; limits of agreement=-15.33 – 24.93; smallest detectable change individual=3.3 and smallest detectable change

group=18.0; Cronbach's alpha=0.89), evaluated in a separate study published in a Swedish-language specialist journal.(140)

Secondary Outcomes

The Self-Assessment Manikin (SAM) is a 3-item scale evaluating emotional valence (positive or negative), arousal, and feelings of control on a 9-point Likert-type scale.(141) This allows for a measurement of psychological effects of the two training conditions on the individual.

Borg's Scale of Perceived Exertion measures rate of perceived exertion (RPE) on a scale of 6 (lowest) to 20 (highest).(142) By evaluating perceived exertion, it is possible to examine whether one training model is perceived as being more difficult. This, taken along with the SAM "arousal" subscale may provide further insight into how participants experience the training. Mean and maximum heart rate was recorded in order to examine whether either training condition was quantitatively more, less, or equally physically demanding (i.e. not only perceived).

Duration of each training condition was also collected in order to take into account a pragmatic view in which the time needed to execute training may be of importance for professionals using either MOTIFS or CaU in a real-world environment. A sub-group of n=18 participants was filmed in order to assess movement quality in the toe-off movement in both training conditions, reflecting an assessment of pragmatism and effectiveness of exercises with the addition of DMI.

Statistics

Treatment effect was analyzed using within-subjects, between-groups mean differences for PACES total scores, and for training duration using a mixed models analysis. Data from SAM, RPE, mean and maximum pulse, and movement quality were analyzed using the Wilcoxon signed-rank test. These results were followed-up with Fisher's Exact test in order to check for period and/or carry-over effects of the cross-over design. Baseline pulse was analyzed parametrically using a paired-samples t-test.

Psychological Readiness and Hop Ability (Paper II)

A randomized controlled trial (RCT) is underway which aims to compare the effects of the MOTIFS model with CaU treatment in people with traumatic knee injury. The trial will be administered according to pragmatic principles to reflect real-world situations by clinically active PTs,(143) and follow the Consolidated Standards of Reporting Trials (CONSORT) statement extension for pragmatic trials.(144)

The MOTIFS training model lacks similar interventions with which to compare, making it difficult to reliably estimate a required sample size. The cumulative adaptive methodology includes an interim analysis(145) to evaluate the need for modification and to more reliably estimate the required sample size. Being an adaptive trial, if no or inconsequential modifications are made to the method following the interim analysis, the included pilot participants are included in the final analyses upon conclusion of data collection.

Participants and Methods

Eligible PTs (n=26; approximate mean 20 years of clinical experience) and patients are randomized to either the MOTIFS or CaU treatment arm on the clinical level in order to reduce the risk of bias and contamination. The 12-week intervention begins when patients have reached the stage of rehabilitation which includes single-leg hop training.

PTs in the MOTIFS group undergo a workshop encompassing theoretical and practical instruction in the MOTIFS model's principles. When working with knee-injured patients, PTs utilize the MOTIFS model to modify existing rehabilitation exercises based on the needs and desires of the patient. This includes creating imagery situations in which the PT and patient work together to make rehabilitation movements as realistic and relevant as possible. The CaU condition includes standard practice rehabilitation training at the discretion of the PT, which typically includes neuromuscular training according to best practice recommendations.

Outcomes:

This study includes two main outcomes: within-subjects between-groups differences from baseline to 12-week follow-up in psychological readiness to return to sport, measured using the Swedish translation of the ACL-Return to Sport after Injury (ACL-RSI) scale, (62, 146) and physical function using a side-hop task. (147) Patient-reported outcomes are evaluated again 12-months after inclusion in the study.

Including both physical and psychological factors as main outcomes is important in this inter-disciplinary study in order to evaluate whether the MOTFS model reaches the goal of being a holistic model that is able to prepare people both physically and psychologically for return to activity. A summary of all outcomes, including secondary and exploratory outcomes, can be seen in Table 3.

Statistics

A sample size calculation indicated a preliminary requirement of n=106 patients to find clinically relevant differences. This was calculated based on studies examining

ACL-RSI(148) and side-hop function.(52) The sample size estimate included controlling for potential cluster effects by estimating an intra-cluster correlation coefficient. As comparable studies are lacking, these figures were estimated, a strategy deemed acceptable due to the adaptive design. Results of the interim analyses will provide more thorough data to increase reliability of the sample size estimation. Simulation analyses to estimate sample size were ruled out as a possibility due to the fact that the parameters needed would be estimated, and therefore equally unreliable. Observed data from the interim analysis, including within- and between-cluster variance, provides more reliable information on which

Table 3. Description of outcomes used in the MOTIFS randomized controlled trial. Adapted from Cederström et al 2021 (134).

Outcome	Type
Patient-Reported Outcomes	
***ACL-Return to Sport after Injury Scale (62, 146)**	12 item self-report scale (0-100 for each item) evaluating emotional response, confidence, and risk appraisal when returning to sport
Knee Injury and Osteoarthritis Outcome Score (33, 149)	Normalized score for subscales: pain, symptoms, sports and recreational activity, activities of daily life, and quality of life
Physical Activity Enjoyment Scale (138)	18-item self-report scale (11 items reverse-scored) examining the degree of enjoyment of a physical activity
Perceived Stress Scale (150, 151)	10-item self-report scale evaluating the patient's perceived stress
Patient Enablement Instrument (152, 153)	6-item self-report evaluating the ability of the patient to understand and cope with the injury
Rehabilitation Outcome Satisfaction (154)	1-item self-report scale evaluating how satisfied the patient is with the outcome of rehabilitation
Rehabilitation Motivation	3 item self-report scale evaluating motivation to complete rehabilitation
Tegner Activity Scale (49)	3-item self-report scale (pre-injury, current, future) measuring activity level
Physical Outcomes	
***Side Hop (147)**	Number of completed hops
Hop Test Battery (155, 156)	Single-Leg Hop for Distance(155) - 3 repetitions, or until improvement <10cm; Distance hopped (cm)
	Side Hop(147) - number completed hops in 30 seconds
Postural Orientation Errors (155, 156)	Single-Leg Mini Squat(157) - 5 repetitions; POEs assessed throughout entire movement
	Stair Descending(158) - 5 repetitions; POEs assessed on loading leg throughout entire movement until both feet are on the floor
	Forward Lunge(156) - 3 repetitions; POEs assessed on front leg from landing until maximum flexion of the knee
	Single-Leg Hop for Distance(155) - POEs assessed from landing until the knee is extended
	Side Hop(147) - 7 repetitions; POEs assessed during landing in 3 medial and 3 lateral jumps
Adherence	Self-Report questionnaire
	Physical Therapist report
Adverse Events	Self-report questionnaire
Exploratory Outcomes	Phenomenological interview

ACL = Anterior Cruciate Ligament; POEs = Postural Orientation Errors; SLMS= Single-leg mini squat; SD = Stair descending; FL = Forward Lunge; ADL = Activities of Daily Life

*Main Outcomes

to base estimations, and allows for determination of potential modifications. The fact that the study includes two main outcomes will also be taken into account following interim analyses by adjusting significance to $p>0.025$.

Data will be analyzed according to intention to treat principles using independent samples t-tests to assess between-group differences of change from baseline to 12-week follow-up. Based on normality testing, and where appropriate, non-parametric testing will be used. Outcome scales with a low number of items will be analyzed using a chi-square test. Rehabilitation motivation(159) and outcome satisfaction(154) will be presented as raw data.

Study Status

At the time of writing 42 participants have been included in the RCT, and another 7 have agreed to take part. Once n=25 have been included in each group, an interim analysis will be performed to evaluate the pre-defined cut-off criteria.

Physical Therapist and Patient Perceptions (Papers III and IV)

Participants and Methods

The PT pool active in the RCT was screened for eligibility and invited to participate in an interview. In order to supplement this, and thereby provide a more geographically diverse participant pool, PTs were recruited from other areas of Sweden. Similarly, patients were screened for eligibility and invited to participate. Interviews were conducted with PTs either face-to-face (n=1) or digitally (n=15), and digitally with patients that had completed the intervention in the RCT (n=5 MOTIFS and n=8 CaU; Table 4).

Table 4. Participant characteristics

Physical Therapists				
		MOTIFS (n=6)	Care-as-Usual (n=8)	Total (n=14)
Gender	Male	3 (50%)	3 (37%)	6 (43%)
	Female	3 (50%)	5 (63%)	8 (57%)
Age (SD)		41 (9.3) years	40 (10.0) years	40 (9.4) years
Clinical Experience (SD)		16 (9.1) years	15 (7.4) years	15 (7.9) years
Patients				
		MOTIFS (n=5)	Care-as-Usual (n=7)	Total (n=12)
Gender	Male	3 (60%)	3 (43%)	6 (50%)
	Female	1 (20%)	4 (57%)	5 (42%)
	Other/Prefer not to answer	1 (20%)	0 (0%)	1 (8%)
Age (SD)		20 (1.9) years	30 (4.8) years	25 (6.1) years
Sport	Soccer	2 (40%)	4 (57%)	6 (50%)
	Floorball	2 (40%)	0 (0%)	2 (17%)
	Handball	1 (20%)	0 (0%)	1 (8%)
	Other	0 (0%)	3 (43%)	3 (25%)

MOTIFS = MOTor Imagery to Facilitate Sensorimotor Re-Learning; SD = Standard Deviation

Data Collection

During the interviews, participants were given verbal information and provided written and verbal (digitally recorded) informed consent to both take part in the interview and for use of citations in text. MOTIFS PTs were asked to "explain, in as much detail as possible, how you experience using MOTIFS training." PTs in the CaU condition were asked to "explain, in as much detail as possible, how you experience rehabilitation following traumatic knee injury." During patient interviews, a priming question (e.g. "who was your physical therapist?") was used to prompt recall of the rehabilitation process.(160) Patients in both groups were then asked to "describe in as much detail as possible how you experienced the rehabilitation process," with follow-up questions to ensure thorough responses.

Data analysis

Analysis of interview data was multifaceted, including methodological aspects from a coding reliability thematic analysis(161) approach, grounded in Interpretive Phenomenological Analysis.(160, 162) Combining qualitative approaches has been used previously to interpret lived experiences, while simultaneously providing a more objective explanation of themes.(163)

The primary coder (NC) identified overarching major themes discussed by participants.(161) These broad themes were further categorized based on shared meaning, in which more detailed information could be generated to inform of specific situations and/or reactions (e.g. strength training or fear).(161) QSR International's NVivo 12 qualitative data analysis software (released March 2020) was used to evaluate inter-coder agreement in an effort to ensure reliability.(161)

For each conceptual model, one interview was deductively coded by coder 2 (SG, expertise in sport psychology). Upon reaching acceptable agreement, defined as

k≥0.60,(164) the process was repeated with coder 3 (EA, expertise in physical therapy). Once acceptable agreement was reached, the model was discussed and finalized following minor alterations (i.e. definition clarification).

Once the themes had been identified, a hermeneutic approach was used to interpret results to explore the context in which participants made sense of the reality of rehabilitation.(160, 162) The primary coder used this identified meaning which participants ascribed to different aspects of rehabilitation to define clusters with shared meaning, and provided a definition.(160)

As qualitative methodology does not allow for statistical comparison, separate conceptual models were generated – one for each participant group. In both PT and patient interviews, the CaU model was presented in order to provide context in which the MOTIFS group perceived their training. This was deemed necessary as an understanding of rehabilitation as a generalized phenomenon allows for understanding of the context of the MOTIFS training model.

Results and Discussion

Enjoyment (Paper I)

Summary of Results

Results of the cross-over study confirmed the hypothesis that higher levels of enjoyment would be experienced by uninjured athletes performing knee injury prevention and/or rehabilitation exercises according to the MOTIFS model than the CaU condition (Table 5). PACES scores showed a mean difference of 23.6 (SD 15.1) in favor of the MOTIFS condition. No period effects were found, independent of the order in which the training conditions were completed. All SAM items indicate more positive outcomes in the MOTIFS condition than the CaU condition. This includes a more positive psychological valence and higher perceived arousal. Feelings of dominance were higher, though there is an indication of a potential period effect (Fisher's Exact = 0.143).

Table 5 – Results of between-groups analyses of PACES, Duration, SAM, RPE, and pulse scores. Adapted from Cederström et al 2021 (165)

	MOTIFS		Care-as-Usual		Difference			
	n	Mean (SD)	n	Mean (SD)	n	Point Est. (SE)	p	95% CI
PACES	30	102.5 (9.3)	30	77.8 (18.1)	30	24.67 (2.77)	<0.001	19.0; 30.3
Duration	30	20.1 (6.3)	30	14.7 (4.1)	30	0.122	<0.0001	0.063; 0.033
	n	Median (IQR)	n	Median (IQR)	n	Median (IQR)	p	Fisher's Exact
SAMVal	30	8 (7;9)	30	6 (5;7)	30	2 (1;3)	<0.001	0.000
SAMAr	30	5 (5;7)	30	5 (3;5)	30	1 (0;2.25)	0.004	0.025
SAMDom	30	7 (5;8)	30	5 (3;7)	30	0.50 (0;2)	0.014	0.143
RPE	30	13 (12;14.3)	30	12.5 (10;13.3)	30	1 (-0.3;2)	0.010	0.027
HRmean	28	101.92 (96.1;108.6)	29	98.77 (93.0;109.8)	28	4.32 (0.7;5.6)	0.005	0.006
HRmax	28	144.50 (130.8;152.5)	29	134.00 (121.5;145.0)	28	7.50 (0.3;16.8)	<0.001	0.021

p = Exact significance (2-tailed); significance set at p=0.05; Fisher's Exact (2-sided) significance set at p=0.05
MOTIFS= MOTor Imagery to Facilitate Sensorimotor Re-learning; SD = Standard Deviation; Point Est. = Point Estimate; SE = Standard Error; CI = Confidence Interval; PACES = Physical Activity Enjoyment Scale; Duration = Training Duration; IQR = Interquartile Range; SAM = Self-Assessment Manikin; SAMVal = SAM Valence subscale; SAMAr = SAM Arousal subscale; SAMDom = SAM Dominance subscale; RPE = Ratings of Perceived Exertion; HRmean = Pulse – mean beats per minute; HRmax= Pulse - maximum beats per minute

Enjoyment and Psychological States

Significantly higher PACES scores may indicate that MOTIFS can influence enjoyment to a greater degree than CaU by focusing on autonomy, competence, and relatedness, the three pillars of SDT.(109) In this training model, the individual is seen as the expert, resulting in an autonomous decision based on their own competence regarding the exercise to be performed. This provides support for the ability of the MOTIFS model to encourage self-determined motivation through context-specific, relevant, and individualized exercise modification discussions.

This is supported by results of the SAM subscale dominance, which indicates feelings of being in control. A potential period effect for this subscale may be an indication that both conditions increase feelings of dominance. However, together with greater feelings of enjoyment and a positive valence, this could be an indication that feelings of control may be influenced by meaning, which MOTIFS supplies by placing control in the hands of the individual. This is an important aspect, as self-determined motivation is thought to be more effective for encouraging training behaviors if it is intrinsic, rather than extrinsic.(166) Therefore, feeling involved and doing something based on one's own experiences and competencies can be a stronger motivator,(167) especially if in the context of a skill or performance which one already has motivation to improve. This can also aid in ensuring lasting enjoyment, as control over the exercise is individual, leading to the ability of the person to adapt and modify to meet new physical and psychological needs.

Focusing on enjoyment also has implications for the ability of the participant to more efficiently learn a movement.(111) Enjoyment is a result of the reward system in the brain, in which dopamine is released, triggering positive feelings.(168) Dopamine is also important for movement, and is thought to be involved in adaptation of motor responses, aided by the translation of enjoyable stimuli and memory.(169) Diekfuss et al. (116) postulate that dopamine may aid in motor control and accelerate learning by creating positive movement expectations using a relevant and recognizable external focus of attention. That is, dopamine release resulting from an external focus related to an enjoyable sport or activity may have greater motor learning effects than from non-relevant stimuli such as sleep or food.

This may also indicate a difference in the degree to which external focus is used in rehabilitation. Participants may find MOTIFS training to be more enjoyable than CaU training due to greater sport relevance. External focus in current rehabilitation paradigms is often described as focusing on a point on the wall, or by using external cues (i.e. "reach towards the ceiling") to instruct movements.(170) However, the relevance of a stronger dopaminergic response to enjoyable and meaningful activities may indicate that CaU training is not external enough. Reaching towards something, then, may be a less relevant external factor for encouraging motor learning than the self-determined simulated situation provided by MOTIFS training.

Training Duration

Training duration was significantly higher in the MOTIFS condition compared to the CaU condition (mean difference 5.08 minutes, SD 5.42), likely as a result of this discussion time. This could indicate a positive aspect of MOTIFS training, in that spending time to discuss individualized meaning and relevance may increase meaning and vividness of the imagery session. In turn, the athlete can take advantage of the enjoyable experience to better learn to control the movement.

Being allowed to create an exercise based on competence and interests is likely to be one that bears significant meaning for the athlete. Given that it is based on their current or previous sport, they are creating a situation based on their experiences, which is important for creating a functionally equivalent imagery scenario according to PETTLEP motor imagery.(8) It is also reasonable to assume that the sport in which one is or has been active is a source of enjoyment. This may serve as an argument to justify the extra time needed to plan these sessions, as the meaningful movement may be more effective at priming learning.

Exertion

Borg's rating of perceived exertion showed that patients perceived greater exertion in the MOTIFS condition, and this was reflected in heart rate data, showing significantly higher mean and maximum pulse than in the CaU condition. Baseline pulse was higher in the first condition, indicating a potential residual effect from the cycling warm-up, which was not performed prior to the second training, possibly resulting in lower baseline heart rate in the second condition training.

Research has suggested that a reduction in perceived physical effort is a result of increased activation in the reward structures, stimulating the release of dopamine.(171) This in turn has been suggested to influence synaptic activity, potentially influencing movement initiation and motor planning.(171) The increased meaning of performing MOTIFS exercises with a relevant external focus may increase participants' ability to relate to their sport and create a movement which is more natural and automatic for them. That is, they are thinking of sport-specific situations, which thereby creates a sport-specific movement. The more automatic nature of this movement may therefore result in a movement in which they are more confident or able to exert themselves.

Movement Quality

External focus may explain results showing that 87% of participants maintained acceptable movement quality. No significant individual or total differences were identified between conditions, indicating that participants were able to maintain acceptable movement quality throughout the MOTIFS training session (Table 6). It

Table 6. Movement Quality Results. Adapted from Cederström et al 2021 (165)

Movement Quality	MOTIFS		Care-as-Usual		Difference			
	n	Median (IQR)	n	Median (IQR)	n	Median (IQR)	p	Fisher's Exact
MQ Total	15	4.0 (1;5)	16	2.5 (1;4.75)	15	0 (-2;1)	0.856	N/A
MQ Overall	16	1 (0;1)	16	1 (0;2)	16	0 (-1;0)	0.248	N/A
MQ Plantar Flexion	15	1 (1;2)	16	1 (1;1)	15	0 (0;1)	0.480	N/A
MQ Knee Extension	16	0 (0;1)	16	0 (0;1)	16	0 (0;0)	0.739	N/A
MQ Hip Extension	16	0 (0;1)	16	0 (0;1)	16	0 (0;0)	1.000	N/A

MOTIFS= MOTor Imagery to Facilitate Sensorimotor Re-learning; IQR = Interquartile Range; MQ = Movement Quality; N/A = Not applicable, test not performed due to non-significant Wilcoxon results

may be reasonable to assume that adding a layer of movement complexity may decrease the resulting quality of the movement.(172) This is a concern for injury rehabilitation or prevention exercises, as performing a movement correctly is important to achieve the goals of the exercise. Therefore, it is important to examine whether movement quality can be maintained in an exercise with additional complex input.

According to the OPTIMAL theory of motor learning, the acquisition of movement knowledge is optimized by successfully performing exercises based on intrinsically self-determined motivation, with high expectancies for success, and with an external focus of attention.(111) Utilizing an external focus and PETTLEP motor imagery can help to mentally simulate a functionally equivalent environment. The 'degree' to which focus is external may be the result of feedback, such as somatosensory or visual,(113) highlighting the importance of creating a vivid imagery scenario.

The benefit of this is that the simulated environment can aid in planning actions. When one perceives an environment, one's perception of that environment is in terms of potential actions that may be taken, known as perception affordance.(173) Perception-action coupling is the connection between what one perceives in the environment, and the action that is planned as a result of this input.(174) Perception affordance is directly related to the individual, in which he or she will ascribe different affordances to the objects perceived depending on previous experiences.(175, 176) An example could be that a person on a soccer field sees a goal (perception) and wants to score in that goal (perception affordance) and plans how to take a shot on goal (perception-action coupling). Using goal-directed imagery has been shown to increase upper-limb movement quality in a reaching task,(177) which may provide evidence for this effect. The vividness of a MOTIFS imagery scenario therefore makes it easier to perform familiar movements more automatically by calling to mind stimuli needed to accurately plan an action. MOTIFS does this by allowing the athlete to create a self-determined situation in which they have competence. This increases expectancies for success by integrating PETTLEP aspects to increase realistic feedback, thereby leading to a more automatic and natural movement in which movement quality is maintained.

Strengths and Limitations

Strengths of this study include the randomized design to allow for pre-determined hypotheses to be tested while being able to statistically control for potential period effects. The fact that movement quality was analyzed by a blinded third party is another strength, in that proper execution was confirmed, indicating that the model provides a plausible method of simultaneously training both physical and psychological factors.

Limitations regarding the study design include the fact that cross-over effects cannot be ruled out, as participants may have been influenced by the first condition to which they were exposed. The same is true of learning effects, in which exercises may be performed better after having already completed them, so a longer wash-out period may be more desirable. Movement quality was evaluated using an un-validated pragmatic method, though is seen as acceptable for this study. Future research may evaluate movement quality using validated methods.

This study aimed to examine the effects of psychological training integrated into physical training. The MOTIFS model was developed for use with knee-injured people, but the principles are applicable for uninjured people as well. Injury rehabilitation and prevention training are similar in many ways, and the exercises chosen in this study are applicable for both populations. For that reason, the use of an uninjured sample is not seen as a limitation; it is rather seen as a benefit in providing support for the ability of the MOTIFS model to influence psychological aspects of training. Further studies are needed to provide information on the effects of this method of training on an injured population.

Psychological Readiness and Hop Ability (Paper II)

Results of the RCT examining the effects of MOTIFS training on physical and psychological outcomes in knee-injured people are not available. An interim analysis will be performed, but in the current absence of this information, potential mechanisms and implications are relevant to discuss. The protocol for this RCT is important in order to provide transparency and provide readers with a detailed plan of how the study will be conducted. This ensures that the study maintains high quality and integrity of the collected data. It also allows an opportunity for a more thorough discussion of the background, methods, and outcomes used in the study.

Potential Mechanisms and Rehabilitation Implications

The MOTIFS model is based on principles which allow PTs to implement psychological skills training to create functional equivalence in a clinical

environment. In the context of knee injury rehabilitation, the effects of imagery are relevant due to plastic changes in the brain following ACL injury,(178, 179) prompting the consideration of a musculoskeletal injury as a neurophysiological dysfunction.(180)

In order to optimize re-learning of physical movements, it is necessary to increase neurological and cognitive activation in order to take a more holistic approach to restoring function to the knee. MOTIFS has the potential to activate the autonomic and sympathetic nervous systems by using imagery in a longer-term and more dynamic motor imagery task,(181) and may engage sensorimotor mechanisms.(182) The dynamic nature of the imagery is also important, as combining psychological and physical training can encourage more activity-specific learning.(129, 131, 183, 184)

Cognitive

MOTIFS training aims to utilize individual expertise to create externally focused and intrinsically motivated exercises for which patients have high expectations and confidence in success. This may play an important role in neural activity during imagery, as meaningful and relevant images are suggested to be more effective in motor learning.(185, 186) Integrating MOTIFS into rehabilitation training shifts to a more external focus of attention, which may reduce cognitive load and lead to more optimal adaptation of movement patterns. Knee injury inhibits and alters somatosensory processing and proprioception,(187, 188) and has been suggested to influence neuroplasticity and processing power required to execute movements.(189) This then decreases ability to maintain postural control, which may in turn result in developing other strategies to maintain this control, for example unbalanced loading.(190) Research has shown that postural control may be positively influenced by dynamic motor imagery interventions.(183) MOTIFS therefore has the potential to provide relevant cognitive effects, including adaptations to physical constraints to more efficiently re-learn activity-relevant tasks, thereby facilitating achieving knee-injury rehabilitation goals.

The MOTIFS intervention may aid in activation of relevant brain structures by imaging functionally equivalent scenarios. Use of DMI has been shown to increase activity in brain regions related to sensory, visual-spatial, and motor planning functions, and can result in reduced movement patterns typically considered maladaptive, such as hip adduction and knee rotation.(184) Successful rehabilitation and/or return-to-activity outcomes include the ability to maintain movement control during activity-specific tasks,(57) which are simulated during MOTIFS training. This then may increase ability to adapt to real-world situations, such as unexpected stimuli (a ball or tackle, for example) more realistically than generic sport movements such as cutting and jumping, which have been suggested as sport-relevant rehabilitation outcomes.(137)

Motor Learning

Using the MOTIFS training model allows for relevance of movements to come into focus, which thereby encourages the patient to solve problems and learn to adapt to the constraints of the injury. Rehabilitation following knee injury includes the essential aspect of addressing these constraints in order that the knee and surrounding musculature develop the strength, stability, and reactivity necessary to handle the loads to which they will be exposed during activity. However, treatment includes, in part, breaking down movements into their component parts,(21, 137) known as decomposition or de-coupling, in order to isolate targeted structures. However, the concept of de-coupling also implies the disconnection from the activity itself. Removing the necessary stimuli which correspond to the real-world execution of the movement may be problematic, as it limits the necessary variability of the movement described by dynamic systems theory.(121) MOTIFS training avoids this de-coupling, and has the potential of improving task learning, leading to improved physical readiness in terms of motor control in dynamic movements. Simplification of the movement is allowed, and indeed encouraged, to adapt to the abilities of the patient, but total de-coupling from the relevant activity may be detrimental.

Studies have suggested that motor imagery may be an effective method of re-learning movements in rehabilitation environments in which the ability to train physically is limited.(191, 192) Using MOTIFS training, factors may be modified to introduce familiarity with training situations to compensate for the individual constraint of the injury, for example by simulating task-specific and environmental factors. The constraint of the knee injury is utilized in such a way as to aid in learning motor skills and movement, allowing for task-specific variation and problem-solving. Other controlled constraints are also encouraged in order to aid in increasing functional equivalence so that performing the movement is more similar to reality, including adapting to stress, time, or accuracy constraints, for example. According to the constraints-led approach, this problem-solving of movement patterns leads to more efficient learning of the correct execution.(119)

The injury itself also acts as a form of “noise” in the execution of movement, which forces the athlete to make adaptations to their movement patterns in order to successfully execute the movement. According to the theory of differential learning,(193) this can aid in more effectively learning the movement. By increasing functional equivalence and ascribing meaning to the performed movement, MOTIFS strives for a more optimal level of noise which will allow for a strengthening of the individually beneficial movement signals (i.e. learning to move properly under a variety of realistic conditions).

If rehabilitation training does not take into account the central nervous system changes and the resulting effects on knee function, there is a higher risk of compensatory, rather than adaptive, strategy development. Compensatory learning

would indicate a degree of avoidance of certain behaviors (unevenly distributing load, for example), while an adaptive strategy modifies behavior to correct errors based on an awareness of the 'new' functional abilities of the knee. This adaptive strategy development can be encouraged by using an external focus on activity execution, which reduces the cognitive load needed to perform these movements. More internal focus of attention may thereby increase the probability of strengthening a maladaptive movement pattern requiring greater neurocognitive demands.

Psychosocial

An important aspect of rehabilitation is also taking into account psychosocial factors.(21) A systematic review has shown that using motor imagery during ACL rehabilitation training has positive effects on perceived pain and fear, with conflicting results for re-injury anxiety.(101) The interventions applied in these studies included motor imagery performed alongside, i.e. not integrated into, physical rehabilitation training. Other included studies included visual imagery or video sessions, and did not show positive effects in these outcomes.(101)

In uninjured populations, imagery has been shown to be positively correlated with confidence and self-efficacy, and negatively with worry. (194, 195) There is also a positive influence of imagery on motor performance, attitudes, and motivation.(98) Physical activity behavior also benefits from imagery training,(196) suggesting that motor imagery use can increase compliance and adherence to training programs. Interestingly, a potential moderator of the ability of imagery to influence performance and psychosocial outcomes is the number of sessions, with more imagery being more effective.(98) This may indicate a problem with traditional imagery which is done separately, thereby limiting the number of available imagery sessions due to time constraints (given that rehabilitation training also takes time).

These results show potential for motor imagery to positively influence psychosocial factors which have been shown to be important for rehabilitation success.(56, 61, 197, 198) MOTIFS training allows for an integration into physical training exercises, potentially indicating a benefit in that the number of sessions can be increased without the need for substantial time investments outside of rehabilitation training. The results of Study I in this thesis support this, showing that time is increased, but enjoyment and affect are also increased using MOTIFS training.(165)

Strengths and Limitations

Strengths of this trial include that it is a randomized controlled trial according to pragmatic guidelines, which increases clinical relevance from an end-user perspective. The adaptive nature also allows for a preliminary analysis which may aid in optimizing the model in later versions.

Limitations include that this trial is blinded only to the test leader. This was done for practical reasons, as the study sport psychologist, patients, and PTs need to be informed of the treatment arm to which they are randomized in order to effectively implement the training model. Due to lack of other similar studies, a reliable sample size estimation is not possible. However, the adaptive nature of this trial allows for a re-estimation following a preliminary interim analysis.

Recruitment is also a limitation, in that a degree of responsibility is placed on the PTs to report potential participants. The strategy follows Swedish national guidelines, in which patients have the right to choose their own rehabilitation care provider, and the study coordinator is responsible for collecting contact information. Therein lies the limitation, in that there may be eligible patients that are missed due to misunderstandings of eligibility criteria, for example. Another issue is the recruitment rate, in which patient in-flow has been slower than anticipated. This is likely due, in part, to the Covid-19 pandemic, which seems to have slowed surgery and sport participation rates temporarily. However, this does not explain the entirety of the problem, and after discussing with PTs involved in the study, it was revealed that there was some confusion regarding inclusion criteria. In order to counteract this, measures have been taken to ensure that PTs are regularly reminded of the inclusion criteria, updated regarding the status of the study (i.e. rate of inclusion), and are visited regularly in order to provide an opportunity for questions to be answered and clarify any remaining confusion. This is an ongoing process, and is constantly being monitored and updated to reflect the needs of the PTs in order to ensure an efficient recruitment process. Another potential issue is that fact that two clinics in the area include PTs active in the research group. Due to potential bias, patients from these clinics are not available for recruitment. These two clinics treat many knee-injured patients, and a third large clinic in the area declined to participate, limiting the number of available patients in the participant pool.

Physical Therapist Perceptions of MOTIFS (Paper III)

Perceptions of Physical Therapists in the MOTIFS Group

In the MOTIFS group, PTs believe that the MOTIFS model increases psychological focus during rehabilitation training. This results in three major themes, presented in descending order of prevalence, with themes with the highest number of references presented first. The conceptual model is presented in Figure 5, and the text refers to the major and subordinate themes in this figure, referred to as “MOTIFS model #x” to direct the reader to the appropriate major and subordinate theme.

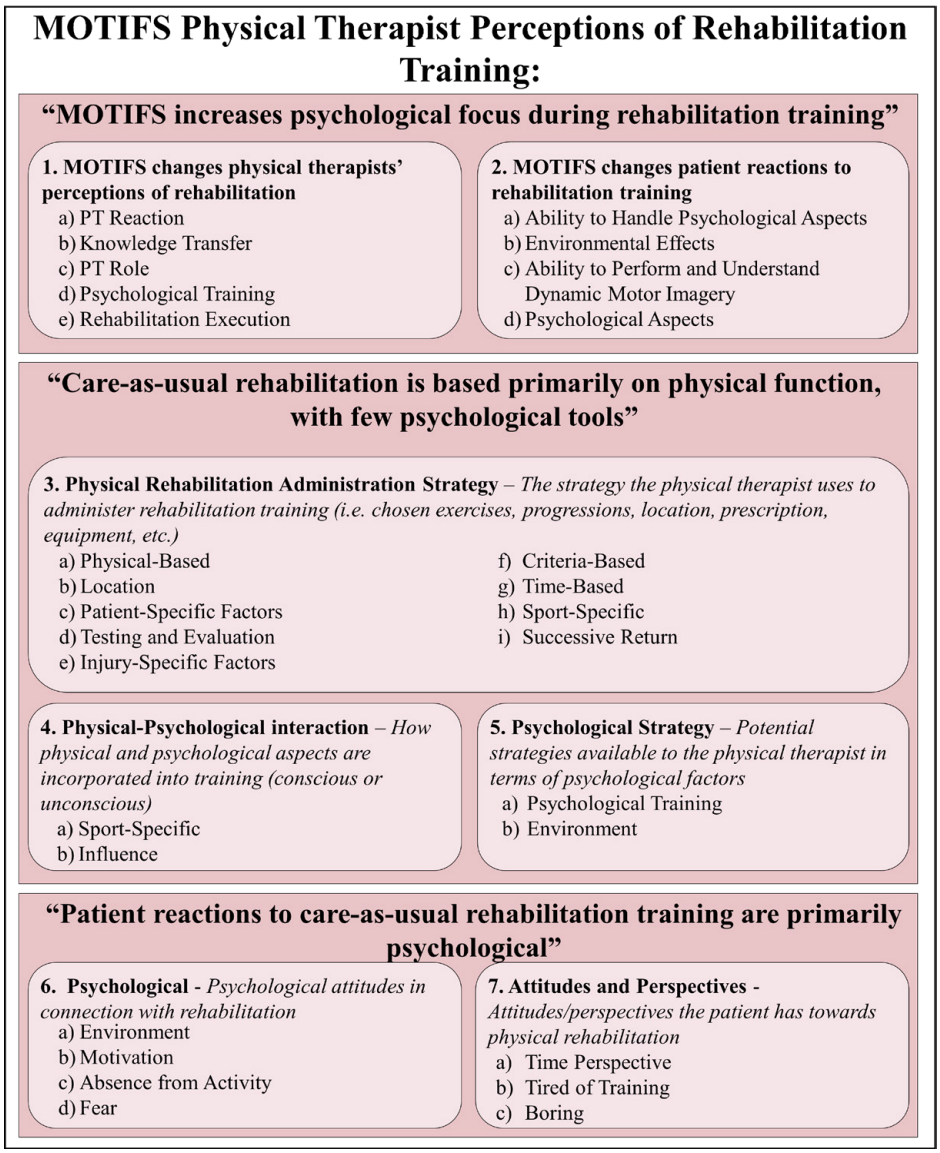

Figure 5. Conceptual model showing MOTIFS physical therapists' perceptions of rehabilitation training, presented as major themes with more detailed subordinate themes

MOTIFS increases psychological focus during rehabilitation training

PTs in the MOTIFS group express an impression that MOTIFS training provides a novel and interesting complement to what is already done in the clinic, with an additional layer of psychological complexity (Figure 5 - MOTIFS Model 1a). PTs perceive a need for more focus on psychological factors, which is in line with

previous research.(83, 199) In some cases, implementation of MOTIFS was perceived as confusing, likely due to incorporation of factors outside the PTs' area of expertise. However, workshops and personal visits clarified confusion (MOTIFS Model 1b) by providing concrete strategies for implementing the MOTIFS model.

The increased focus on psychological training leads PTs to perceive that their role changed while using the MOTIFS model, including more consciously providing psychological support, and being more aware and having concrete knowledge on how to use psychological strategies (MOTIFS Model 1c-d). An important aspect of this is contextualizing training to help the patient understand the relevance and thereby create realistic imagery scenarios. Creating this individualized context requires PT-patient discussion, and integrates shared decision-making with more patient-focus than previous studies, (200) and utilizes evidence-based goal-setting strategies.(64, 84, 91, 200) PTs recognize benefits of contextualization, including improved resilience,(201) self-determined motivation,(109) training quality,(111, 114) motor learning,(121) and readiness to return to activity.(103, 202, 203)

The main differences between MOTIFS training and CaU is perceived as the integration of imagery by including visual, auditory, and other activity-relevant stimuli to increase functional equivalence (MOTIFS Model 1e). Some PTs seem to believe that MOTIFS does not change their strategy, but specifying the addition of evidence-based imagery practice indicates that their methodology has been modified. This perspective may be explained by cognitive dissonance, in that PTs have difficulty accepting that the novel aspect of MOTIFS training is, in fact, novel. They may believe that psychological training is already being applied, or they may misinterpret previous methods as being psychological skills training. Interestingly, PTs discuss a need to focus on situational and contextual factors earlier, allowing more time to apply the MOTIFS principles with the patient. This leads PTs to believe that the MOTIFS model should be implemented earlier in rehabilitation, in contrast with recommendations for later sport-specific training.(21, 57)

PTs also discuss perspectives of how the patient perceives rehabilitation training. This includes an awareness of the patient's ability to handle psychological factors, and the necessity of individualizing treatment based on this ability (MOTIFS Model 2a). PTs see MOTIFS as a feasible method to help patients develop coping mechanisms by encouraging decision-making about application of sport-relevant stimuli. This is important, as it allows for in-clinic implementation rather than relying on external sport psychologists, previously suggested as an alternative.(82)

Some PTs indicate that MOTIFS training encourages more structured environmental modulation to influence psychological aspects, applying MOTIFS principles based on individual ability, motivation, and goals (MOTIFS Model 2b-d). On-field rehabilitation can help by providing social support from teammates, as well as by increasing realism of the imagery scenario, which is important for PETTLEP motor imagery(8) and on-field rehabilitation.(204, 205) The effects of

simulated training in the relevant environment has been shown to be more effective in enhancing sport-specific skills,(206) and PTs perceive that MOTIFS can improve psychological readiness to return to activity. This is supported by studies showing that imagery training can help in reducing fear,(102) improve functional mobility, reduce perceived pain, and increase self-efficacy.(202, 203) A training model which aims to use environmental factors to increase enjoyment and self-determined motivation has also been suggested to be beneficial to motor learning.(207) Level of experience may also be a factor, as previous literature has shown that imagery may more efficiently activate cognitive structures when imaging a task in which the imager has a degree of expertise.(208)

Care-as-Usual rehabilitation is based primarily on physical function, with few psychological tools

In order to provide context to MOTIFS training, PTs in the MOTIFS group discuss CaU rehabilitation training, which is described as aiming mainly to restore physical function. Rehabilitation is described as reflecting best-practice guidelines,(21, 38) in which strength, range of motion, and movement quality are trained to prepare patients for return to activity following criteria-based progression based on functional, symptom-based, and injury-specific factors (MOTIFS Model 3a-g). PTs successively introduce activity-specific training in later phases to individualize and prepare patients for return to activity using relevant functional movements (MOTIFS Model 3h-i).

While the main focus is on physical aspects of rehabilitation, PTs recognize that rehabilitation and movement necessarily includes an interaction between physical and psychological factors. This may include motivational strategies, such as sport-specific training, encouragement, and education to encourage positive rehabilitation behaviors (MOTIFS Model 4a-b). The focus on preparing for physical aspects, such as being able to safely and efficiently push off the floor in a cutting movement, for example, does not take into account psychological factors. This supports the claim that PTs focus on physical therapy, and lack the appropriate skills to be able to implement structured psychological skills training.

Psychological training strategies can include goal-setting, external focus of attention, and modulating the environment (MOTIFS Model 5a-b). Descriptions of goal-setting reflect previous research that patients are only involved in broad goals regarding treatment, rather than specifics.(200) According to sport-psychological goal-setting models, this is not an efficient way of setting goals for an athlete.(91) Goal-setting should provide patients with a sense of involvement and autonomy,(84) further indicating that PTs lack knowledge of applying psychological training.(64, 83) Training physical aspects using an external focus is described as perturbation or reaching towards a point on the wall, which may be more external than focusing on the musculature. However, it is not as external as focusing on environmental and task factors associated with the patient's goal activity. Research suggests that

moving the focus of attention further outside of the body has the potential to influence brain activity to a greater degree than an external focus nearer the body.(186) This may point to the fact that there are degrees of external focus which need to be taken into account to increase movement quality. On-field training may help in increasing the external focus, but PT descriptions indicate this strategy is poorly defined and does not follow structured psychological training interventions. PTs express a desire for knowledge in this area, but lack tools to effectively implement these training methods in the clinic.

Patient reactions to care-as-usual rehabilitation training are primarily psychological

PTs also put themselves in the shoes of the patient to describe CaU rehabilitation training, which includes a number of negative psychological reactions. PTs perceive that patients have difficulty dealing with the clinical environment, motivational aspects, and being away from activity (MOTIFS Model 6a-c). Fear (MOTIFS Model 6d) can come from not understanding what is happening or why, how long rehabilitation will take, or why certain exercises are important, which has support in previous research.(209-211)

PTs also believe that patients have an understanding of the time required to heal, that rehabilitation may take a year or longer, and they may tire and get bored with their training (MOTIFS Model 7a-c). An interesting result of this is not simply what is said, but also how it is said. When describing CaU training as boring, PTs laugh and seem to indicate a sense of inevitability of training as unpleasant. The perspective may refer to a feeling of inability to address this factor, and as nothing can change it, the only option is to accept this fact.

Perceptions of Physical Therapists in the Care-as-Usual Group

PTs that had not been exposed to MOTIFS training were interviewed in order to provide information on what is done in CaU rehabilitation, resulting in a degree of dualism. This includes referring at times to the patient, indicating a personalized and holistic view, while some PTs refer to the knee as a separate entity apart from the person to whom it is attached ("*the knee will soon be able to handle being with their team*" P09). Cross-over and repetition of perspectives of PTs in the MOTIFS group allows for comprehensive presentation of rehabilitation perspectives, but quantitative methodology prevents comparison. Themes are presented in descending order of prevalence, with themes with the greatest number of references presented first. The conceptual model is presented in Figure 6, and the text refers to major and subordinate themes in this figure, referred to as "CaU model #x" to denote the referenced major and subordinate theme.

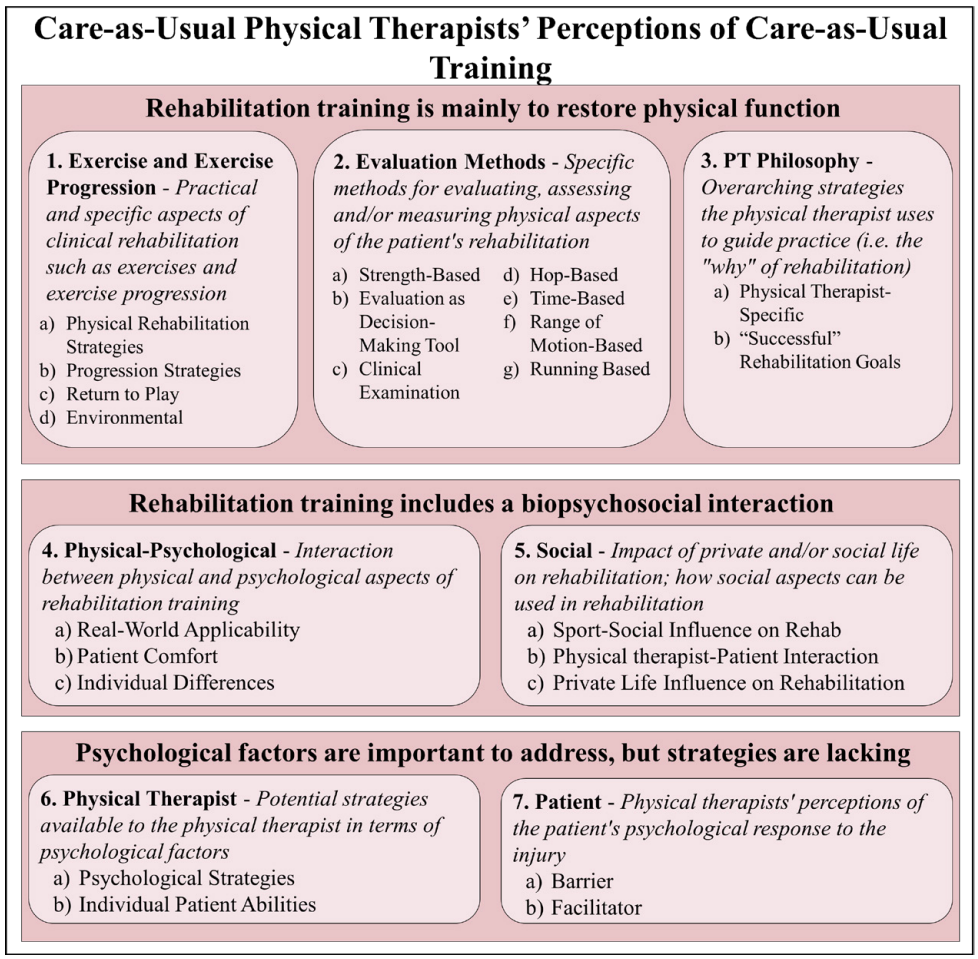

Figure 6. Conceptual model showing care-as-usual physical therapists' perceptions of rehabilitation training, presented as major themes with more detailed subordinate themes

Rehabilitation training is mainly to restore physical function

PTs describe physical rehabilitation strategies (Figure 6 – CaU Model 1a) in line with best-practice guidelines(21, 38) and include individualizing training to improve muscle control, function, and balance. Progression strategies include phase-based and gradual introduction to more difficult and activity-specific training based on physical criteria (CaU Model 1b-d). Evaluations of strength assess function and side-to-side differences (CaU Model 2a), with limb symmetry being an important goal, in line with both best-practice guidelines(21, 38) and return-to-sport criteria.(44, 54) However, PTs admit results may be misleading, as biomechanics are also altered in the uninjured limb following ACL reconstruction rehabilitation.(212) PTs therefore use evaluation as a decision-making tool, using

movement quality, knee laxity, and symptoms, and functional running-, hop-, range of motion-, or time-based testing to determine progression (CaU Model 2b-g).

PTs perceive a personal philosophy as a meaningful aspect in their approach, indicating that perspectives are informed by research or a fixed injury-based program, adapted to the individual (CaU Model 3a). Exercise choice, for example, is based on experiences with favorite exercises, or clinic-specific strategies. PTs are skeptical of an 'optimal' movement pattern, and personal philosophy guides evaluation of whether the movement is appropriate. The question becomes whether one risks introducing suboptimal movement patterns which increase injury risk. This highlights the importance of the PTs judgement of what is necessary for the individual patient, and the definition of 'successful' rehabilitation (CaU Model 3b).

Rehabilitation training includes a biopsychosocial interaction

PTs in the CaU group perceive a biopsychosocial interaction between physical and psychological aspects of training, such as the use of exercises applicable to the patient's real-world situation (CaU Model 4a). This includes using an external focus of attention and utilizing activity-specific exercises. However, the functional equivalence of these is questionable, given the descriptions of focusing on landing mechanics, for example. Strategies are described as including specific instructions and corrections to de-coupled movements, suggesting an attempt to reduce variability and noise, in contradiction to differential learning.(193) Some PTs perceive that muscle-specific activation is important, placing an overly detailed focus on, for example, vastus medialis, shifting focus internally and limiting the ability to create functionally equivalent situation-specific exercises.(114)

PTs also perceive that rehabilitation strategies are influenced by patients' feelings of comfort and individual differences (CaU Model 4b-c), such as fear or anxiety. This can include the movement that resulted in injury, or the patients' target activity. Comfort can be used as a tool in progression by progressively increasing jumping height to help the patient understand their abilities, rather than an arbitrary height.

Another biopsychosocial factor is the effect of social aspects, including that of teammates and coaches, for example (CaU Model 5a). This can provide positive motivational support, but may also be negative, as some coaches are perceived as being less understanding of restrictions. The PT is a source of social support (CaU Model 5b), providing more specific rehabilitation-based support. This also includes discussing fears, personal issues, or being a friend. Social factors from one's private life (CaU Model 5c) can have positive and negative effects on rehabilitation.

Psychological factors are important to address, but strategies are lacking

PTs recognize the importance of psychological factors, and explain strategies used in CaU training to address these, with the caveat that there is room for improvement due to a lack of knowledge (CaU Model 6a). Strategies include providing

information regarding the injury and rehabilitation process, and using psychological measures, though no description of how these are used is provided. Goal-setting is used, although too broadly and vaguely to constitute a structured sport-psychological intervention. PTs perceive providing overall support to the patient based on needs, including verbal support, or by adapting schedules or training load in order to help the patient cope with psychological difficulties. This includes perceptions of what must be done in order to help the patient in their rehabilitation training (CaU Model 6b), and begins with the PT evaluating status of the patient through conversation and observation. This thereby helps the PT determine whether any barriers are influencing the patient's training, whether the patient has the necessary coping skills, and can provide insight into the available strategies.

Psychological factors are also discussed from PTs' perceptions of how patients respond to rehabilitation training, including both barriers and facilitators. Barriers (CaU Model 7a) include a lack of knowledge, and athletic identity. These overall psychological barriers are also perceived to be connected to depressive episodes, fear, or a lack of enjoyment. PTs perceive motivation and self-confidence as being facilitators (CaU Model 7b), helping ensure proper execution of movements and encouraging compliance.

Strengths and Limitations

Strengths of this study include that qualitative interviews provide rich data with nuanced responses, allowing for deeper understanding of their lived experiences. Another strength is that coding was audited thoroughly, with perspectives from both physical therapy and sport psychology, increasing the likelihood that responses are reflective of participant responses. As there is a great deal of cross-over between the groups in regards to CaU training, results indicate that the perspectives on this form of rehabilitation are likely in line with a more generalizable population of clinically active PTs using CaU rehabilitation.

Potential limitations include the fact that interviewer bias cannot be ruled out, as both groups were familiar with the interviewer and the study purpose, which may have led to a greater focus on psychological aspects. However, external PTs were interviewed in the CaU group, and the conceptual model was upheld, indicating that those in the CaU group were not overly biased towards discussing psychological aspects. Confirmation bias may also be an issue, in that the coder may identify themes in line with previously held beliefs. However, given the inter-coder agreement, this risk seems to be low. Another potential limitation is the fact that participants were clinically active in Sweden, which may not be reflective of physical therapy practices in other geographical areas.

Patient Perspectives of MOTIFS (Paper IV)

MOTIFS Patients' Perspectives of Rehabilitation Training

Patients in the MOTIFS group discuss three major aspects of rehabilitation training. The perception of patients include that both physical and psychological aspects of rehabilitation are important, as well as the interaction between these factors. The conceptual model is presented in its entirety in Figure 7, which depicts major themes with more detailed subordinate themes in descending order, from most to fewest references. The text refers to the conceptual model with reference to the specific theme, denoted as "MOTIFS Model #x."

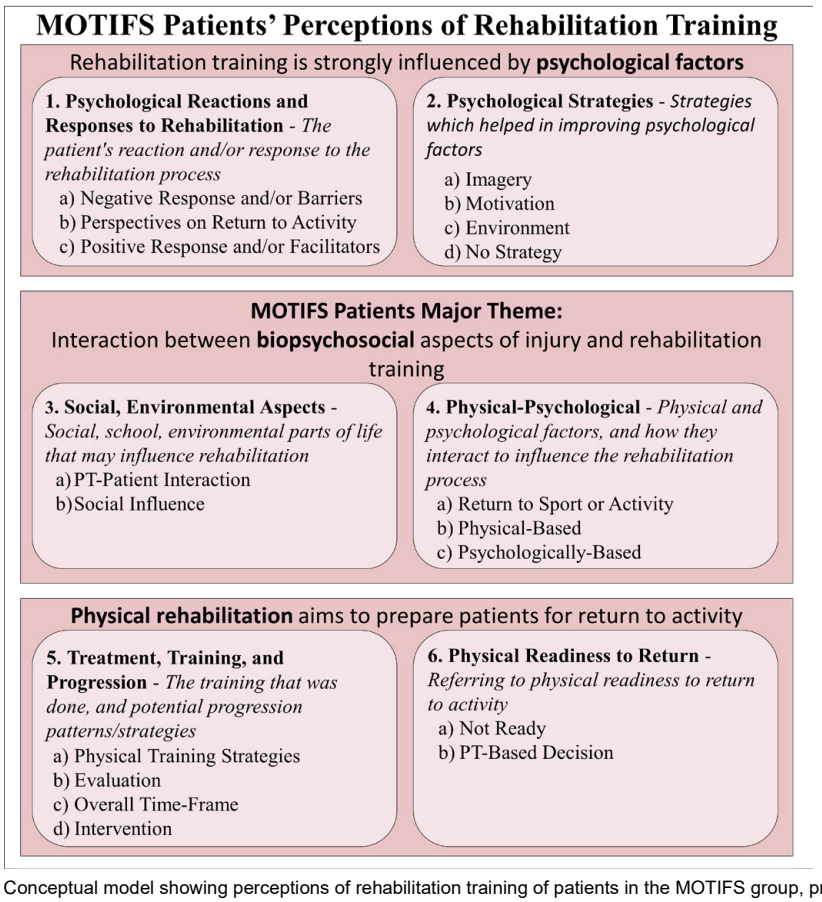

Figure 7. Conceptual model showing perceptions of rehabilitation training of patients in the MOTIFS group, presented as major themes with more detailed subordinate themes

Rehabilitation training is strongly influenced by psychological factors

Negative responses and barriers (MOTIFS Model 1a) include the 'mental bit' as the hardest part of rehabilitation, citing a lack of knowledge, absence from activity, and self-image as resulting in lower confidence, motivation, and greater fear. Being absent from activity is perceived to have the same effect, with motivation being higher during times of transition in which they could see progress, and lower when they felt they had stagnated. The uncertainty of not fully understanding these new constraints may give rise to fear of activity.(75) One aspect they were aware of, however, is the risk of re-injury, which, together with negative self-image, may explain feelings of fear. This is consistent with research showing that readiness to return to sport is negatively associated with fear of re-injury.(56, 61, 64) However, they believe they have coping strategies to deal with these negative aspects, preventing debilitative reactions and aiding in return to activity preparations.

Positive responses or facilitators (MOTIFS Model 1c) include social support, shown to be beneficial for rehabilitation training.(213) Self-confidence is also a perceived facilitator, and one patient discusses accepting rehabilitation as a necessity, which then leads to improvements, enjoyment, self-confidence, and development of coping skills. Sport-specific training is another perceived facilitator, as it directly involves something enjoyable, and provides motivation to work hard to achieve goals. Motivation may also be connected to patient perspectives on return to activity (MOTIFS Model 1b), with one participant describing hopelessness, while others see difficulty as an opportunity to develop a back-up plan, such as a change of activity. Importantly, patients discussing this indicate feelings of autonomy in the decision to change, and do not feel forced into switching, believing that the PT is helping them to achieve their goals, regardless of what those goals may be. Overall, there is a mixed response in regards to readiness to return, with some feeling they are not ready, citing psychological factors such as fear of re-injury. Others feel close to being ready, describing specific strategies and plans for return.

Performing imagery according to the MOTIFS principles helps to establish meaning and relevance in imagery scenarios during training (MOTIFS Model 2a), described as resulting in relevance(134) and enjoyment,(165) and improves knee confidence and sport-specific movement execution.(98, 214). This seems to come through in patient responses, as they discuss enjoying the sport-specific nature of MOTIFS training. Interestingly the activity-specificity of MOTIFS training seems to hide the rehabilitative nature of exercises, and is instead seen simply as training for their activity. This implies that psychological skills training can be integrated into rehabilitation training to train sport-specific skills despite the constraints of the knee injury, resulting in technical and tactical modifications upon return. Patients describe motivational, environmental, and goal-setting strategies (MOTIFS Model 2b-c). On-field or in-clinic training can influence the psychological interpretation of the exercise and situation, with in-clinic training described as being difficult, but becoming easier over time. On-field training is perceived to be most realistic, and

easiest to image relevant situations, which seems to aid in developing self-determined motivation(109, 215) in terms of both learning and performance.(91)This may increase confidence and reduce risk behavior,(62) which patients perceive as playing more intelligently. Current rehabilitation guidelines suggest that psychological strategies include support, goal-setting, mental practice,(21) and education(84) in response to observed psychological changes.(38) Based on the responses of patients in the MOTIFS group, this criteria is addressed well, and is described as being an effective method of preparing for return to activity. One patient indicates that no psychological strategies are available to deal with the pain and frustration of the knee injury (Figure 7 – MOTIFS Model 2d).

Interaction between biopsychosocial aspects of injury and rehabilitation training

Patients discuss the interaction with the PT as being an especially important aspect (MOTIFS Model 3a). They perceive involvement and autonomy in exercise design, adapting and modifying to create activity-specific situations, which positively influences expectation management in reference to future movement requirements. Receiving social support from the PT is also meaningful and positive, feeling that the PT cares and makes an effort to individualize. This may be connected to knowledge transfer, since feeling comfortable around the PT encourages questions and conversations regarding strategies, allowing for clearer understanding of what is being done and why. Included in this is the ability or effort of the PT to adapt communication to the needs of the patient in order to ensure understanding.

Social support from other sources (MOTIFS Model 3b) is perceived positively by many, and can come from teammates, friends, or school, for example. Life changes, such as career transition, are also discussed as having an impact on return to activity decision-making, for example. Another patient perceives negative social support, in which friends and teachers discourage return, and feels that mockery results from others not understanding or taking the injury seriously.

The interaction between physical and psychological aspects (MOTIFS Model 4a) includes the training environment, and patients imply that having both physical and psychological contextual reminders has a positive impact. They express an interesting perspective regarding this, in that they describe a need to rehabilitate sport skills. This may indicate that they view the injury as having not only physical and psychological effects, but also as a sort of injury to their sport abilities. They seem to therefore perceive rehabilitation not as a regaining of ability to play their sport, but as rehabilitating the skills which have been constrained due to the injury. MOTIFS may encourage tactical and technical changes, which could be explained by a degree of ‘creative’ problem-solving in response to the constraints placed on them by the knee injury. This is in line with previous research showing that constraining tasks may produce movement variability and creativity.(216)

Physical-based interactions (MOTIFS Model 4b) such as set-backs, operation, or symptoms are factors which can result in a psychological reaction, most often negative, such as frustration or poor knee-trust. Patients imply a cycle in which negative physical outcomes result in negative psychological outcomes, which in turn further negatively influence physical factors, and vice versa. The interpretation of these factors is individual, with some patients interpreting physical difficulty as a positive challenge, while others see it as a threat which reduces enjoyment and motivation.

Interactions based in psychological factors (MOTIFS Model 4c) are perceived to be those that go in the opposite direction to this, in which aspects such as confidence can influence the physical execution of training in terms of exertion, for example, This is also related to the perceived need to understand sport-specific context, in order to embrace the exercise to create an individually 'correct' movement, in line with constraints-led approach.(118-120) Negative factors are also described, in which patients perceive frustration or trust in the knee as being hindrances which can negatively influence movement execution or avoidance behaviors.

Physical Rehabilitation aims to prepare patients for return to activity

An important part of rehabilitation is the training used to ensure that the patient regains function to the point they can pass the evaluations and continue progression (MOTIFS Model 5a-c). Several patients mentioned that they are unsure of what CaU training is, as they had not undergone rehabilitation before, however, one patient assumes that CaU training likely includes much less sport-specificity. The strategies perceived to be used include endurance, range of motion, hop, and strength training, which seem to be consistent with current recommendations.(21, 38, 46) This result implies that patients are provided with best-practice care, and have been able to understand the purpose of these rehabilitation strategies.

One patient in the MOTIFS group discusses feelings of readiness to return to activity, and perceives a potential feeling of readiness, though is waiting for the PT to approve this (MOTIFS Model 6a). This patient does not feel ready (MOTIFS Model 6b), indicating trust in the PT's professional opinion, wants to put the knee to the test, but also understands that more preparation is needed. For this participant, readiness is based on a timeline provided by the surgeon, who claimed recovery would take approximately one year, leading to a belief that this is a limit for deciding whether return is feasible.

Care-as-Usual Patients' Perspectives of Rehabilitation

Patients in the CaU group discuss physical and psychological factors of rehabilitation, and display cross-over in which aspects are described as belonging to both major themes. Themes are presented in order of prevalence, from most to fewest references. The conceptual model is presented in Figure 8, showing major themes with more detailed subordinate themes. The text refers to the conceptual model with reference to the specific theme, denoted as "CaU Model #x."

Rehabilitation training is strongly influenced by negative psychological factors

The CaU group focuses largely on negative aspects of rehabilitation, possibly indicating inadequate preparation to cope with psychological factors, and subsequently reduced readiness to return to activity.(64) Fear of re-injury and re-injury anxiety are the most common negative perceptions in the CaU group (Figure 8 - CaU Model 1a), related to a cost-benefit balance, in which participation is not worth the risk. This may be connected to perceived lack of control, contributing to negative physical self-image, faltering motivation, and overall negative perspectives such as boredom, uncertainty, symptoms, and absence from activity (CaU Model 1b-i). One participant explicitly denies psychological difficulties, avoiding the topic and believing that these factors are not relevant to think about (CaU Model 1j), while others perceive depressive states (CaU Model 1k). Despite negative perspectives, patients have confidence in their ability to execute exercises, or to overcome the challenges of rehabilitation, indicating that motivation, enjoyment, improvement, and overall positivity are beneficial (CaU Model 2a-b). One patient sees absence from activity as positive (CaU Model 2d), potentially indicating a motivational shift.

Psychological strategies used to help cope with negative factors often lack established principles, such as goal-setting strategies (CaU Model 3a) tending towards an abstract desire to return. Some participants feel they have no psychological strategies (CaU Model 3b), as psychological factors are generally ignored in favor of solving concrete and measurable problems such as strength. Training monitoring and social support are described as ineffective and unstructured (CaU Model 3c-d). Putting pressure and responsibility on oneself to find motivation and using self-talk (CaU Model 3e-f) are also described.

Physical Rehabilitation is a phase-based progression towards recovering physical function

Training is perceived as distinct early and late phases which seems to roughly translate to the stages provided by ACL rehabilitation guidelines.(21) The early phases (CaU Model 4a) are described as aiming to increase muscle activity and range of motion. Later phases (CaU Model 4b) include balance and activity-specific training, and increased loads in strength training. Progression strategies (CaU Model 5a) include range of motion, strength, and functional criteria, also reflecting current guidelines.(21, 46, 217)

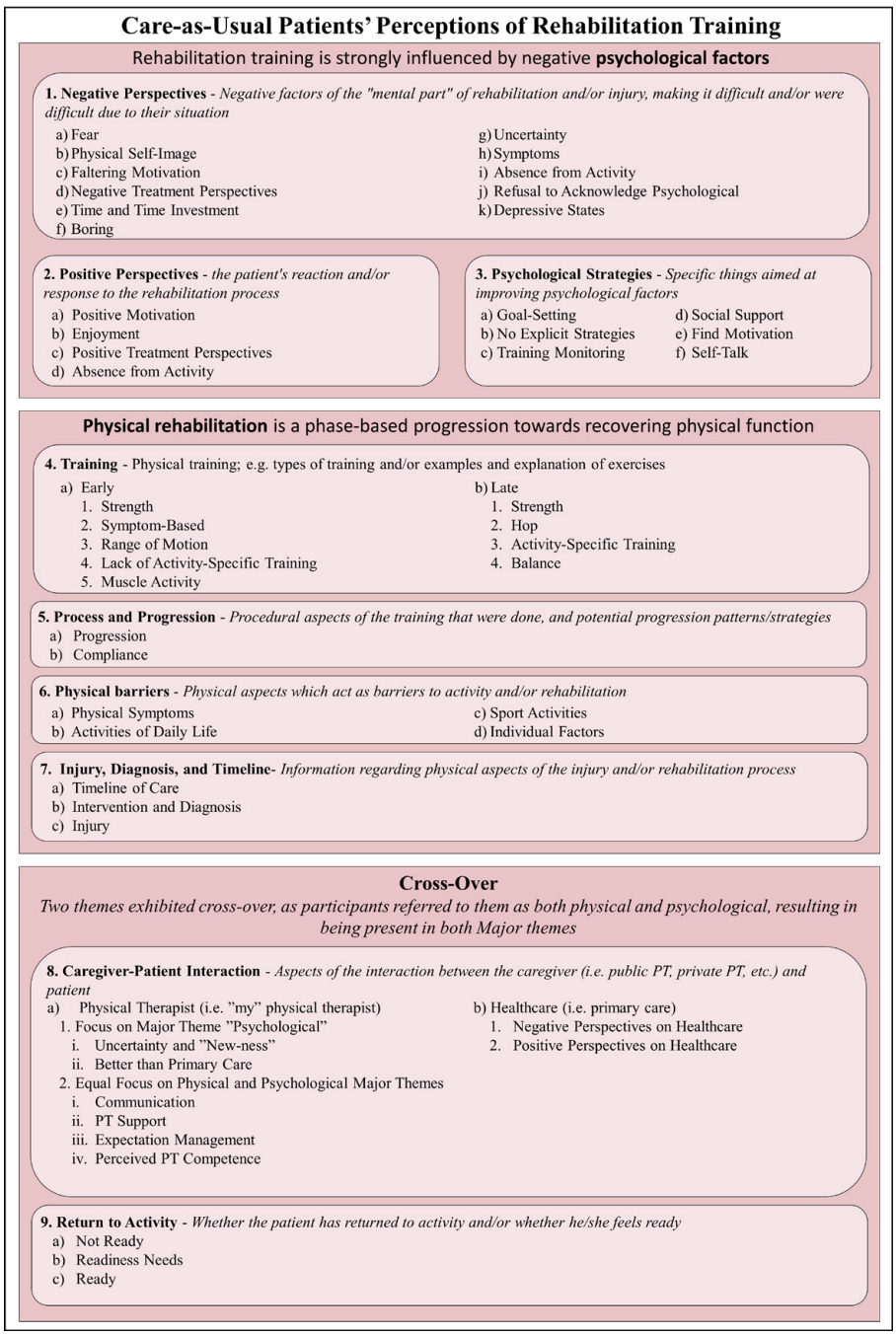

Figure 8. Conceptual model showing perceptions of rehabilitation training of patients in the Care-as-Usual Group, presented as major themes with more detailed subordinate themes

Physical barriers include symptoms (CaU Model 6a) such as swelling, fatigue, and pain, resulting in inability to perform rehabilitation exercises. Individual factors such as pre-existing conditions also cause problems (CaU Model 6d). Rehabilitation is perceived to influence daily life and sports activities (CaU Model 6b-c) in terms of inability to engage in certain activities, as well as factors such as work preventing rehabilitation training. This also includes physical aspects including treatments or diagnostic testing, and timeline (CaU Model 7a-c).

Cross-Over Between Major Themes

Two themes exhibited cross-over, which patients discuss as simultaneously physical and psychological. Interestingly, a biopsychosocial theme was not distinguished, rather patients perceived them as being one and the same (as opposed to an interaction). Therefore, they are separated to reflect this unique perspective.

The interaction between the 'main' PT and the patient is discussed in detail (CaU Model 8a-b), including that the new (i.e. "my") PT is much better than primary care, providing trust and comfort. However, uncertainty an new-ness of exercises and pain is still perceived as a negative influence. The perception of PT competence provides psychological comfort and trust, but also allows for beneficial physical care and expectation management. Some patients feel this is missing due to poor communication, and express a strong desire to be provided with feedback and motivation. Those lacking this support perceive that the PT does not care and simply provides a sheet of exercises, causing unease and low confidence.

Some patients perceive a lack of readiness to return (CaU Model 9a), for which the strategy is to wait, indicating a feeling of uncertainty of their physical ability and a psychological need for certainty to feel ready. However, they describe a dependence on the PT for confirmation of readiness (CaU Model 9b), possibly indicating a lack of autonomy, which may influence feelings of competence.(200) This is interesting given the fact that patients perceive that expertise may influence readiness, with greater experience leading to lower feelings of readiness, which may have support in previous research.(218) Fear is reported as resulting from the automaticity of sport-specific familiar movements, which they may perform at pre-injury intensity or speed without taking into account new constraints. This perspective is supported by previous literature regarding automaticity of movements.(111, 114) This is also true of those that claim a feeling of readiness, indicating that they are simply waiting for the PT to give the OK (CaU Model 9c). This may indicate a reference to physical feelings of readiness while being unsure of psychological readiness.

Strengths and Limitations

Strengths of this study include the fact that it is a qualitative interview study, which provides more nuanced data than quantitative studies. This allows for deeper

analysis of patients' lived experiences. Themes and codes were also audited thoroughly by the coding team from multidisciplinary perspectives to ensure representative interpretation of responses.

The fact that participants were familiar with the interviewer and that fact that he is a sport psychologist is a potential limitation, so interview bias cannot be ruled out. Confirmation bias is a risk, though agreement between several coders seems to indicate that this is not a large risk. There was also a relatively low number of interviews in the MOTIFS group, in part due to the limited number of eligible patients available. However, given that the pre-defined data saturation criteria were fulfilled and confirmed by several coders, the model was deemed stable enough to provide accurate analyses.

General Discussion

The MOTIFS model does not re-invent the wheel; it develops a new category of training to integrate psychological training into existing physical rehabilitation interventions. PTs are not receiving extensive extra education in order to implement psychological skills training. Instead, a series of workshops provide relatively easily implemented tools to address another dimension of rehabilitation by supplementing commonly used training protocols.

The goal of rehabilitation is to prepare athletes for return to activity. Typically, the focus is on physical preparation, but literature has shifted towards a greater focus on psychological readiness, as well. However, while focusing on preparations, PTs claim that progress cannot be made too quickly due to an increased injury risk. This may be an example of cognitive dissonance, in which activity exposure is necessary to prepare for return, but PTs are seemingly unwilling or unable to implement effective change. The result is rehabilitation which has a focus of attention which is, arguably, not external enough for effective return to activity preparation. Following this 'sport-specific' training, the patient may be more or less dropped onto the field to fend for themselves and figure out what the constraints are, how to develop a strategy, and how to implement the strategy. In order to effectively address psychological factors, there needs to be a lay-over period in which the patient is receiving both physical and psychological training in order to prepare for actual sport-specific situations, and be able to handle the pressure, load, fear, fatigue, and many other variables. The MOTIFS model provides an opportunity for rehabilitation which may provide training and education in how to correctly handle specific situations, thereby increasing both physical and psychological readiness to return to activity.

Clinical Relevance and Future Perspectives

The MOTIFS model represents a potential method of addressing psychological concerns, encouraging integration of both physical and psychological training in knee injury rehabilitation. Study I confirms that psychological training integrated into physical training may be effective in increasing enjoyment and meaning during rehabilitation and injury prevention exercises. This was described as a necessity by PTs in Study III, and by patients in Study IV, suggesting that they want training that can provide more individualized meaning, which MOTIFS is perceived to address. If the results of the RCT are positive, it indicates a training model which specifically answers this call, shifting towards a more holistic perspective. This is an important factor, as MOTIFS provides a training model which may be able to bridge the gap between the intricacies and interwoven physical and psychological aspects in rehabilitation training. Given that results are positive, a dissemination plan can be developed in order to educate PTs on implementation of this training for the benefit of patients. The ideal end-point is therefore clinical implementation of a model shown to increase both physical and psychological readiness without negatively influencing the physical training principles used in rehabilitation.

More research is needed to confirm these results, and the RCT will provide valuable information in the relevant population. In order to confidently say that the MOTIFS model works, results of the RCT need to show that there is a significant difference between the MOTIFS and CaU training models in terms of psychological readiness to return to sport, and physical function in a side-hop task. Future research also needs to explore whether the brain is actually being trained. The popular science name for this project is “Train the Brain,” and this needs to be confirmed to determine whether neurological and cognitive motor learning is occurring, and if so, how. Along with this, it is necessary to understand the effect of the MOTIFS model on psychological factors such as readiness to return to sport, enjoyment, and stress, for example, which is currently being investigated in the RCT. Future directions may also explore the effects of this integrated training on self-efficacy and adherence, movement quality, and the potential to apply the model to other injuries. It is also important to gain an understanding of the influence of the MOTIFS training model on return to sport and activity, both in terms of the rate of return, but also sustained return.

Conclusions

Results of the cross-over study (Study I) suggest that the patient-reported outcomes such as enjoyment and psychological states can be influenced using the MOTIFS model. Results support the plausibility of integrating psychological training into physical exercises, showing that the MOTIFS model may be a clinically relevant method of performing exercises with an added psychological dimension. The fact that movement quality is not sacrificed may provide support to this claim, and following continued research to examine the efficacy of the MOTIFS model, it may be relevant for use in future physical training programs.

Results of the randomized controlled trial (Study II) are not yet available, but results will provide valuable information on whether the MOTIFS principles are relevant in an injured population. As the study includes an adaptive design, this also allows for reflection on the dissemination, training methodology, and adherence, which may be meaningful for the efficacy of the training model. The interim analysis will be pivotal in examining these factors.

Results of the qualitative interview with PTs (Study III) indicate that the MOTIFS model provides relevant and feasible tools for more mindful and direct implementation of interventions to address psychological factors in rehabilitation training. These results are important in the context of CaU training, perceived as having a mainly physical focus, though PTs express a desire to learn more about how to influence these factors in the clinic. Comparisons cannot be made, but results suggest that the MOTIFS model may be able to shift the rehabilitation paradigm towards a more holistic focus on both physical and psychological factors.

Results of the qualitative interview with patients (Study IV) suggests a perception of the MOTIFS model as a method of physical and psychological preparation for return to activity by providing structured strategies to develop coping mechanisms. Patients in the CaU group describe rehabilitation in terms of the physical exercises used to prepare physically for return to activity, but perceive few to no tools available which allow them to develop effective coping skills. Taken together, these results suggest that the MOTIFS model may be both plausible and pragmatic for use in real-world, clinical environments as a method of addressing psychological factors in knee-injury rehabilitation.

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