"It's all in my head now" Readiness for return to sport after anterior cruciate ligament reconstruction

Anne Gro Heyn Faleide

Thesis for the degree of Philosophiae Doctor (PhD)
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Scientific environment

The work leading to this thesis started in 2015 and has been performed in the clinical environment of Haraldsplass Deaconess Hospital and the Sports Traumatology and Arthroscopy Research (STAR) Group. From September 2018, I was affiliated to the Department of Clinical Medicine at the University of Bergen as a PhD candidate. From the start, supervisors from the University of Bergen and Western Norway University of Applied Sciences contributed with their extensive experience in orthopedic surgery, rehabilitation and measurement properties of outcome instruments within the field of medicine.

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Abbreviations

ACL	Anterior cruciate ligament
ADL	Activities of daily living
ACLR	Anterior cruciate ligament reconstruction
ACL-RSI	Anterior cruciate ligament – return to sport after injury scale
ACL-RSI-No	Anterior cruciate ligament – return to sport after injury scale Norwegian version
AUC	Area under the curve
BPTB	Bone-patellar-tendon-bone
CFA	Confirmatory factor analysis
CFI	Comparative fit index
CI	Confidence interval
CM	Centimeters
COSMIN	Consensus-based standards for the selection of health measurement instruments
EPIC	Estimated pre-injury capacity
HDS	Haraldsplass Deaconess Hospital
ICC	Intra-class correlation coefficient
ICF	International classification of functioning, disability and health
IKDC SF	International knee documentation committee subjective form

KOOS	Knee injury and osteoarthritis outcome score
KOOS QoL	Knee injury and osteoarthritis outcome score Quality of Life
LESS	Landing error scoring system
LOA	Limits of agreement
LSI	Leg symmetry index
MIC	Minimal important change
MM	Milimeters
NM	Newton meters
NSD	Norwegian centre for research data
OA	Osteoarthritis
OR	Odds ratio
PROM	Patient Reported Outcome Measure
RMSEA	Root mean square error of approximation
ROM	Range of motion
ROC	Receiver operating characteristic
RTS	Return to sport
PROM	Patient-reported outcome measures
PT	Peak torque
SDC	Smallest detectable change
SEM	Standard error of measurement

SRMR	Standardized root mean square residual
STS	Side-to-side
TSK	Tampa scale of kinesiophobia

Contents

1. Introduction to the topic

The topic of this thesis originates from the everyday clinical setting of Haraldsplass Deaconess Hospital (HDS). Working at one of the hospitals in Norway with the highest volume of patients with anterior cruciate ligament (ACL) injuries, it is natural that many questions and dilemmas surrounding the treatment of these patients appear. As a physiotherapist, I see them regularly, from pre-surgery consultation to follow-ups for up to two years after reconstruction. I see how important it is for patients to return safely to an active lifestyle and I do my best to guide them towards reaching their goals.

A particularly crucial consultation is the nine-month follow-up where a return-to-sport assessment is performed. To be able to advise patients whether they are ready to return to "knee-strenuous activities", they answer questionnaires on knee function and undergo different challenging tests. However, I have experienced that some patients who perform perfectly well on all tests still go on to suffer a new ACL injury and some do not return to sport at all despite excellent test results. This has led to contemplation about what these questionnaires and tests actually tell me and whether the test battery is comprehensive enough to provide a complete image of how ready the patients are for returning to sport.

One sentiment that many patients have shared has sparked an interest in me. Quite often, patients will spontaneously tell me at the beginning of the consultation: *"My knee feels fine and I feel quite strong, but it`s all in my head now. I do not trust my knee yet."* This is a clear indication that patients mental responses play a part in being able to return to "knee-strenuous" activities – and mental responses have not directly been evaluated in "conventional" return-to-sport assessments. The aims of the work leading to this thesis were therefore to explore how informative current return-to-sport tests are on a successful outcome for patients and whether assessment of mental readiness for returning has a role in return-to-sport evaluations.

2. Scientific perspective

This thesis will discuss the highly complex process of returning to sport after injury. To illustrate this, the biopsychosocial perspective is used. The biopsychosocial model, originally introduced by George Engel (1), was drafted as a reaction to the traditional biomedical view in which a disease or injury could be seen purely as a consequence of biologic malfunction. Treating this malfunction would solve the problem. By taking the biopsychosocial perspective, one recognizes the impact psychological and social factors also have on the development, treatment course and outcomes of disesase and injury. A biopsychosocial model adapted to the return-to-sport setting has been made (2). In this model it is acknowledged that physical, psychological and social/contextual factors are inter-related and all affect how successful patients are in sports resumption.

The biopsychosocial model forms the basis for The International Classification of Functioning, Disability and Health (ICF) made by the World Health Organization. The ICF provides a common, standardized language and framework for describing and understanding health conditions and functioning (3). It aims to incorporate all factors that may affect a patient's health and functioning (Fig. 1). The model can, therefore, be helpful to describe changes in body structures and function as well as what persons can do within a standardized environment and within their everyday environment. In the ICF, function is described according to three levels: functioning of 1) a body part or body (impairments), 2) the whole person (activity limitations), and 3) the whole person within his/her social context (participation restrictions). Disability involves dysfunction at one or more of these levels and is viewed as the result of interactions between health conditions (i.e. injuries or diseases) and contextual factors (i.e. social attitudes, profession and behavior pattern). As the ICF involves consideration of all aspects of the rehabilitation process, the model can be a useful framework when evaluating outcomes after ACL reconstruction (ACLR).

Many studies have reported results of ACL surgery on the two first levels of function, namely the impairment and activity limitation levels, but there has been a call for studies contributing to knowledge on outcomes at level 3, the participation level (4).

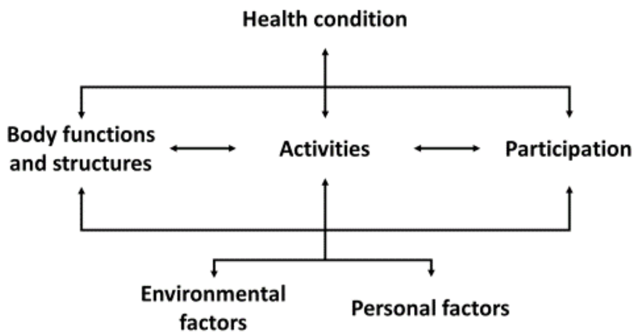

Fig. 1. ICF Diagram

This study has been conducted within a biopsychosocial perspective using the model adapted to the return-to-sport setting and the ICF to shed light on how different factors affect function (impairments, activity limitations and participation restrictions) after an ACL injury. The thesis is written with the recognition that only some of the aspects affecting return to sport are studied and that physical and psychological factors are closely intertwined. Moreover, this work is based on quantitative research methods, with the underlying assumption that meaningful information can be retrieved through standardized questions and tests performed in controlled environments. Relevant information that may shed light on what constitute a successful outcome or how to achieve it after an ACL injury may therefore not be captured using such methods.

3. Abstract

Background: Deciding when patients are ready for returning to sport after an ACL injury is challenging because the evidence for which tests and criteria to include in the return-to-sport assessment is unclear. Inclusion of psychological readiness evaluation has been suggested and the role of knee laxity measures in these assessments is unclear. Few studies have prospectively examined the predictive validity of psychological readiness, physical tests and clinical tests for knee laxity for success after ACL reconstruction.

Purpose: To examine the predictive validity of return-to-sport assessment for ability to *return to pre-injury level of sport* and *risk of further knee injuries* after ACL reconstruction when evaluation of psychological and physical readiness were combined. Further, to explore the relationship between the tests and questionnaires included in the test battery, especially the association between knee laxity and psychological readiness.

Methods: In this prospective cohort study, The ACL-Return to Sport after Injury (ACL-RSI) scale was translated into Norwegian (ACL-RSI-No) before the measurement properties were examined. Nine to 12 months after reconstruction, 197 patients completed the ACL-RSI-No and questionnaires hypothesized to measure related constructs. One hundred and forty-six patients completed single-legged hop tests and 142 patients completed knee extension and flexion strength tests. Sixty-one patients completed the ACL-RSI-No twice with a one-week interval. Face and structural validity, internal consistency, test-retest reliability, measurement error and construct validity were examined.

To examine predictive validity of the return-to-sport assessment including psychological readiness evaluation, 129 patients from the same cohort were followed-up at two years after surgery. Return to sport (yes/no) and knee injuries were registered.

To examine the predictive ability of knee laxity measures and the relationship between knee laxity and psychological readiness, patients from the cohort who had undergone evaluation of psychological readiness and knee laxity nine to twelve months after surgery were included (N=132). The knee laxity measures included The Lachman test, instrumented knee laxity (KT-1000) and the Pivot Shift test.

Results: Paper I: The ACL-RSI-No had good measurement properties with factor analyses indicating that one underlying construct determined the responses. Internal consistency (α 0.95) and test-retest reliability (ICC 0.94) were high and measurement error was low (SEM 5.7). Six of seven hypotheses were confirmed when examining construct validity.

Paper II: Forty-two percent of the patients returned to pre-injury level of sports two years after surgery. Higher ACL-RSI scores (OR=1.03) and older age (OR=1.05) predicted ability to return. An ACL-RSI score of <47 identified patients at risk of not returning to sport (area under the curve 0.69) with 85% sensitivity and 45% specificity. None of the functional tests predicted ability to return. However, none of the 29 patients who passed the return-to-sport criteria sustained a new knee injury during follow-up, compared to the 13 knee injured in the group of non-passers (P=0.037).

Paper III: There were small, but statistically significant associations between the Lachman test and the KT-1000 measurements and the ACL-RSI. There was no relationship between the Pivot Shift test and the ACL-RSI. Higher psychological readiness (OR=1.04), less knee laxity measured with the KT-1000 (OR=0.79) and older age (OR=1.07) predicted ability to return to sport with an explained variance of 33%.

Conclusions: The ACL-RSI-No had good measurement properties. Older age, higher psychological readiness and less knee laxity predicted ability to return to pre-injury level of sports two years after surgery. None of the patients who passed the return-to-sport criteria sustained a new knee injury during follow-up. There was a statistically significant, but small association between knee laxity and psychological readiness.

Implications: Evaluation of psychological readiness and knee laxity should be incorporated into return-to-sport assessments because they provide information about the patient’s ability to return to sport. The functional tests did not predict ability to return to sport, but the finding that none of the patients who passed the return-to-sport criteria suffered a new knee injury indicates that functional tests may be informative about risk of future knee injury. Further studies are needed to determine whether this is the case. Patients who have less knee laxity feel more mentally prepared for sport resumption.

Sammendrag

Bakgrunn: Det er utfordrende for klinikere å avgjøre om pasienter er klare for å returnere til idrett etter en korsbåndsoperasjon. Grunnen til dette er uklarhet knyttet til hvilke tester og kriterier som bør utgjøre grunnlaget for avgjørelsen. I tillegg til funksjonelle tester, har evaluering av psykologisk beredskap for å returnere til idrett blitt foreslått som en komponent i vurderingen. Videre er det uklart om undersøkelse av knelaksitet bør vektlegges. Få studier har prospektivt undersøkt prediktiv validitet av psykologisk beredskap, funksjonelle tester og knelaksitet etter korsbåndsoperasjon.

Formål: Å undersøke prediktiv validitet av et retur-til-idrett testbatteri, som inkluderer psykologisk og fysisk beredskap, for retur til idrett og risiko for nye kneskader etter korsbåndsoperasjon. Et tilleggsmål var å utforske forholdet mellom de fysiske testene og spørreskjemaene, spesielt forholdet mellom knelaksitet og psykologisk beredskap.

Metoder: I denne prospektive studien ble ACL–Return to Sport after Injury Scale (ACL-RSI-skala) oversatt fra engelsk til norsk. Deretter ble måleegenskapene til det norske skjemaet undersøkt. Ni til 12 måneder etter korsbåndsrekonstruksjon ble 197 pasienter inkludert. De fylte ut ACL-RSI-skala og spørreskjema som målte relaterte konstrukt. I tillegg gjennomførte 146 pasienter hoppetester og 142 pasienter styrketester av lårmuskulatur. Sekstien pasienter fylte ut ACL-RSI-skala to ganger med èn ukes mellomrom.

For å undersøke prediktiv verdi av den kombinerte retur-til-idrett vurderingen (psykologisk og fysisk beredskap), ble 129 pasienter fra samme kohort fulgt opp to år etter operasjon. Retur til samme nivå og type idrett som før operasjonen (ja/nei) og nye kneskader ble registrert.

Pasienter som hadde gjennomgått klinisk undersøkelse og som hadde fylt ut ACL-RSI-skala (N=132) ble inkludert i analysene for å undersøke assosiasjon mellom psykologisk beredskap og knelaksitet samt prediktiv verdi av knelaksitet. Klinisk undersøkelse av knelaksitet bestod av Lachman test, instrumentert måling av knelaksitet (KT-1000) og Pivot Shift test.

Resultater: Artikkel I: ACL-RSI-skala hadde gode målegenskaper. Faktoranalyse indikerte at èn underliggende dimensjon kunne beskrive svarene. Intern konsistens (α 0.95) og test-retest reliabilitet (ICC 0.94) var god og målefeilen var liten (SEM 5.7). Seks av syv hypoteser, som utgjorde grunnlaget for å bedømme konstruktvaliditet, ble bekreftet.

Artikkel II: Førtito prosent av pasientene hadde returnert til idretten sin to år etter operasjon. Høyere ACL-RSI skår (OR=1.03) og høyere alder (OR=1.05) predikerte retur til idrett. En ACL-RSI skår på <47 identifiserte pasienter som stod i risiko for å ikke returnere (area under the curve 0.69) med 85% sensitivitet og 45% spesifisitet. De funksjonelle testene predikerte ikke retur til idrett. Ingen av de 29 pasientene som bestod alle kriteriene i testbatteriet fikk en ny kneskade innen to år etter operasjon, sammenlignet med 13 kneskader blant de som ikke bestod kriteriene (P=0.037).

Artikkel III: Det var en liten, men statistisk signifikant assosiasjon mellom psykologisk beredskap for retur til idrett og knelaksitet (Lachman test og KT-1000 måling). Høyere ACL-RSI skår (OR=1.04), mindre knelaksitet (KT-1000 måling, OR=0.79) og høyere alder (OR=1.07) predikerte evne til å returnere til idrett med en forklart varians på 33%.

Konklusjoner: ACL-RSI-skala har gode måleegenskaper. Høyere alder, psykologisk beredskap og mindre knelaksitet predikerer pasienters evne til å returnere til idrett to år etter en korsbåndsoperasjon. De funksjonelle testene hadde ikke prediktiv verdi for retur, men funnet av at ingen av pasientene som bestod kriteriene i testbatteriet skadet seg på nytt frem til to års kontrollen er interessant. Dette indikerer at funksjonelle tester kan ha prediktiv verdi for risiko for kneskade. Det var en liten sammenheng mellom mindre knelaksitet og bedre psykologisk beredskap for å returnere til idrett.

Implikasjoner: Evaluering av psykologisk beredskap og knelaksitet bør inngå i en retur-til-idrett vurdering fordi disse faktorene er informative om pasienters evne til å returnere til idrett etter en korsbåndsoperasjon. Studiene ga indikasjoner på at de funksjonelle testene kan være informative om pasientenes risiko for å skade kneet sitt på nytt, men videre arbeid trengs for å undersøke dette.

4. List of Publications

I. Faleide AGH, Inderhaug E, Vervaat W, Breivik K, Bogen BE, Mo IF, Trøan I, Strand T & Magnussen LH: "**Anterior Cruciate Ligament-Return to Pport after Injury Scale: Validation of the Norwegian Language Version".** Knee Surg Sports Traumatol Arthrosc. 2020 Aug;28(8):2634-2643

II. Faleide AGH, Magnussen LH, Strand T, Bogen BE, Moe-Nilssen R, Mo IF, Vervaat W & Inderhaug E: **"The Role of Psychological Readiness in Return to Sport Assessment after Anterior Cruciate Ligament Reconstruction".** Am J Sports Med. 2021 Apr;49(5):1236-1243

III. Faleide AGH, Magnussen LH, Bogen BE, Strand T, Mo IF, Vervaat W & Inderhaug E: **"Association Between Psychological Readiness and Knee Laxity and Their Predictive Value for Return to Sport in Patients With Anterior Cruciate Ligament Reconstruction".** Am J Sports Med. 2021 Aug;49(10): 2599-2606

5. Introduction

5.1. The Anterior Cruciate Ligament injury

The Anterior Cruciate Ligament (ACL) extends from the posteromedial aspect of the lateral femoral condyle to the anteromedial aspect of the tibia (5). The ACL changes its shape dependent on the knee flexion angle and therefore it has an important role as a dynamic stabilisator of the knee by primarily controlling anterior translation of the tibia relative to femur and by contributing as a secondary restraint to tibial rotation and varus/valgus stress (6-8). In addition, the ACL contains mechanoreceptors that are important for neuromuscular control of the knee (9).

The ACL is typically injured during non-contact activities like running or jumping as the person suddenly decelerates and changes direction, pivots or lands with the knee in rotation and lateral bending (i.e. valgus stress) (10-12). In Norway, the main activities performed while sustaining an ACL rupture are soccer, team handball and alpine skiing (13, 14). As the injury occurs, many will describe a “popping” sound or feeling, followed by the knee “giving way”, acute swelling and varying degrees of pain (15). As the initial pain and swelling subside, the most prominent symptom is a feeling of knee instability (16). Some patients report major functional limitations even in activities of daily living (i.e. descending stairs or turning around to get something from the fridge), while others are only limited in participating at higher level sports (17).

The ACL injury is infamuous within the sporting community (18), with extensive media coverage when elite athletes sustain the injury. The ACL tear is the most common knee injury, representing more than 50% of all knee injuries. Each year, over 200,000 people in the USA sustain an ACL injury (12). The annual incidence of primary ACL reconstructive surgeries in Norway is 34 per 100,000 citizens (85 per 100 000 citizens in main at-risk group 16–39 years) (13). Consequently, ACL injuries are also common in the more general population of young to middle-aged physically active persons who participate at all levels of activity or sports (13, 19-21). Approximately 3% of amateur athletes will sustain an ACL each year, while elite athletes have a higher risk of up to 15% (18). This means that clinicians will meet a spectrum of patients with ACL injury, ranging from the young patient aiming to perform at elite level soccer to the middle-aged patient wanting to return to mountain hiking or running.

5.2. Diagnosis and treatment

Diagnosing an acute ACL rupture can be challenging as the knee might be painful, have hemartrosis and limited range of motion. Other knee structures such as the menisci, joint cartilage and anterolateral structures are often injured concomitantly with the ACL and need consideration during examination and the course of treatment (16, 22, 23). In many cases, the combination of a thorough patient history (i.e. injury mechanism, feeling of "knee giving way" and onset of effusion) and a clinical examination will enable the diagnosis of an ACL injury before a MRI is used to confirm the diagnosis (15, 16, 24-27). As the MRI does not provide information on the degree of knee instability, the Lachman test and Pivot shift test are commonly used to ascertain the degree of knee laxity when swelling has subsided and the patient is able to relax the muscles surrounding the joint (16, 28).

An ACL injury can be treated either operatively or non-operatively. Traditionally, reconstructive surgery has been recommended for young patients who want to return to sports involving pivoting and hard cutting movements, patients who despite adequate rehabilitation experience episodes of knee "giving way" during simple daily activities or patients with substantial concomitant injuries (29-31). However, in the past decade, studies have indicated that selected patients treated with high-quality rehabilitation alone display similar functional, radiographic and patient-reported outcomes as operatively treated patients (16, 32). Therefore, an increasing amount of clinicians are recommending that eligible patients undergo structured rehabilitation primarily and that delayed surgery is considered for those with persistent functional instability (16).

If the patient chooses to undergo surgery, an arthroscopic reconstruction with a graft harvested from the patient's patellar tendon or hamstring tendon (autograft) is the most commonly used procedure (33-35). Bone tunnels are drilled in tibia and femur, before the graft is inserted and secured with various fixation devices. Graft choice and surgical technique vary according to patient-related factors (i.e. occupation and sports participation) and surgeon-related factors (i.e. experience with the different techniques) and are subject to continuous research and debate (36-41). To this date, data is insufficient to conclude that one graft or technique is superior to the others. The current trend in Norway is to use a Bone-Patellar-Tendon-Bone (BPTB) graft and a so-called anatomic approach for graft tunnel placement, in part driven by the finding of lower re-injury risk using BPTB graft in the Scandinavian population (34, 35, 42). There has also been an increased focus on how additional procedures, i.e. lateral extra-articular tenodesis, may enhance knee stability and thus to reducing the failure rate (43).

5.3. Rehabilitation

After an ACLR, patients face a long and challenging period of rehabilitation. Impairments that commonly need to be addressed during rehabilitation are knee effusion, reduced range of motion (ROM), decreased muscle strength, altered movement patterns, disturbed knee joint proprioception and problems with neuromuscular control (16). Several evidence-based guidelines have recently been published to support clinicians and patients during this period (16, 44). Van Melijk et al (44) performed a thorough literature review and concluded that there was insufficient evidence to produce a rehabilitation guideline based on available studies alone. Therefore, todays guidelines are based on available research evidence, background literature and expert consensus (44). Two of the prevailing guidelines by van Melijk et al (44) and Filbay and Grindem (16) roughly follow the same rehabilitation phases and advocate a criteria-based approach where patients progress from one phase to the next as specific goals are achieved. In both guidelines, the aims of rehabilitation is to regain knee function, address psychological barriers for challenging the knee and minimize the risk of new injuries and future osteoarthrosis (16, 44).

Filbay and Grindem (16) describe five rehabilitation phases, starting with a preoperative phase where the main goals are to reduce effusion, achieve full ROM and 90% strength symmetry of knee flexors. Immediately after ACLR (the acute phase), no effusion, full ROM and a controlled straight leg raise without a lag should be achieved. In the intermediate phase, the focus should be on controlling weight-bearing terminal knee extension and regaining 80% knee extension strength symmetry and 80% hop test symmetry with good movement quality. A further increase in strength symmetry and hop test symmetry up towards 90% has been advocated in the late phase of rehabilitation combined with building confidence and a gradual progression to sport-specific skills. During and after return to sport, a continued injury prevention program is recommended (phase five) (16).

5.4. Success and consequences

The aim of reconstruction and rehabilitation is to stabilize the patient’s knee in order to achieve normal daily life functioning and participation at preferred activity levels without incurring further knee injuries (4). However, what constitutes success in reaching these aims after ACL surgery, is a matter of ongoing debate (45-48). Most patients want to return to *pre-injury level of sports participation*, which often involves “knee-strenuous” activities like jumping, cutting and pivoting (45, 49-51). The desire to return to sport is therefore an important factor when deciding whether to undergo surgery or not and return to pre-injury level of sport is considered an important measure of success after ACLR (4, 49, 52, 53). However, despite the fact that most patients regain normal or close to normal function after the injury, many do not return to previous levels of sports participation (4, 49). In a systematic review by Ardern et al. (49) quite discouraging numbers are reported, with only 65% of patients returning to pre-injury level of sports and 55% returning to competitive levels after ACLR.

Returning to sport is one aspect of success after injury. This aspect should not be seen separately from two other aspects of success, namely the avoidance of new knee injuries and preservation of long-term knee-related health. The risk of re-injury is high for those who choose to return to sports involving cutting and pivoting movements, with up to 30% of young patients suffering a second ACL injury (54-59). Sustaining a second ACL injury is devastating for patients, who face both a new period of potential surgery and rehabilitation and worse mid- and long-term outcomes (35, 60). Divergent numbers on the risk of developing osteoarthritis (OA) after ACL injury are reported (61). Patients with isolated ACL injuries are reported to have between 0% and 15% risk of developing tibiofemoral OA 10 to 20 years after surgery, while patients with concomitant meniscal injuries have a considerably higher risk of 20% to 60% - placing these patients in danger of developing painful "old knees" at a young age (20, 61, 62). Optimalizing the treatment course and making sound return-to-sport decisions are therefore crucial steps to support patients in reaching their goals of returning to an active lifestyle, while ensuring long-term health and quality of life by reducing risk of re-injury and OA.

5.5. Return-to-sport assessment

Deciding when a patient is ready to resume sport after an ACLR has challenged clinicians worldwide for decades. Overall, biological healing should be complete and the patients should be physically and mentally prepared for participation in activity and sports (16). Many different criteria and tests have been proposed to guide clinicians and patients in addressing key aspects of return-to-sport readiness in a substantial body of research (53). However, results are divergent and hence no agreed upon criteria exist at this point (44, 53).

In 2019, Burgi et al (53) summarized the literature on return tests and criteria in a scoping review and systematized findings according to the three levels of ICF: The impairment level (functioning of a body part or body), the activity level (the whole person) and the participation level (the whole person within his/hers social context). They found that time from surgery and measures at the impairment level were most commonly used to clear patients for returning. In the 1980s, time from surgery was often the only criterion used for clearance. Since then, there has been a gradual shift towards a combination of time- and criteria-based protocols where the focus has been on allowing sufficient time for biological graft healing and reaching functional milestones before sport resumption (14, 53). Indeed, evidence for keeping time from surgery as a return criteria was recently presented by Grindem et al (14) who found a 51% reduction in re-injury risk for every month the return was delayed (up until nine months after surgery).

Measures of strength have dominated the assessment at *impairment level*, but for example clinical exams and quality of movement assessments have also been used (53). To evaluate patients at the *activity level*, hop tests have often been performed while some have reported use of other measures such as agility tests. Few studies have reported the use of *participation level* measures, e.g. on-field sport-specific tests. Accounting for the *contextual factors* affecting readiness for return, the use of patient-reported criteria including patient-reported outcome measures (PROMs) and subjective statements, were reported in only 12% of the studies (53). Overall, time was still the leading criteria used in return assessments. Physical tests and patient-reported outcomes were surprisingly infrequent despite a widespread perception that some form of functional assessment should be implemented prior to returning to”knee-strenuous sports”. In addition, there was a striking variation in type of tests performed and type of criteria applied to assess patients’ readiness for sport resumption (53).

One explanation for the range of tests and criteria used may be the limited knowledge on whether the tests actually measure what they purport to measure (validity). Rather few studies have examined the validity, including the predictive value, of the proposed return-to-sport tests (44, 53). However, in recent years, some articles on the predictive value of return-to-sport assessments for *ability to return to sports* have been published. Symmetrical hop performance has been associated with returning to pre-injury level sports and hop tests at six months after ACLR are reported to have a predictive ability for short and long-term sports resumption (49, 63, 64). Only weak or no association has been detected between strength measures and ability to return to sport (63, 65-67), while positive self-reported knee function measured with the International Knee Documentation Committee Subjective Knee Form (IKDC) 2000 has been found to favour returning (49). Moreover, even though evaluation of knee laxity has been recommended as part of the return assessment, the predictive value of such tests is rarely examined in a postoperative setting. The utility of knee laxity tests in return to sport assessments is therefore, largely, unknown (65, 68).

Regarding the predictive value of return-to-sport tests for *re-injury risk*, Grindem et al. (69) found that athletes who passed their criteria of ≥90 quadriceps strength (leg symmetry index, LSI), four single-legged hop tests (LSI) and two PROMs about knee function (the Knee Outcome Survey – Activities of Daily Living Scale and the Global Rating Scale) had a 92% lower second ACL injury rate within two years after surgery. Further, in a study on male professional athletes, six criteria were used to clear athletes for sport resumption: ≥90 quadriceps strength (LSI), three single-legged hop tests (LSI), a timed running T-test and completion of an on-field sport-specific rehabilitation program (70). Those who did not pass these criteria had a four times greater risk of sustaining an ACL graft rupture after returning to sport (70).

Tests, combinations of tests and pass criteria applied in the above mentioned studies vary and it is therefore challenging to compare results across the studies (53). Moreover, most of these studies were performed on professional athletes or in cohorts with a large proportion of high level competitive athletes that were followed closely in specialized clinics after surgery (14, 64, 70). Transferability of these results to a more heterogeneous patient population is unknown. It is therefore not possible to draw conclucions on whether return-to-sport assessments are valid or whether they have the ability to predict a successful return to sport (53).

5.6. Expanding the horizon: The biopsychosocial model

To persons sustaining an ACL injury, the consequences extend far beyond the acute pain, a “pop”, the surgery and loss of strength and coordination. The ability to study, fulfil work commitments and/or do much loved leisure activities may be substantially affected and lead to “social isolation” (2). Feelings such as frustration, sadness, hesitation, fear of new injuries and boredom may arise and affect the course of rehabilitation and the final outcome (2, 71).

To make sense of the myriad of factors affecting sport resumption, the biopsychosocial model adapted to the return-to-sport setting is useful by providing a framework for understanding how biological, psychological and social factors can affect treatment choice, rehabilitation and outcome after an injury (2). The model clearly illustrates how complex and multifactorial returning to sport is (2, 53). Both modifiable and non-modifiable factors that influence sport resumption are depicted (Fig. 2) (2). Examples of non-modifiable factors are sosiodemographic factors like age and sex. Young, male patients are reported to have better chance of returning to preinjury level of sport. (49). Knowledge about the non-modifiable factors are important when considering the prognosis of the patient, but as the potential to positively affect a successful outcome lies in the modifiable factors, most of the research is focused on this area.

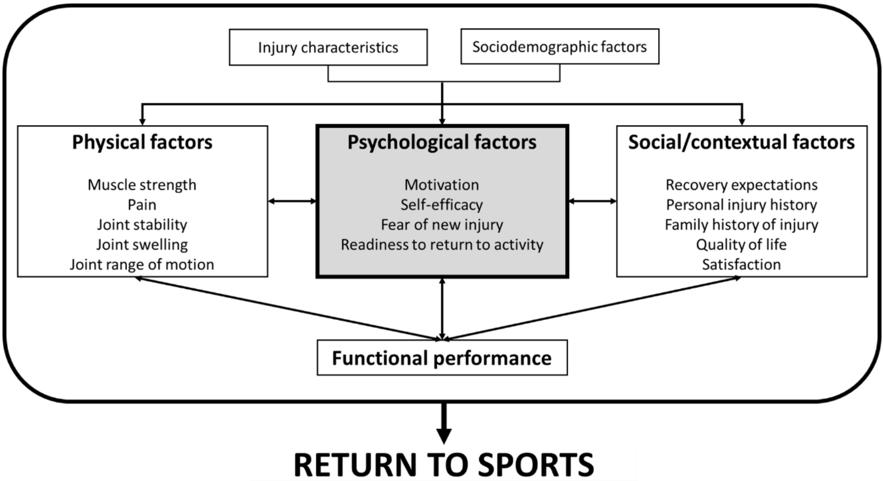

Fig. 2 The Adapted Biopsychosocial model of return to sport after injury (printed with kind permission from authors)

Traditionally, evaluation of physical function has been the dominating focus in return-to-sport assessments (2, 72). However, even though the surgical procedure is judged to be satisfactory (tests of laxity for example) and the functional outcome (hop performance and muscle strength) is good, many patients do not reach their goal of returning to sport (4). This has led to investigations into other factors that may affect whether patients resume sport or not. The role of environmental and psychological factors has been highlighted as an area of special interest in both clinical and reseach communities (4, 72).

5.7. Psychological responses

Physical trauma, like an ACL injury, is inevitably accompanied by some form of psychological response (73, 74). Individuals sustaining an ACL injury have described strong feelings of tension and anxiety immediately after injury and during recovery (72, 73). Further, many have reservations regarding “knee-strenuous” physical activity despite having regained objective and subjective knee stability (72, 73, 75). Over the last decades, these observations have led to an increased interest in how psychological responses to injury affect rehabilitation and the return-to-sport process

(75). Podlog and Eklund (75) published a literature review reporting that a variety of psychological factors may affect return to sport, including fear of re-injury, motivation, emotional disturbance (i.e. frustration, anger), performance concerns and decreased confidence. Later, Ardern et al. (76) performed a systematic review building upon this work (75). They (76) found preliminary evidence for a relationship between *positive* psychological factors and returning to sport. Greater preoperative motivation (measured with a "psychovitality questionnaire") (77), higher psychological readiness (measured with the ACL-RSI) and lower hedonic tone (a person's ability to experience pleasure or satisfaction) were found to be associated with a successful sport resumption (76). Both reviews included patients with different types of sports injuries.

In 2005, focusing on patients with ACL injury only, Kvist et al. (73) observed that 24% of the patients who did not return to pre-injury activity reported fear of re-injury as the reason for not returning. In 2008, Webster et al. (78) studied the literature on psychological responses in athletes and identified three main areas of interest concerning return to sport after ACLR: Emotions, confidence in performance and risk appraisal (78). Fear of re-injury and frustration (measured with the Emotional Response to Injury Questionnaire) were examples of *emotions* that could arise during rehabilitation and return to sport (73, 79). A so-called "emotional U pattern" was described with heightened levels of negative emotions occurring especially immediately after injury and then again around the time when athletes contemplated returning to sport (79). Others reported a gradual shift from predominantly negative emotions directly after injury towards more positive emotions as rehabilitation progressed (80, 81). *Confidence* may in the context of ACL injury have at least two aspects, confidence in the fact that the knee will withstand the forces and pressures of physical activity without giving way and confidence in one's ability to perform well in one's activity or sport (74, 78). Issues related to a person's *risk appraisal* ability have also been identified as important for sport resumption as patients who choose to return prematurely are inclined to underestimate injury severity and focus on short-term goals instead of possible long-term consequences (74). These three psychological responses are reported to be closely related and inter-dependent and constitute a *psychological readiness* for returning to sport (78).

Since then, there has been a noteworthy increase in studies examining psychological responses in patients after ACLR, substantiating the notion that psychological factors like fear of re-injury, knee confidence and psychological readiness influence the rehabilitation and return to sport processes and therefore should be considered in return-to-sport assessments (72, 82, 83). Psychological readiness seems to be a key factor in this context (68, 78, 84). Webster et al (78) developed a 12-item scale called the “Anterior Cruciate Ligament – Return to Sport after Injury Scale” (ACL-RSI). This scale was developed to assess mental preparedness specifically in relation to ACL injury - with the hope of being able to identify patients who may struggle with returning to sport (78). However, there is a need for sound knowledge on 1) the validity of this scale and 2) whether evaluation of psychological responses, like psychological readiness, are informative enough to be incorporated into return-to-sport assessments (68).

5.8. Measurement method

Measurement of health states is the cornerstone in medical research and clinical practice because it forms the basis for evaluating the results of health care interventions. For that reason, the quality of the measurement instruments are essential (85, p. ix and 1). A measurement instrument can for example be a PROM or a device that measures muscle strength. Despite an abundance of instruments to choose from within the field of medicine, knowledge on their validity is often poor (85, p. 1).

Spurred by this lack of evidence on the measurement properties of outcome measures, the international initiative “Consensus-based Standards for the selection of health Measurement Instruments (COSMIN)” was founded in 2005. The organization comprise multidisciplinary research teams who have developed a standardized methodology and guidelines for clinicians and researchers on how to develop, critically appraise and choose the most suitable outcome instruments. This has lead to an increased awareness of, and knowledge on, how measurement instruments should be developed and evaluated to secure good measurement properties (86).

Health professionals often use measurement instruments with the aim of evaluating characteristics that are not directly observable, for example how patients perceive their health. These non-observable characteristics are typically referred to as *constructs* (87, p. 13). However, according to COSMIN, the term construct is also used for observable construct as they describe a construct as *"a well-defined and precisely demarcated subject of measurement"* (87, p. 13). A measurement instrument should be both valid and reliable, meaning that the instrument has to measure what we actually intend it to measure and that the measurements obtained can be trusted. More specifically, validity concerns *"the degree to which an instrument truly measures the construct(s) it purports to measure"* (88, p. 743). In the COSMIN framework, three main types of validity are described (85, p. 150). Content validity informs us on whether the content of a measurement instrument is consistent with the construct we intend to measure with regard to how relevant, comprehensive and comprehensible the PROM is for the construct, the target population and context of use (89). Face validity, concerning the degree to which the questions (or items) of a PROM *"looks as though they are an adequate reflection of the construct to be measured",* is an aspect of content validity (88, p. 743). Criterion validity informs us about how scores of the instrument agree with scores obtained from a gold standard measurement (85, p. 150). In situations where no gold standard exists, construct validity can be used to examine whether the measurement instrument *"provides the expected scores, based on existing knowledge about the construct"* (85, p. 150). Reliability is defined as *"the extent to which scores for patients who have not changed are the same for repeated measurement under several conditions: e.g. using different sets of items from the same multi-item measurement instrument (internal consistency); over time (test-retest); by different persons on the same occasion (inter-rater); or by the same persons (i.e. raters or responders) in different occasions (inter-*

rater)" (88, p. 743). In this context, *items* can be explained as the questions and statements included in the questionnaire.

5.9. Knowledge gaps

Despite a large amount of research articles published on this topic, there is no consensus on which single measure, combination of measures or criteria that should be applied in the decision-making process leading to a return, especially in populations of athletes performing physical activity and sport at varying levels of participation (53). Therefore, there is a need for valid and reliable tools to measure relevant psychological responses affecting the return-to-sport process after ACLR (68). In addition, knowledge on how these responses may relate to the commonly used measures of physical function in return-to-sport assessments is lacking; are pscyhological responses connected to physical function? If so, to what extent? (68). Finally, there has been a call for prospective studies incorporating both physical and psychological measures to better support the return-to-sport decision-making (68, 73).

6. Aims of thesis

The overall aims of this thesis were to investigate the predictive ability of conventional return-to-sport tests on return to pre-injury sport and re-injury and to evaluate whether incorporation of a psychological readiness and knee laxity assessment would have an added benefit for the return-to-sport decision-making.

The specific aims of the thesis were:

1. *To translate the ACL-RSI scale into Norwegian and examine the measurement properties of the Norwegian version* (Study I)
2. *To examine the predictive ability of a return-to-sport test battery on ability to return to sport and risk of re-injury when evaluation of psychological readiness was incorporated* (Study II)
3. *To explore any association between psychological readiness and commonly used knee laxity and functional tests and further, investigate the predictive ability of knee laxity tests on return to sport after ACLR* (Study I and III)

7. Methods

7.1. Study design

A prospective cohort of patients surgically treated for ACL rupture was recruited between 2015 and 2019. Patients were recruited from Haraldsplass Deaconess Hospital, Haukeland University Hospital and Oslo University Hospital. For study I, patients were invited to complete the Norwegian version of the ACL-RSI (ACL-RSI-No) and related questionnaires 9 to 12 months after surgery. All patients recruited from Haraldsplass Deaconess Hospital were given the opportunity to undergo a standard return-to-sports assessment at the physiotherapy department and a clinical knee examination at the orthopedic department. Three months later, when patients were expected to have had the opportunity to return to sport, all patients were asked to report return-to-sport status and any re-injuries or new knee injuries. For study II and III, all patients (from study I) scheduled for standard follow-up at Haraldsplass Deaconess Hospital were invited to participate in a two-year evaluation recording current sports participation and any re-injuries, new knee injuries or surgeries.

7.2. Patient inclusion and exclusion

In all three studies, patients who had undergone ACL reconstructive surgery using a patellar or hamstrings tendon autograft were invited to participate. Inclusion criteria were: age ≥16 years, fluency in Norwegian and engagement in physical activity or sports prior to ACL injury.

Patients with concomitant posterior cruciate ligament injury were excluded from all three studies. In study II, patients with ACL revision procedures and patients who had undergone other major concomitant ligament surgery were also excluded. Further, those who declined functional testing or had incomplete test battery results (i.e. unable to perform hop tests), were excluded from analyses. For study III, patients with concomitant ligament surgery at ACLR and/or a history of previous ACL injury in the contralateral knee were excluded (Fig. 3). In all three studies, concomitant partial menisectomies and meniscal sutures were allowed.

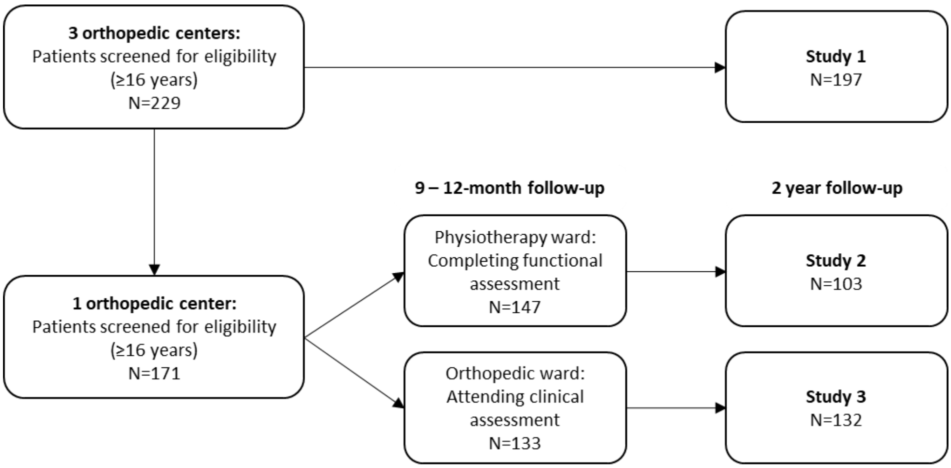

Fig. 3 Flowchart of patients recruited for the tree studies. For detailed information on the individual studies, please refer flowcharts in the papers.

7.3. Surgical technique and postoperative rehabilitation

All ACL reconstructive procedures started with an arthroscopy to diagnose and treat any concomitant pathology, i.e. meniscus ruptures or cartilage injuries. The ACL was reconstructed with an *anatomic* technique utilizing either patellar or hamstrings tendon autograft from the ipsilateral knee.

After surgery, patients were allowed immediate weight bearing as tolerated. They were advised to use crutches for two to four weeks to reduce knee pain and effusion. No knee braces were used as part of the rehabilitation. Before hospital discharge, patients were instructed in a home exercise programme, aimed at eliminating effusion and regaining ROM and neuromuscular control. Further, patients received guidelines for exercise progression and advice on contacting a physiotherapist for further guidance. Patients who underwent concomitant procedures, such as meniscus repairs, were recommended to follow a modified rehabilitation protocol involving restricted ROM and adjusted weight bearing for 6-12 weeks.

Twelve weeks after surgery, patients could start a gradual return to running if they had good muscular control of the leg and if the knee was effusion free and had adequate ROM. Participation in team warm-ups and training sessions in for example soccer or team handball was allowed from six months, without playing. The earliest time point where a full return to pivoting activites and sports was recommended was nine months post-surgery. Patients were advised to undergo a return-to-sports assessment before returning, and not to resume pivoting sports before the leg strength and hop difference was ≤15% between injured and uninjured side (≤10% for those returning to IKDC Level I sports or Level II sport at higher competitive levels).

7.4. Outcome evaluation

7.4.1. Patient-reported outcome measures

The **ACL - Return to Sport after Injury** (ACL-RSI, Appendix 1) Scale was developed to evaluate how ready patients are for returning to sport after ACLR (78). Aided by a literature search, the developers identified three domains of mental responses important for sport resumption: emotions (i.e. fear and frustration), confidence in performance, and risk appraisal (78). These responses were found to be highly inter-related and constituted the construct of psychological readiness for returning to sport (78, 90). The ACL-RSI scale comprises 12 questions where patients grade their answers from 0 to 100 with ten-point increments (11 boxes). A total score is calculated as the average of the responses on each question and higher scores indicate greater psychological readiness for returning to sport (78). Both the original English version of the scale and the many translated versions, are reported to be valid and reliable for patients after ACLR (52, 78, 90-94). Responsiveness has been found sufficient at group level, but not at individual level (95).

The **International Knee Documentation Committee Subjective Knee Form** (IKDC) 2000 (Appendix 2) measures symptoms, function and sports activity in patients with different knee-related complaints, including ligament and meniscal

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injuries (96). It contains 18 items with varying response formats. A total score is calculated by summing the items and dividing them by the maximum possible score × 100 (score range 0 – 100) (97). High scores reflects no knee impairments and high levels of participation (98). The IKDC 2000 has acceptable validity and reliability for patients with knee impairments and was recently recommended for measurements after ACL injury in an expert consensus statement (96-100).

The **Knee injury and Osteoarthritis Outcome Score** (KOOS, Appendix 3) was originally developed to capture the progression of knee-related symptoms from an intial ACL or meniscus injury to a potential onset of osteoarthritis in young and middle-aged patients (101). The five domains of Pain, other Symptoms, Activities of Daily Living (ADL), Sports and Recreation function (Sport/Rec) and knee-related Quality of Life (QoL) are evaluated. A single sum score is usually not calculated, rather, the total score of each domain is reported separately (5 subscales with range 0 to 100). Higher scores suggest better function/fewer kne problems (102). The KOOS has been reported to have adequate content validity, internal consistency, test-retest reliability, construct validity and responsiveness in patients with knee impairments (102).

The **Tampa Scale of Kinesiophobia** (TSK, Appendix 4) was developed to assess pain-related fear of movement (kinesiophobia) in patients with chronic low back pain (103), but the questionnaire has also been used in patients with ACL injury (73, 84, 104-107). The original version of TSK comprised 17 items, but several short versions exist (103). The TSK version 2 has been translated to Norwegian and is therefore used in Study I (Appendix 4) (108). Patients rate their agreement in 13 statements related to fear of movement and physical activity on a four-point Likert scale ranging from “strongly disagree” to “strongly agree”. The total score ranges from 13 to 52 and is calculated by summing the score from each statement. Higher scores indicate greater kinesiophobia (108). The Norwegian version of the TSK has shown adequate test-retest reliability, internal consistency and construct validity (108).

A project-specific activity questionnaire (Appendix 5) was developed by an orthopedic surgeon and a physiotherapist at Haraldsplass Deaconess Hospital to map patients' type and level of activity/sports before and after surgery. Pre-operative return-to-sport goals were also recorded. First, patients are asked to mark their main pre-injury sport on a list of 16 common types of activities and sports. If their sport was not on the list, they could specify in their own words. Next, patients stated at which level they performed their pre-injury sport. Levels were categorized as elite, high/medium level of competition, low level of competition or recreational level. Then, patients' goals for returning to sport (both type and level), were specified before current status on returning was registered. No scores were assigned to the answers and no sum score was used. The questionnaire is made in Norwegian, therefore an English summary of the content is presented in Table 1.

Table 1. Sports and activity before and after ACL reconstruction

Questions		Answer options
1.	What was your main sport/activity before injury?	Soccer, team handball, basketball etc.
2.	At what level did you perform your sport/activity before injury?	1) Elite, 2) Medium to highly competitive, 3) Low competitive, 4) Recreational
3.	What is your goal for return to sports/activity after surgery?	1) Elite, 2) Medium to highly competitive, 3) Low competitive, 4) Recreational
4.	At what level do you perform your main sport/activity now?	1) Elite, 2) Medium to highly competitive, 3) Low competitive, 4) Recreational
5.	If your goal was to return to another sport/activity: At what level do you perform that sport/activity now?	1) Elite, 2) Medium to higlyh competitive, 3) Low competitive, 4) Recreational

English summary of content

In Study II, patients' activity levels are also described according to the commonly used IKDC definition were *Level I* comprise jumping, pivoting and hard cutting movements (i.e. soccer), *Level II* involve lesser pivoting sports and sports with lateral movements (i.e. alpine skiing) and *Level III* include "non-pivoting" activities like cycling and running (51, 109, 110).

7.4.2. Tests of knee laxity

Knee laxity can be assessed both manually or with a device and refers to the degree of passive relative anterior translation in the tibio-femoral joint (16, 111). The knee laxity tests were performed by an experienced orthopedic surgeon, who was not involved in surgery and patient treatment, as part of the standard follow-up regime after ACLR.

The **Lachman test** was performed with the patient in supine position. The examiner stabilized the femur with one hand so that the knee rested in approximately 20-30° of flexion. The examiner placed the other hand on the posterior and proximal part of tibia and applied an anteriorly directed force to evaluate anterior tibial displacement relative to femur (28, 112). Degree of tibial displacement in the injured knee was compared to the uninjured knee and graded as 0 (normal), 1+ (nearly normal) or 2+/3+ (abnormal) (51). Satisfactory sensitivity, specificity and reliability is reported for the Lachman test when diagnosing patients with ACL insufficiency (25, 28, 112-114).

The **KT-1000 arthrometer** (MEDmetric Corp, CA, USA) was developed to further quantify the amount of anterior tibial displacement in ACL injured patients (115). With the patient`s knee resting in 20-25° flexion, the instrument is strapped to the anterior aspect of the leg. The examiner stabilizes the patella via a patella sensor pad with one hand and applies a strong anteriorly directed force to the proximal calf (maximum manual test) (115). Amount of tibial displacement can be read from a dial and is measured in millimeters (mm). The side-to-side (STS) difference is presented (anterior displacement in the injured or reconstructed knee minus anterior displacement in uninjured knee) (115). The KT-1000 has the option of making a sound when the examiner pulls with a force of 15, 20 and 30 pounds. In this way, the examiner can read the laxity on the dial at different forces. However, the maximum manual test is often preferred. Studies have found KT-1000 measurements, in particular from the maximum manual test, to be valid and have fair reliability for experienced examiners (115-119).

The **Pivot shift test** was developed to enable a dynamic evaluation of the so-called shifting phenomenon, the “giving way” of the knee during a rotational movement, in patients with ACL insufficiency (120, 121). This anterolateral rotational instability (ALRI) is evaluated with the patient in a supine position. The examiner holds the relaxed leg at the ankle and moves the knee from extension to flexion with an internal rotation and valgus stress on the proximal tibia. At approximately 30° flexion, the internal rotation and valgus stress is released (120). The test is classified according to the IKDC 2000 knee examination form: 0 (negative), 1+ (glide), 2+ (clunk) or 3+ (gross) compared to the uninjured knee (51). The Pivot shift has high specificity and adequate inter-rater reliability and is therefore recommended to detect ACL isufficiency despite reports of low sensitivity (25, 28).

7.4.3. Return-to-sport tests

Patients warmed up on a stationary bike for 10 minutes before commencing the functional tests. During the tests, patients were only given a minimum of encouragement to standardize the degree of motivation and feedback provided.

The **single-legged hop tests** were designed to uncover lower limb functional limitations in patients with ACL injury by challenging dynamic knee stability (122, 123). There is a substantial variation in type and combinations of hop tests that are used for patients with ACL injury (124, 125). In study I and II, the four single-legged hop tasks most commonly described in the ACL literature was used (123, 126). The tests were performed on a 6-meter-long and 15-centimeter-wide marked line on the floor. The uninvolved limb was tested first and patients had one practice trial before they performed each task two times: a single hop as far as possible (centimeters, cm), triple hops as far as possible (cm), triple crossover hops as far as possible (cm) and six-meter timed hops as fast as possible (seconds) (122, 123, 126). The mean of the two counting performances was calculated before a LSI is made: $\frac{involved\ leg}{uninvolved\ leg} \times 100$. For the timed hop, the LSI was: $\frac{uninvolved\ leg}{involved\ leg} \times 100$ (122). The mean LSI (%) of all four hop tests was analysed in Study I and II (123). The single-legged hop tests utilized in the current studies are reported to be reliable and able to predict mid-term knee function after ACLR (123, 126).

Dynamic knee extension strength was measured using an **isokinetic dynamometer testing** system (Biodex System 3 Dynamometer, Biodex Medical Systems Inc., Shirley, New York) following the protocol recommended by Undheim et al. (127): Concentric mode of contraction, 60°/seconds (sec) angular velocity, five repetitions and range of motion of 0–90° using gravity correction. The uninvolved leg is tested first, and performance is reported as LSI (%) in peak torque (PT; maximal force exerted), with Newton meters (Nm) as the measurement unit. Isokinetic dynamometry provides valid and reliable measurements in healthy individuals and is considered the “gold standard” for measuring muscle strength (127-130). Quadriceps strength deficits, measured with the Biodex system, have been found to predict new knee injuries after return to sport in ACL reconstructed patients (14).

7.4.4. Return-to-sport criteria

As there is a significant reduction in re-injury risk when patients wait to RTS until nine months after surgery (14), this was the earliest point patients attended return-to-sport assessments in the current cohort. At this point, a test battery comprising the IKDC 2000, single-legged hop tests and concentric knee extension strength was applied. To achieve return-to-sport clearance, patients had to reach IKDC 2000, hop test LSI and isokinetic strength LSI (extension PT 60°/sec) of 85% or higher. For patients returning to IKDC Level I sports or Level II sport at high competitive levels, the criteria were adjusted to 90%. If patients did not meet the criteria, they were advised to delay returning to level I or II sports and were given the chance to return for a new assessment after more training.

7.5. Method for translation and cross-cultural adaptation of the ACL-RSI

Study I started with a translation of the ACL-RSI into Norwegian. The translation process followed the guidelines by Beaton et al. (131) where the first stage involved making three independent translations from English to Norwegian (by two physiotherapists experienced in ACL rehabilitation and one person with no medical background). All translators at this stage had Norwegian as their native language, but were also fluent in English. At stage two, the translations were discussed, and a synthesized version was completed. Stage three comprised back translations (from Norwegian to English) by two professional, independent translators with English mother tongue and no medical background. In stage four, an expert committee including all the translators in addition to methodologists (including a psychologist) and orthopedic surgeons was formed to discuss discrepancies and ambiguities before a pre-final version was ready. The original developer of the questionnaire was asked for permission to perform the translation before the project was started and consulted when needed during the process. Stage five involved field testing the pre-final version in the target population. A table displaying the items from the original questionnaire and the corresponding items from the Norwegian version and the back translations was sent to the scale developer for review in stage six.

The measurement properties of the ACL-RSI were then evaluated according to recommendations by COSMIN (132, 133). Construct validity with hypothesis testing is used when there is no gold standard to compare the scores on the measurement instrument to (87, p. 169). The following pre-defined hypotheses were therefore formed based on validation studies of ACL-RSI, studies on return-to-sport after ACLR, findings from previous translations and clinical experience (Table 2).

1	Patients who have returned to *pre-injury activity or sport* (at any level) have a significantly higher score on the ACL-RSI-No than those who have not returned.
2	Patients who have returned to *pre-injury level* have a significantly higher score on the ACL-RSI-No than those who have not returned.
3	There is a medium to large correlation ($0.30<r<0.60$) between IKDC 2000 and ACL-RSI-No.
4	There is a medium to large negative correlation ($-0.30<r<-1.0$) between TSK and ACL-RSI-No.
5	There is a medium correlation ($0.30<r<0.49$) between KOOS and ACL-RSI-No and a large correlation ($0.50<r<1.0$) between KOOS Quality of Life and ACL-RSI-No
6	There is a small to medium correlation ($0.10<r<0.49$) between the hop test (LSI % averaged sum score of all four tests) and ACL-RSI-No.
7	There is a small correlation ($0.10<r<0.29$) between the isokinetic strength tests and ACL-RSI-No.

Table 2. Pre-defined hypotheses on construct validity of the ACL-RSI

7.6. Statistics

Statistical analyses were performed using IBM SPSS Statistics Version 24.0 and 26.0 software (IBM Corp, Armonk, New York), except for the factor analysis which was performed using JASP (Version 0.9). An a priori significance level of ≤ 0.05 was chosen to denote statistical significance. Descriptive data was presented as means and standard deviations for continuous variables and absolute and relative frequencies for categorical variables. Tests of normality were conducted by histogram inspection and the Kolmogorow-Smirnov test.

In Study I, the structural validity of ACL-RSI was examined by confirmatory factor analysis (CFA). Descriptive goodness-of-fit-indices ((Chi Square, standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA) and comparative fit index (CFI)) were used to analyze whether the scale had one underlying factor explaining the construct. Further work was needed to clarify this and scree plot, parallel analysis, reliability of the one-factor solution and a two-factor exploratory factor analysis were examined. Internal consistency of the ACL-RSI-No was assessed using the Chronbach`s alpha (α) coefficient. Relative reliability was evaluated by the two-way random Intra-class Correlation Coefficient ($ICC_{2.1}$). For absolute reliability, the standard error of measurement (SEM) with a corresponding 95% Confidence Interval (1.96×SEM) was calculated from the mean of the variances between tests to describe measurement error and the limits of measurement error. The smallest detectable change was calculated on an individual level ($SDC_{ind}=1.96\times\sqrt{2}\times SEM$) and on group level ($SDC_{group}=SDC_{ind}/\sqrt{n}$). A Bland-Altman plot was made to illustrate the Limits of Agreement (LoA). For construct validity, pre-defined hypotheses on associations between the ACL-RSI and related questionnaires and functional tests were assessed using Pearson`s r. Independent samples t-tests were used to examine whether the scale could discriminate between patients who returned to sport and patients who did not return to sport. Finally, both the scale as a whole and the individual questions were examined for floor and ceiling effects by observing the number the participants who scored within the highest or lowest 15%.

For the purpose of discussing whether psychological readiness vary between different patient groups in this thesis, additional analyses were performed using independent samples t-test (sex), Spearman rho (age) and one-way between-groups ANOVA (levels of activity/sport).

In Study II, between-group comparisons were made using independent samples t-test, Chi Square-analyses and Mann-Whitney U tests as appropriate. To examine the predictive ability of each questionnaire (ACL-RSI-No and IKDC 2000) and functional test for two-year return to sport, logistic regression analyses (with and without adjustments for age and sex) were performed. The possible confounders of age, sex and time from injury to surgery were also assessed separately in logistic regression. The results are presented as odds ratios (OR) with 95% Confidence intervals (CI) and amount of explained variance (Nagelkerke R^2). To evaluate the predictive ability of the questionnaires and functional tests combined, stepwise backwards multivariate regression analyses were conducted and variables that had p-values of ≤0.05 from this analysis were further entered into a receiver operating characteristic-model (ROC). A separate ROC analysis was performed for the ACL-RSI as this was the new addition to the existing test battery. Results are presented as area under the curve (AUC), sensitivity and specificity. Multicollinearity was assessed by inspecting the Tolerance values in linear regression analysis.

For the purpose of discussing whether concomitant knee injury could act as a confounder in the predictive analyses, additional logistic regression including knee concomitant injury as an independent variable was performed.

In Study III, the Spearman rho test was used to study possible associations between psychological readiness (ACL-RSI) and knee laxity (Lachman test, KT-1000 measurement and Pivot shift test). The independent samples t-test was used to assess whether only a slightly increased knee laxity had an impact on ACL-RSI scores. A slightly increased knee laxity was defined as: KT-1000 STS difference 3-5 mm, Lachman 1+ and ALRI 1+. A stable knee was defined as: KT-1000 STS difference <3 mm, Lachman 0 and ALRI 0. The predictive ability of psychological readiness and knee laxity for two-year return to sport was then examined using logistic regression analysis, with and without adjustments for age and sex. Young age is reported to be a predictor of return to sport and was therefore included as an independent variable (49). Variables with a signficance level P≤0.1 (when adjusted for age and sex) in the separate logistic regression analysis were entered into a stepwise backwards multivariate logistic regression to examine overall predictive ability of a combined evaluation of psychological readiness and knee laxity. Results are presented as ORs with 95% CI and amount of explained variance (Nagelkerke R^2). Multicollinearity was assessed by the same method as in Study II.

7.7. Ethics

All patients were asked to give their written consent after receiving oral and written information about the studies. They were informed that study participation was voluntary, that they could withdraw at any time without providing a reason and that information about them would be deleted upon request. To secure anonymity, the list of patients' names was stored separately from the data collected for the study. The study was approved by the NSD (Norwegian Centre for Research Data) Data Protection Official for Research, project number 44708 and the Regional Committee for Medical and Health Research Ethics West 2015/1159.

8. Summary of papers

8.1. Paper I

Anterior Cruciate Ligament-Return to Sport After Injury Scale: Validation of the Norwegian Language Version

Aims: To translate the ACL-RSI scale from English to Norwegian and examine the measurement properties of the Norwegian version (ACL-RSI-No).

Patients: Patients who had undergone ACLR were recruited from three orthopedic centres in Norway. Two hundred and twenty-nine patients were found eligible for enrollment and all agreed to participate. After initial acceptance, three patients withdrew from the study, three were lost to follow up and 20 patients never returned the questionnaires. One hundred and ninety-seven patients were therefore included in the analyses, 107 men (54%) and 90 women (46%).

Methods: The ACL-RSI was translated according to internationally accepted guidelines before the ACL-RSI-No was piloted on five patients. Face validity was assessed by the expert committee and testers of the pre-final version. Hypotheses on the association between ACL-RSI-No and questionnaires measuring similar constructs and functional test performance were defined to establish construct validity.

The participants completed a set of questionnaires nine to twelve months after ACLR: The ACL-RSI-No, the project-specific activity questionnaire, the TSK, the IKDC 2000 and KOOS. A subgroup of 61 patients completed the ACL-RSI twice for evaluation of test-retest reliability. All patients recruited from one of the orthopedic centres were invited to complete functional assessment consisting of isokinetic strength tests (N=142) and single-legged hop tests (N=146) upon questionnaire completion.

Results: The ACL-RSI-No had good face validity and no cultural adaptation was necessary. The patients who participated in pilot testing the questionnaire conveyed that the ACL-RSI was relevant to them and shed light on challenges that no other test or questionnaire covered. The initial CFA revealed that a one-factor solution had a poor fit to the data: Chi Square 274.80 (degrees of freedom 54, P <0.01), SRMR 0.05, RMSEA 0.14 (95% CI 0.13-0.16, P<0.01) and CFI 0.90, meaning it was not immediately confirmed that the items in the scale measured only one underlying factor or construct (psychological readiness). Further analyses were performed to evaluate whether a one- or two-factor solution gave the best fit. The reliability of the one-factor solution was high (0.93) meaning that 93% of the variance of the scale was explained by true variance (the common factor). Further, factor loading sizes were robust regardless of whether the correlated error terms were included in the model or not (max loading change was 3%). Scree plot and parallel analysis also indicated a one-factor solution (the ratio between the two first eigenvalues was eight). Finally, a two-factor explorative analysis revealed a high correlation (0.85) between the extracted factors, indicative of a lack of discrimantive validity. These findings together suggested that a one-factor solution provided the best fit. Therefore, the scale should be treated as unidimensional and using a single sum score was reasonable.

Internal consistency was good (α 0.95) and test-retest reliability was very high ($ICC_{2.1.}$ 0.94, 95% CI 0.84-0.97). A measurement error (SEM) of 5.7 meant that a score change for one individual needs to exceed 15.8 points (and 2.0 on a group level) to be interpreted as a true change beyond measurement error.

Good construct validity was found as six of seven pre-defined hypotheses were confirmed. Patients who had returned to pre-injury level of activity or sport scored significantly higher on the ACL-RSI-No compared to those who had not returned. There was a medium to large correlation (r =0.61) between the ACL-RSI-No and the IKDC 2000 and a medium to large negative correlation (r =-0.34) between the ACL-RSI-No and the TSK. A medium correlation was found between ACL-RSI-No and KOOS (r =0.37–0.49), with a large correlation (r =0.66) between ACL-RSI-No and KOOS QoL. There was a small to medium correlation (r =0.28) between the ACL-

RSI-No and hop tests. The hypothesis on a small correlation between the ACL-RSI-No and the isokinetic strength tests was not completely confirmed as only a small, statistically significant correlation (r =0.17, P=0.04) was found to the extension peak torque LSI at 60˚/sec.

No floor or ceiling effects were found.

Conclusion: The ACL-RSI-No had adequate to good measurement properties and can be used in evaluation of psychological readiness to return to sport after ACL reconstruction.

8.2. Additional analyses Study I (unpublished material)

To explore whether psychological readiness differed between groups of patients after ACLR, additional analyses on sex, age and level of activity were performed. There was no statistically significant difference in mean ACL-RSI score between men (56, SD 23.8) and women (55, SD 22.3, Fig. 4) and there was no significant association between the ACL-RSI and age (Fig. 4). Psychological readiness was not statistically different between patients performing sport at different levels, with a mean ACL-RSI score varying from 51 (SD 23.2) for those performing sports at a low competitive level to 65.3 (SD 21.9) at elite level between nine to 12 months after surgery (Fig. 5).

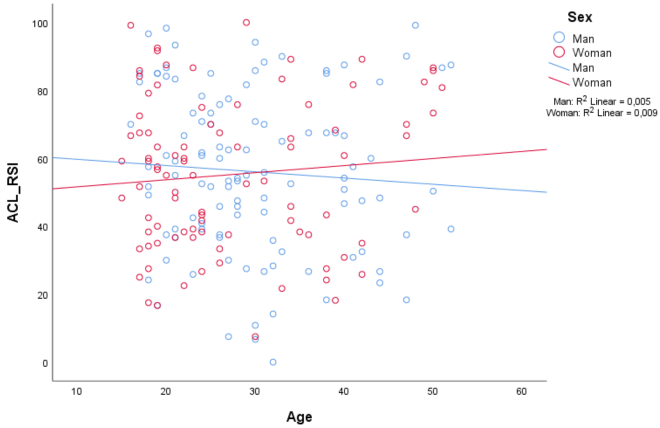

Fig. 4 Scatterplot of ACL-RSI score, age and sex (N=197)

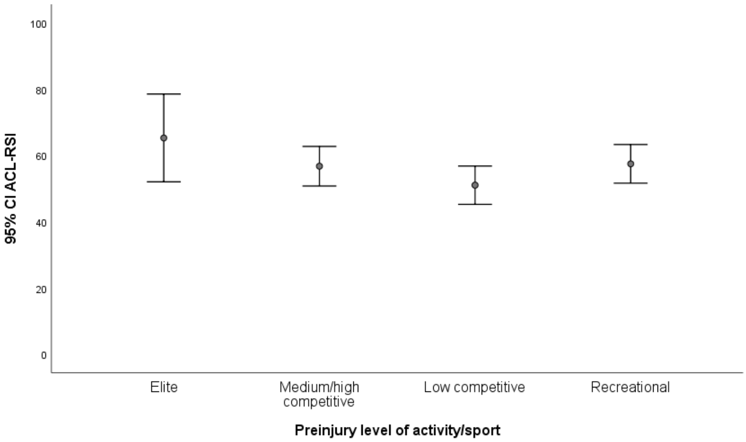

Fig. 5 Mean ACL-RSI score with 95% CI for each level of activity/sport (N=197)

8.3. Paper II

The Role of Psychological Readiness in Return to Sport Assessment After Anterior Cruciate Ligament Reconstruction

Aims: To examine the predictive value of return-to-sport assessment when evaluation of psychological readiness was included.

Patients: Of 147 patients who performed return-to-sport assessment at Haraldsplass Deaconess Hospital and were screened for eligibility, 13 patients were excluded because their index procedure was ACL revision surgery, one patient had a neurological condition affecting function and four patients declined participation. This left 129 patients who had complete data for the return-to-sport test battery. Twenty-six of these did not respond to the two-year evaluation, leaving 103 patients for the predictive ability analyses: Fifty-five (53%) men and 48 (47%) women with a mean age of 28 years. The main primary sports they engaged in were soccer (49.5%), handball (12.6%), skiing (5.8%) and cross country or mountain running (5.8%) across all levels of participation. The main part of patients participated below elite level (95%), but at some form of competitive level (65%).

Methods: At the nine to twelve months return-to-sport assessment, patients first completed the questionnaires (the IKDC 2000, the ACL-RSI and the project-specific return-to-sport questionnaire) before they underwent functional testing (single-legged hop tests and isokinetic strength tests). Two years after surgery, data on return to sport and re-injuries were gathered. Return to sport was defined as a return to pre-injury sport at pre-injury level of participation. A re-injury was defined as a graft rupture or contralateral ACL rupture confirmed by either 1) arthroscopy, 2) MRI scanning or 3) anamnestic episodes of knee trauma followed by an increased objective laxity compared to earlier controls (KT-1000 side-to-side difference ≥5, Lachman test 2+ or Pivot shift 2+). Any other surgery to the knees (i.e. meniscal resection) was also registered.

Results: Twenty-nine patients (28%) passed the test battery criteria of ≥85%. Forty-three (42%) patients had returned to sport two years after surgery. Only ACL-RSI score (OR =1.03) and age (OR =1.05) were independent predictors of sports resumption. Patients with an ACL-RSI score of <47 were at risk of not being able to return (AUC 0.69) with a sensitivity of 85% and a specificity of 45%. Single-legged hop tests and isokinetic knee strength did not predict return to sport.

Six patients suffered new ACL injuries and seven patients had undergone knee surgery due to other complaints between return-to-sport testing and 24 months after surgery, resulting in a total re-injury rate of 13.6%.

None of the patients who had passed the return-to-sport criteria were re-injured or underwent additional knee surgery compared to 13 re-injuries among the non-passers (P=0.037). Regression analysis on predictive ability for re-injuries was not feasible due to the low re-injury numbers.

Conclusion: Age and psychological readiness, not functional tests, were predictors of two-year return to sport. None of the patients who passed the 85% cut-off in the test battery suffered a new knee injury. This study therefore highlights the importance of incorporating psychological readiness evaluation into return-to-sport assessments and further, indicate that there may be an association between functional tests and re-injury risk.

8.4. Additional analyses Study II (unpublished material)

As 45 patients (44%) had concomitant surgery to the ACLR, logistic regression analysis was performed to examine whether concomitant knee damage was a confounder. Having concomitant surgery at ACLR did not significantly affect ability to for return to sport two years after surgery (P=0.262).

To enhance readability, only predictive ability of knee extension strength was presented from the isokinetic strength tests in Paper II. However, the predictive validity of knee flexion strength was also examined. Knee flexion strength (PT at 60°/sec) did not predict ability to return to sport two years after surgery (Table 3).

Table 3. Unadjusted and adjusted binary logistic regression predicting returning to pre-injury sport (N=102).

	OR	95 % CI	Sig.	R^2
Separate logistic regression				
Isokinetic flexion strength, PT60	0.98	0.96 – 1.01	0.147	0.03
Isokinetic flexion strength, PT60 adjusted*	0.99	0.96 – 1.01	0.293	0.08

*Adjusted for age and sex

PT, peak torque

8.5. Paper III

Association Between Psychological Readiness and Knee Laxity and Their Predictive Value for Return to Sport in Patients With Anterior Cruciate Ligament Reconstruction

Aims: To examine 1) whether there was an association between measures of knee laxity and psychological readiness for return to sport and 2) the predictive ability of these measures on returning to sport.

Patients: One hundred and seventy-one patients were screened for eligibility. Twenty-four patients were excluded due to a history of contralateral ACL injury and 12 patients did not attend the knee laxity assessment. One further patient was excluded because of neurological disease, leaving 132 patients for the analysis of association between knee laxity and psychological readiness. These had a mean age of 28 and 75 (57%) were men. At the two-year follow-up, three patients declined to participate, and 17 patients were lost to follow-up. One hundred and twelve patients were therefore included in the analyses on predictive ability for return to sport.

Methods: Patients completed the questionnaires (ACL-RSI and the project-specific activity questionnaire) before they underwent knee laxity testing nine to 12 months after surgery. Knee laxity was evaluated by an experienced knee surgeon using the Lachman test, a KT-1000 arthrometer and the Pivot shift test. The surgeon was not involved in the treatment of these patients and had many years of experience in performing the laxity tests (≥30 years). Two years after surgery, return-to-sport status and data on re-injury were collected. The definitions of return to sport and re-injuries were the same as in Paper II.

Results: There were statistically significant, but small negative associations between the Lachman test and ACL-RSI (rho=20.18, P=.046) and the KT-1000 measurements and the ACL-RSI (rho=20.18, P=.040). No association was found between the Pivot shift test and the ACL-RSI. When combining the three laxity tests to create a measure of more “allround” knee laxity, no significant difference was found for psychological

readiness between patients with stable knees versus patients with slightly increased laxity (ACL-RSI 62 vs 54 points; P = .21). Forty seven patients (36%) had returned to sport two years after surgery.

Higher age, feeling more psychologically prepared and having less anterior tibial displacement (KT-1000 measurement, STS difference) predicted return to sport with a shared explained variance of 33%.

Conclusions: Small, but significant associations were found between the tests that measure anterior-posterior knee laxity and psychological readiness. This suggests that patients who have less anterior-posterior knee laxity feel more ready for resuming sport. There was no association between the Pivot shift test and psychological readiness. Both the ACL-RSI and the KT-1000 measurements were independent predictors of return to sport and therefore have a place in return-to-sport evaluations.

9. Discussion

The aims of this thesis were 1) to cross-culturally translate and validate the Norwegian version of the ACL-RSI, 2) to investigate whether physical performance tests and psychological readiness predict return to sport and re-injury and 3) to investigate how knee laxity and psychological readiness combined predict return to sport. The ACL-RSI-No was found to have good clinimetric properties. Further, neither self-reported outcome measures about knee function nor tests of physical function predicted sport resumption in the current population. However, psychological readiness, anterior-posterior knee laxity and age were independent predictors of return to sport. Further, none of the patients who passed the 85% criteria on the test battery went on to suffer a second knee injury during the next year, while 13 patients (17.6%) sustained new knee injuries among those who did not pass. There was a small, but significant association between psychological readiness and knee laxity and between psychological readiness and single-legged hop tests. Of the isokinetic strength tests, only extension peak torque LSI at 60˚/sec had a small, statistically significant correlation to psychological readiness.

The discussion section starts with methodological considerations, continues with discussions surrounding the main results and finishes with reflections on clinical implications and future perspectives.

9.1. Discussion of methods

9.1.1. Participants

Much of the earlier research on return-to-sport test batteries after ACLR is focused on athletes at competitive levels. However, in the studies in this thesis, the participants are to a large degree non-professional athletes, who participate in their sports at purely recreational levels. Non-professional athletes have lower return-to-sport rates than professional athletes (49). This can be explained by professionals having higher internal motivation for returning and by attending closely supervised rehabilitation in specialized clinics with sophisticated equipment (49). However, most persons who ruptures their ACL are not elite athletes, but rather athletes participating at varying levels of sport (59). The population in the current project mirrors this by including patients representing all levels of sport participation, with most non-professional athletes. This makes the present results generalizable to many patients with ACL injury, but transferability to elite athletes may be limited.

One might speculate that evaluation of psychological readiness for sport resumption is most relevant for those who are aiming to return to sport at elite or highly competitive levels of sport. However, injury has been found to have a psychological impact on recreational athletes as well (83, 134). Supplementary analyses were therefore performed to examine this. We also investigated whether there were differences in ACL-RSI scores between age groups or sex. No significant differences were found and this suggests that the scale may be relevant for patients at all levels of sports participation, from young to "older" athletes of both male and female sex.

Associated injuries are common in patients with ACL injury (14, 22, 59, 84, 135, 136). In Study II, 44% of the patients needed additional procedures at time of ACLR. The presence of other knee injuries concomitant to the ACL injury, i.e. a meniscus tear, could possibly act as a confounder in the predictive analyses for return to sport because meniscus and cartilage damage have previously been associated with worse outcomes (110, 137, 138). However, additional regression analyses in Study II revealed no association between having an accompanying knee injury at time of surgery and ability to return to sport two years after surgery. Further, in a large cohort of patients with ACLR, the presence of meniscal or cartilage injury at time of surgery did not affect return to sport rate nor risk of revision or knee replacement surgery (59). Therefore, the inclusion of patients with a concomitant injury is considered reasonable and increases transferability to other populations with ACL injury.

9.1.2. Study design

Return-to-sport test batteries should be informative on both an athlete's readiness for returning to sport and the risk of sustaining new injuries (139). In study II, the number of patients who went on to sustain a graft rupture or a contralateral ACL injury was too low to perform regression analyses on the test battery's predictive ability for re-injury. The current finding that none of the patients who passed the return-to-sport criteria sustained a new knee injury in the follow-up period is promising, but a larger cohort of patients is needed to perform more robust analyses on the test battery's predictive ability on subsequent knee injury.

There was little high quality research to inform the choice of cut-off values for return to sport in study II (14, 70, 140). For the current cohort, the cut-offs on the hop and strength tests are somewhat lower (≥85%) than the LSIs of ≥90% that are used in other studies (14, 64, 70). The reason for this is a heterogeneous group of patients, including a large proportion of recreational and lower competitive level athletes, in the current study. In addition, cut-offs of 85% and lower have been found in previous studies on predictive ability (63, 141), and the available evidence for setting the LSI limit to 90% is quite sparse as it has not been validated in large cohorts (63, 124, 140). Further, the regression analyses in study II were performed with the LSIs as continuous variables so that cut-offs did not put any restraint on the analyses on the predictive ability for return to sport. Future efforts are planned to examine the test battery's predictive ability for re-injury and – if the tests are found useful – to establish appropriate cut-off values for a safe return to sports.

The current study design is observational, and conclusions should be drawn with this in mind. By following a prospective cohort, we have explored associations between modifiable (i.e. muscle strength) and non-modifiable (i.e. age) factors that may affect patients' ability to return to sport and risk of re-injury. The goal has been to identify relevant and valid methods for clinicians to use when they assess whether patients are ready for sport resumption. The current studies bring information about which modifiable factors that predict return to sport (psychological readiness and anterior-posterior knee laxity), which factors that show promise for predicting re-injury (not passing functional test battery) and cut-off values for the functional tests and ACL-RSI are proposed. However, to be able to draw conclusions about the *effect* of implementing the return-to-sport tests and proposed cut-offs – do they accurately predict who returns or not or who will sustain a re-injury? – further studies are needed. Future studies should include large cohorts where the proposed tests and cut-off values are tried in a new population not focusing on establishing associations, but on examining how accurate the tests and cut-offs predict success (142). To answer the question of whether passing the test battery protects patients from re-injury, another studie design using for example site randomization could be valuable (143).

In Study II, all patients were advised to wait a minimum of nine months before returning to pivoting sports. We did not however, record the exact time patients returned – they could have returned before nine months or some time after. We were therefore not able to adjust for the effect of time alone (waiting nine months to allow for sufficient tissue healing) in our analyses. Further, patients were advised on delaying return to sport and continue systematic training if they did not pass the test criteria. This may have protected the patients from re-injury and may have contributed to the relatively low re-injury rate. Indeed, some argue that the question of whether patients need to pass a test battery prior to returning can not be answered by studies where returning was postponed if patients failed the criteria (143). However, the patients in the current studies were given consistent advice, based on the test results. Regardless of how the participants acted on this advice, the approach in our studies may be similar to procedures in many clinical setting. We, therefore, argue that useful information can be inferred from both type of cohorts, if conclusions are drawn with caution.

A strength of the current study design is the examination of a broad range of factors that may affect a successful outcome after ACLR – including relevant factors that few have considered. To the best of our knowledge, no other studies have evaluated predictive ability of psychological responses, knee laxity and functional performance in the same patient group using regression analyses. The included factors represent two of three ICF levels; impairments (i.e. strength and laxity) and activity limitations (i.e. hop tests). PROMS were also included, covering some of the contextual aspects of ICF (53). In the current cohorts, the third ICF level of participation restrictions is covered by registering return to sports. However, functional tests addressing participation restrictions, i.e. on-field tests, are not included. Burgi et al. (53) emphasize the need for valid participation measures as participation is a major concern for these patients and such measures probably better mimic the important physical, physiological and psychological demands patients face in their activity or sport. However, standardizing and quantifying participation-based tests have proven challenging as advanced equipment like video set-ups might be needed. Further, the tests should be performed in settings similar to where the athlete normally would perform (i.e. soccer field). As the present study was performed in a hospital clinic, such “on-field” testing was not within the scope of our study. Further, factors related to type of surgery (i.e. tunnel positioning and graft choice) and rehabilitation (different protocols) may also affect return to sport (38, 65, 84, 144, 145), but were not controlled in the current cohort.

A two-year follow-up was chosen because most patients were expected to have attempted a return to sport within this time period (146). Although the majority of re-injuries tend to occur within the first two years after surgery, re-injuries and especially contralateral injuries also occur after this time (59, 60, 147). A longer follow-up might have resulted in higher re-injury numbers – allowing for analyses about predictive ability of return-to-sport tests on re-injury risk. Further, a recent study has emphasized that when evaluating the predictive validity of return-to-sport assessments on future re-injury risk, only patients that *actually* return to *pivoting* sports should be included (148). This is because most re-injuries occur in pivoting situations and if patients who do not expose themselves to this risk are included, they may dilute the predictive ability of the tests (148). The finding that none of the patients who passed the return-to-sport criteria in study II underwent further knee surgery or sustained a new knee injury in the current population brings preliminary evidence that return-to-sport tests may also have a predictive ability in cohorts including both pivoting and non-pivoting sports.

By using the dichotome outcome return to sport yes/no, the present studies only shed light on one element of the return-to-sport continuum (45). Information on how the athletes perform (quality of performance) when they return to their activity/sport and how long they maintain their sport participation can therefore not be inferred from these studies.

9.1.3. Outcome evaluation

In Study I and II, several aspects of the validity and reliability of the ACL-RSI were examined. Test-retest reliability, internal consistency, construct validity and predictive validity were found to be adequate to good. However, two important measurement properties were not evaluated in the present studies, namely content validity and responsiveness.

The results of factor analysis in study I indicate that the ACL-RSI is best described as a one-dimensional scale, i.e. the 12 questions measure the same construct. Similar findings have been presented by others and it is therefore fair to conclude that the scale measures one single construct (construct validity). However, support for adequate *construct* validity is not to be confused with evidence for *content* validity. Content validity is considered the most important measurement property of PROMs and it relates to whether the content of a PROM is an adequate reflection of the construct to be measured (do we measure what we actually set out to measure?) (88). In this area of measurement methodology, there has been considerable development over the last decades. Holding the described development process for the ACL-RSI (78) up against the COSMIN recommendations for assessing content validity of PROMS (89), some limitations should be mentioned. The article presenting the development process for the ACL-RSI was published in 2008 (78). Since then, an array of studies has examined different aspects of the ACL-

RSI's reliability and validity, but no studies have critically examined content validity guided by today's standards. Webster et al. (78) described an extensive literature search followed by identification of three key psychological responses before questions were developed within each key response. However, information on how systematic the search was and who performed it is missing. Further, there is no information on whether a theoretical framework or model was used in establishing the construct to be measured. There is no description of who decided on the three key psychological responses or a theoretical reasoning for how these are related. Moreover, there is no description of who was involved in choosing the questions and formulating them. In addition, there are strong recommendations for including experienced clinicans in the item development process to capture the essential signs, characteristics and consequences of a condition (85). Further, the COSMIN guidelines emphasize the importance of patient involvement when aiming to capture sensations, experiences and perceptions (85, 89). This is best achieved through focus groups or in-depth interviews early in the process of formulating items (89). There is no description of using such methodology in the ACL-RSI development. The abovementioned shortcomings in the development process may affect the content validity of the ACL-RSI. However, this does not necessarily mean that the content validity is poor. Strenghts of the ACL-RSI are that the target population is well described, and the preliminary questionnaire was pilot-tested in 28 patients after ACLR (78). Further, in the current study I, patients were involved through pilot-testing of the ACL-RSI-No and all commented that the questionnaire was relevant to them and that it shed light on current problems that the other tests or questionnaires did not cover. Inadequate content validity is common in PROMs used in orthopaedic medicine and it is problematic because PROMs are increasingly used as primary outcomes in research leading to changes in clinical guidelines (86). A lack of content validity may potentially affect all of the other measurement properties. If irrelevant items are included in a PROM (relevance), internal consistency, structural validity and interpretability may decline (89). If important items are missing (comprehensiveness), validity and responsiveness may decrease (89). The guidelines from COSMIN are detailed and strict and few of today's available PROMs meet these standards. This should should be kept in mind when we choose questionnaires and analyse results from them.

Responsiveness, i.e. the ability to measure change in the construct of interest over time, is an important measurement property of a PROM (85). The calculation of SEM and smallest detectable change (SDC) for the ACL-RSI-No in Study I brings information about measurement error and amount of change needed to be interpreted as true change beyond measurement error. However, the current study was not designed to determine *minimal important change* (MIC) using an external criterion to evaluate whether the change in score is perceived as valuable for the patients (anchor-based methods) (149). The SDC must be smaller than the MIC to distinguish important changes from measurement error (150). Using different anchor-based methods, two studies have evaluated the responsiveness of the ACL-RSI (the Dutch and English versions) (95, 151). Both studies report an SDC exceeding the MIC at individual level, meaning that the scale has limited ability to detect important changes in psychological readiness over time in individual patients (95, 151). In study I, the smallest detectable change values were similar to the values calculated by Slagers et al. (95) (Dutch ACL-RSI SDC_{ind} 15.3 compared to Norwegian ACL-RSI SDC_{ind} 15.8). If the MIC of 2.6 from Slagers et al. (95) is applied to the present study I, the same interpretation of limited responsiveness on an individual level would be reasonable. Despite these limitations, the ACL-RSI has been judged as the best-quality measurement instrument within the field of ACL research (152).

The PROMs used for examination of construct validity have some limitations. The IKDC 2000 has been recommended as the outcome measure to use for patients after ACL injury because of sufficient construct validity, responsiveness and reliability (99, 153), although low level evidence suggest that content validity may be low; i.e. essential questions may be missing for patients with ACL injury (86, 153, 154). Further, multidimensionality was found when modern test theories (CFA and item response theory) were applied and it may therefore be problematic to use a single sum score for the IKDC 2000 (153, 155). The use of KOOS for patients with ACL injury is debated as the scale originally was developed to monitor the long-term consequences of different knee complaints (86, 99). The subscales for ADL and pain have been deemed irrelevant for patients with ACL injury, with ceiling effects reported for both (154). This may affect content validity and responsiveness (86, 154). Moreover, problems with structural validity may be present (156), but firm conclucions cannot be drawn due to low methodological quality of the evidence (102). The Norwegian translations of the IKDC 2000 and KOOS have not been cross-culturally validated.

Despite increasing use of the TSK in populations with ACL injury, no proper validation studies seems to have been performed for this patient group (152). Preliminary evidence for adequate internal consistency and structural validity for shortened TSK versions have been reported in two studies of limited methodological quality (104, 152, 157). The TSK was originally developed for patients with chronic musculoskeletal pain and it may therefore be expected that some aspects of the scale are less relevant for patients with ACL injury (52, 103). Indeed, the scale had low validity in a Japanese population with ACL rupture (158). However, the TSK has elements that are important after ACL injury, with items covering fear of re-injury, and high TSK scores have been found to be associated with not returning to sport and even re-injury risk (73, 104, 159). The only Norwegian version available was used for the current studies. This version has shown adequate test-retest reliability, internal consistency and construct validity in patients with sciatica (108).

The limitations of the questionnaires used in the current studies are quite common within the field of orthopaedic research (86, 152). This can, at least partially, be explained by the fact that many of them were developed before the manuals and checklists for development of questionnaires and critical appraisal of their measurement properties were published (88, 89, 152). Some advocate that the lackings of the PROMS currently used should lead to them being discarded and replaced by new ones (86). However, currently and to the best of my knowledge, there is no PROM within ACL research that has both adequate validity and reliability according to the new guidelines. Development of such questionnaires are extremely laborious and discouraged if not strictly necessary (85). Despite this, some have taken on the task of developing new PROMs, for example the Knee-Numeric-Entity Evaluation Score, but measurement properties should be evaluated before they are adapted (160). In the mean time, researchers and clinicians should not be discouraged from using the available PROMs, but their limitations needs to be taken into account when results are analysed and interpreted.

The KT-1000 has proven accurate in identifying individuals with ACL injury in several studies and is acknowledged as a good instrument to use for quantifying anterior-posterior laxity in research (114, 115, 117, 119, 161-165). However, studies on the KT-1000 arthrometer are conflicting with regards to some measurement properties (166-169). There may, for example, be problems with reliability as adequate reliability has been linked to examiner experience (164, 165). The Pivot Shift test also has some limitations despite being the most specific maneuver for diagnosing an ACL rupture (28). Different techniques are used and the grading system has not been thoroughly standardized and is based on the subjective judgement of the examiner (120). Because the test mimics the phenomenon of the knee "giving way", patients may show protective muscle activation (28). Further, the test requires a quite complex maneuver where translation and rotation of the tibia relative to femur is required and may therefore also rely on examiner experience (28). In study III, an experienced ortopedic surgeon performed the laxity tests to eliminate inter-rater variability and increase probability of reliable measurements. However, no test-retest reliability study was performed for this surgeon and hence, information on measurement error for the current cohort cannot be presented.

Although single-leg hop tests are frequently used in return-to-sport assessments and have been reported to have fair association with self-reported knee function and ability to return to sport (124, 125), evidence is still sparse or lacking on certain measurement properties. Reports on the *predictive* ability of hop tests are equivocal and studies examining validity and reliability have used different test methodologies and to some extent have low methodological quality (125). Test-retest reliability of the four hop tests used in study II is reported to be excellent with ICC`s ranging from .82-93 and minimal detectable changes of ± 7.05% to ± 12.96% (123), however inter-tester reliability is unknown.

Isokinetic (peak torque and total work) dynamometry have been found to have high test-retest reliability and to accurately measure strength in knee extensors and flexors (127). However, many different test protocols exist and the predictive validity of isokinetic strength measurement in relation to returning to sport and risk of sustaining new injuries after ACLR is largely unknown (127).

9.1.4. Statistics

The use of stepwise backwards regression analyses is debated because they can be influenced by random variation in the data with variables being included or excluded based on statistics only (automatic variable selection) (170). However, the current regression analyses were also theory driven as only variables assumed to affect the outcome, based on previous research, were entered. Further, each of the independent variables and possible confounders (age, sex and time from injury to surgery) were examined with univariate logistic analyses before the stepwise procedure was performed.

9.2. Discussion of results

9.2.1 Psychological readiness for return to sport

One of the main findings from the current studies was that psychological readiness, measured with the ACL-RSI, had predictive value for patients' ability to return to sport. This finding is in line with Ardern et al. (84) who found that even before surgery, lower scores on the ACL-RSI were predictive of struggling with sport resumption. These findings are promising as psychological readiness has the potential to be mapped before surgery and modified during rehabilitation (2). However, the knowledge about how psychological readiness may be targeted during rehabilitation -

to put patients in a "ready" state for knee-challenging tasks - is still sparse (171). In order to develop and test strategies for mental preparedness, there is a need for understanding what the construct of "psychological readiness" actually comprise and furthermore, which factors that informs this readiness (171, 172).

In the original article presenting the ACL-RSI development, Webster et al. (78) did not mention the term "psychological readiness", but rather used the phrases "psychological factors" and "psychological impact of returning". Ten years later, as knowledge on psychological factors related to sport resumption had evolved, the original authors described that the three "psychological domains" they had used for scale development were highly related and therefore could be seen as one single construct labelled "psychological readiness" (90). However, the authors still did not provide a precise definition of what the construct of psychological readiness for returning to sport constituted. Even though Webster et al. (78) described how they selected the scale items (literature review), they did not seem to apply a theoretical framework as a basis for their scale development. Therefore, it may be challenging to judge whether the scale covers all important aspects of being psychologically ready for returning to sport.

Few high-quality studies have aimed to define psychological readiness. Systematic reviews have summarized the evidence on which psychological *factors* that may *affect* return-to-sport readiness, but an agreed upon definition for what the term "psychological readiness to return to sport" actually comprise is still lacking (172). In 2015, a qualitative study on what the term contained was performed (173). Seven patients with various sport injuries across different levels of performance were interviewed by experienced sports psychologists. Psychological readiness was found to be a "dynamic, psychosocial process" consisting of three components or dimensions that improved patients' perception of being able to return to sport: Confidence in returning, realistic expectations in sporting capabilities and motivation to regain former performance standards (173). In 2019, Kunnen et al. (81) also found that psychological readiness was a construct comprising multiple dimensions, specifically confidence and a love of the game (which can be interpreted as a motivational factor). In both these studies, the confidence dimension was reported to have several components, for example confidence in the rehabilitation professionals, confidence that the injured body part had healed and confidence in ability to perform well upon return to sport (81, 173). Based on the abovementioned studies and their "state-of-the-art" review, Podlog et al. (172, p. 7) recently proposed the following definition "*psychological readiness to RTS [return to sport] after injury reflects an individual's state of mental preparedness to resume sport-specific activities and likely comprises three dimensions, including cognitive appraisals (confidence, expectations, motivations, risk appraisals, internal or external pressures), affective components (anxiety or fears about re-injury or movement, moods) and behavioral components (approach-avoidance behaviors to demonstrate physical function/neuromuscular control and engage in sport-specific tasks)".* In this definition, motivation and fears of re-injury are part of the construct of psychological readiness. However, in the adapted biopsychosocial model for return to sport presented by Ardern et al. (2), motivation, fear of re-injury and readiness for return are listed as three separate entities under "psychological factors" (please refer illustration in section 5.6 in this thesis). This illustrates that there are different understandings of what psychological readiness constitute.

The lack of an agreed-upon definition of what psychological readiness is, may affect the content validity of current psychological readiness measures because they were developed before the definition was proposed by Podlog et al. (172). In other words, if we do not understand what psychological readiness is – how do we know that the developed scales measure what they aim to measure? Such ambiguities in construct definitions are not uncommon when new constructs are being developed (85, p. 154). When knowledge in a subject area is progressing, the initial theories about the constructs and underlying theories are quite weak. Through testing of the theories, new information is provided - leading to increased knowledge and more robust theories and constructs (85, p. 154). The abovementioned ambiguities should therefore not lead to a total discard of the scales developed before the definition was proposed, but they should be kept in mind when results and conclusions from the questionnaires are interpreted. Further, researchers are encouraged to clearly describe how they define psychological readiness in future work. Moreover, studies are needed to clarify what the term should contain and not contain in order to successfully take the next step – which is to explore how we may better put patients in a ready state for returning to sport (172).

Even though the construct of psychological readiness may not be finalized at this time (172), the fact stands that the responses measured with the ACL-RSI have been found important for patients during rehabilitation and the return-to-sport process (84, 174). The scale is predictive for patients' ability to return to sport and factor analysis support interpreting the responses as one construct (72, 84, 90, 173, 174). However, with an OR of 1.03 for returning to sports (explained variance of 12%) in the current study and 1.10 in the study by Ardern et al (84), there is still uncertainty around the results. Some of the explanation may lie both in factors that are included and factors that are not included in the term psychological readiness. For example, motivation was identified as an important part of the construct by Podlog et al. (173), but not included in the ACL-RSI. For many patients, rehabilitation can be a tedious process requiring many hours of systematic and strenuous exercise before they can return to the activities they enjoy. Setbacks and periods without progression are not uncommon and can take their toll on motivation to adhere to rehabilitation (175). Information about re-injury risks and feedback on rehabilitation progress from professionals, like ortopedic surgeons and physiotherapists, may also affect how motivated patients are for returning (175). Indeed, motivation to regain previous activity and performance levels has been highlighted as a key issue during rehabilitation and return to sport after ACLR in studies of both qualitative and quantitative nature with patients describing that motivation goes "hand in hand with being psychologically ready" (72, 77, 173, p.8, 175). Especially intrinsic motivation, characterized by an inherent tendency to seek out challenges for further development and mastery of skills, is interesting (72). Patients with a high degree of intrinsic motivation often display more autonomy and self-determination leading to better chances of sport resumption (72, 176). Further, while several items in the ACL-RSI concern some of the abovementioned aspects of confidence - realistic expectations of ability to reach certain performance levels and confidence in rehabilitation professionals, for example, were not identified as part of the prominent dimensions in the literature search that formed the basis for the ACL-RSI.

The short and concise form of the ACL-RSI is appealing to both patients and clinicians. However, several relevant factors may be overlooked. Examples of other psychological responses that may affect return to sport that are not covered by the ACL-RSI are feelings of being in control of one's own return-to-sport process (autonomy), feelings of strong social support and connectedness to team mates (relatedness), perceived self-efficacy, locus of control (feeling that the outcome after injury is within one's own control and not affected by i.e. bad luck), self-esteem and personality traits (65, 76, 177-180). A change of priorities (i.e. changing career, focusing on education) and major life events (becoming a parent) also affect the return-to-sport decision, but to a smaller degree than originally assumed - as studies report that fear of re-injury is the most common reason for not returning (4, 72, 141, 181, 182).

When planning future interventions to improve mental preparedness for returning to sport, it is crucial to understand what informs psychological readiness. Previous studies have found age, subjective knee function, preoperative pain levels, gait asymmetry, hop performance and postoperative quadriceps strength to be associated with how ready patients feel for returning (183-186). This suggests that if patients perceive that they are physically progressing and regaining pre-injury function, they also feel more psychologically ready for returning (172). Interestingly, there seems to be a closer relationship between how patients rate their function (perceived function) and how mentally prepared they feel for returning than between measured function and degree of mental preparedness (185, 187). This is in line with the moderate to strong correlations found between the ACL-RSI and PROMs (KOOS, IKDC 2000 and TSK) in study I. Further, only a small to medium correlation was found between the hop tests and psychological readiness in the current cohort (Study I), consistent with findings by others (186, 188). In addition, only a small or no correlation was found between laxity tests and psychological readiness and strength and psychological readiness in the current cohort (Study I and III), which is also reported by other authors (185, 187, 188). This indicates that even though there may a relationship between physical function and psychological readiness, this relationship is quite small. This may explain the clinical observation that patients who feel that their knee is strong and stable do not necessarily feel mentally prepared for a return. And conversely, patients who feel psychologically ready, may not be physically ready. In other words, physical and psychological readiness for returning to sport may not always coincide (4) and therefore, both should to be evaluated in return-to-sport assessments. Moreover, as the abovementioned associations are relatively small, there is probably an array of other factors influencing psychological readiness which is not yet understood (183). It should be mentioned that all the comparative studies in this section are of cross-sectional design and conclusions should therefore be drawn with caution.

9.2.2. Sosiodemographic factors and injury characteristics

The modified biopsychosocial model for return to sport illustrates how the abovementioned psychological factors have an impact on the sport resumption decision (2). The model also show how sosiodemographic factors and injury characteristics may impact return to sport. Previous studies have reported that younger age, pre-injury participation at higher competitive levels and being male favour return to sports (49). In the current cohort, there was no association between having additional injury/surgery and ability to return to sport nor did sex affect the ability to resume pre-injury sport or activity (Study II). In contrast to previous studies, older age significantly increased the odds of returning to sport in the current cohort. We hypothesize that this is due to the relatively large proportion of “older” patients performing recreational level sports. As it may be easier to return to recreational levels of sports than elite levels it is thinkable that age acts as a proxy for level of activity in the current cohort.

9.2.3. Physical readiness for return to sport

Addressing the “bio” in the biopsychosocial model, one of the main findings of this thesis was that the physical tests could not predict return to sport (Study II). The ACL contains mechanoreceptors and damage to the ACL therefore cause partial deafferentation and impaired spinal and supraspinal motor control (9). This can lead to altered proprioception, poorer postural control, reduced muscle strength, poorer movement and impaired recruitment patterns (44, 189). The tests used in the current cohort are developed to evaluate functional knee status by addressing these impairments and they represent some of the most established return-to-sport tests in ACL research (16, 53, 190). The hop tests mimic some of the tasks an athlete performs during common sports, i.e. take-off, direction changes, pivoting and landing manoeuvers (64) - and it would therefore be logical that these tests have at least some predictive ability for sports resumption. Indeed, Müller et al. (63) found six-month single hop for distance to predict seven-month sports resumption in a cohort of recreational level athletes. However, the short timeframe for predictive ability (one month) makes transferability of the results questionable. Ardern et al. (146) and Webster et al. (191) published promising results where hop test limb symmetry was reported to be associated with being able to return to sport. Ardern et al. (146) examined the predictive validity of hop tests for two-year return to sport, but the study was performed exclusively on patients who had *not* been able to return to sport at one-year post-surgery and only univariate analyses were performed. The study by Webster et al. (191) had a retrospective, cross-sectional design which limits the results’ utility for prospective prediction. Nawasreh et al. (64) examined predictive validity in a longer time span and reported that hop tests six months after surgery (especially the six meter timed hop) were consistent predictors for 12 and 24 month return to pre-injury level of sport with up to 43% explained variance. However, the participants in that study had fewer concomitant injuries at the time of surgery, underwent specialized and supervised rehabilitation and participated in Level I or II activities only (64). In a study on young athletes, absolute hop performance (i.e. not using LIS's) at time of return to sport was associated with participation at pre-injury level one year later (192). More recently, Kitaguchi et al. (141) found predictive value for one-year return to sport (OR 2.86) using six-month single-leg hop for distance in a cohort of young, competitive-level athletes after ACLR.

The finding that hop tests did not predict ability to return to sport in Study II contrasts the abovementioned findings. A reason for this may be the broad inclusion of patients to the current cohort in terms of age (mean age 28.7), concomitant injury and type and level of sports. Patients at all levels of sports, and both pivoting and non-pivoting sports were included to mirror the heterogeneous patient group seen at many hospital clinics. As the hop tests imitate movements that may be more often performed at higher competitive level and in pivoting sports, this may partially explain why hop tests did not display a predictive ability for return to sport in the current cohort. In support of this, Langford et al. (174) found no difference in hop performance (single hop for distance and cross-over hop for distance) for returners and non-returners in a cohort study involving recreational athletes only. However, in that study, hop tests were performed at 12 months post-surgery – at the same time that return to sport was registered and hence, analyses on predictive ability of hop tests were not feasible.

The other physical test included in the current test battery, isokinetic leg strength, also failed to predict ability to return to sport (Study II). This is in line with other studies - where only small or no predictive ability has been reported (63, 65-67). Lentz et al. (159), however, reported that both six months mean extension LSI's (isokinetic) and knee extensor torque normalized to body weight were higher in those who had returned to sport one year after surgery. The study population was quite small however (N=46), and regression analyses were not performed. Welling et al. (67) reported that isokinetic flexor strength at the end of rehabilitation was significantly associated with two-year return to sport. This was, however, not the case in the current material (please refer section 8.4. Additional analyses Study II). Some of the explanation for these diverse findings may be the dominance of reconstructions performed using hamstring tendon graft in the study by Welling et al. (67) compared to the 60% Bone-Patellar Tendon-Bone grafts in Study II.

A potential explanation for a lack of or weak predictive ability of the physical tests in Study II is the use of leg symmetry indexes. The rationale for using LSIs to measure change in knee function is that each patient is compared to themself and, therefore, any biological differences between patients will not influence the measurement. A leg symmetry of ≥90 have been associated with reduced re-injury and osteoarthritis risk and better self-reported function and quality of life in patients with ACL injury (14, 70, 193, 194). However, several researchers have raised concern about relying on LSIs alone when measuring function. In a case-control study performed by Gokeler et al. (195), two problems with using hop test LSIs were highlighted. First, the mean LSI for patients who had undergone ACL surgery was 95.5%, which is well above proposed cut-offs of 85 or 90%. These findings are supported by others (67) and the current Study II where mean LSI for the cohort was 96.1% (SD 8.5) with a mean LSI of 97.0 (SD 8.6) for the returners and 95.5% (SD 8.4) for the non-returners. This implies that the hop tests lack discriminative validity. Second, despite the high mean LSI, patients who had undergone ACL reconstruction showed deficits in hop performance in both the *involved* and the *uninvolved* limb compared to age- and sex-matched healthy controls (195). This finding has been confirmed by others. Patterson et al. (196) for example, examined hop test performance up to five years after surgery and found a significant worsening of the *uninjured* leg leading to significant improvements in LSI scores. In other words, the use of LSIs may cause an overestimation of knee function (197). Similar problems are reported for the use of LSIs when measuring strength. Hiemstra et al. (198) found up to 25% reduced knee extensor strength in both *injured* and *uninjured* leg compared to healthy controls at a mean of 40 months after surgery. Larsen et al. (199) found the uninjured leg of patients after ACL surgery to be significantly weaker compared to age- and sex-matched healthy controls in recreational athletes around time of return (9-12 months post-surgery). These findings have led researchers to conclude that the observed improvement in LSI after ACLR may be driven mainly by *deteriorating* function in the *uninjured* leg – not by improvement in the injured leg (196-200). In the study by Welling et al. (67), no difference in hop test LSI were found between returners and non-returners, but higher absolute scores in both injured and uninjured leg were associated with ability to resume sport. Therefore, the assessment of absolute strength in relation to healthy control groups has been advocated (199, 201). For this to be a valid method, there is a need for several large cohorts presenting normative data on healthy subjects to allow for matching on variables such as age, sex, height, weight and type of activity/sport (187). Van Melick et al. (148) have started this work by syntezising currently available studies.

Wellsandt et al. (197) proposed another solution, using so-called estimated pre-injury capacity (EPIC) levels, where hop and strength performance on the involved limb six months *post-surgery* is compared to *pre-surgery* performance on the uninvolved limb. Their research showed that EPIC levels were more sensitive and specific in predicting new ACL injuries (197). However, the analyses only included 11 re-injuries and predictive ability for return to sport was not evaluated. Further, in the current study II, the mean time from injury to surgery was 8 months. Function in the uninvolved leg may decrease significantly during this time period due to reduced activity levels and hence, affect the pre-surgery test results. The evidence for using EPIC is therefore scarce at this point. It could also be tempting to raise the bar on the LSI-demands by setting more stringent criteria for passing, i.e. LSI ≥95% to see whether this makes the tests more informative. However, at this point there is no reason to believe that hop tests will have a better discriminative ability for those who achieve an LSI of 95 – 100% and the already low pass rates on the 85 – 90% criteria on strength tests would only be amplified without improving predictive ability (195, 202).

Another viable reason for the lack of predictive value of hop and strength tests may be the oversimplified quantification of performance. By reporting only time and distance on hop tests, we do not account for movement quality, including various compensation strategies, poor trunk control, dynamic valgus failure or stiff landings (187). These are factors considered important to look for and address during rehabilitation – yet few studies have incorporated them in return-to-sport research. Landing kinematics have, for example, been found to predict re-injury (203). In another study, athletes had a mean LSI of 97% on the single-legged hop for distance, but using three-dimensional biomechanical video analysis, the authors found an LSI of 69% for the knee moments and work during propulsion (204). This indicates that patients adapt to their injury by shifting load from their knee to their ankle and hip – even though they hop the same distance. In other words, single-leg hop distance symmetry does not mean that there is biomechanical or functional symmetry in knee joint performance (204). The authors of that paper therefore argue for a shift of focus from measuring distance hopped to assessing the quality and stability of the landing phase (204).

Even though the hop tests in the current study II are frequently used in return-to-sport testing, an array of other hop tests exist (123, 205). Both older and newer studies present hop tests that hold the potential to better capture functional deficits. Vertical hops, for example, may require more strength and power from the lower limbs than horizontal jumps (205). In support of this, the relative contribution of the knee to the propulsive phase of horizontal jumping have been found to be 4% to 12%, while its contribution to vertical jumping is about 24 to 33% (206, 207). Variations of lateral and medial jumps may better challenge sideways propulsion, arm swing strategies and valgus stability (187). Dingenen et al. (208) propose using medial jumps – with the addition of rotational hop tests to better reveal functional limb asymmetries. The Drop Vertical Jump Test has gained interest as it allows for assessment of lower limb valgus alignment in both landing and takeoff (209). However, at this point no studies have found any predictive value of this test (66). Padua et al. (210) developed a Landing Error Scoring system (LESS) based on the Drop Test, where the kinetic chain from ankle to head is evaluated in both the frontal and sagittal plane during a drop jump. Patients who did not return to sport after ACL surgery had poorer scores on the LESS, indicating poor biomechanics in landing and take-off, in a study by Welling et al. (67).

While isokinetic peak torque provide information on maximal voluntary contraction (127), researchers have highlighted a paucity in studies addressing potential deficits in other strength “sub-qualities” or in more “overall” neuromuscular function, such as ability to generate force rapidly (rate of force development), eccentric strength, power development, reactive strength and endurance (45, 200, 201). These are all important aspects of overall strength - and deficits may affect performance, return to sport and risk of re-injury (211). For example, reduced quadriceps torque development has been described after ACLR, which means that ability to generate force rapidly is impaired (200). Being able to generate force rapidly may be just as relevant for daily functioning and sports performance as maximal strength (45, 200). Assessment of these aspects of strength could, therefore, hold the potential to improve our ability to predict sport resumption and re-injury in patients after ACL surgery (201).

Condition-specific testing seems logical based on the principle of specificity: you get good at what you practice – under the conditions you practice them (212, p. 465). While the hop tests are designed to mimic some of the general elements of many sports, both the hop and the strength tests are performed in a controlled laboratory setting. Open skills, including reactive agility (reacting to an external stimuli) and direction changes, are largely not covered by these tests (45). Further, the hop tests are performed on an even surface, and the person being tested does not have to adapt to different surfaces under different conditions (uneven surfaces, slippery surfaces due to rain). Isokinetic strength is measured with the patient strapped in a seated position and hence, the stability and strength of the entire kinetic chain is not evaluated when extension and flexion strength is measured this way (127). A future area of research interest is therefore to develop tests that more specifically evaluates the function needed to perform the different sports – and preferably under the conditions where the sport is performed (16, 45, 68).

Self-reported function, measured with the IKDC 2000, did not display a predictive ability for return to sport either (study II). This is in contrast to a previous meta-analysis where a higher score on the IKDC 2000 was found to favour returning to pre-injury level of sports (49). The meta-analyses combined results from only one cross-sectional study (213) and one prospective study with a one-year follow-up (84). The predictive value of self-reported function is therefore unclear. It may be that the IKDC 2000 holds a predictive value earlier in the rehabilitation process (four month to one-year) than in a mid-term perspective such as in the current study II (nine-month to two-years).

Based on the findings of study II and the abovementioned studies on predictive ability of physical tests, the overall conclusion is that the evidence for predictive ability is ambiguous (211), leaving clinicians with a great deal of uncertainty on what tests to use and how to interpret them. The use of different hop and strength test protocols and the varying findings about which hop tests and protocols that are useful makes comparisons and drawing conclusions challenging (124, 127). Even though the physical tests did not display predictive abilities in the current cohort, others have reported a small effect for hop tests' predictive ability for return to sport (49, 146). Further, even though single-legged hop tests may not be informative on return to sport, they have been found informative on other relevant aspects of function, for example one-year self-reported knee function (The IKDC 2000) (126). Moreover, one can speculate whether the physical tests may be better at predicting short-term return in young athletes who participate at competitive and/or professional levels of sports including pivoting movements (63, 64, 192). However, in a more heterogeneous cohort of patients with varying levels of sport participation, the tests do not seem to be informative on return to sport (Study II).

A return-to-sport assessment needs to be informative about both a patient's physical and mental readiness for returning and on the *safety* of returning (139). Even though the physical tests show ambiguous results when it comes to predicting sport resumption, promising evidence for their predictive value on *the risk of sustaining a new injury* is emerging. In study II, none of the patients who passed the return-to-sport criteria underwent further surgery or sustained a new knee injury during the follow-up period, compared to 13 re-injuries among those who did not pass (P=0.037). Grindem et al. (14) found that patients who passed their return-to-sport criteria had an 84% lower knee injury rate (though not statistically significant). Especially those who achieved more symmetrical quadriceps strength before sport resumption had a substantially reduced risk of sustaining a second knee injury (14). Further, not passing a battery of six return-to-sport tests (including tests of isokinetic strength, running and hop tests) was reported to increase the risk of sustaining a second ACL rupture by four times in male soccer players (70). Paterno et al. (55) found the triple hop for distance to have a predictive ability for a second ACL injury in a cohort of young athletes. On the other hand, Welling et al. (67) found that patients who passed a return-to-sport test battery consisting of PROMs, hop tests and strength tests failed to identify patients at high risk of sustaining a new knee injury. Meta-analyses have been perfomed to evaluate the value of return-to-sport assessments (139). Even though the analyses displayed a 60% reduction in risk of graft rupture after passing a test battery, it also revealed a 235% increase in risk of a contralateral rupture (139). It should be noted that this review created controversy as authors of several of the articles included in the meta-analysis did not agree with the methods for inclusion of data and thus the conclusions drawn (143). These authors performed new meta-analyses after excluding the papers they judged to be inappropriately included and found that patients who passed return-to-sport assessments had a 72% lower risk of any knee injury, 75% lower odds of a second ACL injury and 78% lower odds of a graft rupture than those who did not pass. Further, they found data on risk of contralateral injury to be too sparse for meta-analysis (143).

Summed up, despite the great clinical and research interest in physical return-to-sport tests, the predictive value of these tests is still questionable. Many different tests are used, many are under development and their clinical utility and interpretation is unclear (53, 211). Welling et al. (67) suggest that today's tests may be useful to predict ability to return to sport, but not risk of re-injury. I would argue the opposite based on the current cohort and abovementioned studies. At this point, it seems like the available tests may hold potential for predicting re-injury risk, but they do not seem to be much informative on ability to resume sport. This is supported by a recent systematic review (214). Psychological readiness is, however, informative about ability to return to sport and is also showing promise in predicting re-injury (215, 216).

9.2.4. The role of knee laxity in return-to-sport assessment

Clinical examination of the knee, such as knee laxity testing has been recommended as part of the return-to-sport assessment (68). Knee laxity testing has been found to predict which patients that will need an ACL reconstruction and to predict poorer outcomes after reconstruction (217-219). As the purpose of reconstructive surgery is to restore knee stability, the inclusion of knee laxity measures in post-operative follow-ups is reasonable – both to examine whether knee laxity is normalized and to monitor whether post-operative strains and exercises have led to laxity changes (99). However, the clinical relevance of postoperative laxity measurements has been questioned because laxity refers to the *passive* response of the joint when external forces are applied and does not account for *dynamic* control of the knee (16, 99, 220). In support of this, instrumented knee laxity measures, like the KT-1000, have been found *not* to correlate with functional outcome measures or return to sport (55, 141, 146, 217). The current finding in study III that KT-1000 measurements predicted return to sport indicate the opposite – namely that patients with smaller post-operative anterior-posterior knee laxity have higher odds of sport resumption. Ardern et al. (49) also found that patients classified as having "normal" knee function according to the IKDC form (where evaluation of knee laxity is included) had greater odds of returning to sport compared to patients with "nearly normal" function. Further, a recent study by Lindanger et al. (221) showed that slightly increased laxity (KT-1000 STS difference 3 to 5 mm) six months after ACLR increased the incidence of long-term graft failure and revision surgery and were indicative of significantly shorter sports careers. It can therefore be argued that knee laxity measures should be incorporated into return-to-sport assessments.

As the Pivot Shift test is designed to evaluate both anterior-posterior translation and rotational instability of the ACL and has been related to post-operative self-reported function (217, 222), one might expect that this laxity test would be the one most informative about patients' ability to return to sport. However, this was not the case in study III, and we hypothesize that this is due to the test's rather low sensitivity, meaning that it may not capture all patients with an ACL rupture (28). The movements performed during the test mimics the knee "giving way" and may lead to muscle guarding in patients - increasing the likelihood of false negative tests (223).

Until now, the focus of most return-to-sport test batteries has been on the physical tests, like hop and strength tests, and few have investigated the role of laxity tests (45, 53). Interestingly, laxity measures have been applied in a recent publication of a return-to-sport protocol, the BEAST (BEtter And Safer reTurn to sport) tool (224). Here, the Lachman test is used to monitor graft integrity as part of the criteria applied before the patient is cleared for training progression (224). Even though the Lachman test has been found to have high sensitivity and is recommended for diagnosing ACL ruptures (28), the results from study III indicate that the use of instrumented measures to quantify anterior-posterior translation may be more informative post-operatively as the KT-1000 displayed predictive ability, not the Lachman test. This is supported by others who conclude that quantification of laxity tests increases their validity and reliability (99, 115).

Introducing instrumented measurement of knee laxity in clinical practice may pose some challenges. Contrary to the Lachman test, which can be performed without any equipment, an instrument is needed for KT-1000 measurements. As previously discussed (please refer section 9.1.3.), reliability of KT-1000 measurements is debated as it is dependent on for example examiner experience (118). Proper training and the use of manual maximum pull is recommended to increase reliability of the measurements (225). Further, most studies on laxity tests' reliability and validity have been performed on patients *before* they undergo treatment. Knowledge on how to interpret post-operative results is somewhat uncertain as "normative values" for populations who have undergone ACLR are largely lacking. To enhance interpretability of post-operative laxity measures, further studies on what these values actually mean would be useful. Some support for how to understand post-operative findings is offered in the IKDC knee ligament standard evaluation form that was developed to quantify disability after knee injury and to evaluate results *after* treatment (51). Here, a STS difference of 3-5 mm is categorized as "nearly normal" and a difference of >5 mm is defined as "abnormal" and hence a graft failure (51). In study III, mean KT-1000 value was 3.2 (SD 2), which would be the "nearly normal" category. However, according to Lindanger et al. (221) it would mean that many of the patients in the current study were in the "slightly loose" category, at risk of future graft failure and shorter "sports careers". KT-1000 measurements can therefore at this point, with some caution, be used to guide clinicians on how to advice patients upon return to sports. Patients with slightly loose or loose grafts are at higher risk of graft failure and should take this into consideration when they contemplate returning to strenuous knee activities.

9.3. General considerations

9.3.1. Success and consequences: Should they return?

One can debate whether returning to pre-injury level of sport is a correct measure of success after ACLR. Ideally, health professionals should assist patients in re-gaining function to enable an active lifestyle, whilst preventing further damage to their knees (226). Knowing that re-injury risk is quite high for those who return to sport - with potentially devastating mid- to long-term consequences such as early onset osteoarthritis (48, 58, 59, 226): Should we be encouraging return to cutting and pivoting sport at all?

Most patients who sustain an ACL injury expect to return to the sport they love and want to lead an active lifestyle (50). This is considered an important reason for undergoing ACLR in the first place. Further, new reports have found that returning to pre-injury sport is associated with *better* self-reported function and a *lower* risk for developing osteoarthritis (227, 228). That being able to return to sport is very important to patients is also evident in studies showing that a return is linked to higher quality of life (229). On the other hand, patients have described that they in time accept the limitations in sports and that exercise could be fun again without returning to pre-injury level of sport (71). The role of health professionals should therefore be to assist patients in making a well-informed choice. A close dialogue between the ortopedic surgeon, physiotherapist and patient is crucial to clarify the patient's expectations and discuss what a return to pivoting sports means in term of long-term knee health. This should be done before surgery is chosen, to clearly align the treatment options and their consequences for the patient. A discussion about returning to slightly less "knee-challenging" sports like running or cycling is important as returning to activities involving less pivoting can reduce knee re-injury rates more than 4 times (14). Only when the patient is sufficiently informed, he or she may make their decision on what risks they are prepared to run in the future. However, for those who choose to go back to "knee-strenuous" activities, health professionals need to be equipped with the tools to guide them towards a safe return.

9.3.2. The decision to return

Only the patients themselves can choose what risks they are willing to take when they contemplate returning to sport. However, the decision about sport resumption is made with many stakeholders involved (45). If the patient is young, parents probably have opinions about what to do. Friends and team mates may also influence the decision. Health professionals (i.e. local physiotherapist, ortopedic surgeon, physiotherapist specialist) may perform tests and provide advice on when the patient is as prepared as possible for a successful return to sport. Coaches and other members of the support team may exert pressure for returning.

The decision to make a full return to “knee-strenuous” sports is recommended to be multidisciplinary and involve the patient, parents if patients is under 18 years, surgeon, team physician, physiotherapist and athletic trainer (68). Shared-decision making draws on the principles of patient-centered care and requires active involvement from all parties, well-defined roles, good communication and a clear strategy for resolution of disagreements (45, 230, 231). The goal is to share the available evidence and support patients in making informed choices. This can be done by 1) introducing choice to the patient, 2) describing options and 3) helping the patient to explore their preferences and then make their decision (232). Further, the decision should not just at the made at the end of rehabilitation, but it should be seen more as an ongoing *process along the return-to-sport continuum* (68).

9.3.3. Are fears and reservations protective?

The significant relationship between more knee laxity and less psychological readiness in study III, indicate that those who feel less stable in their knee also feel less psychologically prepared for returning to sports. Based on this finding, one may infer that fear serves a healthy and protective purpose. Some degree of reservation and caution might hold patients back from engaging in knee-strenuous activities and may therefore be a healthy reaction leading to behaviour that protects the knee from further damage (2). For some patients this may be true, but for others a low degree of readiness and high degree of fear may lead to inactivity and a feeling of a “restricted” lifestyle. As the associations between psychological readiness and knee laxity (study III) and between psychological readiness and physical tests (strength and hop tests, study I) were quite small, this indicates that the notion that low psychological readiness is an expression of a “healthy reservation” based on how strong and stable the patient’s feel their knee is, does not hold. In support of this, Burland et al. (72)

found that psychological responses like hesitation, fear of re-injury and lack of confidence may be independent of physical function in their qualitative study.

9.3.4. Overall readiness

Using the terms *psychological* and *physical* readiness to return to sport, brings the Descartean mind-body dualism to mind (233). Allocating symptoms to mind or body may lead to an artificial divide between two aspects of the same "construct" (the human) and get in the way of an integrated understating of human behaviour. The whole person, not just the knee, is affected by an ACL injury (71). Many will say that the dualistic approach to medicine, where the body and soul are seen and treated as separate entities, is far gone. However, traces of the dualistic approaches are visible in for example the use of the "physical tests" and the "psychological responses". Inevitably, performance on the physical tests is affected by the patients psychological state (fear of pain may lead to unloading of the operated limb on hop tests for example) and the patients psychological responses are affected by their physical state (adequate strength and stability may lead to less fear and anxiety). It seems appropriate to reflect on this as we never measure just the psychological responses or the physical performance – they are just two aspects of a person's *overall readiness* for returning to sport.

10. Clinical implications

Psychological readiness and instrumented measurement of anterior-posterior translation in the knee were the only tests that were informative on ability to return to sport in the current cohort. Integrating these measures into return-to-sport assessments may therefore be useful. The Norwegian version of the ACL-RSI was found to be valid and reliable for assessing psychological readiness for return to sport and is therefore ready for use in the Norwegian population. The thorough factor analyses performed bring further knowledge on the measurement properties of the scale that can be used internationally.

The lack of predictive validity of the functional tests and the relatively small (but statistically significant) ORs for the ACL-RSI and KT-1000, suggest that there are many other factors that affect whether a patient chooses to return to sport or not. These factors should be mapped in close communication with the patient.

The finding of a low overall pass rate at time of return to sport in the current cohort is in line with reports from others and may have two important clinical implications (224, 234). First, it may indicate that evidence-based rehabilitation is not implemented in clinical practice because the patients still demonstrate functional deficits around the time they return to sport (48). Systematic and supervised rehabilitation is often terminated approximately six months after ACLR, around the time patients start contemplating sport resumption (224, 235). This is in spite of several reports of functional impairments (in both legs!) for up two years after surgery (236). Implementing this knowledge - to make sure that patients continue systematic training with proper progression and continued functional testing for up to two years post-surgery - is therefore important to assist patients in reaching their goals. Second, the low pass rates makes the clinical utility of the criteria questionable (139).

The finding that none of the patients who passed the return-to-sport criteria underwent further surgery or sustained a second knee injury is supported by others, and indicate that the test battery may be useful in predicting risk of re-injury.

However, different populations, tests and test criteria (cut-offs) are used in the studies and further studies on large populations are still needed to clarify the predictive validity on both re-injury risk and ability to return to sport. Clinicians should not be discouraged by the equivocal evidence, but exercise caution when they interpret results of their questionnaires and tests. Capin et al. (143) apty wrote “keep calm and carry on testing”. I take the liberty of adding to the phrasing and advice clinicians to “keep calm and carry on testing – but add evaluation of psychological readiness and knee laxity”.

11. Future perspectives

Based on the findings of the current studies and the other available evidence, it seems clear that we need to develop today's return-to-sport batteries further to make them more informative about the patients' readiness for returning and the safety of sport resumption. Since the work on this project started, a myriad of functional tests and criteria have been proposed (140). Many of them are designed to better mimic the challenges that athletes face in their sport with for example on-field testing and agility testing. However, before we start developing even more tests, the tests we have need to be sufficiently investigated in different populations. The current studies add knowledge about the test's predictive ability, however the number of patients who sustained new knee injuires was too low to perform regression analyses on risk of re-injury. The issue of whether return-to-sport tests can help us predict further knee injuries is therefore not resolved and future efforts are planned to expand the current cohort and answer this question. Further, rigorous methods (i.e. ROC analyses) are rarely used to determine the cut-off values that may form the basis for return-to-sport criteria. Using such methods may help us improve future test batteries.

A definition of what the construct of psychological readiness constitute has been proposed by Podlog et al. (172). However, there is a need for further investigation of the appropriateness of the construct. In the meantime, researchers should carefully describe how they define psychological readiness in relation to their work to avoid confusion.

So-called bridge programs are being developed to support athletes in the time period between being released from standard rehabilitation and returning to sport (approximately between 6 and 12 months after surgery). These programs have mainly consisted of physical interventions like lower extremity strengthening and neuromuscular training (i.e. agility, perturbations and plyometrics). Even without any specific psychological intervention, such programs show promise not only for improving function, but also for increasing psychological readiness and improving self-efficacy (237-239).

Even though a variety of techniques have been proposed to target negative psychological responses in the return-to-sport phase, only a few studies with small sample sizes and limited methodological quality explore such interventions (75, 240). Clinicians, i.e. physiotherapists, are in a favorable position to assist patients during rehabilitation and the return-to-sport process (75, 173). A potential approach to increase the patient's readiness for returning to sport, may be the use of strategies aimed at building the patient's *confidence* in the reconstructed knee (241, 242). An important next step is, therefore, to map, develop and test strategies to increase patients' overall readiness for returning to sport. Several focus areas have been suggested, such as realistic goal setting, visual imagery, facilitating social support and feelings of control while reducing feelings of external pressure (76). Routine screening for maladaptive psychological responses, such as lack of motivation and psychological readiness, has also recommended (76). Further, most of the qualitative studies on interventions to improve psychological readiness have included those who managed to return to sport. Interviewing patients who were not able to return may add new knowledge to this field (243).

12. Conclusions

In this cohort of mainly non-professional athletes, the return-to-sport rate was 42%. Psychological readiness, age and instrumented knee laxity predicted return to sport. The Norwegian version of the ACL-RSI is valid and ready for use to assess psychological readiness for return to sport in the Norwegian population. There was a small, but statistically significant association between the ACL-RSI and anterior-posterior knee laxity. This indicates that how psychologically ready patients feel for returning to sport is to a small degree affected by the anterior-posterior laxity in their knee. Fourteen percent of the patients sustained re-injuries from return-to-sport assessment to two years post-surgery. This was too low of a number to perform analyses on the test battery’s predictive ability for re-injury risk. However, none of the patients who passed the return-to-sport criteria sustained new knee injuries during the follow-up period - indicating that physical tests may have a role in predicting re-injury. At this point, we need to acknowledge that the validity of return-to-sport tests are uncertain and results from the tests should be interpreted with caution.

13. References

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Anterior cruciate ligament—return to sport after injury scale: validation of the Norwegian language version

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Abstract

Purpose Evidence is emerging on the importance of psychological readiness to return to sport after anterior cruciate ligament (ACL) reconstruction. The ACL-Return to Sport after Injury scale (ACL-RSI) is developed to assess this. The aim of the current study was to translate ACL-RSI into Norwegian and examine the measurement properties of the Norwegian version (ACL-RSI-No).

Methods ACL-RSI was translated according to international guidelines. A cohort of 197 ACL-reconstructed patients completed ACL-RSI-No and related questionnaires nine months post-surgery. One hundred and forty-six patients completed hop tests and 142 patients completed strength tests. Face and structural validity (confirmative factor analysis and explorative analyses), internal consistency [Cronbach's alpha (α)], test–retest reliability [Intraclass Correlation Coefficients (ICC)], measurement error [Standard error of measurement (SEM) and smallest detectable change at individual (SDC_{ind}) and group level (SDC_{group})] and construct validity (hypotheses testing; independent *t* tests, Pearson's *r*) were examined**.**

Results ACL-RSI-No had good face validity. Factor analyses suggested that the use of a sum score is reasonable. Internal consistency and test–retest reliability were good (α 0.95, ICC 0.94 (95% CI 0.84–0.97) and measurement error low (SEM 5.7). SDC_{ind} was 15.8 points and SDC_{group} was 2.0. Six of seven hypotheses were confirmed.

Conclusions ACL-RSI-No displayed good measurement properties. Factor analyses suggested one underlying explanatory factor for "psychological readiness"—supporting the use of a single sum score. ACL-RSI-No can be used in the evaluation of psychological readiness to return to sport after ACL injury.

Level of evidence III.

Keywords ACL-RSI · ACL reconstruction · Return to sports · Psychological response · Psychological readiness · Fear of injury

Abbreviations

ACL	Anterior Cruciate Ligament
ACLR	Anterior Cruciate Ligament reconstruction
ACL-RSI	Anterior Cruciate Ligament-Return to Sport after Injury (Scale)
ACL-RSI-No	Anterior Cruciate Ligament-Return to Sport after Injury (Scale)-Norwegian Version
CFA	Confirmatory factor analysis
CFI	Comparative fit index
CI	Confidence interval
Cm	Centimeters
COSMIN	Consensus-based Standards for the selection of health Measurement Instruments
DF	Degrees of freedom
EFA	Exploratory factor analysis
ICC	Intraclass correlation coefficient
IKDC 2000	International Knee Documentation Committee Subjective Knee Form 2000

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KOOS	The Knee injury and Osteoarthritis Outcome Score
LoA	Limits of Agreement
LSI	Leg symmetry index
MIC	Minimal important change
Nm	Newton-meters
NSD	Norwegian Centre for Research Data
PCA	Principle component analysis
QoL	Quality of life
r	Pearson product moment correlation coefficient
RMSEA	Root mean square error of approximation
RTS	Return to sports
SD	Standard deviation
SDC	Smallest detectable change
SDC_{ind}	Smallest detectable change at individual level
Sec	Seconds
SEM	Standard error of measurement
SRMR	Standardized root mean square residual
TSK	Tampa Scale of Kinesiophobia
W	Watt

Introduction

A majority of patients with an anterior cruciate ligament (ACL) tear choose to undergo surgery since their aim is to return to pre-injury level of sports [1, 2]. Recent research brings daunting news for these patients as up to 30% are reported to experience recurrent instability or a new ACL injury in the contralateral knee [3, 4]. In spite of stabilizing surgery and extensive postoperative rehabilitation, up to 40% of patients fail to return to their pre-injury level of sports and less than half return to competitive sport [1, 5].

Rehabilitation after ACL reconstruction (ACLR) has been focused on identifying, measuring and treating physical factors like muscle strength and neuromuscular function [6]. Over the past decade, several reports have displayed how fear of re-injury is a common reason for changing or ceasing sports participation—thereby increasing the focus on psychological responses [1, 5]. The term "psychological readiness" is frequently used to describe mental factors influencing return to sports (RTS) after ACL injury. These factors include realistic expectations, confidence in performance, high levels of self-efficacy and low levels of fear and anxiety [6].

Low fear of re-injury and high "psychological readiness" have been found to favor a return to pre-injury level of sport [1, 5, 7]. It is not necessarily desirable for the patients to remove fear completely, as some reservation may be protective in the gradual return to vigorous activity [6]. Nevertheless, if patients make well-informed choices aiming to RTS, assessing psychological readiness can aid clinicians in identifying patients who are inhibited by inexpedient mental responses. Hopefully, early detection can lead to proper interventions in a joint effort towards reaching the athletes' goals.

The Anterior Cruciate Ligament-Return to Sport after Injury (ACL-RSI) scale was developed with the aim of identifying patients who may struggle with the resumption of sports [7]. The questionnaire covers key aspects of psychological readiness for RTS including emotions (e.g. fear and frustration), confidence in performance and risk appraisal [7]. These aspects are hypothesized to be intimately related and evidence for one common construct, named "psychological readiness", exists. This means that one underlying construct account for most of the variance in scores on the ACL-RSI—therefore, the use of one single sum score on the scale can be justified [2, 7–10]. The ACL-RSI has several translations all reported to have adequate to good measurement properties [2, 9, 11–14]. Currently, no Norwegian translation of the scale exist.

Previous evidence on structural validity of ACL-RSI has been based on principal component analysis (PCA) [2, 7, 9, 10]. In the current study, a confirmative factor analysis (CFA) was planned as this has not been performed on the ACL-RSI previously. CFA is highly recommended when a predetermined hypothesis on the construct exist [15, p. 72]. The hypothesis was that a Norwegian version of ACL-RSI (ACL-RSI-No) would be valid and reliable—and that one common construct (psychological readiness) for all items of ACL-RSI could be confirmed (one-factor solution). The aim of the present study was to provide Norwegian clinicians with a tool to pinpoint patients who may struggle with RTS and, further expand knowledge on validity of the ACL-RSI by translating the scale from English to Norwegian and examine face and structural validity, internal consistency, test–retest reliability, measurement error and construct validity.

Materials and methods

The study was approved by the NSD (Norwegian Centre for Research Data) Data Protection Official for Research, project number 44708 and the Regional Committee for Medical and Health Research Ethics West 2015/1159.

Patients who had undergone ACLR at three Norwegian Orthopedic Centers were recruited from 2015 to 2018. They were eligible for participation if ≥ 16 years at the time of follow-up, fluent in Norwegian and had engaged in physical activity or sports. Patients with concomitant posterior cruciate ligament injury were excluded. All patients were asked to give their written, informed consent.

Two hundred and twenty-nine patients met the inclusion criteria and all of these volunteered for the study (see Fig. 1 for flowchart and Tables 1 and 2 for demographic data and descriptive statistics on the measurements).

Translation and cross-cultural adaptation

ACL-RSI was translated and cross-culturally adapted into Norwegian applying the guidelines described by Beaton and colleagues involving the author of the original scale [16]. As part of this work, an expert committee consisting of two researchers experienced in questionnaire translation, six health professionals (three physiotherapists specializing in orthopedic physiotherapy, two orthopedic surgeons, one psychologist) and two language professionals were established. Five patients who had undergone ACLR completed the questionnaire and were interviewed about their interpretation of questions and potential ambiguities in wording. Face validity and cultural adaptation of the Norwegian version were assessed by both the expert committee and testers of the pre-final version.

Test procedure

Participants completed a battery of questionnaires nine to twelve months after surgery—the point where many consider RTS [1]. In one of the centers (recruiting the majority of patients), patients underwent functional testing (single-leg hop tests and isokinetic strength tests) for assessment of readiness to RTS after questionnaire completion. Patients recruited from the two other centers received questionnaires by mail.

Table 1 Baseline patient characteristics, including pre-injury activity/sport level and main types of activity/sports performed ($N = 197$)

Characteristics	
Age, mean (SD), min–max	29.5 (9.7), 16–53
Gender, *N* (%), men	107 (54)
Months after ACLR, mean (SD), min–max	11 (2.0), 7.8–20.6
Hamstrings tendon graft, *n* (%)	64 (33)
Patellar tendon graft, *n* (%)	115 (59)
Quadriceps tendon graft, *n* (%)	6 (3)
Revisions, *n* (%)	12 (6)
Preinjury level of activity/sport	
Elite, *n* (%)	13 (7)
Medium to high level of competition, *n* (%)	59 (30)
Low level of competition, *n* (%)	64 (32)
Recreational level, *n* (%)	61 (31)
Three main primary activities/sports	
Soccer, *n* (%)	94 (48)
Alpine skiing, *n* (%)	21 (11)
Handball, *n* (%)	19 (10)

The *ACL-RSI* comprises 12 questions where patients grade their answers on a Likert scale ranging from zero to 100 with ten-point increments [7]. Higher scores indicate greater psychological readiness towards RTS [10]. The *International Knee Documentation Committee Subjective Knee Form (IKDC) 2000* measures symptoms, function and sports activity in a variety of knee conditions (including

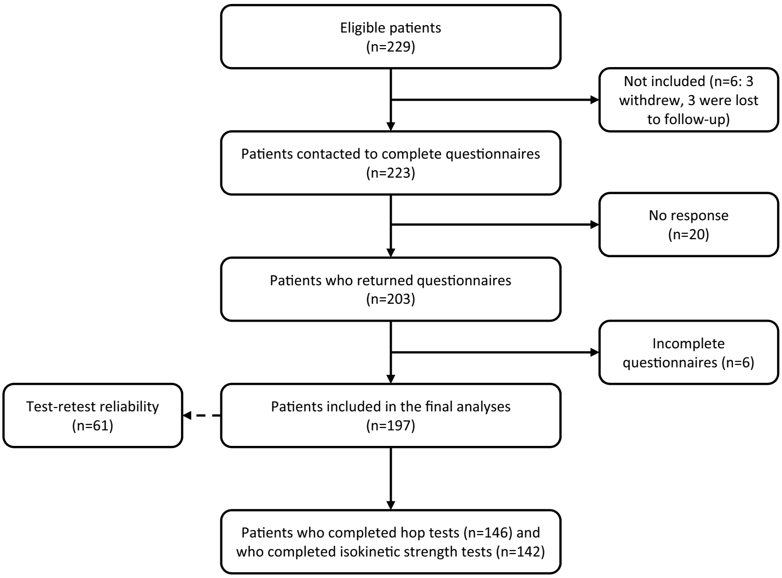

Fig. 1 Flowchart of patients' participation

Table 2 Descriptive statistics on measurements used in hypothesis testing ($N=197$)

Measurements	Mean (SD), min–max	Pearson's r	p-value
ACL-RSI	55.7 (23), 0–100		
IKDC 2000	78.7 (13.2), 26.4–100	0.61	<0.01
TSK[a]	24.3 (6.1), 13–47	− 0.34	<0.01
KOOS pain	89.4 (9.9), 44–100	0.48	<0.01
KOOS symptoms	83.4 (12.5), 43–100	0.37	<0.01
KOOS function in daily living	95.9 (7.4), 54–100	0.43	<0.01
KOOS function in sport and recreation[b]	73.7 (19.6), 5–100	0.49	<0.01
KOOS knee-related Quality of Life	64.7 (18.1), 6–100	0.66	<0.01
Hop test, LSI %[c]	95.5 (9.2), 44.8–112.4	0.28	<0.01
PT extension 60°/s LSI %[d]	−17.7 (14.8), −60.2 to 30.5	0.17	0.04
PT flexion 60°/s LSI %	−4.3 (17.5), −47.4 to 49.5	0.14	n.s
TW extension 60°/s LSI %	−11.6 (15.6), −59.6 to 42.5	0.13	n.s
TW flexion 60°/s LSI %	2.9 (28.3), −56.7 to 109.7	0.10	n.s

Includes correlations (Pearson's r) between nine-month follow-up scores on ACL-RSI-No, and measures of fear of movement and function

ACL-RSI Anterior Cruciate Ligament-Return to Sports after Injury Scale, *IKDC 2000* The International Knee Documentation Committee Subjective Knee Form 2000, *TSK* Tampa Scale of Kinesiophobia, *KOOS* The Knee injury and Osteoarthritis Outcome Score, *LSI* Leg Symmetry Index, *PT* peak torque, *TW* Total Work

[a]1 missing questionnaire in TSK

[b]2 missing questionnaires in KOOS subscales Sport and recreation and Quality of Life

[c]146 patients completed hop tests

[d]142 patients completed isokinetic strength tests, invalid results for flexion in three of these

ligament surgeries) with score range from zero (low function) to 100 (high function) [17]. The *Tampa Scale of Kinesiophobia (TSK)* measures fear of movement in patients with low back pain [18] but has also been used to examine fear of re-injury in patients with ACL injuries [19]. The *Knee injury and Osteoarthritis Outcome Score (KOOS)* was developed for patients with knee injuries and/or osteoarthritis and is frequently used in patients after ACLR. It comprises five domains: pain, other symptoms, function in daily living, function in sports and recreational activities and quality of life (QoL) [20]. Total score of each subscale ranges from zero to 100 where a higher score indicates good function [21]. A custom-made questionnaire included questions about the surgery, previous injuries/surgeries, type and level of activity/sport performed before injury and status on RTS after ACLR. Level of participation was categorized as elite level, medium/high level of competition, low level of competition and recreational level.

The single-leg hop tests comprise four tasks: a single hop for distance (centimeters (cm)), a triple hop for distance (cm), a six-meter timed hop (seconds (sec)) and a triple crossover hop for distance (cm). Results are presented as a percentage difference between the performance of the limbs (Leg Symmetry Index, LSI %) for each test individually and as a sum score where all four tests are combined. The hop tests are reliable and valid performance tests for patients undergoing rehabilitation after ACLR, with reported test–retest Intra-class Correlation Coefficient (ICC) of 0.93 and Standard error of measurement (SEM) 3.0 for the sum score of all four tests [22, 23].

Isokinetic strength testing of knee flexion and extension was performed at 60°/sec (five repetitions) angular velocity using a dynamometer system (Biodex system 3 dynamometer, Biodex Medical Systems Inc., Shirley, New York). Performance is reported as an LSI (%) in peak torque (Newton-meters, Nm) and total work (Watt, W). Isokinetic strength testing is reliable (test–retest ICCs for peak torque and total work >0.90) and considered to be the gold standard performance measure in ACL rehabilitation [24, 25].

Examination of measurement properties

The Consensus-based Standards for the selection of health Measurement Instruments (COSMIN) were applied [26, 27]. These guidelines provide definitions and criteria for evaluation of the quality of a questionnaire's measurement properties.

For evaluation of *structural validity*, CFA was performed to examine whether the proposed one-factor solution (psychological readiness) had a good fit to the data. Descriptive goodness-of-fit indices were used: Chi square, standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA) and comparative fit index (CFI) [28, pp. 67–73]. The recommended criteria for good fit of a model are CFI close to or higher than 0.95, SRMR close to or lower than 0.08 and RMSEA close to or lower than 0.06 [29]. If a poor fit was found, explorative analyses would be applied to determine whether the scale was unidimensional enough to be treated as such or if more factors were needed to model the item responses [30].

Internal consistency was assessed by Cronbach's alpha coefficient (α): 0.70 is acceptable, 0.80 is preferable and >0.95 might indicate item redundancy [27]. *Test–retest reliability* was examined in a subgroup of 61 patients—1 week prior to and again at the start of the follow-up evaluation. Two-way random $ICC_{2.1}$ for relative reliability was calculated [27]. The ICC should be at least 0.70 (0.70–0.89 indicate high correlation, 0.90–1.00 indicate very high correlation) [15, p. 120]. To establish absolute reliability, which is an expression of the *measurement error*, SEM was calculated from the mean of the variances between tests [27]. A 95% Confidence Interval (CI) of SEM was made to suggest the limits of measurement error (1.96*SEM). Based on SEM, smallest detectable change at individual level (SDC_{ind}) was calculated ($1.96 \times \sqrt{2} \times SEM$), reflecting the smallest change score that with $P<0.05$ can be interpreted as real change, not measurement error. The SDC for a group of persons (SDC_{group}) was calculated ($SDC_{ind}/\sqrt{n}$) [27]. Limits of Agreement (LoA) was evaluated using a Bland–Altman plot [15, p. 113].

Construct validity with hypothesis testing is recommended when there is no gold standard to compare the scores on the measurement instrument to [15, p. 169]. Predefined hypotheses were formed based on validation studies of ACL-RSI, studies on RTS after ACLR, findings from previous translations and clinical experience (for hypotheses, see Table 5). A disparity between performance on functional tests and RTS has been highlighted as a reason for focusing on psychological responses in ACL rehabilitation [1]. We, therefore, included hypotheses on associations between functional tests and ACL-RSI. Correlations were investigated using Pearson's r; 0.10–0.29 were considered small, 0.30–0.49 medium and 0.50–1.0 large [31, pp. 79–81]. For discriminative ability, independent t tests were used.

The ACL-RSI-No as a whole and each individual item was examined for *floor and ceiling effects*. If more than 15% of the patients achieve the lowest or highest score possible on the scale, this suggests that floor or ceiling effects are present [32].

Statistical analysis

IBM SPSS Statistics Version 24.0 software was used for descriptive statistics, testing of normality, the examination of internal consistency, test–retest reliability, Bland–Altman plot, hypothesis testing (significance level $P<0.05$ for t tests) and floor and ceiling effects. For continuous variables, means and standard deviations (SD) are presented and for categorical variables absolute and relative frequencies are presented. CFA, scree plot and parallel analysis were performed using JASP (Version 0.9). Measurement error was calculated in Microsoft Excel 2010.

Results

The expert committee and the five testers agreed that the ACL-RSI-No had good *face validity* with relevant content for the patient group at the time of administration. The questions were easy to understand and contained aspects of importance for RTS that were not covered in the other questionnaires. No special cultural adaptation was recommended.

Results from the *CFA* displayed that a one-factor solution had a poor fit to the data (Chi Square 274.80 (degrees of freedom (df) 54, $P<0.01$), SRMR 0.05, RMSEA 0.14 (95% CI 0.13–0.16, $P<0.01$) and CFI 0.90). Correlations between 15 pairs of residuals were needed to achieve a satisfactory fit by conventional standards and COSMIN criteria (χ^2 64.30 (df = 39, $P<0.01$), SRMR 0.03, RMSEA 0.06 (95% CI 0.03–0.08, n.s. and CFI 0.99). Further explorative analyses were, therefore, conducted. These suggest that treating the scale as unidimensional is justified: The reliability of the one-factor solution (when the correlated error terms were accounted for) was high (0.93), which means that 93% of the variance of the scale is explained by true variance (the common factor). The size of the factor loadings in the one-factor CFA solution remained robust (none of the factor loadings changed more than 3%) regardless of whether the correlated error terms were included in the model or not. Inspection of scree plot and parallel analysis strongly indicate a one-factor solution (Fig. 2). The ratio

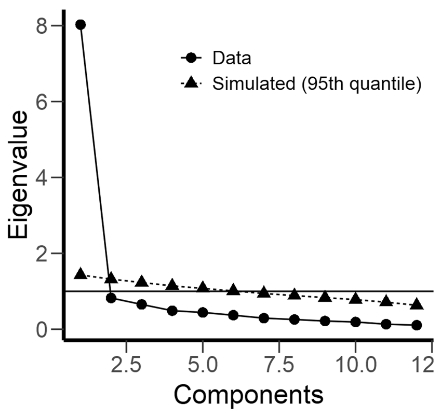

Fig. 2 Scree plot and parallel analysis

Table 3 ACL-RSI-No scores in returners and non-returners to pre-injury activity/sport and pre-injury level of activity/sport ($N = 197$)

	Yes Mean (SD)	No Mean (SD)	Mean difference	95% CI of difference	*p*-value
Return to same activity	68.0 (19.5) $n = 95$	44.2 (19.9) $n = 102$	23.9	18.3–29.4	< 0.01
Return to same level	70.6 (18.6) $n = 48$	50.8 (22.3) $n = 149$	19.8	12.8–26.8	< 0.01

ACL-RSI Anterior Cruciate Ligament-Return to Sports after Injury Scale

Table 4 Test re-test reliability of the ACL-RSI-No ($N = 61$)

ACL-RSI-No 1. administration, mean (SD)	49.6 (22.0)
ACL-RSI-No 2. administration, mean (SD)	53.8 (24.2)
Mean difference	4.2
ICC 2.1. (95% CI)	0.94 (0.84–0 .97)
SEM	5.7
1.96*SEM	11.2
SDC individual	15.8
SDC group	2.0

ACL-RSI Anterior Cruciate Ligament-Return to Sports after Injury Scale, *ICC* Intra-class Correlation Coefficient, *SEM* Standard Error of Measurement, *SDC* Smallest Detectable Change

between the two first eigenvalues was eight. A two-factor explorative factor analysis (EFA) was performed and correlation between the extracted factors was very high (0.85). This suggests lack of discriminative validity and further support the fact that item responses are determined by one dominant factor.

Internal consistency (α) was 0.95 which is close to the model-based alpha derived from the CFA (0.93). *Test–retest reliability* was very high (Table 3). Measurement error (SEM) was 5.7 implicating that change in score for one individual needs to exceed 15.8 points and on group level 2.0 to be interpreted as true change (exceeding measurement error). For LoA, see Bland Altman Plot in (Fig. 3).

Six of seven pre-formulated hypotheses were confirmed indicating good *construct validity* (Tables 2, 4 and 5). The hypothesis on a small correlation between ACL-RSI-No and isokinetic strength tests was not supported. A small, but statistically significant ($P = 0.04$) correlation was found between ACL-RSI-No and performance on extension peak torque LSI at 60°/s, but for the rest of the isokinetic strength tests no significant association was found.

No *floor or ceiling effects* were found for the overall score (0.5% of the patients had the lowest possible score (zero) and 0.5% had the highest score (100)). 3% of patients had a sum score of 10 or less and 5% had a score of 90 or more. For each question, the percentage of patients who had the lowest possible score ranged from 2 to 17%. The percentage of patients who had the highest score on each item ranged from 3 to 20%. Mean score on the individual items varied between 41.2 (SD 31.3) and 64.3 (SD 27.6).

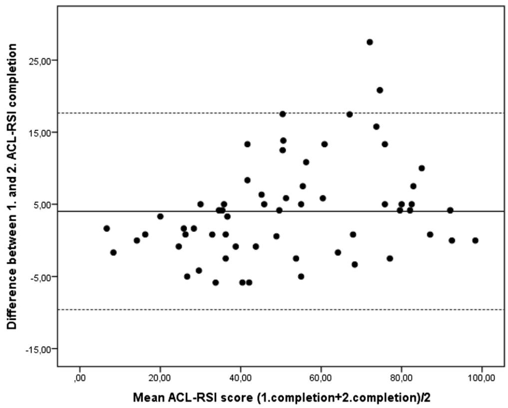

Fig. 3 Bland Altman Plot displaying Limits of Agreement

Discussion

The most important finding of the present study was support for good validity and high reliability of the ACL-RSI-No. Six of seven hypotheses were confirmed providing evidence for good construct validity. In the factor analyses, support for a one-factor structure (psychological readiness) was found—justifying the current use of a single sum score (from 0 to 100) for the scale.

Support for an one-factor solution (psychological readiness to return to sport) has been found in previous studies using PCA, except for the Spanish version were two dimensions (confidence in performance and fear/insecurity) were found [2, 7, 9, 10, 33]. PCA is widely used but has limitations as it is a data reduction method computed without regard for latent variables [34]. In accordance with COSMIN recommendations, the current study, therefore, started with CFA to evaluate whether the items fit a one-factor solution [15, p. 169]. As the analysis indicated an inadequate fit, explorative analyses were applied to determine whether the scale is unidimensional enough to be treated as such [30]. Findings from these analyses suggest that it is probably most parsimonious to treat the scale as essentially unidimensional: The scree plot and

Table 5 Pre-defined hypotheses, including the result of hypothesis testing: + hypothesis confirmed, – hypothesis not confirmed

1	Patients who have returned to *pre-injury activity or sport* (at any level) have a significantly higher score on the ACL-RSI-No than those who have not returned	+
2	Patients who have returned to *pre-injury level* have a significantly higher score on the ACL-RSI-No than those who have not returned	+
3	There is a medium to large correlation ($0.30 < r < 0.60$) between IKDC 2000 and ACL-RSI-No	+
4	There is a medium to large negative correlation ($-0.30 < r < -1.0$) between TSK and ACL-RSI-No	+
5	There is a medium correlation ($0.30 < r < 0.49$) between KOOS and ACL-RSI-No and a large correlation ($0.50 < r < 1.0$) between KOOS QoL and ACL-RSI-No	+
6	There is a small to medium correlation ($0.10 < r < 0.49$) between the hop test (LSI % averaged sum score of all four tests) and ACL-RSI-No	+
7	There is a small correlation ($0.10 < r < 0.29$) between the isokinetic strength tests and ACL-RSI-No	–

parallel analysis displayed that the ratio between the two first eigenvalues was well above the recommended rule of thumb (which is three) for regarding a scale as essentially unidimensional [30]. In line with this finding, the single factor in the CFA explained as much as 93% of the variance in ACL-RSI-No scores. The two-factor solution (EFA) had poor discriminative ability and is not recommended [28, p. 146]. Item response data is seldom strictly unidimensional and it is well known that it can be determined by a strong common factor even when the fit of a one-factor solution does not meet the recommended criteria of good fit [35]. To our knowledge, the current study is the first to apply CFA in the investigation of ACL-RSI factor structure. More studies applying such methodology should, therefore, follow the current work.

The finding of high test–retest reliability is in line with previous results [2, 9, 11, 13, 14]. For this study, a week between completions was chosen to ensure that the questionnaire was not fresh in memory at second administration which is recommended by Terwee et al. [27]. The phenomenon of psychological readiness to RTS was expected to be relatively stable in this period.

In the current study, SDC was calculated, providing information on how much scores must change to be interpreted as change exceeding measurement error [27]. The SDC should be smaller than the amount of change that is considered *clinically meaningful* (Minimal Important Change, MIC) [21]. To allow for the evaluation of treatment or monitor changes in health status (longitudinal validity), the questionnaire should be able to detect changes over time [15, pp. 202–203]. In this study, MIC and longitudinal validity were not assessed. For the Dutch version of ACL-RSI, responsiveness has been found to be sufficient on group level but limited for individuals [36].

Support for good construct validity was found as six of seven pre-defined hypotheses were confirmed. Patients who returned to pre-injury activity scored significantly higher on ACL-RSI-No than patients who had not returned – indicating good discriminant validity of the scale. This finding is in line with previous studies [2, 7, 13]. The finding of medium to large associations between the ACL-RSI-No and the IKDC 2000 and KOOS also corresponds to results from other studies [2, 9, 11, 13, 14]. IKDC 2000 and KOOS assess constructs of symptoms, pain and function [17, 20]. We, therefore, hypothesized some association between low levels of symptoms/pain and higher levels of functioning and psychological readiness to RTS. Since fear of re-injury, confidence and emotions are not directly assessed in IKDC 2000 and KOOS, we did not expect large associations. For the current young and active population, it is reasonable to infer that the ability to return to an active lifestyle is intimately related to high QoL. This may explain the finding of a high correlation between ACL-RSI-No and KOOS QoL. A higher score on the TSK has been associated with not returning to sport and inferior self-reported function [37]. The TSK displayed a medium negative correlation with ACL-RSI-No. This is slightly different from others reporting medium to large negative correlations and may possibly be explained by the use of the 13-item version (the only Norwegian translation available) in the current study compared to the 17-item version the other studies [2, 9, 11, 13, 14, 38].

Psychological and physical readiness to RTS does not necessarily coincide [1]. Physical function and psychological aspects are quite different constructs. Still, if a patient experiences a stable and well-functioning knee this will probably affect the psychological responses. Others have found a weak correlation with isokinetic strength tests and hop tests [39]. Therefore, a small significant correlation between performance on functional tests and ACL-RSI-No score was expected. This was confirmed for hop tests, but not for strength tests (except for a small, significant association for extension peak torque) in the current study. These results support the clinical observation that patients may score poorly on the ACL-RSI while performing well on physical tests and vice versa. This is a critical finding since the use of physical tests—such as dynamometer testing or hop-testing—is at current a dominant approach in RTS assessment [6, 40]. Studies aiming to evaluate psychological responses as part of the RTS testing are, therefore, warranted.

The current population is comparable to the populations described in studies of the original version of ACL-RSI and other language translations. Most studies include both elite athletes and patients involved in recreational activities, but different methods for describing type and level of sport makes comparing activity level across the studies difficult [2, 7, 9, 11–14]. A difference between studies in the postoperative time for assessment (from six to 24 months) should be taken into consideration as it might affect comparability.

The prospective design and large number of participants included in analyses represent strengths of the current work. A thorough factor analysis, including exploration of associations between physical tests and psychological responses, adds new knowledge to this research field. Our motivation for validation of a Norwegian version the ACL-RSI was to nuance the assessment of readiness to RTS after ACLR. This assessment is commonly performed approximately nine months after surgery [41], therefore—validation of the questionnaire in the timeframe it is intended used, pose a further strength of the study.

In the examination of construct validity, the measurement properties of the related questionnaires are important [15, p. 174]. The IKDC is reported to be valid in patients with mixed knee pathologies and injuries, but evidence on validity in ACL injured patients is limited with reports of problems with structural validity and in distinguishing clinically relevant changes from measurement error [42–44]. KOOS has been criticised for not having adequate measurement properties for use in patients after ACLR [21, 45]. Limited information is available about the Norwegian versions of IKDC 2000, TSK and KOOS. A proper assessment of measurement properties of the Norwegian IKDC 2000 has not been performed, procedures for translating KOOS are not published and TSK was validated for patients with sciatica [38, 46]. Although the Norwegian versions of IKDC 2000, KOOS and TSK are in widespread use and are well accepted in clinical and research communities—limitations in the comparative use of these questionnaires should be acknowledged.

The current study adds to the growing evidence on the validity of the ACL-RSI and implies that clinicians need to use more than physical tests in their evaluation of readiness to RTS after ACLR. Norwegian clinicians are provided with a tool to evaluate psychological readiness during rehabilitation and in RTS assessment to complement the physical tests.

Conclusions

The Norwegian version of ACL-RSI has adequate to good measurement properties and can, therefore, be applied for use in the evaluation of psychological readiness to return to sport after ACL injury.

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Author contributions AF: Conception and design of study, acquisition of data, analysis and interpretation of data and drafting of manuscript. EI: Conception of study, acquisition, analysis and interpretation of data and critically revising manuscript. WV: Conception and design of study, acquisition of data and critically revising manuscript. KB: Acquisition, analysis and interpretation of data and critically revising manuscript. BB: Conception and design of study, acquisition of data, analysis and interpretation of data and critically revising manuscript. IM: Acquisition of data and critically revising manuscript. IT: Acquisition of data and critically revising manuscript. TS: Acquisition of data and critically revising manuscript. LM: Conception and design of study, acquisition of data, analysis and interpretation of data and critically revising manuscript.

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Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to declare.

Ethical approval The study was approved by the NSD (Norwegian Centre for Research Data) Data Protection Official for Research, project number 44708 and the Regional Committee for Medical and Health Research Ethics West 2015/1159.

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The Role of Psychological Readiness in Return to Sport Assessment After Anterior Cruciate Ligament Reconstruction

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Background: Knowledge about the predictive value of return to sport (RTS) test batteries applied after anterior cruciate ligament reconstruction (ACLR) is limited. Adding assessment of psychological readiness has been recommended, but knowledge of how this affects the predictive ability of test batteries is lacking.

Purpose: To examine the predictive ability of a RTS test battery on return to preinjury level of sport and reinjury when evaluation of psychological readiness was incorporated.

Study Design: Cohort study; Level of evidence, 2.

Methods: A total of 129 patients were recruited 9 months after ACLR. Inclusion criteria were age ≥16 years and engagement in sports before injury. Patients with concomitant ligamentous surgery or ACL revision surgery were excluded. Baseline testing included single-leg hop tests, isokinetic strength tests, the International Knee Documentation Committee (IKDC) Subjective Knee Form 2000, a custom-made RTS questionnaire, and the Anterior Cruciate Ligament-Return to Sport after Injury (ACL-RSI) scale. The RTS criteria were IKDC 2000 score ≥85% and ≥85% leg symmetry index on hop and strength test. At a 2-year follow-up evaluation, further knee surgery and reinjuries were registered and the RTS questionnaire was completed again. Regression analyses and receiver operating characteristic analyses were performed to study the predictive ability of the test battery.

Results: Out of the 103 patients who completed the 2-year follow-up, 42% returned to their preinjury level of sport. ACL-RSI 9 months after surgery (odds ratio [OR], 1.03) and age (OR, 1.05) predicted RTS. An ACL-RSI score <47 indicated that a patient was at risk of not returning to sport (area under the curve 0.69; 95% CI, 0.58-0.79), with 85% sensitivity and 45% specificity. The functional tests did not predict RTS. Six patients sustained ACL reinjuries and 7 underwent surgery for other knee complaints/injuries after RTS testing. None of the 29 patients who passed all RTS criteria, and were therefore cleared for RTS, sustained a second knee injury.

Conclusion: ACL-RSI and age were predictors of 2-year RTS, while functional tests were not informative. Another main finding was that none of the patients who passed the 85% RTS criteria sustained another knee injury.

Keywords: anterior cruciate ligament (ACL); return to sports; ACL reinjury; psychological aspects of sport

The definition of success after anterior cruciate ligament reconstruction (ACLR) is a matter of ongoing debate.[2,29,33] For many patients, the major concern is whether a safe return to sport (RTS), without incurring reinjuries, is possible. A common expectation is to return to the preinjury level of sport participation, often in demanding activities involving jumping, pivoting, and cutting.[2,3,14,21] These goals seem difficult to reach, as recent reports suggest that only 65% of patients return to their preinjury level of sport and only 55% to competitive sports.[3] For those who return to cutting or pivoting sports, the risk of reinjury is high. Up to 30% suffer a second ACL injury, with the young, active population at greatest risk.[9,40,41,52]

RTS testing after ACLR has emerged to help assess patients' readiness for the resumption of former activities. A range of test batteries with various criteria for RTS has been suggested.[2,7,40,53] As there is little knowledge on the validity of these tests, we do not know which test—or combination of tests—can help us predict a timely and safe RTS.[2,10,28,40,49] Establishing predictive validity is therefore a much-needed step in the further development of readiness test batteries.[2,10,45]

RTS is multifactorial, requiring both physical and psychosocial recovery after surgery.[5,10] Physical functioning assessment has traditionally dominated RTS evaluation, but there is emerging evidence for incorporating psychological factors in these decisions.[2-4,6,25] The Anterior Cruciate Ligament–Return to Sport after Injury (ACL-RSI) scale

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evaluates patients' psychological readiness to RTS. Adding the scale in the RTS assessment is recommended,[2,34,51] but little is known about how this affects the predictive validity of RTS test batteries.

Therefore, the aim of this study was to examine the predictive ability of a commonly used test battery on return to preinjury level of sport and reinjury when evaluation of psychological readiness was incorporated. The hypothesis was that a combination of physical function and psychological readiness would better predict success than physical function alone.

METHODS

Patient Selection

From 2015 to 2018, patients in this cohort were prospectively recruited at the 9-month follow-up after ACLR at a local hospital's orthopaedic clinic. Inclusion criteria were age ≥16 years at inclusion, fluency in Norwegian, and being engaged in physical activity or sports before injury. Exclusion criteria were concomitant ligamentous surgery or ACL revision surgery. Patients who declined functional testing, or had incomplete test battery results (ie, were unable to perform hop tests), were excluded from analyses. Of 147 patients screened for eligibility, 129 were enrolled in the study after exclusions (Figure 1). All patients gave their written, informed consent before inclusion. The study was approved by the regional committee for medical and health research ethics (ID No. 2016/1896). Patients in this cohort also participated in a validity study of the Norwegian language version of the ACL-RSI.[13] All patients recruited to the validity study from the current clinic were screened for eligibility in the present study.

Testing Procedure

Baseline testing of all patients was performed 9 months after ACLR. At this point, any early ACL reinjuries to the same, or contralateral, knee were registered. A custom-made RTS questionnaire was completed (Table 1). To enhance comparability with other studies, sports levels were also defined by the International Knee Documentation Committee (IKDC) as Level I sports, which include pivoting, hard cutting, and jumping movements (ie, soccer); Level II sports, which comprise lateral movements and sports with lesser pivoting (ie, alpine skiing); and Level III sports, which involve straight-ahead activities (cycling and running).[17,18,21]

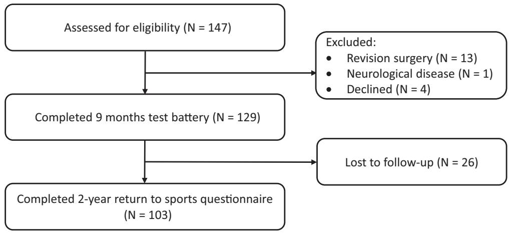

Figure 1. Flowchart of study participants.

Measurements

The ACL-RSI scale was used to measure psychological readiness for RTS.[51] The questionnaire comprises 12 questions covering key aspects of RTS: emotions related to returning (eg, fear and frustration), confidence in sports performance, and appraisal of reinjury risk.[51] For example, a question about reinjury is "Are you fearful of reinjuring your knee by playing your sport?"[51] Patients grade their answers from zero to 100 with 10-point increments. A total score is calculated as the average of the responses on each question, and higher scores indicate greater psychological readiness.[50,51] The Norwegian version of the ACL-RSI is valid and reliable for patients after ACLR.[13]

The IKDC Subjective Knee Form 2000 was used to measure symptoms, function, and sports activity.[23] The score ranges from zero (low function) to 100 (high function).[23] The IKDC 2000 has adequate validity and reliability for patients with knee injuries.[11,23]

The single-leg hop test was used as a performance test to measure dynamic knee stability.[15] It comprises 4 tasks: single hop for distance (in centimeters); triple hops for distance (in centimeters); triple crossover hops for distance (in centimeters); and 6-m timed hops (in seconds).[35,37] The uninvolved leg was tested first. The results are presented as a mean Limb Symmetry Index (LSI%; the percentage difference in the performance between limbs) of the 4 tasks. A score of 100% means there is complete symmetry in the performance of the legs. Values <100 indicate a deficit in the involved leg.[40] Hop tests are reliable and valid for patients after ACLR.[27,44]

Concentric knee extension strength was measured at 60 deg/s (5 repetitions) angular velocity using an isokinetic dynamometer testing system (Biodex System 3 Dynamometer; Biodex Medical Systems Inc). The uninvolved leg was tested first. Performance is reported as an LSI (%) in peak torque (PT) Newton meters (N·m). Isokinetic strength tests are reliable and valid outcome measures after ACLR.[47,49]

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TABLE 1
Sports and Activity Before and After ACLR[a]

Questions		Answer Options
1.	What was your main sport/activity before injury?	Soccer, team handball, basketball, etc.
2.	At what level did you perform your sport/activity before injury?	(1) Elite, (2) Medium to high competitive, (3) Low competitive, (4) Recreational
3.	What is your goal for return to sport/activity after surgery?	Type and level are specified as above
4.	At what level do you perform your main sport/activity now?	(1) Elite, (2) Medium to high competitive, (3) Low competitive, (4) Recreational
5.	If your goal was returning to another sport/activity: At what level do you perform that sport/activity now?	(1) Elite, (2) Medium to high competitive, (3) Low competitive, (4) Recreational

[a]English summary of content. ACLR, anterior cruciate ligament reconstruction.

RTS Criteria

The earliest point where patients were advised to return to pivoting sports was 9 months after surgery, as recommended by Grindem et al.[20] The conventional test battery used for RTS clearance consisted of the IKDC 2000, single-leg hop tests, and concentric knee extension strength. The RTS criteria were IKDC 2000 score ≥85%, ≥85% LSI on hop test, and ≥85% LSI on isokinetic strength test (extension PT 60 deg/s). If a patient was returning to IKDC Level I or Level II sports at higher competitive levels, the criteria were adjusted to 90%. Patients who did not pass the criteria were advised against returning to Level I or II sports and were given the opportunity to return for repeat testing.

Two-Year Follow-up Evaluation

Two years after surgery, the RTS questionnaire was used to acquire data on return to sport and level of participation. Meniscal and cartilage surgery (resection or repair), or additional surgery to knee ligaments, were registered between baseline and follow-up. Furthermore, details on any reinjuries were acquired based on telephone interviews and data from routine clinical follow-ups performed by experienced orthopedic surgeons. An ACL reinjury was defined as a graft rupture or contralateral ACL rupture confirmed by either (1) arthroscopy, (2) magnetic resonance imaging, or (3) anamnestic episodes of knee trauma followed by an increased objective instability compared with earlier controls (KT-1000 arthrometer [Medmetric] ≥5, Lachman test 2 + or pivot-shift test 2 +).

Surgical Technique and Postoperative Rehabilitation

The ACLR was performed arthroscopically by an anatomic technique using either the patellar tendon or hamstring tendon autograft from the ipsilateral knee. No brace was used and immediate weightbearing was allowed, supported by crutches for 2 to 4 weeks. For patients who underwent additional surgery (such as meniscal repair), progression of rehabilitation was adjusted according to restrictions. Before hospital discharge, all patients performed postoperative supervised exercises and received guidelines regarding exercise progression and advice on contacting a physical therapist for further guidance. If the knee was effusion-free and the patient had a satisfactory range of motion and muscular control, running was allowed after 12 weeks. Gradual sport-specific training was allowed 6 months after surgery (ie, participating in team warm-ups/training, but not playing football or handball).

Statistical Analysis

IBM SPSS Statistics Version 24.0 software (IBM Corp) was used for analyses. For continuous variables, means ± SD are presented, and for categorical variables, absolute and relative frequencies are presented. Between-group comparisons were made by independent samples *t* tests, chi-square analyses, and Mann-Whitney U tests as appropriate. Logistic regression analyses were used to examine the predictive ability of questionnaires (ACL-RSI and IKDC 2000) and functional tests for return to preinjury sport level 2 years after surgery, with and without adjustments for age and sex. The variables were entered as continuous variables, not applying the 85% cutoffs. In addition, variables (age, sex, and time from injury to surgery) that could potentially affect RTS were examined separately in the logistic regression. To further examine the predictive ability of the complete test battery, stepwise backward multivariate logistic regression was performed. Results are presented as odds ratios (ORs), 95% CIs, and amount of explained variance (Nagelkerke R^2). Variables with significant association with RTS in the final stepwise backward model were entered into a receiver operating characteristic (ROC) model to evaluate predictive ability. A separate ROC analysis was performed for the ACL-RSI. Results are presented as area under the ROC curve (AUC), sensitivity, and specificity. The explanatory variables were checked for multicollinearity using linear regression analysis. Tolerance values <0.1 indicate unwanted high correlations between variables.[39]

RESULTS

Patient Characteristics

For information on patient characteristics, see Table 2. Of the patients, 60% received a bone–patellar tendon–bone autograft and 40% received a hamstring tendon autograft. Fifteen patients had a history of ACLR in the contralateral limb. Of 103 patients, 69% performed IKDC Level I sports before injury; 16%, Level II; and 15%, Level III. Most

TABLE 2
Baseline Patient Characteristics (n = 103)[a]

Age at surgery, y	28.7 ± 10
Male sex	55 (53)
Median time from injury to surgery, mo (IQR)[b]	8 (11)
Concomitant surgery	
Meniscal resection	18 (18)
Meniscal repair	25 (24)
Cartilage debridement	1 (1)
Microfracture[c]	1 (1)
Preinjury level of activity/sport	
Elite	5 (5)
Medium/high competitive	29 (28)
Low competitive	37 (36)
Recreational	32 (31)
Four main activities/sports	
Soccer	51 (50)
Handball	13 (13)
Alpine skiing	6 (6)
Cross-country/mountain running	6 (6)

[a]Data are reported as n (%) or mean ± SD unless otherwise indicated. IQR, interquartile range.
[b]Information missing in 5 patients (n = 98).
[c]This patient also had a meniscal repair.

patients stated that they wanted to return to their preinjury sport/activity (87). Seven patients stated that they had returned to full sports participation before RTS testing at baseline. Forty-three patients declined functional testing or had incomplete results. The 14 patients who declined or interrupted testing because of knee pain or instability had lower ACL-RSI scores than patients who did not perform testing because of other reasons (ie, lack of time or Biodex out of order; ACL-RSI, 35 vs 54; $P = .001$).

Baseline Results

Baseline testing was performed on average 10.4 ± 1.3 months after ACLR. For information on measurements, see Table 3. Twenty-nine patients passed the ≥85% RTS criteria in all 3 tests (hop test, strength test, and IKDC 2000). These patients were younger (26 vs 30 years; $P = .037$), had higher ACL-RSI (69 vs 51; $P < .001$), and IKDC 2000 (92 vs 77; $P < .001$) scores and performed better on the functional tests (hop test sum score, 100% vs 95%; LSI and isokinetic strength test, 96% vs 78% LSI; $P < .001$) than those who did not pass. More patients performing IKDC Level I sports before injury passed ($P < .001$).

New Injuries and Repeat Surgery at Follow-up

The final follow-up evaluation was undertaken at mean 25.5 ± 2.9 months after surgery. Six patients had sustained graft reinjuries (1 before RTS testing, 5 after) and 1 patient sustained a contralateral ACL injury between the baseline RTS testing and follow-up (5.8% reinjury rate). Three of those with an ACL reinjury returned to preinjury level sports although they had sustained graft failure. Seven patients underwent surgery for other knee complaints/injuries from RTS testing until follow-up evaluation: 4 patients had meniscal resections, 1 had a meniscal repair, 1 had cartilage resection, and 1 underwent a microfracture procedure. The total reinjury rate after RTS (combining ACL reinjuries and additional injuries) was 13.6%.

None of the 29 patients who passed the 85% RTS criteria were reinjured or underwent additional surgery after RTS testing compared with 13 reinjuries in the group who did not pass ($P = .037$). Fourteen (48%) of those who passed had returned to preinjury level sports compared with 29 (39%) of the 74 who did not pass ($P > .05$). Because of the low number of reinjuries, further analyses of predictive ability on new injuries were not feasible.

RTS at Follow-up

A total of 43 (42%) patients had returned to their preinjury level of sport 2 years after surgery. Returners were older (mean age, 31 vs 27 years; $P = .035$) and had higher 9-month ACL-RSI scores (64 vs 50; $P = .003$) than nonreturners (Table 3). More patients performing at the recreational level returned to their preinjury level ($P = .026$). Patients participating at a recreational level were older than patients at competitive levels (mean age, 37 vs 25 years; $P < .001$)

Predictive Ability on RTS

In the logistic regression, age, ACL-RSI, and IKDC 2000 had a significant association with returning to preinjury level of sport (Table 4). In the stepwise backward regression, the IKDC 2000 no longer displayed a significant effect: age and ACL-RSI were the only variables predicting RTS, with ORs of 1.05 ($P = .037$) and 1.03 ($P = .005$), respectively (Table 4). Of the variance in RTS, 17% could be explained by this model. For each 1-point increase in ACL-RSI score, the likelihood for returning increased by 3%. Tolerance values ranged from 0.55 to 0.88, indicating absence of multicollinearity. Results on backward regression did not change when patients with previous contralateral ACL injury were removed from analyses: age (OR, 1.06; 95% CI, 1.01-1.11; $P = .022$) and ACL-RSI (OR, 1.03; 95% CI, 1.01-1.06; $P = .004$) were still the only variables left in the final model.

For the ACL-RSI, the AUC was 0.69 (95% CI, 0.58-0.79; $P = .002$), with 85% sensitivity and 45% specificity at an ACL-RSI score of 47 (Figure 2). When ACL-RSI and age were combined in an ROC analysis, the AUC was 0.70 (95% CI, 0.60-0.80, $P < .001$), with a sensitivity of 98% and a specificity of 63% (Figure 3).

DISCUSSION

In the current study, age and psychological readiness displayed a predictive ability for return to preinjury level of sports, while conventional RTS tests did not. Of the patients, 42% returned to their preinjury level within 2 years after surgery. Those who returned were older and had better self-reported function and higher psychological readiness 9 months after surgery. The ACL reinjury rate

TABLE 3
Baseline Results of Psychological Readiness, Self-Reported Knee Function, and Performance on Functional Tests (n = 103)[a]

	All Patients (n = 103)	Returners (n = 43)	Nonreturners (n = 60)	Mean Difference (95% CI)	*P* Value
Subjective scores					
ACL-RSI (0-100, high score best)	55.8 ± 22.4	63.5 ± 20.8	50.3 ± 22.0	−13.3 (–21.9 to –4.8)	.003
IKDC 2000 (0-100, high score best)	81.4 ± 11.4	83.6 ± 9.8	79.9 ± 12.2	−3.8 (–8.2 to 0.7)	.099
Hop tests					
Mean sum score, LSI %	96.1 ± 8.5	97.0 ± 8.6	95.5 ± 8.4	−1.6 (–4.9 to 1.8)	.363
Isokinetic strength test					
PT extension 60 deg/s, LSI %	83.3 ± (14.8)	85.0 ± 14.2	82.0 ± 15.2	−2.9 (–8.8 to 2.9)	.324

[a]Data are reported as mean ± SD unless otherwise indicated. ACL-RSI, Anterior Cruciate Ligament-Return to Sport after Injury scale; IKDC 2000, International Knee Documentation Committee Subjective Knee Form 2000; LSI, limb symmetry index; PT, peak torque.

TABLE 4
Unadjusted and Adjusted Binary Logistic Regression Predicting Likelihood of Returning to Preinjury Sport (n = 103)[a]

	OR	95% CI	*P* Value	R^2
Separate logistic regression				
Age at surgery	1.05	1.00-1.09	**.030**	**0.06**
Sex	0.61	0.28-1.36	.225	0.02
Time from injury to surgery[b]	0.75	0.99-1.02	.749	0
ACL-RSI	1.03	1.01-1.05	**.004**	**0.12**
ACL-RSI adjusted[c]	1.03	1.01-1.05	**.006**	**0.17**
IKDC 2000	1.03	0.99-1.07	.102	0.04
IKDC 2000 adjusted[c]	1.04	1.09-1.09	**.049**	**0.12**
Hop test, LSI%	1.02	0.97-1.07	.362	0.01
Hop test, LSI% adjusted[c]	1.02	0.97-1.07	.425	0.08
Isokinetic extension strength, PT 60 deg/s, LSI%	1.01	0.99-1.04	.322	0.01
Isokinetic extension strength, PT 60 deg/s, LSI% adjusted[c]	1.02	1.00-1.10	.138	0.10
Stepwise backward regression, final model				**0.17**
Age	1.05	1.00-1.10	**.037**	
ACL-RSI	1.03	1.01- 1.05	**.005**	

[a]Boldface indicated statistical significance. ACL-RSI, Anterior Cruciate Ligament-Return to Sport after Injury scale; IKDC 2000, International Knee Documentation Committee Subjective Knee Form 2000; LSI, limb symmetry index; OR, odds ratio; PT, peak torque.
[b]Information missing for 5 patients (n = 98).
[c]Adjusted for age and sex.

was 5.8%. None of the patients who passed the ≥85% RTS criteria test battery sustained a second knee injury.

Few studies have examined the predictive ability of ACL-RSI for RTS in prospective cohorts. In the current study, patients' ACL-RSI scores 9 months after surgery had a small, but significant, predictive ability on 2-year RTS. Similar findings are reported from cohorts comparable with the current cohort. Ardern et al[4] found preoperative and 4-month postoperative scores to be predictive of return to preinjury level at 1 year after surgery. Sadeqi et al[46] reported a greater predictive ability when regression analysis was performed with ACL-RSI as a binary outcome (cutoff, 60 points). The explained variance in the current study was low, but the ACL-RSI was developed to cover only psychological readiness.[51] Mental factors such as recovery expectations and motivation may also influence the rehabilitation process.[4,6,42] Further, factors related to surgery (ie, tunnel positioning) and rehabilitation (ie, different protocols) are also important for RTS.[4,8,12,22,48] In this sense, the ability of the ACL-RSI to explain 12% of the variance in RTS outcomes alone can be considered a fairly good result.

Fair to good predictive ability is reported for ACL-RSI scores at 4 to 6 months' follow-up with varying cutoffs (51.3-65.0), AUC values (0.77-0.80), and ranges of sensitivity (57%-97%) and specificity (63%-84%).[4,32,46,50] In the present cohort, patients with ACL-RSI scores <47 were at risk of not returning to their preinjury level of participation, with a sensitivity of 85% and a specificity of 45% indicating a fair predictive ability. Knowledge on cutoff values will enable clinicians to identify patients in need of treatment strategies targeting unfavorable psychological responses.[51] Hopefully, these strategies will contribute to improving patients' overall readiness to resume sports, but more research is needed to clarify what the strategies should comprise.[4,51] The relatively high sensitivity and the lower specificity means that the ACL-RSI is better at identifying patients who will struggle to resume sports than identifying those who will return (many false-positives). As the main focus for clinicians is to identify patients needing extra

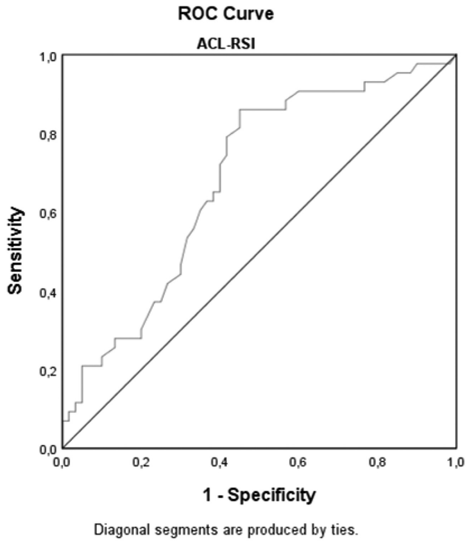

Figure 2. Receiver operating characteristic (ROC) curve for Anterior Cruciate Ligament-Return to Sport after Injury scale (ACL-RSI) for predicting return to preinjury level of sport.

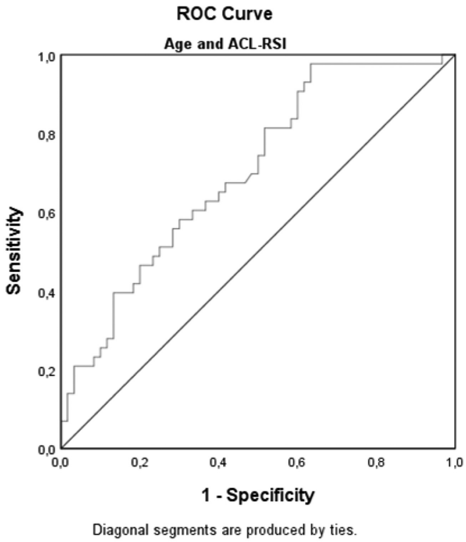

Figure 3. Receiver operating characteristic (ROC) curve for Anterior Cruciate Ligament-Return to Sport after Injury scale (ACL-RSI) and age for predicting return to preinjury level of sport.

assistance in returning to sports, the high sensitivity is of great importance.

In the current study, older age was a predictor of return to preinjury level, even though it added only a small amount of explained variance in the final regression model (5%). This contrasts with other reports where younger age favored returning.[4,26,55] The relatively high proportion of patients performing recreational-level sports in the present study can explain this finding. More patients performing recreational-level sports returned to their preinjury level, and patients in this group were significantly older; hence, more of these "older" patients returned.

Symmetrical single-leg hop performance has been associated with successful return to preinjury level of sport, and 6-month postoperative hop tests are reported to predict short- and long-term RTS, with up to 45% explained variance.[3,32,34] These results differ from the current study, where no predictive ability was found for hop tests. Differences in patient populations can be a reason for the discrepancies, as comparative studies include larger proportions of patients performing pivoting sports, with fewer concomitant injuries at surgery.[32,34] Isokinetic quadriceps strength, another common indicator for RTS readiness, also did not have an effect on sport resumption in the current study. Others have reported weak to no association between quadriceps strength and RTS.[12,32,36,55] These results on functional tests are surprising but may emphasize that the controlled setting of isokinetic testing and hop tests represents different challenges than the unpredictability of sports participation. Including other aspects of function through movement quality analysis, open skill tasks, reactive agility tests, and sport-specific tests could potentially lead to functional tests being predictive of RTS.[2,16,40]

The relationship between self-reported knee function and RTS is unclear.[12] Indications of a relationship between higher IKDC scores and return to preinjury level of sport have been reported.[3-5,26,55] This was also found in the current study, but the effect disappeared as other factors were added to the regression analysis. An explanation for the lack of association between knee function and RTS may be that physical and psychological readiness to RTS do not always coincide.[4,12,25,43] The relationship between psychological readiness and isokinetic strength and hop test LSIs has been investigated and little to no relationship seems to exist.[5,13,38] This indicates that physical and psychological recovery are distinct and different constructs and both should be addressed in rehabilitation.[38]

Test batteries must be informative regarding risk of reinjury. An interesting observation in the current study was that none of the patients passing the 85% criteria were reinjured or underwent additional surgery. Similar findings were reported by Grindem et al,[20] as only 1 out of 18 patients passing their RTS criteria suffered a new knee injury compared with 21 new injuries in the 55 nonpassers. Meeting the criteria on these conventional RTS tests was associated with a 92% lower reinjury rate.[19,20] Another study found nonpassers of a comprehensive test battery to be 4 times more likely to sustain a graft rupture.[24] Neither of these studies included psychological readiness evaluation, but 2 other studies have reported a higher risk for a second ACL injury in young patients with low ACL-RSI scores.[30,31]

Strengths of the present study include the prospective evaluation of both physical and psychological readiness to RTS in a population representative of many hospital and outpatient clinics. The current cohort was recruited from a public hospital and represents patients performing a broad spectrum of sports; many participated at a lower competitive level or a recreational level. Patients were given a standardized rehabilitation protocol and were followed by local physical therapists for the main part of the rehabilitation. The authors believe that information on the predictive ability of RTS assessments in a population such as this will provide useful information to many outpatient and orthopaedic clinics, as some of the previous research has been biased toward specialized clinics treating athletes.[19,24,54] Further, to the authors' knowledge, there are no other studies examining the predictive value of 9-month scores, and only 1 study has followed patients for up to 2 years.[46] Testing at 9 months after surgery is relevant because this is the earliest time patients are advised to return to sports.[20]

The results of the present study may not be comparable with populations of elite athletes following strict protocols at specialized clinics. In accordance with other studies, the RTS criteria were set to 85% (90% for those returning to IKDC Level I/II sports at higher levels of competition).[10,20,25,49,56] This is slightly lower than recommended by some and may limit comparison with other studies.[1,48] We argue that knowledge on which cutoffs to use in different populations is still limited, especially in more heterogeneous patient groups. The independent variables were therefore analyzed as continuous data, not applying cutoffs. A further limitation may be the lack of movement quality assessment, as this has previously been found to predict RTS.[55] Also, the use of LSIs may be debated. While some support their use,[19] others have questioned it, as symmetrical performance alone will not provide information on whether patients have regained preinjury function.[15,26,48,55,56] Interestingly, the results of the regression analyses did not change in the current study when patients with a previous history of contralateral ACL injury were removed from analyses. However, it cannot be ruled out that by evaluating movement quality or using different metrics (ie, absolute norm values or quadriceps strength/hop performance normalized to body weight), functional tests could have a predictive ability for RTS.

CONCLUSION

This study highlights the importance of incorporating evaluation of psychological responses in RTS testing. Age and psychological readiness measured 9 months after surgery were found to be predictors of RTS 2 years after ACLR, while functional tests had no predictive value. None of the patients who passed the 85% cutoff in the current test battery sustained a new knee injury, which may indicate an association between functional tests and risk of reinjuries.

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Appendix 1

Haraldsplass
Diakonale sykehus

ACL-RSI SKALA

Instruksjon: Vi vil be deg besvare de følgende spørsmål om din hovedidrettsaktivitet før skaden. Kryss av i den boksen som best beskriver hvordan du føler deg akkurat nå.

Navn:______________________________________ **Fødselsnummer:**______________

Dato for utfylling av skjema:__________________________

1. Er du sikker på at du kan drive idretten din på samme nivå som tidligere?

Ikke sikker i det hele tatt	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Helt sikker
	0	10	20	30	40	50	60	70	80	90	100	

2. Tror du det er sannsynlig at du kommer til å skade kneet ditt på nytt ved å delta i idretten din?

Ekstremt sannsynlig	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Ikke sannsynlig i det hele tatt
	0	10	20	30	40	50	60	70	80	90	100	

3. Er du engstelig for å drive med idretten din?

Ekstremt engstelig	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Ikke engstelig i det hele tatt
	0	10	20	30	40	50	60	70	80	90	100	

4. Føler du deg sikker på at kneet ditt ikke vil gi etter når du driver med idretten din?

Ikke sikker i det hele tatt	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Helt sikker
	0	10	20	30	40	50	60	70	80	90	100	

5. Føler du deg sikker på at du kunne drevet med idretten din uten å bekymre deg for kneet ditt?

Ikke sikker i det hele tatt	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Helt sikker
	0	10	20	30	40	50	60	70	80	90	100	

6. Synes du det er frustrerende å måtte ta hensyn til kneet ditt når det gjelder idretten din?

Ekstremt frustrerende	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Ikke frustrerende i det hele tatt
	0	10	20	30	40	50	60	70	80	90	100	

Oversatt av kirurgisk klinikk og avdeling for rehabiliteringstjenester ved Haraldsplass Diakonale Sykehus i 2014 fra Original versjon: Webster, K.E., J.A. Feller, and C. Lambros, *Development and preliminary validation of a scale to measure the psychological impact of returning to sport following anterior cruciate ligament reconstruction surgery.* Physical Therapy in Sport, 2008. 9(1): p. 9-15.

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Appendix 2

Haraldsplass
DIAKONALE SYKEHUS

2000 IKDC Kneevalueringsskjema

Navn:______________________________ **Dato:**______________ **Skadedato:**______________

SYMPTOMER:

Grader symptomene på det høyeste aktivitetsnivå som du tror du kan fungere uten betydelige symptomer, selv om du egentlig ikke driver med aktiviteter på dette nivået.

1. Hva er det høyeste aktivitetsnivå du tror du kan drive med uten betydelige knesmerter?

- ☐ Veldig harde aktiviteter som hopping og vendinger ved basketball eller fotball *5p*
- ☐ Harde aktiviteter som tungt fysisk arbeid, ski eller tennis *4p*
- ☐ Moderate aktiviteter som moderat fysisk arbeid, løping eller jogging *3p*
- ☐ Lette aktiviteter som gange, husarbeid eller hagearbeid *2p*
- ☐ Umulig å foreta seg noen av de overnevnte aktiviteter på grunn av knesmerter *1p*

2. I løpet av de <u>siste 4 uker</u> (eller siden kneskaden); hvor ofte har du hatt smerter (sett ring rundt)?

Aldri	0	1	2	3	4	5	6	7	8	9	10	Alltid
	11p	*10p*	*9p*	*8p*	*7p*	*6p*	*5p*	*4p*	*3p*	*2p*	*1p*	

3. Hvis du har smerter, hvor intense er de (sett ring rundt)?

Ingen smerte	0	1	2	3	4	5	6	7	8	9	10	Verst tenkelige smerte
	11p	*10p*	*9p*	*8p*	*7p*	*6p*	*5p*	*4p*	*3p*	*2p*	*1p*	

4. I løpet av <u>de siste 4 uker</u> (eller siden kneskaden); hvor <u>stivt</u> eller <u>hovent</u> har kneet ditt vært?

- ☐ Ikke i det hele tatt *5p*
- ☐ Litt *4p*
- ☐ Moderat *3p*
- ☐ Veldig *2p*
- ☐ Ekstremt *1p*

5. Hva er det høyeste aktivitetsnivå du tror du kan drive med uten betydelig <u>hevelse</u> i kneet?

- ☐ Veldig harde aktiviteter som hopping og vendinger ved basketball eller fotball *5p*
- ☐ Harde aktiviteter som tungt fysisk arbeid, ski eller tennis *4p*
- ☐ Moderate aktiviteter som moderat fysisk arbeid, løping eller jogging *3p*
- ☐ Lette aktiviteter som gange, husarbeid eller hagearbeid *2p*
- ☐ Umulig å foreta seg noen av de overnevnte aktiviteter på grunn av hevelse *1p*

6. I løpet av <u>de siste 4 uker</u>, (eller siden kneskaden); har kneet låst seg (sett ring rundt)?

JA *1p* **NEI** *2p*

7. Hva er det høyeste aktivitetsnivå du tror du kan drive med uten betydelig <u>svikt</u> av kneet?

- ☐ Veldig harde aktiviteter som hopping og vendinger ved basketball eller fotball *5p*
- ☐ Harde aktiviteter som tungt fysisk arbeid, ski eller tennis *4p*
- ☐ Moderate aktiviteter som moderat fysisk arbeid, løping eller jogging *3p*
- ☐ Lette aktiviteter som gange, husarbeid eller hagearbeid *2p*
- ☐ Umulig å foreta seg noen av de overnevnte aktiviteter på grunn av svikt av kneet *1p*

<u>IDRETTSAKTIVITETER:</u>

7. Hva er det høyeste aktivitetsnivå du vanligvis kan delta i (nå)?

- ☐ Veldig harde aktiviteter som hopping og vendinger ved basketball eller fotball *5p*
- ☐ Harde aktiviteter som tungt fysisk arbeid, ski eller tennis *4p*
- ☐ Moderate aktiviteter som moderat fysisk arbeid, løping eller jogging *3p*
- ☐ Lette aktiviteter som gange, husarbeid eller hagearbeid *2p*
- ☐ Umulig å foreta seg noen av de overnevnte aktiviteter på grunn av kneet *1p*

9. Hvordan påvirker kneet din evne til å (sett kryss):

	Ikke vanskelig i hele tatt	**Litt vanskelig**	**Moderat vanskelig**	**Ekstremt vanskelig**	**Kan ikke i det hele tatt**
Gå opp trapper					
Gå ned trapper					
Knele/ gå ned på kne					
Gå ned på huk/gjøre knebøy					
Sitte med bøyd kne					
Reise deg opp fra stol					
Løpe rett frem					
Hinke på ditt skadete ben					
Starte og stoppe raskt					
	5p	*4p*	*3p*	*2p*	*1p*

FUNKSJON:

Hvordan vil du gradere din knefunksjon på en skala fra 0 til 10 der 10 er normal, utmerket funksjon og 0 er at du ikke kan gjøre noen av dine daglige aktiviteter, som også kan inkludere idrett?

10. FUNKSJON FØR KNESKADEN (sett ring rundt) *(poeng registreres ikke)*:

Kan ikke gjøre daglige aktiviteter	0	1	2	3	4	5	6	7	8	9	10	Ingen begrensninger i daglige aktiviteter

10. NÅVÆRENDE KNEFUNKSJON (sett ring rundt):

Kan ikke gjøre daglige aktiviteter	0	1	2	3	4	5	6	7	8	9	10	Ingen begrensninger i daglige aktiviteter
	1p	*2p*	*3p*	*4p*	*5p*	*6p*	*7p*	*8p*	*9p*	*10p*	*11p*	

IKDC 2000 ((x-18/87)*100)= ________________________

(Orginalartikkel: Irrgang et al. Development and validation of the International Knee Documentation Committee Subjective Knee Form. The American Journal of Sports Medicine 2001;29(5):600-13 Oversatt av Norsk Senter for Aktiv Rehabilitering, Ullevål Universitetessykehus, Oslo, 2005, til og med trinn 4 etter retningslinjer utarbeidet av: Guillemin F, Bombardier C, Beaton D. Cross-cultural adaptation of health-related quality-of-life measures: Literature review and proposed guidelines. J Clin Epidemiol 1993;46:1417-32)

Appendix 3

Knee injury and Osteoarthritis Outcome Score (KOOS), Norwegian version LK 1.0

KOOS – SPØRRESKJEMA FOR KNEPASIENTER

DATO: _____/_____/_____ FØDELSENR (11 siffer): ________________

NAVN: ____

Veiledning: Dette spørreskjemaet inneholder spørsmål om hvordan du opplever kneet ditt. Informasjonen vil hjelpe oss til å følge med i hvordan du har det og fungerer i ditt daglige liv. Besvar spørsmålene ved å krysse av for det alternativ du synes passer best for deg (kun ett kryss ved hvert spørsmål). Hvis du er usikker, kryss likevel av for det alternativet som føles mest riktig.

Symptom

Tenk på de **symptomene** du har hatt fra kneet ditt den **siste uken** når du besvarer disse spørsmålene.

S1. Har kneet vært hovent?

Aldri	Sjelden	I blant	Ofte	Alltid
☐	☐	☐	☐	☐

S2. Har du følt knirking, hørt klikking eller andre lyder fra kneet?

Aldri	Sjelden	I blant	Ofte	Alltid
☐	☐	☐	☐	☐

S3. Har kneet haket seg opp eller låst seg?

Aldri	Sjelden	I blant	Ofte	Alltid
☐	☐	☐	☐	☐

S4. Har du kunnet rette kneet helt ut?

Alltid	Ofte	Iblant	Sjelden	Aldri
☐	☐	☐	☐	☐

S5. Har du kunnet bøye kneet helt?

Alltid	Ofte	I blant	Sjelden	Aldri
☐	☐	☐	☐	☐

Stivhet

De neste spørsmålene handler om **leddstivhet**. Leddstivhet innebærer vanskeligheter med å komme i gang eller økt motstand når du bøyer eller strekker kneet. Marker graden av leddstivhet du har opplevd i kneet ditt den **siste uken**.

S6. Hvor stivt er kneet ditt når du nettopp har våknet om morgenen?

Ikke noe	Litt	Moderat	Betydelig	Ekstremt
☐	☐	☐	☐	☐

S7. Hvor stivt er kneet ditt **senere på dagen** etter å ha sittet, ligget eller hvilt?

Ikke noe	Litt	Moderat	Betydelig	Ekstremt
☐	☐	☐	☐	☐

Smerte

P1. Hvor ofte har du vondt i kneet?

Aldri	Månedlig	Ukentlig	Daglig	Hele tiden
☐	☐	☐	☐	☐

Hvilken grad av smerte har du hatt i kneet ditt den **siste uken** ved følgende aktiviteter?

P2. Snu/vende på belastet kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P3. Rette kneet helt ut

Ingen	Lett	Moderate	Betydelig	Svært stor
☐	☐	☐	☐	☐

P4. Bøye kneet helt

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P5. Gå på flatt underlag

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P6. Gå opp eller ned trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P7. Om natten i sengen (smerter som forstyrrer søvnen)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P8. Sittende eller liggende

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

P9. Stående

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Funksjon I hverdagen

De neste spørsmål handler om din fysiske funksjon. **Angi graden av vanskeligheter du har opplevd den siste uken ved følgende aktiviteter på grunn av dine kneproblemer.**

A1. Gå ned trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A2. Gå opp trapper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Angi graden av **vanskeligheter** du har opplevd ved hver aktivitet den **siste uken**.

A3. Reise deg fra sittende stilling

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A4. Stå stille

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A5. Bøye deg, f.eks. for å plukke opp en gjenstand fra gulvet

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A6. Gå på flatt underlag

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A7. Gå inn/ut av bil

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A8. Handle/gjøre innkjøp

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A9. Ta på sokker/strømper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A10. Stå opp fra sengen

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A11. Ta av sokker/strømper

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A12. Ligge i sengen (snu deg, holde kneet i samme stilling i lengre tid)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A13. Gå inn og ut av badekar/dusj

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A14. Sitte

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A15. Sette deg og reise deg fra toalettet

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Angi graden av **vanskeligheter** du har opplevd ved hver aktivitet den **siste uken.**

A16. Gjøre tungt husarbeid (måke snø, vaske gulv, støvsuge osv.)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

A17. Gjøre lett husarbeid (lage mat, tørke støv osv.)

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Funksjon, sport og fritid

De neste spørsmålene handler om din fysiske funksjon. Angi graden av vanskeligheter du har opplevd **den siste uken** ved følgende aktiviteter på grunn av dine kneproblemer.

SP1. Sitte på huk

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

SP2. Løpe

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

SP3. Hoppe

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

SP4. Snu/vende på belastet kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

SP5. Stå på kne

Ingen	Lett	Moderat	Betydelig	Svært stor
☐	☐	☐	☐	☐

Livskvalitet

Q1. Hvor ofte gjør ditt kneproblem seg bemerket?

Aldri	Månedlig	Ukentlig	Daglig	Alltid
☐	☐	☐	☐	☐

Q2. Har du forandret levesett for å unngå å overbelaste kneet?

Ingenting	Noe	Moderat	Betydelig	Fullstendig
☐	☐	☐	☐	☐

Q3. I hvor stor grad kan du stole på kneet ditt?

Fullstendigl	I stor grad	Moderat	Til en viss grad	Ikke i det hele tatt
☐	☐	☐	☐	☐

Q4. Generelt sett, hvor store problemer har du med kneet ditt?

Ingen	Lette	Moderate	Betydelige	Svært store
☐	☐	☐	☐	☐

Takk for at du tok deg tid og besvarte samtlige spørsmål!

Appendix 4

Navn

Personnr Dato for utfylling

"TAMPA"
Spørsmål om smerte og fysisk aktivitet

Vennligst svar på de følgende spørsmål. Svar i forhold til dine egne følelser, ikke i forhold til hva andre synes du skal mene. Sett ring rundt det tallet ved siden av hvert spørsmål som best tilsvarer dine følelser.

	SVÆRT UENIG	LITT UENIG	LITT ENIG	SVÆRT ENIG
1. Folk tar ikke min medisinske tilstand alvorlig nok……	1	2	3	4
2. Kroppen forteller meg at noe er alvorlig galt…………	1	2	3	4
3. Skaden har gjort at kroppen min vil være utsatt resten av livet……………………………………………………..	1	2	3	4
4. Jeg er redd for at jeg kan skade meg ved et uhell......…	1	2	3	4
5. Smertene ville blitt verre hvis jeg hadde prøvd å overvinne dem……………………………………………	1	2	3	4
6. Det sikreste jeg kan gjøre for å hindre at smertene blir verre, er å unngå unødvendige bevegelser………………..	1	2	3	4
7. Jeg ville ikke hatt så mye smerte hvis det ikke foregikk noe potensielt farlig i kroppen min………………………..	1	2	3	4
8. Smerter betyr alltid at jeg har skadet kroppen…………	1	2	3	4
9. Smertene sier fra når jeg skal stoppe treningen, slik at jeg ikke skader meg………………………………………..	1	2	3	4
10. Det er faktisk ikke trygt for en person med min tilstand å være fysisk aktiv………………………………	1	2	3	4
11. Jeg er redd jeg kan komme til å skade meg hvis jeg trener………………………………………………………	1	2	3	4
12. Jeg kan ikke gjøre alle de tingene folk flest gjør, fordi jeg har så lett for å bli skadet………………………………	1	2	3	4
13. Ingen burde være nødt til å trene når han eller hun har smerter………………………………………………………	1	2	3	4

(The Tampa scale. Kori, Miller & Todd
oversatt av Haugen, AJ og Grøvle, L 2004)

Appendix 5

Idrett og aktivitet før og etter korsbåndsoperasjon

Haraldsplass Diakonale sykehus

Navn:	*Fødselsnr:*	*Dato for utfylling:*

1. Hva regner du som din primæridrett/aktivitet og sekundæridrett/aktivitet? Sett et 1-tall bak din primæridrett/aktivitet og et 2-tall bak din sekundæridrett/aktivitet.

Fotball	Aerobic	Svømme
Håndball	Alpint	Turn
Basketball	Telemark	Sykle
Volleyball	Langrenn	Gange i terreng
Tennis/badminton	Løp i terreng	Annet
Kampsport	Løp jevnt underlag	Beskriv annen idrett:

2. På hvilket nivå utførte du primæridrett/aktivitet før skaden? Sett kun ett kryss.

Elitenivå	☐	Konkurranse middels til høyt nivå	☐
Konkurranse lavere nivå	☐	Mosjonsnivå	☐

3. På hvilket nivå utfører du primæridrett/aktivitet nå? Sett kun ett kryss.

Elitenivå	☐	Konkurranse middels til høyt nivå	☐
Konkurranse lavere nivå	☐	Mosjonsnivå	☐
Sluttet/driver ikke lenger med	☐	Ikke prøvd ennå	☐

4. Hvordan fungerer kneet ditt nå ved din primæridrett/aktivitet?

Som før skaden, uten plager	☐	Med små plager eller begrensninger	☐
Betydelige plager eller begrensninger	☐	Forsøkt, men gitt opp grunnet kneskaden	☐
Ikke forsøkt pga frykt for ny skade	☐	Ikke gjenopptatt, annen årsak	☐

5. På hvilket nivå utførte du sekundæridrett/aktivitet før skaden? Sett kun ett kryss.

Elitenivå	☐	Konkurranse middels til høyt nivå	☐
Konkurranse lavere nivå	☐	Mosjonsnivå	☐

6. På hvilket nivå utfører du sekundæridrett/aktivitet nå? Sett kun ett kryss.

Elitenivå	☐	Konkurranse middels til høyt nivå	☐
Konkurranse lavere nivå	☐	Mosjonsnivå	☐
Sluttet/driver ikke lenger med	☐	Ikke prøvd ennå	☐

7. Hvordan fungerer kneet ditt nå ved din sekundæridrett/aktivitet? Sett kun ett kryss.

Som før skaden, uten plager	☐	Med små plager eller begrensninger	☐
Betydelige plager eller begrensninger	☐	Forsøkt, men gitt opp grunnet kneskaden	☐
Ikke forsøkt pga frykt for ny skade	☐	Ikke gjenopptatt, annen årsak	☐

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