NORWEGIAN SCHOOL OF SPORT SCIENCES

Dorthe Bro Strauss

Evaluation of young adults one year after anterior cruciate ligament reconstruction

- muscle strength, hop performance, patient reported- and structural outcomes.

Master thesis in
Department of
Norwegian School of Sport Sciences, 2019

Abstract

Background: Young and active athletes are at high risk of sustaining an Anterior Cruciate ligament (ACL) injury. In Norway, close to 50% receive surgery, often with the primary goal of returning to the previous level of sports performance. Unfortunately, not all return to sport (RTS) and many experiences short- and long-term problems. The main purpose of this master project was to examine a small sample of young and active adults 12 months after ACL reconstruction pertaining to muscle strength, hop performance, and patient-reported and structural outcomes.

Methods: Data was obtained from the baseline testing for the SHIELD cohort, a research collaboration between Sweden and Norway. The study sample (n=21), age 18-35, was collected in Oslo, Norway. Aims were evaluation of the injured and non-injured leg for isokinetic knee and isometric hip and trunk muscle strength and hop performance, RTS rate and patient reported- and structural outcomes. Investigation of associations between patient-reported outcomes (PROs), The Tegner Activity Scale, RTS, and isokinetic knee and isometric hip and trunk muscle strength and hop performance. Investigation of cartilage defects with The Anterior Cruciate Ligament OsteoArthritis Score (ACLOAS) for magnetic resonance (MRI) and associations between the findings of cartilage defects and the Knee Injury and Osteoarthritis Outcome Score (KOOS).

Results: The injured leg was significantly weaker in hop performance and isokinetic knee extension compared to the non-injured. Some association was found between KOOS, Tegner Activity Scale, RTS, and isokinetic knee and isometric hip and trunk muscle strength and hop performance. Nine participants had findings of cartilage defects, and no associations were found between these participants and the KOOS score. 50% had returned to sport, and 24% had returned to pre-injury level. No associations were found between RTS and isokinetic knee and isometric hip and trunk muscle strength and hop performance.

Conclusion: 12 months after the ACLR the participants had significant difference between isokinetic knee muscle strength and hop performance, where the non-injured leg was stronger. These results are similar to other studies. There were significant associations between KOOS, Tegner Activity scale and isokinetic knee and isometric hip and trunk muscle strength and hop performance. 52% of the participants had returned to sport, and 24% had returned to pre-injury level, which is similar to a Norwegian study but lower than an international study. 43% had cartilage defects. No associations were found between KOOS, and the present of cartilage defects, which is equivalent to other data.

Table of content

Definitions and explanations

Patient-reported outcomes: The definition used for patient-reported outcomes is "answers reported by the patient, on questions about the patient´s health condition, quality of life and functional status without interference by the clinician or anyone else." (*https://www.qualityforum.org/Projects/n-r/Patient-Reported_Outcomes/Patient-Reported_Outcomes.aspx*, 2019)(Weldring & Smith, 2013).

Return to Sport: Returning to some type of sport, but not at the pre-injury level (Clare L Ardern et al., 2016)

Return to pre-level sport: Return to performance (Clare L Ardern et al., 2016)

Short- and long-term: No consensus is found in the literature of how long short- and long term is, but many articles describe short-term as up to two years after ACL injury and/or reconstruction and long term to be more than ten years.

Hop performance: Includes both hop performance tests: The Single Leg Hop for Distance test (the SLHD test) and the Side-hop test.

Acknowledgments

This research paper is part of achieving master-degree in sports physiotherapy from The Norwegian School of Sports Sciences in the years of 2017-2019.

The research used in this paper is from a larger cohort named "SHIELD," a research collaboration between Sweden and Norway. The research used in this paper is from the Norwegian contribution to the SHIELD study´s baseline testing.

I am grateful to Professor Eva Ageberg, assistant researcher Anna Cronström and colleagues for letting me use the Norwegian data for my master project. You have been so helpful, kind and shown patience in every step of the data collection for an inexperienced researcher. It has been a privilege to be a part of SHIELD.

I have been so fortunately, to have Professor May Arna Godaker Risberg as my supervisor. Thank you for introducing me to SHIELD and letting me take part in a research project of this magnitude.
It has indeed been an interesting journey, where I have learned tremendously in every step of the process. Thank you for your patience, your impressive knowledge, and your friendship.

At Oslo University Hospital, Department of Orthopedics, Professor Lars Engebretsen, have been extremely helpful with findings of eligible participants, Thank you. Research coordinator and nurse Elise Berg Vesterhus thank you for all of your help with the set-up of MRI times, communication with participants, and blood sample collection. Research coordinator and nurse Anne Christine Brekke thank you for stepping in when Elise could not be there.
Senior consultant and Head of department Johan Castberg Hellum thank you for organizing and Senior consultant Øyvind Fidje, thank you for taking your time with the scoring of the MRI pictures with very short notice and for helping me navigate through radiology. Thanks to all of the workers at the "radiologic department" at OUS for helping out and always meet me with a smile.

Thanks to all of my colleagues at the Norwegian Institute for Sports Medicine in Oslo (NIMI), for help with testing, statistics and discussions, thank you all for making NIMI a great place to work!
Thank you, Kristin Bølstad MSc., for always having time for "my problems" whatever it was data, language (Norwegian and Swedish) or Biodex, you took your time to help me, and always with a smile on your face. You have been a real "life saver."
Consultant Ph.D., Gilbert Moatshe and Mitchell Kennedy, thank you for helping me with langue (English). A special thanks to Grant Dornan M.S. Director at Center for Outcome-Based Orthopaedic Research, for your impressive knowledge and patience in statistics!

A last, thank you to my beautiful family. My kids for their patience when mom had to study and to my husband for all of your knowledge, work-related discussions, and never-ending patience and love.

Dorthe Bro Strauss
Vail May 2019

1.0 Introduction

1.1 Background

The data obtained for this master project is baseline data of a larger longitudinal cohort named SHIELD (ClinicalTrials.gov ID: NCY03473873). SHIELD is a research collaboration between Norway (Oslo) and Sweden (Lund), as Norway contributed with 20 participants. Professor Eva Ageberg is the primary investigator. The research aim of SHIELD is to investigate the possible role of knee-, hip- and truncus muscle strength, hop performance and postural orientation on the development of osteoarthritis (OA) in patients that have received anterior cruciate ligament reconstruction (ACLR) between the ages 18 and 35 years.
The cohort in SHIELD includes more than 100 participants for baseline (approximately 12 months after ACLR) and a two-year follow-up testing.
The data used in this project is from the SHIELD baseline testing.

Injury to the ACL is a common injury, especially in the young population between the ages of 15 and 40 (van Melick et al., 2016), usually occurring during sports activity (Moses, Orchard, & Orchard, 2012). Recent data from The Norwegian Anterior Cruciate Ligament Records (Kvalitetsregister.no) shows approximately 4000 patients suffer from an ACL injury, with close to 50% (n=1860) receiving reconstruction surgery and about 200 furthermore needing revision surgery. (*https://www.kvalitetsregistre.no/registers/527/resultater*, 2018).

Recent developments have been made from research on these injuries, including detection of risk factors, and improved surgical techniques and rehabilitation protocols, resulting in a higher return to sport (RTS) and improved postoperative outcomes.

Rehabilitation after ACLR usually lasts 12 months, with early protocols incorporating range of motion (ROM), neuromuscular and muscular activation exercises, and strength exercises, and later proceeding into functional exercises as hop performance and RTS specific exercises (Clare L Ardern et al., 2016)(van Melick et al., 2016).

RTS has been one of the latest topics in ACL research, with the ability to RTS being a primary indicator of patient-reported satisfactory outcomes after injury (Kocher et al., 2002). Not all patients are able to return (Clare L Ardern, Taylor, Feller, & Webster, 2014), with only 55% returning to competition level (Clare L Ardern et al., 2014). RTS is vital in improving patient Quality of Life (QOL) (S. R. Filbay, Ackerman, Russell, & Crossley, 2017), making it a very important influence in postoperative outcomes. Factors contributing to improved RTS include younger age, male gender, previously elite athletics, symmetric Limb symmetry index (LSI) scores for hop performance, normal knee function, and lower fear of re-injury (Clare L Ardern et al., 2014).
For health care providers and the patient; age, sex, and previous sports history are not able to be altered, but the physiological and psychological improvements are achievable and should be pursued in rehabilitation to improve RTS ability.

The risk of additional injuries (meniscal and contra-lateral ACL) and re-injury of the ACL (ipsilateral) have been linked together by weak asymmetrical quadriceps strength and early attempted RTS (Hege Grindem, Snyder-Mackler, Moksnes, Engebretsen, & Risberg, 2016), poor outcomes on self-reported knee function (Paterno, Flynn, Thomas, & Schmitt, 2018)(Wylie, Marchand, & Burks, 2017), decreased neuromuscular control (hip and knee)(Paterno et al., 2010), surgical procedures (Paterno, 2015), graft failure (Andernord et al., 2015) and young age at injury (Paterno, Rauh, Schmitt, Ford, & Hewett, 2014).

Re-injury often happens in the first few years after reconstruction (Paterno, 2015). Self - reported fear resulted in a lower level of activity, hop performance, and isometric knee extensor strength, thereby increasing the risk of re-injury (Paterno et al., 2018). About 10% of all patients experience less than average or un-satisfactory knee function after ACLR (C. L. Ardern, Webster, Taylor, & Feller, 2011).

The risk of sustaining an additional injury or re-injury increases the risk of developing knee Osteoarthritis (OA) (May Arna Risberg et al., 2016).
Long-term outcomes for more than 50% of the ACL injured and ACLR patients exhibit knee OA (Britt Elin Øiestad, Engebretsen, Storheim, & Risberg, 2009) with several factors being influential on its the development from functional knee performance

(Shelbourne, Benner, & Gray, 2017)(ØIestad, Holm, Gunderson, Myklebust, & Risberg, 2010)(Bennell, Wrigley, Hunt, Lim, & Hinman, 2013)(Roos, Herzog, Block, & Bennell, 2011) and poor result on self-reported knee function at 2 years, postoperatively (ØIestad et al., 2010).
Detection of radiologic changes in cartilage can be detected on MRI approximately 12 months after ACL injury (Theologis et al., 2014).

When we know the risk of re-injury or sustaining an additional injury and that later development of knee OA can be reduced with better outcomes after rehabilitation with the physiological and psychological factors being addressed. Do we (health-care providers) implement these into rehabilitation? How well do young and previously active random population do one year after ACLR? Have they returned to sport? Are they safe from risk?

1.2 Purpose

The main purpose of this project was to evaluate outcomes in young adults one year after ACLR with regard to muscle strength, hop performance, patient-reported- and structural outcomes.

1.3 Research Aims

Research Aim 1: Evaluate inter-rater reliability of isokinetic knee extension and flexion muscle tests, isometric hip- and trunk muscle strength tests, hop performance tests, and intra-rater reliability of isometric hip- and trunk muscle strength tests.
Research Aim 2: Conduct literature search of normative data for isokinetic knee and isometric hip and trunk muscle strength, hop performance tests, patient-reported outcomes (KOOS) and physical activity level (Tegner Activity Scale).

Research Aim 3: Evaluate isokinetic knee and isometric hip and trunk muscle strength and hop performance between injured and non-injured knee one year after ACLR. Compare the outcomes to normative data.

Research Aim 4: Evaluate patient-reported outcomes (all KOOS subscales) and physical activity level (Tegner Activity Scale) one year after ACLR and compare the outcomes to normative data.

Research aim 5a: Investigate associations between patient-reported outcomes (all KOOS subscales) and physical activity level (Tegner Activity Scale), and isokinetic knee and isometric hip and trunk muscle strength and hop performance tests.

Research aim 5b: Describe the return to sports rates one year after ACLR.

Research aim 5c: Investigate association between returned to sport, and isokinetic knee and isometric hip and trunk muscle strength and hop performance.

Research aim 6a: Describe knee MRI findings one year after ACL reconstruction (ACLOAS).

Research aim 6b: Investigate differences between KOOS (all subscales) for those with and without cartilage defects one year after ACLR.

1.4 Null hypotheses

1. No difference between the injured leg and contralateral non-injured leg for isokinetic knee and isometric hip and trunk muscle strength and hop performance one year after ACLR.
2. No associations between KOOS and isokinetic knee and isometric hip and trunk muscle strength and hop performance one year after ACLR.
3. No differences between MRI findings and KOOS (subscales) one year after ACLR.

2.0 Theory

2.1 Anatomy and Function of the Anterior Cruciate Ligament

The ACL originates at the medial aspect of the lateral femoral condyle, inserting at the medial tibial eminence (Petersen & Zantop, 2007). The ACL consists of two bundles, an anteromedial bundle, and a posterolateral bundle. The two bundles run through the intercondylar fossa and twists just about 180^0 (Petersen & Zantop, 2007)(Girgis, Marshall, & Monajem, 1975). The function of the ACL is primarily to inhibit the anterior translation of the tibia in relation to the femur (Butler, Noyes, & Grood, 1980), while also to limiting internal rotation, especially when the knee joint is close to full extension (Duthon et al., 2006).

2.2 Anterior Cruciate Ligament injury

ACL injuries have been known since the early Egyptian time, having been described by Papyrus and Hippocrates (Davarinos, O'Neill, & Curtin, 2014). Since then, an impressive amount of research has been done in describing and developing the diagnostic (Wagemakers et al., 2010) and surgical procedure for the ACLR (Davarinos et al., 2014), helping to reveal several risk factors for ACL injuries (H. C. Smith et al., 2012a, 2012b), and with developing an adequate rehabilitation after injury (Cavanaugh & Powers, 2017) and prevention strategies (Nessler, Denney, & Sampley, 2017).

Injury to the ACL often happens in the young and active population (Stephanie R. Filbay & Grindem, 2019) from participation in sports activity (Moses et al., 2012). It is occasionally accompanied with concomitant injuries, with the most common being meniscal and cartilage injury, and/or additional ligamentous injury like the medial collateral ligament (MCL) (Stephanie R. Filbay & Grindem, 2019).
Approximately 75% of the ACL injuries occur as non-contact, low energy injuries (Wetters, Weber, Wuerz, Schub, & Mandelbaum, 2016).

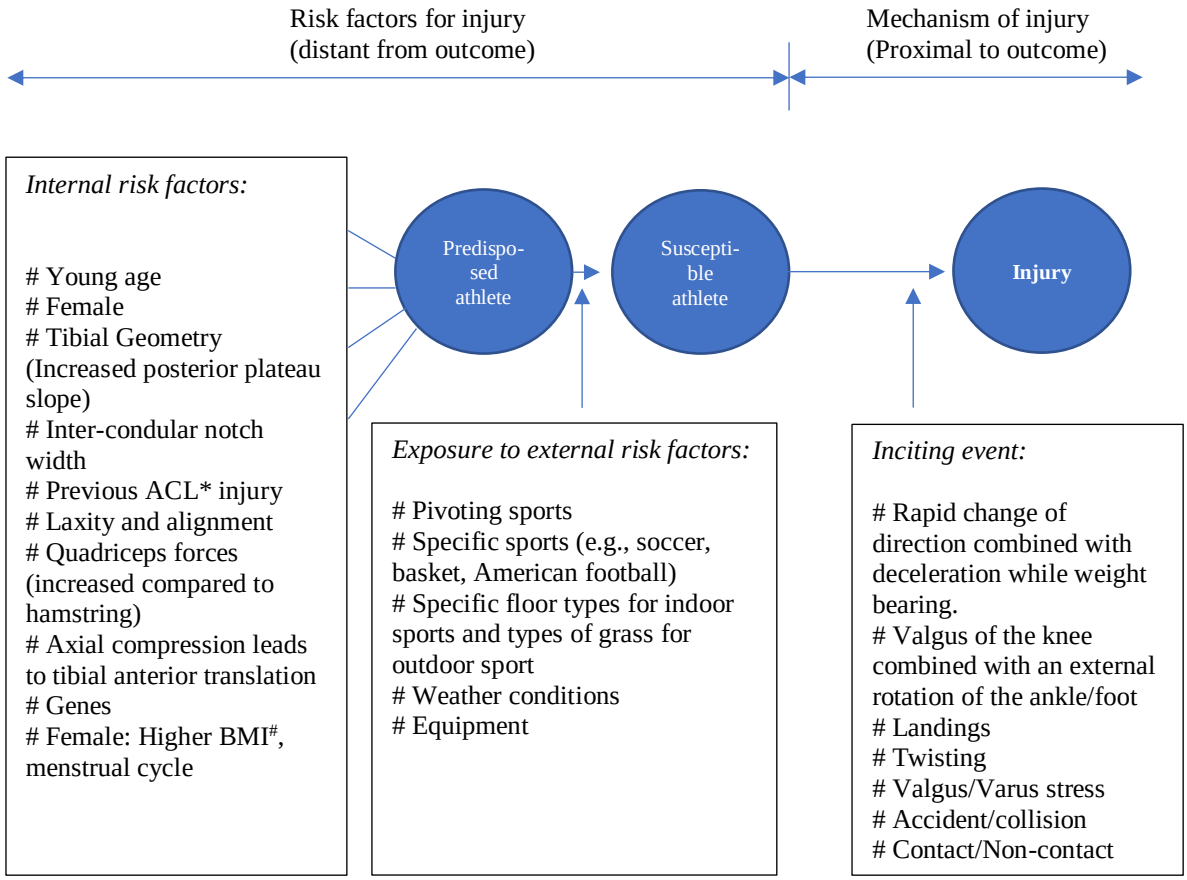
2.3 Anterior Cruciate Ligament Injury Incidence

Data from www.kvalitetsregistre.no shows that approximately 4000 people were diagnosed with an ACL injury in Norway in 2017 (*https://www.kvalitetsregistre.no/registers/527/resultater*, 2018).
The incidence of ACL injuries occurs approximately 34 per 100.000 in Norway, 32 per 100.000 in Sweden, and 47 injuries per 100.000 in Denmark (Moses et al., 2012) (Singh, 2018).
These compare similarly to data in the United States of America, which range from 29-30 per 100.000 (Csintalan, Inacio, & Funahashi, 2008)(Singh, 2018).

2.4 Anterior Cruciate Ligament Injury Risk Factors

The risk of sustaining an ACL injury is complex and multifactorial, and despite years of research, the epidemiology is still debated (Kobayashi et al., 2010).
What research has presented is; it varies from person to person *(internal risk factors)* from sport to sport *(external risk factors)*, and from situation to situation *(Inciting event)*.
Figure 1 illustrates a comprehensive model for injury causation developed by Bahr and Krosshaug in 2005 (Bahr, 2005). The model shows the complexity of risk factors when sustaining an injury. Some risk factors are more fixed as to how the tibia and intercondylar notch width develop anatomically, age (youth more at risk), and genetics. All internal risk factors increase the risk of injury as *the predisposed athlete.*
Participating in pivoting sports or type 1 sports such as e.g., soccer, handball, or basketball, within special weather conditions or upon certain surfaces can increase the risk when *exposed* to these factors making the athlete more *susceptible* to an injury.
Additionally, the *inciting event*, the moment the ACL tears, can elevate the risk of injury due to specific movement patterns like the cutting maneuver in soccer or landing after a jump on skies.

Figure 1: ACL injury causation (the model used with permission from the authors)



*ACL: Anterior Cruciate Ligament, #BMI: Body Mass Index

(Uhorchak et al., 2003)(Myer, Ford, Paterno, Nick, & Hewett, 2008)(Wetters et al., 2016)(Flynn et al., 2005)(John Orchard, Seward, McGivern, & Hood, 2001)(Olsen, Myklebust, Engebretsen, Holme, & Bahr, 2003)(J. Orchard, Seward, McGivern, & Hood, 1999)(Lambson, Barnhill, & Higgins, 1996)(Boden, Dean, Feagin, & Garrett, 2000)(Kobayashi et al., 2010)(Alentorn-Geli et al., 2014).

2.5 Diagnosis of Anterior Cruciate Ligament Injury

An ACL injury is diagnosed with a combination of patient history, clinical examination and if relevant/needed para-clinic investigations as MRI and X-ray (Kaeding, Léger-St-Jean, & Magnussen, 2017)(Stephanie R. Filbay & Grindem, 2019). MRI together with X-rays are used for the verification of the injury, in addition to detection of injuries in the knee joint (intra-articular fractures, cartilage injuries and meniscus injuries) that

may lead to the development of osteoarthritis (Van Ginckel, Verdonk, & Witvrouw, 2013)(Hunter et al., 2014).

The patient often describes the injury with hearing a "pop," and often the incidence happened when doing a decelerated or accelerated movement in combination with knee valgus force (Wagemakers et al., 2010)(Stephanie R. Filbay & Grindem, 2019). The presence of knee effusion or hemarthrosis shortly after the incidence is also considered to be of significant importance (Wagemakers et al., 2010)(D. S. Logerstedt, Snyder-Mackler, Ritter, Axe, & Godges, 2010).
The most used tests for the clinical examination are the Lachman test, the anterior drawer test, and the pivot shift test (Benjaminse, Gokeler, & van der Schans, 2006).
The combination of patient history and clinical examination if often enough to diagnose an ACL injury. However, the risk of concomitant injuries, and difficulties of performing physical assessments when the patient is in pain or fear and with the knee effusion or hemarthrosis, MRI may be a valuable alternative for confirmation (Stephanie R. Filbay & Grindem, 2019).

2.6 The treatment of an Anterior Cruciate Ligament

Treatment of ACL injuries must first be addressed by restoring knee function, with the return to activities and RTS participation being progressively tasked. Prevention of re-injury or/and new knee injuries along with attention to the risk of knee OA should carefully be monitored (Stephanie R. Filbay & Grindem, 2019).
The treatment options for the ACL injured patient can, according to Filbay and Grindem (2019) be:

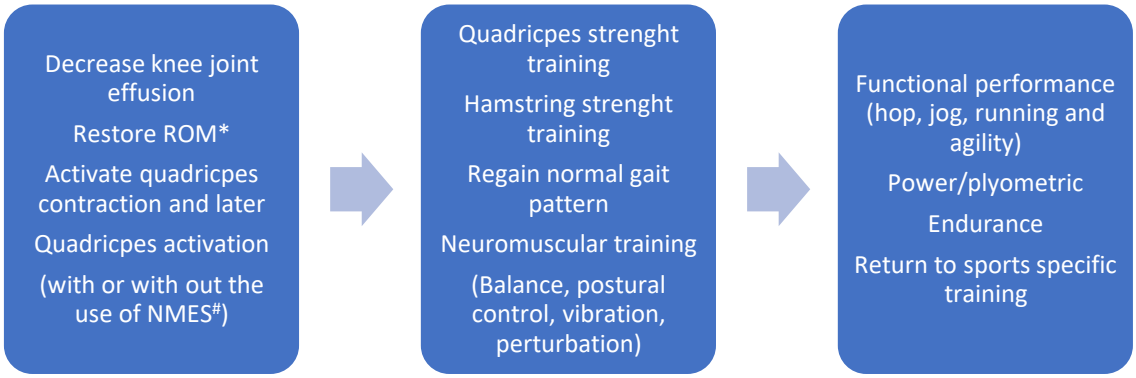
- Rehabilitation and in-case of functional instability; ACLR is done
- ACLR and then rehabilitation following surgery
- Pre-habilitation before ACLR followed by rehabilitation

2.7 Anterior Cruciate Ligament Rehabilitation

Rehabilitation of the ACL injuries has been reported to play an important role in both short and long-term outcomes after ACLR surgery (Paterno et al., 2014)(van Melick et al., 2016).

Rehabilitation should be applied to both the non-surgically and surgically treated patients as described by Filbay and Grindem (2019) (Stephanie R. Filbay & Grindem, 2019). Focus areas in rehabilitation for both groups of patients should include a range of different modalities, as presented in figure 2.

Figure 2: Focus areas in ACL rehabilitation:



*ROM: Range of Motion, #NMES: Neuromuscular Electric stimulation

(Adams, Logerstedt, Hunter-Giordano, Axe, & Snyder-Mackler, 2012)(Cavanaugh & Powers, 2017)(Myer, Paterno, Ford, Quatman, & Hewett, 2006)(Failla, Arundale, Logerstedt, & Snyder-Mackler, 2015)(van Melick et al., 2016).

Rehabilitation programs should be adjusted in case of additional ligament injury, articular cartilage lesions and/or meniscal injuries (Wilk & Arrigo, 2017)(Adams et al., 2012) and for the surgical group: the different graft types (Wilk & Arrigo, 2017) (Adams et al., 2012).

Throughout rehabilitation, patients progress should be monitored and tested to ensure progression, for example, knee joint effusion can be tested with The Stroke test (Adams et al., 2012), ROM can be tested with a goniometer (Risberg, Holm, Tjomsland, Ljunggren, & Ekeland, 1999), strength with isometric- (handheld dynamometer) or isokinetic (Biodex dynamometer) tests (Wilk & Arrigo, 2017). Hop performance can be

tested with specific hop tests as the Single leg hop for distance (SLHD) test and the triple leg hop for distance test (Adams et al., 2012)(Wilk & Arrigo, 2017). General progression and mental/psychologic wellbeing, PROs and self-reported status can be tested with specific questionnaires designed for the specific patient population as Knee injury and Osteoarthritis Outcome Score (KOOS) (Adams et al., 2012).

2.8 Anterior Cruciate Ligament Reconstruction

The Norwegian anterior cruciate ligament records (Kvalitetsregister.no) from 2017 shows that approximately 1860 ACL injured patients were treated surgically, accounting for roughly 50% of patients diagnosed with ACL injury (*https://www.kvalitetsregistre.no/registers/527/resultater*, 2018).

Even-though the ACL injuries have been known for centuries; the optimal treatment is still debated. Should the ACL injury be surgically reconstructed or not? Which patient groups have the better outcome?
Even though a few articles present better outcome *with* reconstruction (Hinterwimmer, Engelschalk, Sauerland, Eitel, & Mutschler, 2003)(Zysk & Refior, 2000) the majority of research presents similar results for both patients groups (T. O. Smith, Postle, Penny, McNamara, & Mann, 2014)(Richard B. Frobell, Roos, Roos, Ranstam, & Lohmander, 2010)(R. B. Frobell et al., 2013)(Ageberg, Thomeé, Neeter, Silbernagel, & Roos, 2008).

The goals for reconstruction is restoring anatomy and knee laxity, ultimately allowing for the return to pre-injury activity with the intention of prolonging knee joint health long term (Failla et al., 2016).
Patients receiving surgery are often younger and participating in level one sports (for example, soccer, handball, basketball) (Hege Grindem, Eitzen, Engebretsen, Snyder-Mackler, & Risberg, 2014).

Various graft choices are utilized for ACL reconstruction as of today; Autografts (Bone-patella Tendon-Bone (BTB), Hamstrings tendon (tendon from the semitendinosus muscle or quadriceps tendon) or Allograft (tendon from donor site).
In Norway, the most commonly used autografts are hamstring tendon and BTB, which are utilized in approximately 90% of the cases (*https://www.kvalitetsregistre.no/registers/527/resultater*, 2018).

According to the literature the timing of surgery (immediately or later) have no influence on outcome (R. B. Frobell et al., 2013). However several studies have shown improvement in outcome (KOOS, knee function and muscle strength) after following a pre-habilitation programs with an emphasize on improving quadriceps and hamstring strength and neuromuscular control before the surgery (Failla et al., 2016)(Alshewaier, Yeowell, & Fatoye, 2017)(H Grindem et al., 2015). Studies have presented data with improved outcome (knee function and return to pre-level activity) when surgery is postponed until full knee extension of the injured knee, absent or minimal knee joint effusion, no knee extension lag during straight leg raise (Shelbourne, Wilckens, Mollabashy, & DeCarlo, 1991)(Mayr, Weig, & Plitz, 2004), and minimal knee extension strength deficit (Eitzen, Holm, & Risberg, 2009).

2.9 Return to sport

RTS has been a hot topic in the last several years and to determine if a patient is ready for return, many factors have been outlined as important for a safer return to sport: *Strength* (Clare L Ardern et al., 2016)(Risberg, Holm, Tjomsland, Ljunggren, & Ekeland, 1999)(Thomeé et al., 2012), here in particular *Quadriceps muscle strength* (Adams, Logerstedt, Hunter-Giordano, Axe, & Snyder-Mackler, 2012)(Barber-Westin & Noyes, 2011)(Myer, Paterno, Ford, Quatman, & Hewett, 2006)(Hege Grindem, Snyder-Mackler, Moksnes, Engebretsen, & Risberg, 2016).
ROM is also considered important (Clare L Ardern et al., 2016)(de Fontenay, Argaud, Blache, & Monteil, 2014) and *quadriceps/hamstring ratio* (Hewett, Di Stasi, & Myer,

2013)(Czuppon, Racette, Klein, & Harris-Hayes, 2014)(Kyritsis, Bahr, Landreau, Miladi, & Witvrouw, 2016).
Neuromuscular control (Clare L Ardern et al., 2016) together with *Performance and skills* (Clare L Ardern et al., 2016)(Thomeé et al., 2012) are also listed as important.
Psychological and mental readiness is by several listed as important factors for RTS (C. L. Ardern et al., 2011)(Paterno et al., 2018). Ardern et al., (2011) reported that close to one out of five would not return to pre-injury level of sports because of the fear of re-injury (C. L. Ardern et al., 2011). Another study found that patients with greater self-reported fear, to predict lower functional performance and higher rates of second ACL injury (Paterno, Flynn, Thomas, & Schmitt, 2018).

Not all ACL reconstructed patients return to sport. A systematic review from 2014 by Ardern et al., (2014) presented an average of 81% RTS, and 65% returned to the same level of sport as before the surgery (Clare L Ardern et al., 2014). The same article presented that 55% returned to competitive sports after the reconstruction.
The author listed several factors as important for returning to the same level and competitive level of sport as before; younger age and male, previously elite athletes, symmetric LSI for hop performance, normal knee function and lower fear of re-injury (Clare L Ardern et al., 2014).
For the patient, RTS is an important factor for having a satisfying outcome after the reconstruction (Kocher et al., 2002) and can improve the patients QOL (S. R. Filbay et al., 2017).

Different test batteries for RTS have been developed, often including both physical tests and questionnaires regarding mental/psychological readiness, PROs and self-evaluation of function and progress.
Some test-batteries are developed for usage halfway through the rehabilitation, either to identify weakness and risk factors or as a predictor for outcome after one year of rehabilitation (Logerstedt et al., 2014). Other test batteries are developed for the use of cut-off point for the return to play (Davies, McCarty, Provencher, & Manske, 2017) or before the return to activities or sports participation (Wilk & Arrigo, 2017).

In 2016, leading experts in this field suggested a gradual RTS with an increase in load as the patient progresses, starting with Return to Participation, followed up by Return To Sport and last a Return To Performance (Clare L Ardern et al., 2016).

2.10 Short term outcomes after Anterior Cruciate Ligament Reconstruction

Short term outcomes after ACLR can be categorized into the World Health Organization (WHO) international classification of Functioning, Disabilities, and Health, also called the ICF (*https://www.who.int/classifications/icf/en/*, 2019).
ICF was introduced in 2001 as an international standard used for the description of health conditions and disabilities.

ICF is a framework describing how a particular health condition could impact body function and structures (impairments and disabilities), activities (limitations) and participation (restriction), together with the influence of environmental and personal factors (contextual factors), overall finding how these all are capable of impacting each other (*https://www.who.int/classifications/icf/en/*, 2019)(Cieza et al., 2002)(Üstün, Chatterji, Bickenbach, Kostanjsek, & Schneider, 2003).

Using ICF with the health condition; an ACLR knee can give the patient the following:

Body function and structures (Impairments and disabilities):
Knee laxity (C. L. Ardern et al., 2011)(Risberg, Holm, Tjomsland, Ljunggren, & Ekeland, 1999) Even-though ACLR have a high success rate (George, Dunn, & Spindler, 2006) some patients experience *giving away symptoms* (Lynch et al., 2015) and a subjective feeling of instability. Revision surgery has been reported to be necessary for 10-15% of ACLRs due to insufficient graft caused by e.g., surgical technical failure or trauma (The MARS Group et al., 2010).
Reduced muscle strength (C. L. Ardern et al., 2011)(Risberg, Holm, Tjomsland, Ljunggren, & Ekeland, 1999) of the injured leg but also the non-injured leg is still seen

after 12 months of rehabilitation (Chung et al., 2015), and even longer (M. A. Risberg et al., 1999). Decreased *quadriceps muscle strength* can have an impact on participation since it can reduce the chance of RTS (Myer et al., 2006)(Adams et al., 2012) and may also influence knee joint loading which may increase the risk of developing knee OA (Bennell et al., 2013). Flosadottir et al., (2016) found a connection between low muscle function and low score on patient-reported outcomes (Flosadottir, Roos, & Ageberg, 2016) and decreased muscle power was associated with lower activity scores in the future (Flosadottir et al., 2016).

Muscles other than the quadriceps muscle and hamstring muscle may also be affected after ACLR. Reduced *trunk muscle strength* may increase the risk of ACL injury (Hickey Lucas, Kline, Ireland, & Noehren, 2017)(Hewett et al., 2005) while reduced *external hip rotation strength* can impact activities in the form of reduced hop performance (Kline et al., 2018).

Decreased ROM (Risberg et al., 1999), full knee extension can be difficult to achieve if not achieved before discharge (Shelbourne, Freeman, & Gray, 2012)(Shelbourne et al., 2017). Decreased ROM increases the risk of developing knee OA (Shelbourne, Urch, Gray, & Freeman, 2012). Knee flexion deficits may be implicated by arthrofibrosis, where joint fibrosis occurs due to an inflammatory response (Eckenrode, Carey, Sennett, & Zgonis, 2017), potentially leading to ROM complications in the years to come (Shelbourne et al., 1991)(Mayr et al., 2004). Decreased ROM may also increase the risk of developing knee OA (Shelbourne, Freeman, et al., 2012). Anterior arthrofibrosis (cyclops lesion) may be present after ACLR if the patient experience a decrease ROM in extension with *Pain* (Dhanda, 2010).

Pain (Risberg et al., 1999) can occur from different sources; pain from the graft donor site, especially from BTB grafts (Hardy, Casabianca, Andrieu, Baverel, & Noailles, 2017), and/or the decreased muscle strength can change or alternate the knee kinematics and the patient can be more vulnerable to other pain symptoms as patellofemoral pain syndrome (Ferber, Bolgla, Earl-Boehm, Emery, & Hamstra-Wright, 2015)(Boling & Padua, 2013).

Knee joint effusion (Lynch et al., 2015) can reduce the activity of the quadriceps strength and muscular activity (Palmieri-Smith, Villwock, Downie, Hecht, & Zernicke, 2013).

Decreased neuro-muscular control (Clare L Ardern et al., 2014), decreased muscular strength and proprioception after reconstruction affect the neuromuscular control (Shim, Choi, & Shin, 2015) and decreased neuromuscular control may increase the risk of a new injury (Lepley, Lepley, Onate, & Grooms, 2017)(Ewa M. Roos & Arden, 2015).

Activities (limitations): the impairments and disabilities can *Reduce the function of the knee* (C. L. Ardern et al., 2011)(Lynch et al., 2015)(Clare L Ardern et al., 2014) and limit the number of activities done. Also *decreased hop performance* (C. L. Ardern et al., 2011)(Lynch et al., 2015)(Clare L Ardern et al., 2014) is seen after rehabilitation, and since many activities include lifting of the ground with the feet, it will limit the activities done. Flosadottir et al., (2016) found an association between worse hop performance and increased risk of future knee pain (body function and structures) after ACL injury (Flosadottir et al., 2016)

Participation (restrictions): This gives restrictions for what the patient can participate in, and the wish of returning *to sport or pre-injury sport or competitive level may fail* (Clare L Ardern et al., 2014)(Lynch et al., 2015). Returning to sport, here in particular pivoting sports (Britt Elin Øiestad, Holm, & Risberg, 2018) have showed to increase self-reported activities of daily living (ADL), decrease the risk of knee OA (Britt Elin Øiestad et al., 2018) and decrease QOL (S. R. Filbay et al., 2017).

Contextual factors as environmental and personal: *Age and gender* (Paterno et al., 2014)(Clare L Ardern et al., 2014) can affect return to sport, with young patients seeming to have better outcomes and RTS, while female patients have worse outcomes than males (Clare L Ardern et al., 2014). *Family situation* can be affected, maybe the patient cannot play with his/her kids and misses out on family active event because the *knee is not functioning as it should* (C. L. Ardern et al., 2011) and giving the *feeling of unsatisfactory outcome* (Kocher et al., 2002)(Sonesson, Kvist, Ardern, Österberg, & Silbernagel, 2017). *Low outcome on PROs as e.g., KOOS* (Grindem, Snyder-Mackler, Moksnes, Engebretsen, & Risberg, 2016)(Liechti et al., 2016)(Clare L Ardern et al., 2014). Leading experts have suggested threshold scores from 85 to 90 (Lynch et al., 2015) and low score on PROs decrease the chance of RTS

(D. Logerstedt et al., 2014). *Low outcome on self-reported knee function* at two years follow up can increase the risk of developing knee OA long-term (Britt Elin Øiestad et al., 2010). *Psychological factors and fear of re-injury* (C. L. Ardern et al., 2011)(Clare L Ardern et al., 2014)(Clare L. Ardern, Taylor, Feller, Whitehead, & Webster, 2013) is maybe one of the biggest sources of not returning to sport and activity, which again leads to activity limitations and participation restrictions and self-reported fear of re-injury may also increase the risk of a re-injury (Paterno et al., 2018).

For healthcare providers, it is therefore critical to measure and test these impairments and disabilities, limitations, participation restriction and contextual factors for reducing the risk of additional injuries (hence meniscus and ACL injury to contralateral knee) or a re-injury of the ACLR knee (Stephanie R. Filbay & Grindem, 2019). The risk for young and active patients to suffer from ACL re-injury is about 30% (Paterno et al., 2014) and 50% have experienced surgery to the meniscus with-in five years postoperatively (R. B. Frobell et al., 2013).

Table 1, illustrates possible measurements and goals for a successful outcome after ACLR (Lynch et al., 2015) and thereby reduce the risk of additional injuries or re-injury (Petersen, Taheri, Forkel, & Zantop, 2014)(Paterno et al., 2014)(Paterno et al., 2018).

Table 1: Measurements and goals for ICF factors after ACLR

ICF	Measurements	GOAL:
Body function and structures		
Strength	Isometric Isokinetic 1 RM*	LSI# 90% or more (Adams, Logerstedt, Hunter-Giordano, Axe, & Snyder-Mackler, 2012) Symmetrical quadriceps strength (Grindem et al., 2016)
Laxity	KT-1000♦	<3 mm difference (Lynch et al., 2015)
Pain	Visual analog scale Numeric rating scale	
Neuromuscular control	Postural Orientation Errors	Score: 0= good 1=fair, 2=poor, 3= very poor (Nae, Creaby, Nilsson, Crossley, & Ageberg, 2017)
	Balance tests	Increasing in time and difficulty (Adams et al., 2012)
Activities:		
Functional knee performance	Test battery for testing functional knee performance	LSI 90% or more Symmetrical performance (Lynch et al., 2015)
Hop performance	Test battery for testing hop performance	LSI 90% or more Symmetrical performance (Adams et al., 2012)
Participation:		
RTS♣	RTS testing	Passing RTS test with scores >90% (Grindem et al., 2016)
Contextual factors:		
Self-reported function	Example: International Knee Documentation Committee (IKCD), Lysholm Knee Score, Cincinnati Knee Scale, Tegner Activity Scale, and Knee injury and Osteoarthritis Outcome Score (KOOS)	Scoring: 85 – 90% (Lynch et al., 2015)
RTS	Early returning to pivoting sports.	Return ≥ 9 months and passing RTS tests (Grindem et al., 2016)
Psychological factors	Coaching, goal setting, cognitive-behavioral strategies	No fear of re-injury and mental readiness for RTS (Clare L. Ardern et al., 2013)

1RM*: 1 repetition max, LSI#: Limb Symmetry Index, ♦KT-1000 knee arthrometer, RTS♣: Return to Sport

Healthcare providers should be familiar with two "simple decision rules" presented by Grindem et al., in 2016 that potentially can reduce the risk of a re-injury by 84% (Hege Grindem et al., 2016). The rules are; the time for RTS should be limited to the earliest of 9 months from surgery upon return, quadriceps strength should be more symmetrical; LSI above 90% (Hege Grindem et al., 2016).

Re-injury often occurs the first few years after reconstruction (Paterno et al., 2014) and there seems to be an increased risk of re-injury to the young (10-19 years of age) and active patients (Hege Grindem et al., 2014). Re-injury increases the risk of developing knee OA (Britt Elin Øiestad et al., 2009).

2.11 Long term outcome after ACL reconstruction

Long term outcome after ACLR can also be presented in the ICF classification.

Body function and structures:
Abnormal or reduced muscle strength (Ageberg et al., 2008)(B.E. Øiestad, Juhl, Eitzen, & Thorlund, 2015)(May Arna Risberg et al., 2016)(Roos, Herzog, Block, & Bennell, 2011) increases the risk of developing knee OA (B.E. Øiestad et al., 2015)(ØIestad et al., 2010), while *knee ligament laxity* (Salmon et al., 2006)(Britt Elin Øiestad et al., 2010) may increase the risk of a new injury, concomitant meniscus and articular cartilage damage increases the risk of developing knee OA (Shelbourne et al., 2017). *Reduced ROM (lack of full knee extension)* (Leys, Salmon, Waller, Linklater, & Pinczewski, 2012), the presence of decreased knee extension ROM at discharge from rehabilitation increases the risk of developing knee OA (Shelbourne et al., 2017), *Pain* (Leys et al., 2012)(Britt Elin Øiestad et al., 2010) and *Decreased proprioception* (Roos et al., 2011) may also increase the risk of future knee OA.

Activities: *Decreased hop performance* (Ageberg et al., 2008) *Reduced knee function* (May Arna Risberg et al., 2016).

Participation: *Reduced level of participation in sport* (S. R. Filbay et al., 2017) *or activity level* (May Arna Risberg et al., 2016), *Decreased QOL* (Lohmander, Englund, Dahl, & Roos, 2007).

Contextual factors: *Increase bodyweight* (S. R. Filbay et al., 2017) which can increase the risk of developing knee OA (Ewa M. Roos & Arden, 2015) and *depression* (S. R. Filbay et al., 2017), both factors have shown to have an impact on QOL (S. R. Filbay et al., 2017). *Low outcome on PROs and other questionnaires* (Lohmander et al., 2007) as mention in short-term outcome; low outcome on self-reported knee function at two years follow up can increase the risk of developing knee OA long-term (Britt Elin Øiestad et al., 2010) *Age* (Shelbourne et al., 2017) here *older age*, also increases the risk of developing knee OA (Cinque, Dornan, Chahla, Moatshe, & LaPrade, 2018).

The most common long-term consequences after ACL injury and reconstruction is the risk of developing knee OA. More than 50% of patients receiving ACLR develop knee OA (Britt Elin Øiestad et al., 2009) regardless of the treatment (Lohmander et al., 2007) with radiologic changes in cartilage able to be detected on MRI as early as 12 months after ACLR (Theologis et al., 2014). Additional injuries as meniscal lesion and/or meniscectomy increases the chance of developing knee OA (medial more than lateral meniscectomy) (Englund, 2008)(Shelbourne et al., 2017)(May Arna Risberg et al., 2016).

Findings in research show knee muscle strength (Macías-Hernández et al., 2016) (Eckstein, Hitzl, Duryea, Kent Kwoh, & Wirth, 2013) and KOOS score (Su et al., 2016) correlates with radiographic findings 12 months after ACLR.
The risk of knee OA may seem to increase slightly with reconstruction (T. O. Smith et al., 2014) while other authors have shown of no difference of the development of knee OA regarding treatment (van Yperen, Reijman, van Es, Bierma-Zeinstra, & Meuffels, 2018)(Tsoukas, Fotopoulos, Basdekis, & Makridis, 2016).

3.0 Methods

3.1 Study design and participants

This master project is a cross-sectional study, including the baseline test results from the SHIELD participants 9-18 months after ACLR.

Participants were selected from medical records from week 40, 2017 to week 35 in 2018, at Oslo University Hospital (OUS) using the following inclusion and exclusion criteria´s listed in table 2.

Table 2: Inclusion and exclusion criteria for participants selection

Inclusion criteria	**Exclusion criteria**
I. Patients who received ACLR one year prior, with or without associated injuries to other structures of the knee (e.g., collateral ligament(s), meniscal injury)	I. Less than 9 months after ACLR
II. Age-group: 18-35 years of age	II. More than 18 months after ACLR
	III. Injury or surgery to other knee (e.g., ACL, meniscal)
	IV: Previous knee surgery index knee
	V: Previous serious knee injury resulting in pain, swelling, and/or requiring inpatient or outpatient health care (e.g., ACL, meniscus, patella luxation)
	VI: Diseases or disorders overriding the knee condition (e.g., neurological disease)
	VII: Contra-indications for MRI
	IIX: Not understanding the languages of interest (Scandinavian or English)

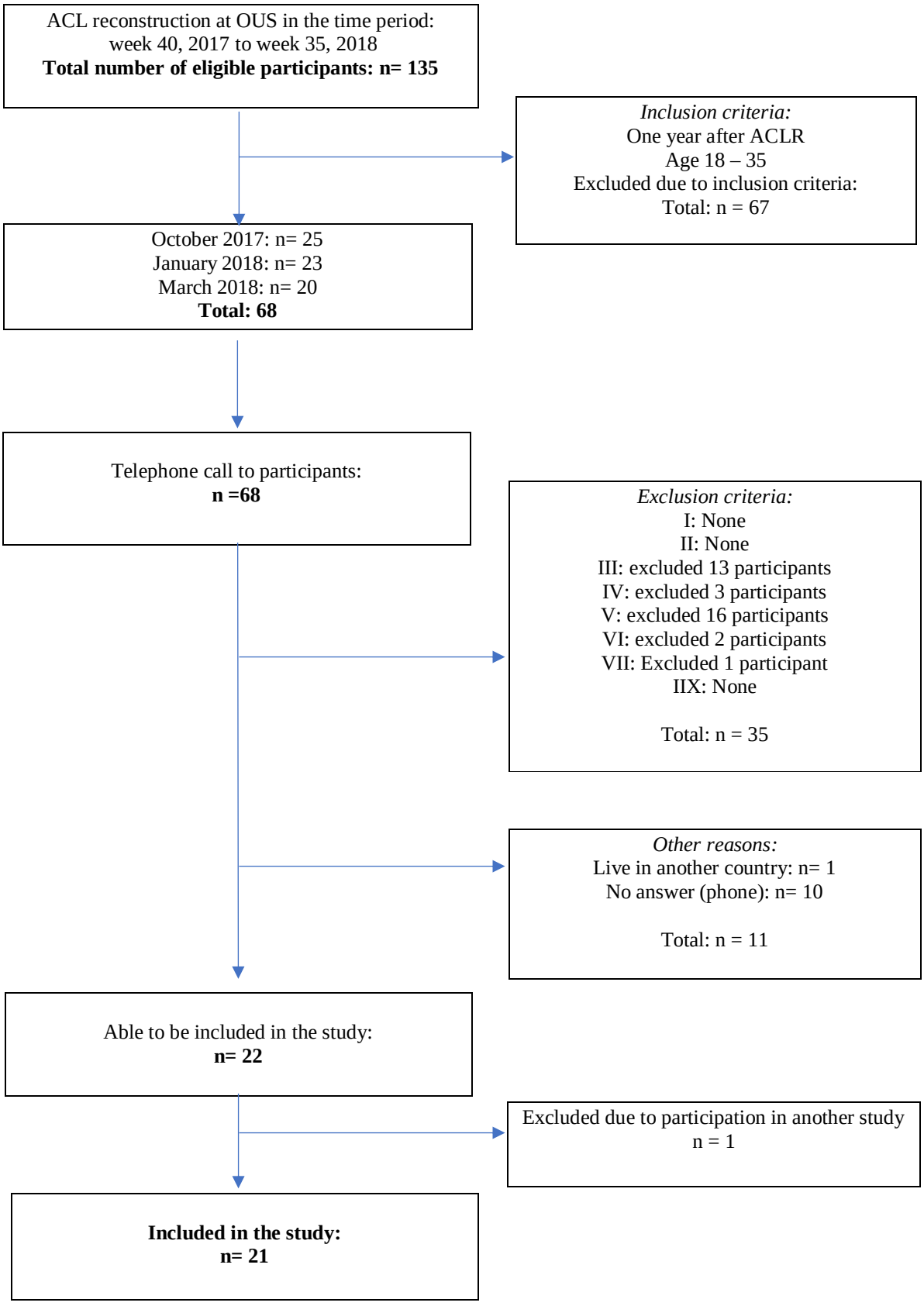
Due to the importance of the same interpretation of the exclusion criteria between Sweden and Norway, several meetings and email correspondence were undertaken. Especially exclusion criteria III (Injury or surgery to other knee (e.g., ACL, meniscal) and V (Previous serious knee injury resulting in pain, swelling, and/or requiring inpatient or outpatient health care (e.g., ACL, meniscus, patella luxation) was subject for further discussion and clarification. For exclusion III it was made clear that all injury, even when the injury was not apparent to the participant as "a potentially partly tear in the ACL" or "a possibly meniscal injury" they were excluded.

For exclusion criteria V, it was agreed that even though the participant had experienced injury *after* the ACL injury (meniscal, swelling/edema) he/she was considered for inclusion, but a re-injury to the ACL was considered an exclusion (exclusion criteria IV).

A few changes were made to the exclusion criteria after the ethical approval was received from Regional committees for medical and health research ethics (Regionale Kommiteer for medisinsk og helsefaglig forskningsetikk), and these changes were sent and later accepted before the study inclusion started. These changes can be seen in Appendix I.

The recruitment of the study participant is giving in figure 3.

Figure 3: Flowchart of the study participants



3.2 Sample size

As previously described the Norwegian part of the SHIELD study was 20 participants. With an expected potential "drop-out" of 10% for the follow-up testing, 22 participants were included. One participant was excluded *after* inclusion and testing due to an overlap with participation in another research study.
No sample size calculations were performed for this cross-sectional study.

3.3 Assessments

3.3.1 Test battery for knee and hip muscle strength and hop performance

The following three different standardized tests were included; 1. Isokinetic knee muscle strength tests (flexion and extension), 2. Isometric hip muscle strength tests (extension, external rotation, and abduction) and trunk muscle strength test (side-bridge). 3. Hop performance tests (The SLHD test and the Side-hop test). A short warm-up was done before the testing, and the participants wore athletic clothes and shoes.

1.
Isokinetic knee muscle strength (flexion and extension) tests were measured using Biodex dynamometer (BiodexMedical Systems, Shirley, New York) at 60^0 per second, concentric/concentric mode. The participant was sitting in the Biodex chair, with their knees flexed at 90^0. The range of motion (ROM) was from 90^0 - 10^0. Trunk, hips and the opposite leg were securely strapped to inhibit counter movement, and arms were crossed over the chest. Four trial repetitions with increasing force were performed before the actual test, that consisted of 5 repetitions with maximum force. The participants first performed four warm-up trials at submaximal performance, before they performed the real test consisting of 5 repetitions. They were instructed to extend and flex their knee during the test entirely. The machine was calibrated before each time testing.
Peak torque (Nm) and peak torque/kilogram body weight (Nm/kg) were recorded. The non-injured leg was tested before the injured leg. Data on the injured versus non-injured

leg was given in percent, as LSI score, and data were compared to normative data.

Biodex isokinetic dynamometer has been used as valid and reliable measurements for decades for investigating quadriceps and hamstring muscle strength in ACL injured and ACLR patients (de Vasconcelos et al., 2009). The use of Biodex is considered the "Gold" standard for isometric muscle strength testing (David C. Feiring, Ellenbecker, & Derscheid, 1990).

2.

A hand-held dynamometer (HHD) was used for the measuring of isometric hip- and trunk muscle strength. HHD is easy to use in a clinical setting (K. Thorborg, Petersen, Magnusson, & Hölmich, 2009).

The hip muscles strength tests included in the study were; hip external rotation, hip extension, hip abduction, and trunk muscle strength and tested in that order. The muscles were tested in either prone (extension and external rotation), supine (abduction), or side-lying position (trunk). Force was recorded in Newton (N) and given in Newton x meter divided with bodyweight (Nm/Kg). The lever arm was recorded with a measuring tape, the participant standing with feet shoulder width apart and no shoes;

- Medial joint line of the knee to 5 cm proximal of the medial malleoli
- Major Trochanter to the back of the thigh
- Major trochanter to lateral malleoli
- Acromion to lateral malleoli

A mark was made with a pen, for the placement of the HHD: 5 cm proximal of the medial malleoli, back of the thigh, and lateral malleoli.

The right leg was tested first in all four tests regardless if the right leg were the injured leg. The HHD used for all four tests was a Power Track II Commander Echo (JTECH Medical, Salt Lake City, Utah, USA). Each test was repeated three times with maximum effort for 5 seconds, with a 15 seconds rest period in-between tests. The investigator matched the force produced by the participant, thereby performing a "make" test (Kristian Thorborg et al., 2011).

Hip external rotation was performed with the participant lying prone on a therapeutic plinth and the measured leg in 90º knee flexion. Arms were hanging at the side, and belts were strapped around the pelvis and the opposite thigh, restricting counter movement. The dynamometer was placed 5 cm proximal from the medial malleoli, and the participant was asked to press against the dynamometer with maximum effort in an inward movement.

Hip extension was measured in the same position as hip external rotation with the arms hanging, and the knee in a 90º flexion and a belt fixating the pelvic area and the opposite thigh. The dynamometer was placed just proximal of the back of the popliteal region of the knee, and the participant was asked to lift the thigh off the bench and press against the dynamometer with maximum effort.

Hip abduction was measured with the participant lying supine on the bench and arms crossed over the chest. Belts were strapped around the pelvic area and the opposite thigh to restrict counter movement. The dynamometer was placed 5 cm proximal for the lateral malleoli, and the participant was asked to press against the dynamometer, sliding the heel in an outward (abduction) movement but with no rotation in the hip and with maximum effort.

Trunk muscle strength was performed as described by Nakagawa and colleagues (2015) (Nakagawa, Maciel, & Serrão, 2015), with the patient side-lying on a plinth with the upper leg in front of the lower leg and the opposite arm resting on the opposite shoulder thereby resting on both legs and the elbow. A belt was put around the pelvic area with the dynamometer between the belt and the area between the major trochanter and Gluteus Medius. A test movement was conducted to assure the belt length was allowing the participant to perform a side-plank but not come into full end-range. The participant was asked to perform a side-plank with straight legs and press against the dynamometer with maximum effort.

The highest score out of the three measurements was used for analyses, calculated into Nm/kg and was compared to injured versus non-injured leg. LSI was calculated, and data were compared to normative data.

HHD has shown to be a valid and reliable testing method by several authors (Martins, da Silva, da Silva;, & Bevilaqua-Grossi, 2017)(Kemp, Schache, Makdissi, Sims, &

Crossley, 2013)(K. Thorborg et al., 2009), with inter-rater intraclass correlation coefficient (ICC) reliability scores ranging from: 0.77 – 0.96 and intra-rater reliability scores from 0.82-0.95 (Kemp et al., 2013). Thorborg et al., (2009) presented Standard Error of Measurements (SEM) values for Hip abduction muscle strength tests in supine position of 2.5% (3.4 N) and Minimal Detective Change (MDC) at 9.4N. Hip extension (short lever) a SEM of 11.4% (24.9N) and a MDC of 13.5N. Hip external rotation in prone position SEM of 6.1% (7.1N) and MDC of 19.6N (K. Thorborg et al., 2009). No data on MDC or SEM have been reported for isometric trunk muscle strength tests.

3.

Hop performance was tested using two different tests: The Single Leg Hop for Distance (SLHD) test, a maximum effort test, and the Side-hop test for 30 sec. The right leg was tested first regardless of whether it was the injured or non-injured leg.

The SLHD test: White tape illustrated the start line, and the participant stood on one foot, placing the toes on the edge of the tape, raising the other knee in front of the body. The participant performed at single leg hop as far as possible, with a secure landing for 2-3 sec, where the use of arms was allowed for speed and balance. The verbal instructions were at a secure landing "1, 2 and stop," and then the participant was allowed to put down the other foot for balance while the investigator measured the hop distance. In case no secure landing was possible, the participant would have a new attempt.

The exercise was performed until three successful landings on each side was accomplished. If the distance measured was more than 10 cm from hop 2 to 3, the participant was allowed to hop again until the distance was less than 10 cm from hop to hop.

The hop length was measured in centimeters, and the longest hop was compared injured versus non-injured leg, and Limb symmetry index was calculated.

The Side-hop test: Two white tape lines, 50cm long and 40cm apart was taped to the ground. The participant stood with the medial side of the right foot close to the same side tape line. The participant was asked to jump as many side-hops as possible for 30 seconds with a landing outside the tape stripes. If the landing was inside the tape, the

participant should keep on jumping, but this hop would not count. The exercise was video recorded for later assessment, where the total number of jumps outside the white tape stripes was counted. Data was compared to injured versus non-injured leg, and Limb symmetry index was calculated.

The tests used for the evaluation of hop performance have been validated and has shown high reliability with ICC values from 0.85 – 0.97 (Gustavsson et al., 2006) and 0.84 – 0.98 (Kockum & Heijne, 2015). According to Kockum et al., (2015), the smallest Real Difference (SRD) was reported to be 9,9% for the SLHD test and 22.9% for the Side-hop test. SEM was 5.15cm for the SLHD test and 3.95 (4 hops) for the Side-hop test (Kockum & Heijne, 2015). Ross et al., (2002) reported similar SEM for the SLHD test of 4.61 cm (Ross, Langford, & Whelan, 2002).

3.3.2 Patient characteristics

Patient characteristics were collected from an interview at the test day and cross-checked with data from medical and patient records. The characteristics consisted of measurements of height, weight, date of birth and information about the injury such as; date of injury, primary sport before the injury, injury situation, contact/non-contact, date of surgery, which graft was used and additional injuries.
Height was measured with a tape measure on the wall and the patient standing with their back against the wall (no shoes) for measurement. The participant's weight was measured on the same digital weight located at NIMI also without shoes, but with the athletic clothes on. The questions asked about the date of injury and surgery, graft and additional injuries were cross-checked with the participant's medical record.

3.3.3 Patient-reported outcomes (PROs) and physical activity scale

Patient-reported outcomes:
KOOS was developed in 1990 in a research collaboration between Sweden (Ewa Roos and colleagues) and The United States of America (Colleagues at the Vermont University) as a patient outcome measure (PROs) for patients with knee injury and knee osteoarthritis (Ewa M. Roos & Lohmander, 2003)(*http://koos.nu*, 2018).
The total number of questions is 42, divided into 5 subscales; Pain (7 questions), Symptoms (9 questions), Activities of Daily Living (ADL) (17 questions), Sport and

Recreation Function (Sport/Rec) (5 questions) and QOL that is knee-related (4 questions). The period the patients are answering for is the last week. To each question, there are five pre-given answers: Never, rarely, sometimes, often and always. Each answer is transformed into 0 (Never) 1(Rarely) 2 (Sometimes) 3 (Often) and 4 (always) and transferred to the KOOS excel file, found on www.KOOS.nu and calculated into scores where 0 was equal the worst possible score and 100 the best possible score. KOOS can be used both for short- and long-term evaluations and has been validated, shown to be reliable and responsive by many authors (N.J. Collins et al., 2016)(Ewa M. Roos & Lohmander, 2003)(Wang, Jones, Khair, & Miniaci, 2010). The Norwegian version used in this paper was translated and validated from the Swedish version in 2006-2007 and named KOOS Norwegian version LK1.0 (*http://koos.nu*, 2018).
The MDC for people with knee injury is as followed for each subscale: Pain: 6 – 6.1. Symptoms: 5 – 8.5. ADL: 7 – 8. Sport/Rec: 5.8 – 12. QOL: 7 – 7.2 (Natalie J. Collins, Misra, Felson, Crossley, & Roos, 2011).
The result was evaluated and compared to normative data.

Tegner Activity Scale:
Tegner Activity Scale was developed in 1985 to complement the Lysholm scale for patients with ACL injuries with/without additional injuries. (Briggs, Lysholm, et al., 2009). The questionnaire is describing 11 categories, where the 10^{th} category is considered the most active activity level, and 0 is considered the lowest activity level.

For the Tegner Activity Scale, the participant was asked to circle the "best fit" activity level for their activity level and also, if different, circle the activity level *before* the injury.
Tegner Activity Scale has been proven to have a high test-retest reliability score (ICC: 0.8) (Briggs, Lysholm, et al., 2009) and a valid tool for patients with an ACL injury (Briggs, Lysholm, et al., 2009).
MDC is one category and SEM range from 0.4 – 0.64 (Natalie J. Collins et al., 2011).
The result was evaluated and compared to normative data.

Level of Pain and Global Rating of knee function:
The participants level of pain was measured on a numeric rating scale (NRS), where the

participant circles the level of pain, he or she had at the moment, meaning the period the person was tested at NIMI. Instructions from the investigator were "This question should be answered on a scale from 0 – 10, where 0 is zero pain, and 10 is the worst pain ever, circle the number equivalent to the pain you are experiencing when testing". The participant's self-reported knee function was measured using Global Rating of knee Function, an NRS scale from 1 – 10, where 1 is the worst function and 10 the best. Instruction from the investigator was; "on a scale from 1 – 10, where 1 being the worst knee function and 10 being the best function, where would you score your knee function today?" NRS has been proven to be valid and reliable measuring tool (Karcioglu, Topacoglu, Dikme, & Dikme, 2018).

Return to Sport:

RTS consisted of 5 questions regarding which sports activity the participant did before the injury and at what level if they had returned to sports activity again and at which level or if they had begun with other activity. The questions were as followed;

Return to Sport Questionnaire:

Return to Sport Questionnaire
Q1: What type of Sport did you participate in before the injury: 1.Soccer 2.Handball 3.Indoor bandy 4. Basket 5. Other 6. None
Q2: At what level: 1. Recreational 2. Recreational/Compete 3. Elite
Q3: Have you returned to sport again: 1. Yes 2. No
Q4: Have you return to same sport and at same level as before the injury: 1. Yes 2. No
Q5: After my injury, I have: 1. Started with another sport 2. Same sport but lower level 3. Same sport but higher level 4. Other

The RTS questionnaire was developed in Lund, Sweden, and was designed according to leading experts in this field (Clare L Ardern et al., 2016).

3.3.4 Magnetic Resonance Imaging

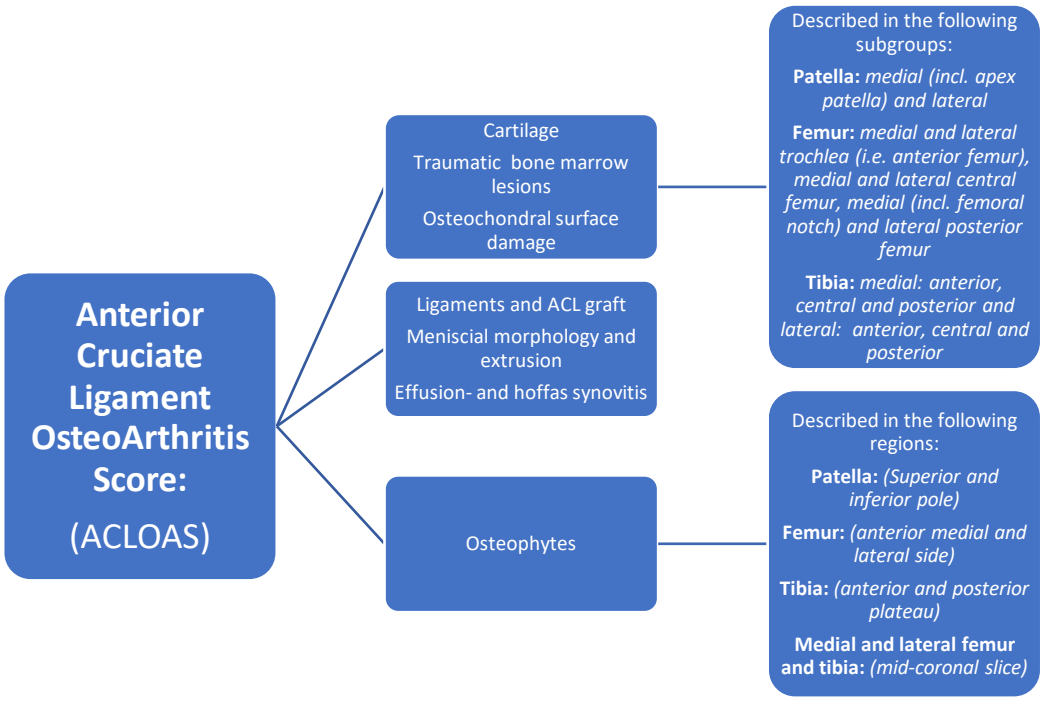
MRI of the injured knee was used to investigate morphological degeneration of knee joint structures and to describe the injury and post-traumatic alterations in joint structures. The ACLOAS was used for the investigation and description.
The ACLOAS is a detailed whole joint description of MRI investigations of the ACL injury and later follow-ups. It was developed by Roemer et al. (2014) and has proven to be able to detect early changes in cartilage and morphology in ACLR patients (Roemer, Frobell, Lohmander, Niu, & Guermazi, 2014). The ACLOAS is presented in figure 4.
For the ACLOAS description at baseline visits, all MRI sequences are used for scoring and consist of 14 articular subgroups where the following are described: cartilage, traumatic bone marrow lesions, and osteochondral surface damage.

The 14 subgroups are as followed:

Patella;	2 sub-regions: medial (incl. apex patella) and lateral,
Femur;	6 sub-regions: medial and lateral trochlea (i.e. anterior femur), medial and lateral central femur, medial (incl. femoral notch) and lateral posterior femur,
Tibia;	3 medial sub-groups: anterior, central and posterior 3 lateral sub-groups: anterior, central and posterior

In addition; ligaments and ACL-graft, meniscal morphology and extrusion, effusion- and Hoffa´s synovitis are scored together with osteophytes.
Osteophytes are scored in the following regions: Femur (anterior medial and lateral site), Tibia (anterior and posterior plateau), Patella (superior and inferior pole) and medial and lateral femur and tibia (mid-coronal slice) (Roemer et al., 2014).

Figure 4: ACLOAS description areas and subgroups



Scoring:

Cartilage is scored from 0-6, where 0 is normal (no damage), and 6 is equal full-thickness loss.

Traumatic bone marrow lesion and osteochondral surface damage are scored for the *type of injury* and the *injury size*.

Type of injury is scored from 0-4, where 0 is normal, and 4 is a detached osteochondral fracture.

Injury size is scored from 0-3, where 0 is absent, and 3 is severe injury (more than 66% involved).

Ligaments and ACL graft are divided into *Collateral ligaments*, *ACL*, and *PCL*.

Collateral ligaments are scored from 0-3, where 0 is normal ligament, and 3 is a complete disruption. *ACL* is scored from 0-3, where 0 is normal, and 3 is graft rupture, and *PCL* is also scored from 0-3 where 0 is normal, and 3 is absent ligament or a complete discontinuity.

Meniscal morphology is scored from 0-8, where 0 is normal meniscus, and 8 is a complete maceration or resection.

Extrusion is scored from 0 -2, where 0 is no extrusion and 2 is more or equal to 50% of the meniscal coronal length.
Joint effusion is scored from 0-3, where 0 equal less than 2mm and 3 is more or equal to 10 mm.
Hoffas synovitis is scored from 0-3 where 0 is normal, and 3 is severe hyperintensity signal changes.
Osteophytes are scored from 0-7, where 0 is absent, and 7 is very large osteophyte.
A full scoring description is listed in appendix II.

For this master project, joint effusion and Hoffa`s synovitis will not be scored.

ACLOAS has shown intra- and inter-reliability kappa values between 0.8 – 1.00 for 73% of all the assessments (Roemer et al., 2014).

3.4 Test – day procedures

MRI was conducted at OUS by the same personnel and analyzed later by Senior consultant Øyvind Fidje. The remaining data collection was performed at NIMI by one investigator (Dorthe Strauss – DS) using a total of 1.5 hours per participant, including a short warm up. The warm-up was standardized and consisted of 5 min at a stationary bike, 2 times 10 squats, 2 times 10 toe raises, 10 jumps on both legs, and 5 jumps on the right and left leg. The testing was also standardized and done in this particular order: measuring leverage for the isometric test, isometric testing with HHD dynamometer, the SLHD test, isokinetic muscle strength with the use of Biodex machine, the side-hop test, recording patient characteristic and asking the patient to answer PROs and other questionnaires.

3.5 Inter-rater and intra-rater reliability studies

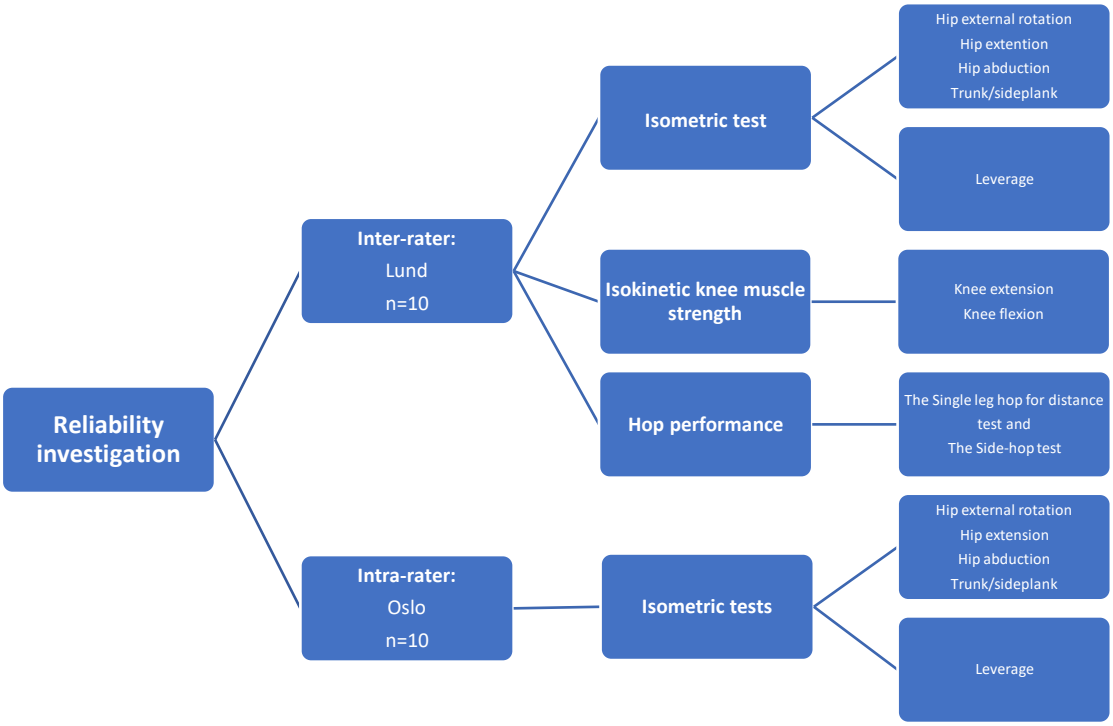
To ensure the quality of the data used in the project, inter and intra-reliability studies, both including 10 participants, was conducted at Lund, Sweden, and Oslo, Norway respectively.
The procedures for the inter and intra-reliability investigations were as follows:
The investigation for inter-reliability between the two researchers from Lund, Sweden (Anna Cronström - AC) and Oslo Norway (DS), did two days testing in Lund. The test procedures had been described beforehand, and both investigators had practiced the procedures before the meeting.
The inter-reliability investigation included the following tests, as seen in figure 5:

1. Isometric tests, including four measurements of leverage used for the calculation of Nm/Kg. The leverage measurements are as previously described on page 34.
2. Isokinetic Knee strength (extension and flexion)
3. Hop performance: The SLHD test (centimeter measurement) and the Side jump test (counting numbers of approved jumps) and were tested in that order.

Ten volunteers (friends, family, and colleagues of AC) participated (six volunteers were tested on day one and four on day two), and everyone started with a 5 min stationary bike warm-up. The volunteers had 1.5 – 2 hours of rest in-between the testing from one researcher to the other to prevent fatigue and thereby differences in measurement.
The Inter-rater reliability study in presented in figure 5.

Learning curve improvement was possible for the participants second testing, and therefore, the first testing of volunteers was alternated between the two researchers:
Example: Test person 1, tested by researcher AC first and researcher DS second
Test person 2, tested by researcher DS first and researcher AC second.

Figure 5: Inter-rater and intra-rater reliability studies



Intra-reliability testing was performed in Oslo, as presented in figure 5.
Ten volunteers (colleagues and family of DS) were tested twice with approximately one week in-between the two tests and was done by the same researcher (DS), who also did the testing in Lund.
The tests investigated was: Leverage and isometric hip and trunk strength tests, as measured in Lund previously for the inter-reliability testing.

3.6 Systematic literature search for normative data

3.6.1 Definition of "Normative data."

No clear definition for "normative data" in medical research was found.
The definitions and explanations presented through-out the literature agreed on:

- Data comes from a specific reference population and data summarize the typical

or average for the group of people or the individual in the reference population at a specific time, time period, or age.

- Data establish a baseline for a score or measurement where other scores can be compared since data from the reference population are considered what the "norm," "normal," or "standard is."
- Data is typically collected from a randomly and large sample, representative for the wider population.

(*https://euroqol.org/eq-5d-instruments/population-norms/*, 2019)(O'Connor, 1990) (*https://en.oxforddictionaries.com*, 2019)(Turkington & Anan, 2007)(Zimmerman, 2011)("https://www.yourdictionary.com/normative," 2019) (*http://www.businessdictionary.com/definition/normative.html*, 2019).

According to the article by O´Connor (1990), the optimal study design for collecting normative data are Cross-sectional, Case-control, Longitudinal cohort studies, or existing data sets. (O'Connor, 1990).

3.6.2 Search for "normative data."

A literature search was conducted at the 1st of February 2019 at 2 PM through; U.S National Library of Medicine (PubMed database) (https://www.ncbi.nlm.nih.gov/pubmed/) for finding the relevant articles for normative data. PICO guidelines (Laake, Olsen, & Benestad, 2008) were used for finding relevant search terms (table 4), and Preferred Reporting Items for Systematic review and Meta-Analysis Protocols (PRISMA-P) guidelines (*http://www.equator-network.org/reporting-guidelines/prisma-protocols/*, 2019) was used for reporting (PRISMA-P Items 6-12 and 14).

The following criteria outlined in Table 3 were developed as a guiding tool for finding the most comparable normative data for this study group.

Table 3: inclusion and exclusion criteria for finding Normative data

Inclusion criteria	Exclusion criteria
PROs and in general for all measurements Healthy individuals/General population Large group Similar patient characteristics as the Study sample Include Men and Woman	Younger than 18 and older than 50 Control groups in studies Injured Only Men or only Woman
Isometric testing for hip and truncus (Hip extension (prone), hip external rotation (prone), hip abduction (supine) and trunk/side-bridge (side-lying)) Minimum 3 tests	Less than two tests tested equivalent to the study group Test procedure not described
Isokinetic testing for knee extension and flexion	Other test procedures than concentric/concentric and 60 degrees per sec
Hop performance: SLHD* and Side-hop	The test procedure was not described

*SLHD: Single leg Hop for Distance

Table 4: PICO guidelines search terms

Population	Intervention	Comparison	Outcome
"Healthy Individual*." "General population." "Adult" NOT "Patient" "Patients" "Elderly"	"Muscle Strength" "Hop performance." "Jump performance." "Muscle test." "Strength test." "Hop test." "Isometric test*." "Isokinetic test*." "Dynamometer" "Biodex" "Functional assessments." "Patient-reported outcome measure*." "Tegner Activity Scale" "KOOS" "Knee injury and Osteoarthritis Outcome Score."		"Normative data." "Reference value*." "Limb symmetry index," "Lower extremities." "Lower extremity." "Knee" "Hip"

*Truncation

First search; Pub Med database: 01.02.2019 at 2 PM:

Search ("Healthy Individual*" OR "General Population" OR "Adult*") AND ("muscle strength" OR "hop performance" OR "jump performance") AND ("Muscle test*" OR "Strength test*" OR "Hop test" OR "Isometric test*" OR "Isokinetic test*" OR Dynamometer* OR "Biodex" OR "Functional

assessment*" OR "Patient-reported outcome measure*" OR "Tegner Activity Scale" OR "KOOS" OR "Knee Injury and Osteoarthritis Outcome Score" OR "Normative Data" OR "Reference Value*" OR "limb symmetry index") AND ("Lower extremities" OR knee OR "lower extremity" OR hip) NOT (patient OR patients OR elderly)

This search revealed 385 articles, and with the corrections on "Humans," a total of 378 articles was ready for further inspection. After reading the title and abstract, six articles were found of interest, but no articles were included after using the in- and exclusion criteria.

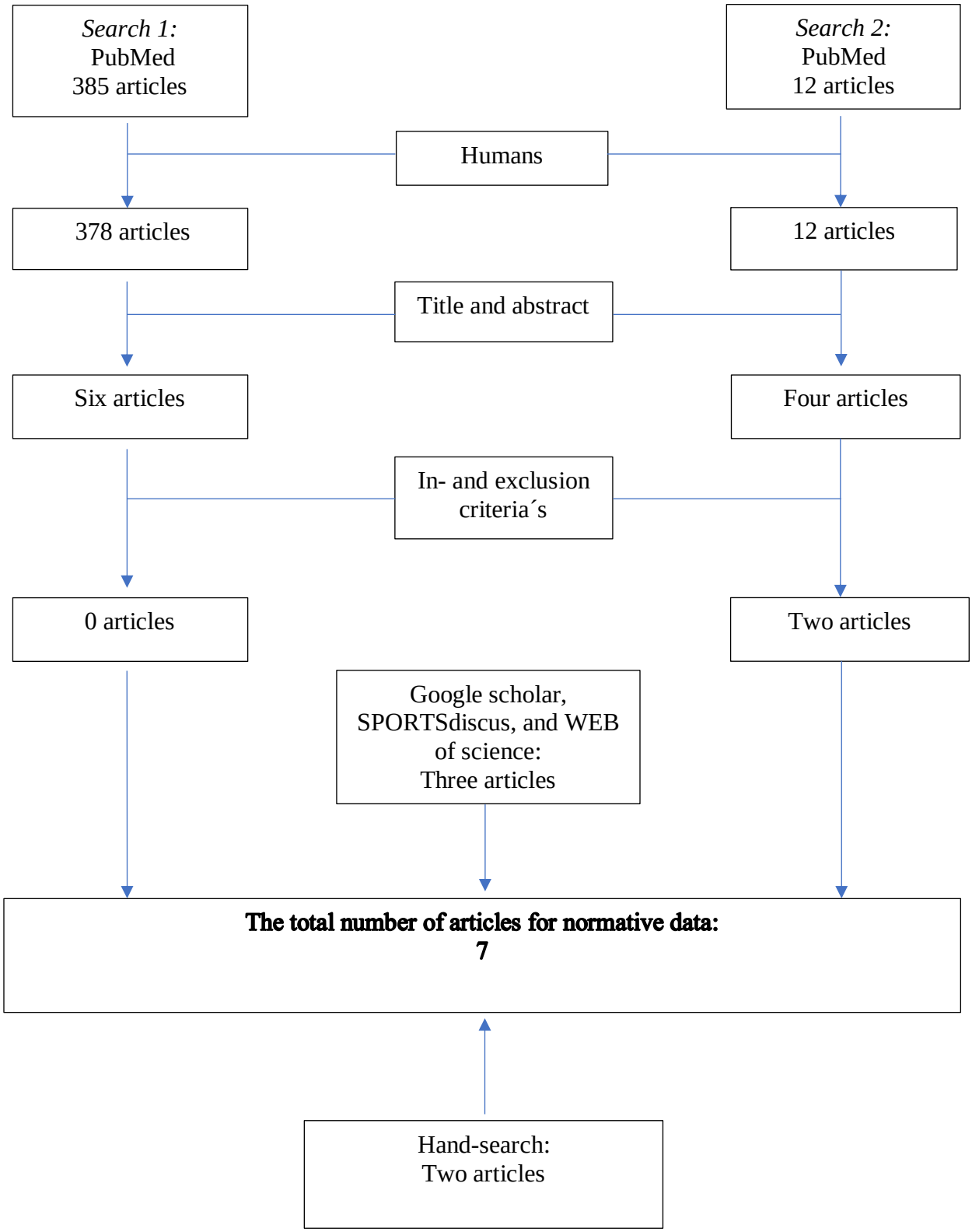
Since no data was found on the KOOS and Tegner Activity Scale, a new search was done, but only with the some of the search terms used in the initial search:
Search two: Pub Med database: 06.02.2018 at 10 AM;

Search ((((("Normative data") OR "Reference Value*")) AND ((((("Patient reported outcome measure*") OR "Tegner Activity Scale") OR "KOOS") OR ("Knee injury and Osteoarthritis Outcome Scale"))

This additional search found 12 articles where four was of interest after reading the title and abstract, and two articles were included after applying the inclusion and exclusion criteria. A similar search as the first one was performed at the following databases: SPORTSdiscus, WEB of science, and Google Scholar to optimize the numbers of relevant articles. Here a total of 3 additional articles was found after reading the abstract and applying the in- and exclusion criteria. Hand-search revealed two relevant articles, resulting in a total of 7 articles with normative data that were comparable to the study sample. Figure 6 illustrates the literature search.

All articles were checked with critical appraisal tools. The Appraisal tool for Cross-sectional Studies (AXIS) was used for the 6 Cross-sectional studies (Downes, Brennan, Williams, & Dean, 2016). Critical Appraisal Skills Programme; CASP (https://casp-uk.net, 2018) was used for the observational study. The result can be seen in Appendix III.

Figure 6: Flowchart of the literature search for normative data



3.7 Ethics

Approval from the Regional committees for medical and health research ethics ("Regionale Kommiteer for medisinsk og helsefaglig forskningsetikk") was given to this study in September 2016 under the document id: 2016/1128 (Appendix IV). Approved application from the Oslo University Hospital Data Inspectorate was also given (Appendix V).

Letter of information (Appendix VI) with a detailed description of the study and potential risks for the patient, together with a written consent (Appendix VI) form and a pre-posted envelope were sent to all of the eligible participants. In the letter, it was made clear that in case they had no desire to participate in the study, they could send an email declining participation. It was also made clear the participant´s right to leave the study at any time for whatever reason.
Seven letters with a signed consent were returned by mail, and no email was received with a decline to participate.
A telephone call was made to all of the participants except for ten potential participants where the call was not answered. During the telephone interview, additional information was given about the study as well as answering questions and screening participants for exclusion criteria.

No payment was offered to the participant, but in case the participant had travel expenses, these were refunded using a standard "reiseregning" (Appendix VII).

3.8 Statistical analysis

For all data Shapiro-Wilk (due to the number of participants was < 50) together with histograms was used for normality tests.

Descriptive statistics were used for participant characteristics and is presented with mean and standard deviation (SD), number of participants, and right/left side.

The level of pain was not normally distributed, and data is be presented with median and lower and upper quartiles. Since the result presented in median was 0.00. For later comparison with other studies in the discussion the scores was presented in mean, the result from the study sample will be presented in mean and SD in the discussion only.

For the evaluation of Inter-rater and Intra-rater reliability (aim 1), ICC was used. The ICC model used is 3,1 since the reliability is calculated from the max value from every test.
(*https://www.uvm.edu/~dhowell/methods9/Supplements/icc/More%20on%20ICCs.pdf*, 2019) and in SPSS: Two-way mixed, single measures, consistency was used.
ICC result between 0.5 and 0.75 is considered moderate reliability, results between 0.75 and 0.9 are considered good reliability, and above 0.9 is considered excellent reliability (Koo & Li, 2016).

For the evaluation of the patient´s muscle strength and hop performance between the non-injured and injured leg (aim 3), Paired T-test was used.
For the interpretation of the result, a difference in mean above 0 indicates non-injured was stronger or scored better, and a mean value below 0 (negative) indicates the injured leg was stronger or scored higher than the non-injured.

LSI (aim 3) was calculated by dividing injured with non-injured and multiplied with 100, given the percent. LSI score at 100% indicates no difference between the injured and non-injured. Scores above 100% indicate the injured leg was stronger than non-injured and scores lower than 100% indicates the non-injured leg was stronger. Several articles have used LSI and considered a LSI above 90% is considered normal limb asymmetry and LSI under 90% is considered too significant of an asymmetry (Fitzgerald, Axe, & Snyder-Mackler, 2000)(Gustavsson et al., 2006)(Adams et al., 2012).

For calculations of the difference between the study sample result and normative data, the Aspin Welch Unequal Variance T-test was used (NCSS10, 2015, NCSS, LLC).

Data from the Tegner Activity Scale is considered ordinal data, and the results should, therefore, be presented with Median and range/min-max. For the comparison of the result from the study sample and the normative data from Briggs et al., (2009) this was not possible since Briggs et al., (2009) presented data with mean hence the comparison is made with mean. Briggs et al., (2009) did not reveal the standard deviation, and therefore, it was not possible to use the Aspin Welch Unequal Variance T-test for calculations.

For evaluation of aim 4, the score sheet from the webpage: www.koos.nu was used, and descriptive statistics used for mean and standard deviation.
Simple linear regression model was used to analyze associations between KOOS and isokinetic knee and isometric hip and trunk muscle strength and hop performance tests (aim 5a). For the association between RTS and isokinetic knee and isometric hip and trunk muscle strength and hop performance tests (aim 5c), logistic regression model was used. Due to the low sample size, only bivariate analysis was done together with Fisher's exact test.

Regarding aim 5a, simple linear regression analysis can be used with a sample size of a minimum of 20 (O'Donoghue, 2012). With 21 participants in the sample size, the use of simple linear regression analysis was undertaken. The result must be interpreted with caution, and a wide range is expected for the confidence interval due to the low sample size.
For aim 6b, the ACLOAS scoring sheet was used to find how many participants had cartilage defects (scored 2 or above in ACLOAS) in either area (patella, trochlea, femur or tibia). The investigation of any differences between cartilage score (yes/no) and KOOS (all subscales) is presented with box plots and Mann-Whitney test for KOOS PAIN, SYMPTOM, and ADL since data was not normally distributed. For KOOS SPORT and RECREATION and QOL, data is presented with independent T-test; p-value, mean difference ± SD and 95% Confidence Interval (95% CI) since data was normally distributed.

All data were double-checked by the author and an independent person, before statistical analysis (IBM SPSS statistics, version 25).

4.0 Results

4.1 Study sample presentation

Participants` eligibility and final inclusion are presented in figure 3, page 32. Twenty-one participants were included in the study, a total of 11 male and ten females. The participants are presented in table 5.

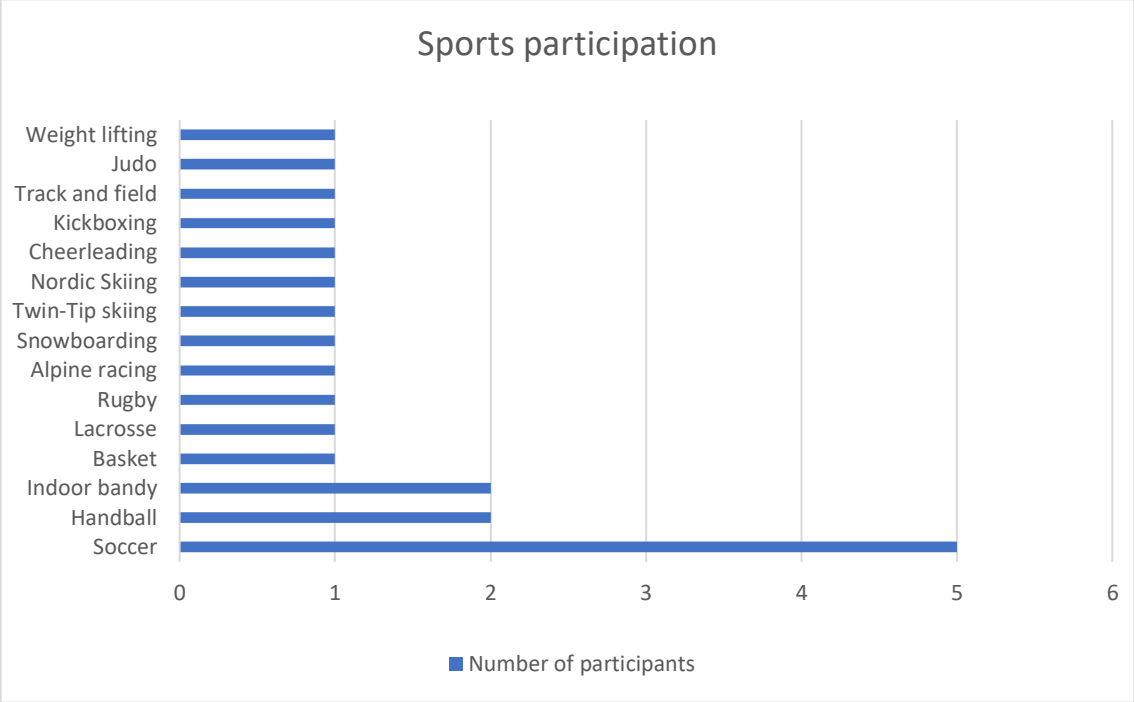
Table 5: Study sample presentation

Study sample characteristics:	
Number of participants	21
Male/Female (n•)	11/10
Age at test date (years): Mean ± SD*	24.1 ± 5.0
Height (centimeters): Mean ± SD	174.7 ± 9.8
Weight (kilogram): Mean ± SD	76.1 ± 14.8
BMI♣: Mean ± SD	24.6 ± 3.4
Side of injury: Right / Left	13/8
Time from injury to ACLR♦ (months): Mean ± SD	9.5 ± 10.9
Time from ACLR to test date (months): Mean ± SD	11.8 ± 1.2
Concomitant injuries: Yes / No	14/7
2+♠ injuries: (n)	3
NRS# Pain: median (lower and upper quartiles)	0.0 (0.0 – 1.0)
Global Ration of knee function: Mean ± SD	6.52 ± 2.04

•N: Number, *SD: Standard Deviation, ♣BMI: Body Mass Index, ♦ACLR: Anterior Cruciate Ligament Reconstruction, ♠2+: more than two additional injuries #NRS: Numeric Rating Score

The participants represented a broad range of activities, as seen in figure 7:

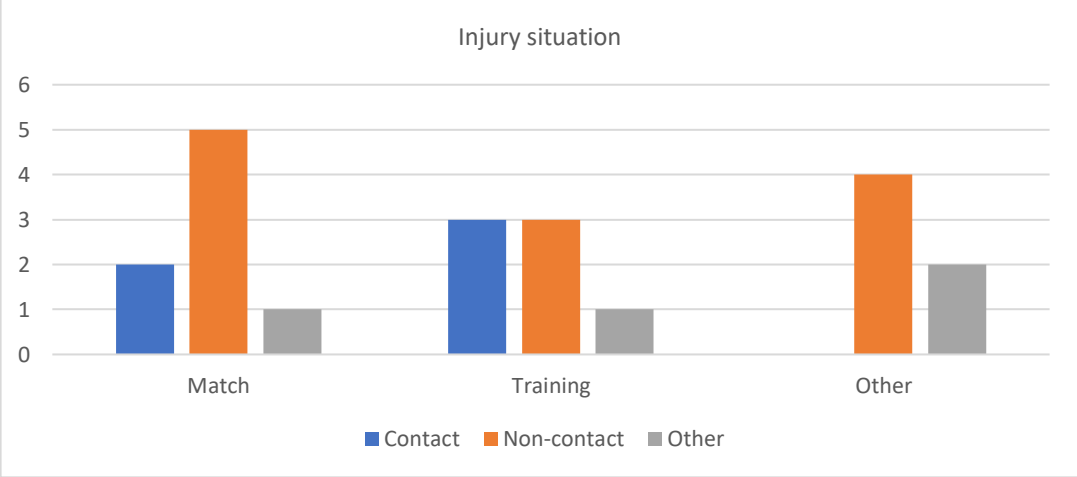
Figure 7: Study sample sports participation



All but one (n=20) were participating in some type of sport when the ACL injury happened, only one injury occurred doing a non-sport activity. In this case, the participant was injured falling down stairs.

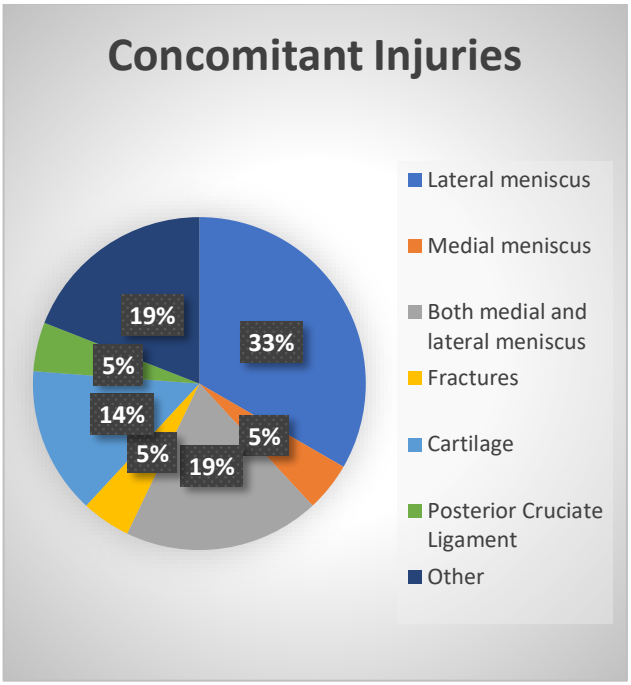
The injury occurred both during a match, training and other situations described as; falling down stairs, jumping on trampoline and crash on alpine skies, and happened as a contact, non-contact injury or other situations (landings or change of directions) as illustrated in figure 8.

Figure 8: Injury situation



The most used graft was BTB (n=15), but 3 participants had hamstring tendon grafts, and 3 receiving quadriceps tendon grafts. The most common injury was meniscal injury, as seen in figure 9. Other injuries included collateral ligaments and bone bruises.

Figure 9: The study sample´s concomitant injuries



4.2 Research aim 1

4.2.1 Inter-rater and Intra-rater Reliability Studies

The result of both inter-rater and intra-rater reliability tests was satisfactory and are illustrated in table 6 and 7.

Table 6:

Inter-rater reliability study

Measurement n=10	ICC*
Isometric:	
Hip external rotation	0.931
Hip extension	0.666
Hip abduction	0.759
Trunk/ Side-bridge	0.726
Isokinetic:	
Knee extension	0.849
Knee flexion	0.838
Hop performance:	
SLHD♣	1.0
Side-hop	0.994

*ICC: Intraclass Correlation Coefficients,
♣SLHD: Single leg Hop for Distance

Table 7
Intra-rater reliability study

Measurement n=10	ICC*
Leverage:	
1. Medial joint line of the knee to 5 cm proximal of the medial malleoli	0.877
2. Major Trochanter to the back of the thigh	0.834
3. Major Trochanter to lateral malleoli	0.900
4. Acromion to lateral malleoli	0.990
Isometric Right side:	
Hip external rotation	0.975
Hip extension	0.884
Hip abduction	0.894
Trunk/Side-bridge	0.810
Isometric Left side:	
Hip external rotation	0.976
Hip extension	0.823
Hip abduction	0.871
Trunk/Side-bridge	0.921

*ICC: Intraclass Correlation Coefficients

4.3 Research aim 2

4.3.1 Results from the systematic literature search

The articles found in the systematic literature search are presented in table 8.
No data on Trunk assessment were found, and therefore, only LSI is used for that particular test. No data was found on hop performance tests, and therefore, no comparison could be made between the study sample and the normative data.
Some of the articles Kemp et al., (2013), Paradowski et al., (2006), Cameron et al., (2013), Baldwin et al., (2017), Williamson et al., (2015) presented data as males and females. Since this master project does not investigate the difference between male and female, and due to the small sample size, data from the study sample will only be listed as "all."
Comparison has been made by calculating the result from each article´s listed below, presented in male and female and divided the result by 2 for finding the result for "all" the participants.

Table 8: Articles containing normative data

Article	Participants	Study design	Measurements
Kemp et al. (2013)	n=57 Age-group: 18-50	Cross-sectional	Isometric measurements for hip extension, abduction, and external rotation.
B. Danneskiold-Samsøe et al. (2009)	n=28 Age-group: 20-29	Cross-sectional	Isokinetic measurements for knee flexion and extension.
Cameron et al. (2013)	n=1005 Mean age: 18.8 ± 0.8	Cross-sectional	KOOS*
Paradowski et al. (2006)	n=134 Age-group: 18-34	Cross-sectional data from a Cohort	KOOS
Baldwin et al. (2017)	n=66 Age-group: 18-29	Observational study	KOOS
Williamson et al. (2015)	n=292 Age-group 18-25 and 26-35	Cross-sectional	KOOS
Briggs et al. (2009)	n=488 Age-group 18-30	Cross-sectional	Tegner Activity Scale

*KOOS: Knee Injury and Osteoarthritis Score

4.4 Research aim 3

4.4.1 Muscle strength and hop performance: Injured versus non-injured

The non-injured leg showed better muscle strength and hop performance compared to the injured leg except for; isometric hip extension and trunk/side-bridge tests, where the injured leg had better muscle strength. The results are presented in table 9.

The hop performance tests showed significant differences between the injured and non-injured leg for both the SLHD test and the Side-hop tests (Table 9)

For isokinetic knee muscle tests, the difference between injured and non-injured was significant for knee extension (p-value <0.001), but not for flexion (Table 9). All of the isometric tests (hip and trunk muscle strength tests) showed no significant differences between injured and non-injured leg.

Tests, where the non-injured leg scored significantly higher/was stronger, are highlighted.

Table 9: Results for the non-injured and injured leg for hop performance tests, isokinetic knee and isometric hip and trunk muscle strength tests and Comparison between non-injured and injured leg presented with mean difference, standard deviation, P-value and Confidence Interval

Value	Non-injured (Mean ± SD[#])	Injured (Mean ± SD[#])	Mean difference ± SD[#]	P-value (95% CI[+])
Hop performance				
SLHD* (cm[♣])	152 ± 33	135 ± 39	**16.3± 16.9**	**0.000 (8.6 – 24.0)**
Side-hop (n=[♦])	41 ± 17	38 ± 17	**3.0 ± 6.1**	**0.039 (0.2 – 5.7)**
Isokinetic knee muscle strength (Nm/kg[♠])				
Knee extension	269.9 ± 63.7	213.6 ± 62.9	**56.3 ± 54.2**	**0.000 (31.6 – 81.0)**
Knee flexion	132.2 ± 34.0	125.7 ± 33.5	0.9 ± 27.6	0.877 (-11.6 – 13.5)
Isometric hip muscle strength (Nm/kg[♠])				
Hip external rot.[×]	0.65 ± 0.16	0.64 ± 0.19	1.4 ± 26.6	0.811 (-10.7 – 13.5)
Hip extension	0.98 ± 0.26	1.00 ± 0.25	-5.8 ± 9.3	0.540 (-25.1 – 13.5)
Hip abduction	1.79 ± 0.47	1.74 ± 0.53	12.8 ± 28.5	0.053 (-0.2 – 25.1)
Trunk/Side-bridge	4.95 ± 1.97	5.05 ± 2.19	-8.5 ± 59.7	0.521 (-35.7 – 18.7)

*SLHD: Single Leg Hop for Distance, [♣]Cm: centimeters, [♦]n=: number of side-hops, [♠]Nm/kg: Newton x meter/bodyweight, [×] Hip external rot.: Hip external rotation, [#]SD: Standard Deviation, [+]CI: Confidence Interval

4.4.2 Limb symmetry index

The results for LSI are presented in table 10.

When the participants scored exactly 90% it has been listed as greater to or equal to (≥) in the table.

No single test showed scores where all of the participants had LSI above 90%. The highest score was found for the isometric hip muscle strength tests and the Side-hop test.

The highest number of participants meeting the LSI score at ≥90% was 15.

The lowest number was found for isokinetic extension, where only 7 of the participants meet the criteria.

Table 10: Mean Limb Symmetry Index (LSI) and LSI < or ≥ 90%

Tests	Mean ± SD*	LSI <90% n=♣ (%)	LSI ≥90% n= (%)
Hop performance			
SLHD, %	88.0 ± 13.2		
SLHD, n (%)		12(57.1%)	**9 (42.8%)**
Side-hop, %	104.1± 21.2		
Side-hop, n (%)		6 (28.5%)	**15(71.4)**
Isokinetic knee muscle strength			
Knee extension, %	80.4 ± 17.7		
Knee extension, n (%)		14(66.66%)	**7 (33.33%)**
Knee flexion, %	96.2 ± 14.7		
Knee flexion, n (%)		9 (42.86%)	**12(57.14%)**
Isometric hip muscle strength			
Hip external rotation, %	98.8 ± 18.9		
Hip external rotation, n (%)		6 (28.57%)	**15(71.42%)**
Hip extension, %	104.8 ± 22.2		
Hip extension, n (%)		6 (28.57%)	**15(71.42%)**
Hip abduction, %	97.3 ± 13.2		
Hip abduction, n (%)		6 (28.57%)	**15(71.42%)**
Trunk/Side-bridge, %	104.1 ± 21.2		
Trunk/Side-bridge, n (%)		6 (28.57%)	**15(71.42%)**

*SD: Standard Deviation, ♣n=: number of participants

4.4.3 Comparison to Normative data; Hop performance

No normative data was found on hop performance.

4.4.4 Comparison to Normative data; Isometric hip and trunk strength

The result from the comparison between the study sample and normative data from Kemp et al., (2013) was for hip extension and hip external rotation; study sample scored significantly lower than data from Kemp et al. (2013) for both the non-injured and injured leg. For hip abduction, the study sample scored higher for the non-injured leg, but lower for the injured leg than the data presented by Kemp et al. (2013) both not significant with P-values above 0.05. The comparison is listed in table 11. The data from Kemp et al., (2013) was presented as male and female values, where the values were added and divided by two before presented in the present paper.
There were no normative data on trunk measurements and therefor no comparisons.

Table 11: Comparison between isometric hip and trunk muscle strength for non-injured and injured side and normative data from healthy controls

Test: Isometric Nm/kg*	**Study sample n=21 (Mean ± SD♦)**	**Kemp♣ et al., 2013, n=57 (Mean ± SD)**	**P-value difference**
Hip external rotation			
Non-injured	0.65 ± 0.16	0.79 ± 0.23	P= 0.004
Injured	0.64 ± 0.19		P= 0.006
Hip Extension			
Non-injured	0.98 ± 0.26	1.55 ± 0.45	P= 0.000
Injured	1.00 ± 0.25		P= 0.000
Hip abduction			
Non-injured	1.79 ± 0.47	1.75 ± 0.40	P= 0.731
Injured	1.74 ± 0.53		P= 0.938

Isometric muscle strength was tested with a "make test", *Nm/kg: Newton x meter/bodyweight, ♦SD: Standard Deviation, ♣Kemp: dominant leg tested.

4.4.5 Comparison to Normative data; Isokinetic knee muscle strength

When comparing the study sample to normative data from Danneskiold-Samsøe et al. (2009), the study sample had significantly higher values compared to the data from the article for extension (injured and non-injured leg) and flexion (non-injured leg). For knee flexion, for the injured leg, the data from the study sample was higher but not significantly. The comparison is listed in table 12.

Table 12: Comparison between isokinetic knee muscle strength for non-injured and injured side and normative data from healthy controls

TEST: Isokinetic Nm/kg*	Study sample n=21 (Mean ± SD♣)	Danneskiold-Samsøe♦ et al., 2009, n= 28 (Mean ± SD)	P-value difference
Extension			
Non-injured	269.9 ± 63.7	149.17 ± 37.0	P= 0.000
Injured	213.6 ± 62.9		P= 0.000
Flexion			
Non-injured	132.2 ± 34.0	113.34 ± 29.7	P= 0.049
Injured	125.7 ± 33.5		P= 0.187

*Nm/kg: Newton x meter/bodyweight, ♣SD: Standard Deviation, ♦Danneskiold-Samsøe: The dominant side tested. Isokinetic knee muscle strength was tested with: 60degrees/sec and concentric/concentric mode.

4.5 Research aim 4

4.5.1 Patient-reported outcomes

The result from the study sample and normative data from Baldwin et al., (2017), Paradowski et al., (2006), Cameron et al., (2013) and Williamson et al., (2015) are presented in figure 10.

No mark is equal to no significant difference, one ♣ is equal significance <0.05 and two ♣♣ equals significance <0.001.

Figure 10: Patient-reported outcomes results comparison with normative data

*ADL: Activities of Daily Living, *Sport/Rec: Sport and Recreational, *QOL: Quality of Life

Cameron et al., (2013) had a total of 1005 participants included with the mean age of 18.7 ± 0.8 (Cameron et al., 2013), Baldwin et al., (2017) had 66 participants in the age-group 18-29 (Baldwin et al., 2017), Paradowski et al., (2006) had 134 participants age-group 18-34 (Przemyslaw T Paradowski, Bergman, Sundén-Lundius, Lohmander, & Roos, 2006) data from Williamson et al., (2015) was used for the age-group 1: 18-25, n=122 and 2: 26-35, n=170 (Williamson, Sikka, Tompkins, & Nelson, 2016).

None of the five subgroups from the study sample had a mean score of 100. The lowest scores were found in Sport and recreational and QOL with 63.6 and 60 respectively. The highest score was 91.90 in the ADL subgroup.

All subgroups for all four articles, except ADL from Paradowski et al., (2006) had a

significant difference compared with the study group. The biggest difference was found under the subgroups: Sport and Recreational and QOL with a significant difference of more than 30 points.
Comparing the study sample to data from the study by Paradowski et al., from 2006 (Paradowski, 2016) the study sample scored lower in all five categories, significant in all except ADL subgroup, and with the highest difference found in the subgroups: Sport and Recreational and Quality of Life with more than 20 points difference.

4.5.2 Tegner Activity Scale

The study sample had a mean score for the Tegner Activity Scale *before* the injury at median 9 (min: 6 – max: 9).
Approximately 12 months *after* the ACLR (*present*), the Tegner Activity Scale was reduced to median 5 (min: 1 – max: 9), meaning four categories.
Compared to Briggs et al., (2009) who presented result from the Tegner Activity Scale with mean and no standard deviation, the mean score was 5.7 (Briggs, Steadman, Hay, & Hines, 2009), and the mean from the study sample was 5.7 (present) and 8.2 before the injury.

4.5.3 NRS scores Pain and Global rating of knee function

The participants in the study sample had a median NRS score of; 0.00 (0.00 – 1.00) for pain, Global Ration of knee function score was mean: 6.52 ± 2.04 (min: 2 – max: 10).

Return to sport questionnaire, is described under research aim 5.

4.6 Research aim 5a

4.6.1 Patient-reported outcomes and isokinetic knee and isometric hip and trunk muscle strength and hop performance tests

The full analysis of all the KOOS subscales and values are illustrated in appendix VIII.

Significant associations were found between KOOS PAIN, and hip extension of the injured leg was found (p-value: 0.020, R^2: 0.252) and for KOOS ADL, significant associations between isokinetic knee muscle strength for knee extension of the injured leg (p-value 0.036, R^2: 0.211). SLHD test for both legs were significant associated (injured leg: p-value: 0.028, R^2: 0.229, non-injured leg: p-value: 0.028, R^2: 0.229), the Side-hop test for the non-injured leg (p-value: 0.027, R^2: 0.223) and isometric hip muscle strength for hip external rotation of the injured leg (p-value: 0.023, R^2: 0.242).

KOOS SPORT/REC showed significant associations between the injured leg for isokinetic knee extension (p-value: 0.007, R^2: 0.325) and isokinetic knee flexion (p-value: 0.002 R^2: 0.391), both hop performance tests: the SLHD test injured leg (p-value: 0.004, R^2: 0.365), non-injured leg: (p-value: 0.003, R^2: 0.371). The side-hop test injured leg (p-value: 0.043, R^2: 0.119) non-injured leg: (p-value: 0.030, R^2: 0.224). Isometric hip extension of the injured leg (p-value: 0.022, R^2: 0.248), hip external rotation injured leg (p-value: 0.008, R^2: 0.320) and non-injured leg (p-value: 0.031, R^2: 0.222) and trunk/side-bridge of the non-injured side (p-value: 0.026, R^2: 0.234).

KOOS QOL showed significant associations between: isokinetic knee extension (p-value: 0.012, R^2: 0.228) and flexion (p-value: 0.050, R^2: 0.188) of the non-injured leg, isometric hip extension of the injured leg (p-value: 0.027, R^2: 0.233) and hip external rotation injured leg (p-value: 0.028, R^2: 0.229) and hip abduction (p-value: 0.022, R^2: 0.246) (non-injured leg).

No significant association was found between KOOS SYMPTOM and isokinetic knee- and isometric hip muscle strength or hop performance.

4.6.2. Tegner Activity Scale and isokinetic knee and isometric hip and trunk muscle strength and hop performance tests

Between the level of the Tegner Activity scale (*present* level) and isokinetic knee and isometric hip and trunk muscle strength and hop performance, there were significant associations with all isokinetic knee- and isometric hip muscle strength and hop performance tests for the injured leg. The non-injured leg also indicated significant associations in all categories except for isometric hip extension strength and trunk muscle strength. The full analysis is illustrated in Appendix VIII.

The regression analysis is illustrated in table 13, with p-value, R^2, and Confidence Interval, and the significant values are bold.

Table 13: Regression analysis between the Tegner Activity Scale and isokinetic knee and isometric hip and trunk muscle strength and hop performance tests

TEGNER ACTIVITY SCALE	P-value	R^2	95% CI*
Isokinetic (Nm/kg♣):			
Knee extension			
Injured	**0.005**	**0.344**	**0.01 – 0.04**
Non-injured	**0.022**	**0.247**	**0.00 – 0.03**
Knee flexion			
Injured	**0.000**	**0.493**	**0.03 – 0.07**
Non-injured	**0.001**	**0.436**	**0.02 – 0.07**
Hop performance:			
SLHD (cm♦)			
Injured	**0.006**	**0.339**	**0.11 – 0.58**
Non-injured	**0.003**	**0.354**	**0.02 – 0.07**
Side-hop (n♠)			
Injured	**0.011**	**0.294**	**0.02 – 0.13**
Non-injured	**0.001**	**0.363**	**0.03 – 0.13**
Isometric (Nm/kg):			
Hip extension			
Injured	**0.003**	**0.374**	**2.1 – 0.1**
Non-injured	0.097	0.138	-0.7 – 7.5
Hip external rotation			
Injured	**0.000**	**0.567**	**5.3 – 12.97**
Non-injured	**0.041**	**0.202**	**0.3 – 12.9**
Hip abduction			
Injured	**0.008**	**0.317**	**0.7 – 4.2**
Non-injured	**0.041**	**0.202**	**0.2 – 4.4**
Trunk/Side-bridge			
Injured	**0.023**	**0.243**	**0.08 – 0.97**
Non-injured	0.110	0.129	-0.1 – 0.95

*CI: Confidence Interval, ♣Nm/kg: Newton x meter/bodyweight, ♦Cm: Centimeter, ♠n: number of side-hops

4.7 Research aim 5b

4.7.1 Return to Sport questionnaire results

According to the questionnaire: Return to Sport, the result is listed in table 14.

Table 14: Results from Return to Sport questionnaire

Return to Sport Questionnaire result:	**Results** n=*
Q1: What type of Sport did you participate in before the injury:	
1.Soccer	5
2.Handball	2
3.Indoor bandy	2
4. Basket	1
5. Other	11
6. None	0
Q2: At what level:	
1. Recreational	1
2. Recreational/Compete	14
3. Elite	6
Q3:Have you returned to sport again:	
1. Yes	11
2. No	10
Q4: Have you return to same sport and at same level as before the injury:	
1. Yes	5
2. No	16
Q5: After my injury, I have:	
1. Started with another sport	2
2. Same sport but lower level	5
3. Same sport but higher level	1
4. Other	13

*n=: number of participants

These results illustrate that 11 of the 21 participants (52%) had RTS 12 months after injury, and 5 (24%) had returned to the same level as pre- injury, or according to Ardern et al., (2016); return to performance.

4.8 Research aim 5c

4.8.1 Return to Sport and isokinetic knee and isometric hip and trunk muscle strength and hop performance tests

No significant associations were found between isokinetic knee and isometric hip muscle strength and hop performance and whether they had RTS or not.

No significant associations were found between isokinetic knee and isometric hip muscle strength and hop performance and if they had returned to the same level as before the injury (Return to performance) (Clare L Ardern et al., 2016).

See appendix IX for the full logistic regression analysis with Fisher's exact test.

4.9 Research aim 6a

4.9.1 Knee Magnetic Resonance Imaging results

The scores for the different ACLOAS subgroup are presented in table 15 - 20.

Table 15: ACLOAS results for cartilage

Subgroup: CARTILAGE (total for all 14 sub-groups)	n=• (%)
Score 2.0: Focal partial-thickness defect	13 (62%)
Score 2.5: Focal full-thickness defect	1 (4.9%)
Score 3: Multiple areas of partial-thickness defects and areas of normal thickness in sub-region, or a grade 2.0 defect ≥10% but <75% of the sub-region	2 (9.5%)
Score 4: Diffuse partial-thickness loss	1 (4.9%)
Score 5: Multiple areas of full-thickness loss or a grade 2.5 lesion ≥10% but <75% of the sub-region	1 (4.9%)
Score 6: Diffuse full-thickness loss	0 (0%)

•n=: number of scores

Table 16: ACLOAS evaluation results for traumatic bone marrow lesions (TBM) and osteochondral surface damage

Subgroup: TBM and OSTEOCHONDRAL SURFACE DAMAGE	n=• (%)
TBM Type of injury score	
Score 1: Subchondral fracture	0 (0%)
Score 2: Osteochondral depression with intact articular surface	0 (0%)
Score 3: Osteochondral depression with disrupted articular surface	0 (0%)
Score 4: Detached osteochondral fracture	0 (0%)

TBM Type of size score	
Score 1: Mild; <33% of sub-regional volume involved	10 (47.6%)
Score 2: Moderate; 33–66% of sub-regional volume involved	1 (4.9%)
Score 3: Severe; >66% of sub-regional volume involved	0 (0%)
OSTEOCHONDRAL SURFACE DAMAGE Type of injury score	
Score 1: Subchondral fracture	0 (0%)
Score 2: Osteochondral depression with intact articular surface	4 (19%)
Score 3: Osteochondral depression with disrupted articular surface	1 (4.9%)
Score 4: Detached osteochondral fracture	0 (0%)
OSTEOCHONDRAL SURFACE DAMAGE Type of size score	
Score 1: Mild; <33% of sub-regional volume involved	6 (28.5%)
Score 2: Moderate; 33–66% of sub-regional volume involved	1 (4.9%)
Score 3: Severe; >66% of sub-regional volume involved	0 (0%)

•n=: number of scores

Table 17: ACLOAS results for ligaments and grafts

Subgroup: LIGAMENTS AND ACL GRAFTS	n=• (%)
Collaterale ligaments	
Score 1: Continuous ligament with normal signal, surrounding hyperintensity reflecting edema and/or hematoma	2 (9.5%)
Score 2: Partial rupture/discontinuity with some preserved fibers	0 (0%)
Score 3: Complete disruption	0 (0%)
ACL* graft	
Score 1: Hyperintense, regular thickness	19 (90%)
Score 2: Thinned or elongated graft	0 (0%)
Score 3: Graft failure, complete discontinuity	3 (14%)
PCL#:	
Score 1: Thickened ligament and/or high intra-ligamentous signal with normal course and continuity	2 (9.5%)
Score 2: Thinned or elongated but continuous ligament	0 (0%)
Score 3: Absent ligament or complete discontinuity	0 (0%)
+ Tibia and femoral tunnels are assessed in regard to adjacent bone marrow edema and cysts	
Score: Absent	14 (66.6%)
Score: Present	7 (33.3%)

*ACL: Anterior Cruciate Ligament, #PCL: Posterior Cruciate Ligament, •n=: number of scores

Table 18: ACLOAS evaluation results for meniscal morphology and extrusion

Subgroup: MENISCAL MORPHOLOGY AND EXTRUSION	n=• (%)
Morphology	
Score 1: Intra-meniscal hyperintensity not extending to meniscal surface	6 (28.5%)
Score 2: Horizontal tear	5 (23.8%)
Score 3: Radial and vertical tear	0 (0%)
Score 4: Bucket-handle tear, displaced tear (including root tears) and complex tears	1 (4.9%)
Score 5: Meniscal repair	1 (4.9%)
Score 6: Partial meniscectomy and partial maceration	0 (0%)
Score 7: Progressive partial maceration or re-partial meniscectomy (i.e., loss of morphological substance of the meniscus)	0 (0%)
Score 8: Complete maceration or resection.	0 (0%)

Extrusion	
Score 1: Extrusion <50% of meniscal coronal length	8 (38%)
Score 2: ≥50% of meniscal coronal length	1 (4.9%)

•n=: number of scores

Table 19, ACLOAS results for osteophytes

Subgroup: OSTEOPHYTES (total for all 10 sub-groups)	n=• (%)
Score 1: Equivocal or questionable osteophyte	30
Score 2: Small beak-like definite osteophyte	22
Score 3: Small-moderate osteophyte	1
Score 4: Moderate osteophyte	3
Score 5: Moderate-large osteophyte	0
Score 6: Large osteophyte	0
Score 7: Very large osteophyte	0

•n=: number of scores

4.10 Research aim 6b

4.10.1 Differences between patient-reported outcomes (all subscales) for those with and without cartilage defects one year after ACLR

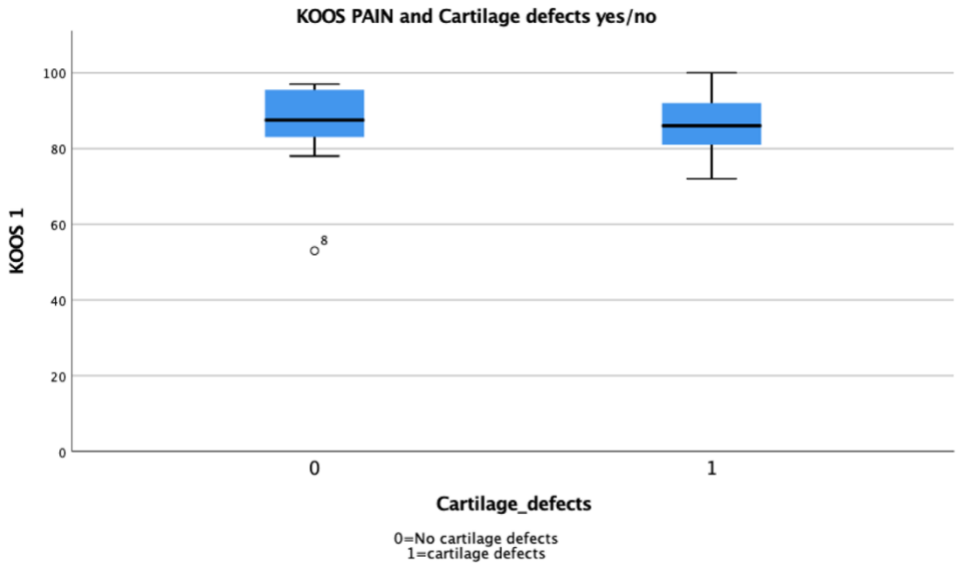
A total of 9 participants had ACLOAS cartilage scores, indication cartilage defect, or full-thickness loss (see Appendix II for a full description of the ACLOAS scoring of cartilage). Mean age and standard deviation for the 9 participants were 25.2 ± 5.9, (5 female, 4 male).

Cartilage defects were ranging from 2 (Focal partial-thickness defect ≤10% of the sub-regional area affected) to 5 (Multiple areas of full-thickness loss or a grade 2.5 lesion ≥10% but <75% of the sub-region).

Box plots (figure 11-15) are used to present the difference between the participants with cartilage defects and the participants without and the KOOS score.

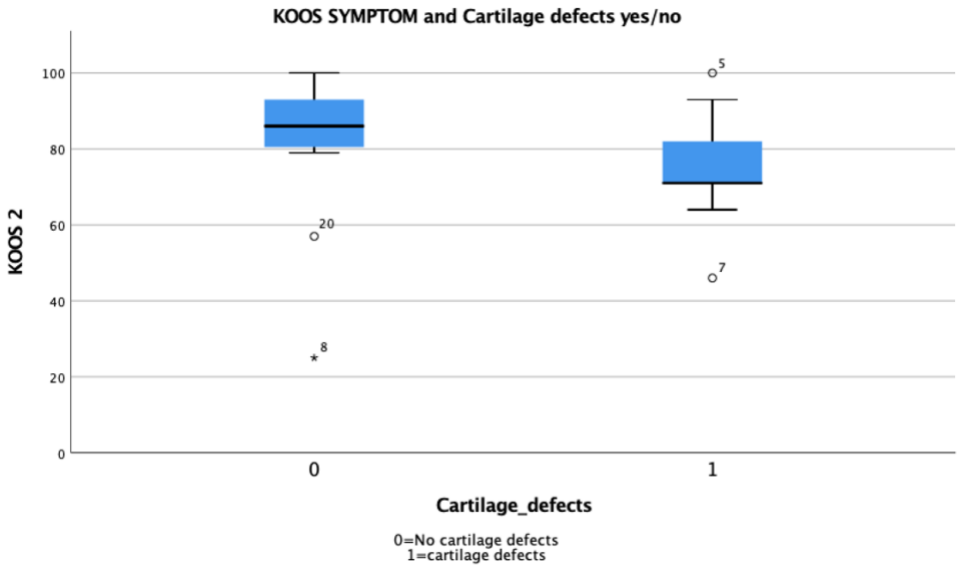
The box plot shows lower minimum scores for KOOS Pain and KOOS Symptom and lower median scores for KOOS Symptom, KOOS Sport and Recreation and KOOS QOL for the participants with cartilage defects. No significant differences were found.

Figure 11: Differences between KOOS PAIN (KOOS 1) and cartilage defects yes/no:



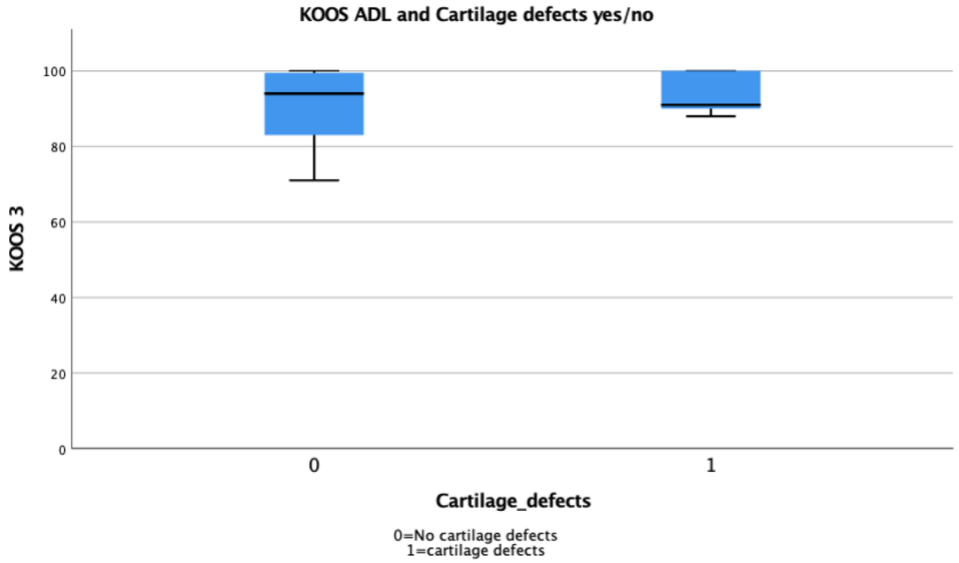
Mann-Whitney Test: Asymp. Sig: 0.803

Figure 12: Differences between KOOS SYMPTOM (KOOS 2) and cartilage defects yes/no:



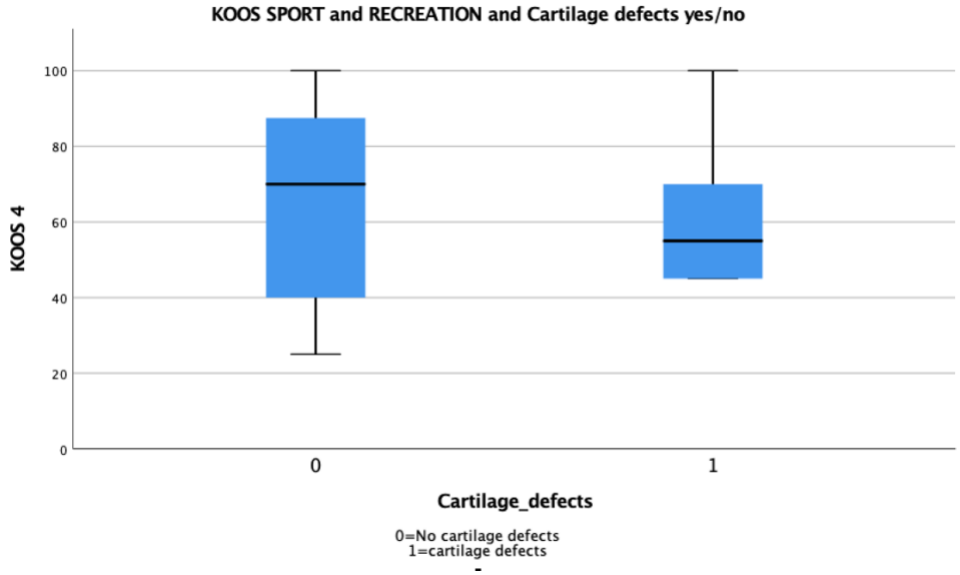
Mann-Whitney Test: Asymp. Sig: 0.199

Figure 13: Differences between KOOS ADL (KOOS 3) and cartilage defects yes/no:



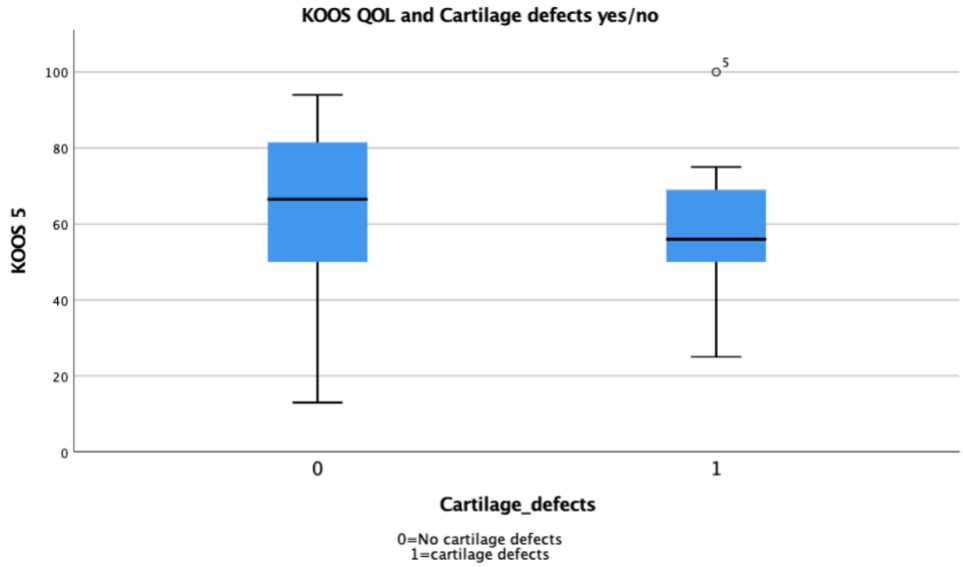
Mann-Whitney Test: Asymp. Sig: 0.665

Figure 14: Differences between KOOS SPORT and RECREATION (KOOS 4) and cartilage defects yes/no:



Independent T-test p-value: 0.665, 95%, Mean difference: 1.667 ± 10.415, 95% CI: -20.133 – 23.466

Figure 15: Differences between KOOS QOL (KOOS 5) and cartilage defects yes/no:



Independent T-test p-value: 0.504, Mean difference: 2.306 ± 10.205,
95% CI: -19.054 – 23.665

5.0 Discussion

The main purpose of this master project was to investigate 21 young and previously active participants approximately one year after ACLR.

One year after ACL reconstruction, the participants still had quadriceps muscle strength deficiency as well as hop performance deficiency in the injured leg compared to the non-injured leg. However, between 7 and 15 participants meet the LSI cut off point at ≥90% for the different tests.

Compared to normative data, the study sample showed significantly worse outcomes for isometric hip extension and hip external rotation muscle strength and the isokinetic knee extension muscle strength as well as for all the KOOS subscales.
The Tegner Activity Scale showed similar physical activity level after ACLR compared to the normative data.

Significant associations were found between KOOS and isokinetic knee and isometric hip and trunk muscle strength and hop performance. Significant associations were found between the Tegner Activity Scale and isokinetic knee and isometric hip and trunk muscle strength and hop performance.

The number of participants who had returned to sport was 52%, and 24% had returned to pre-injury level. No associations were found between returned/not returned to sport and returned to/not returned to pre-injury level, and their isokinetic knee and isometric hip and trunk muscle strength and hop performance.

ACLOAS was used for the evaluation of MRI, and 9 participants were found with cartilage defects. No differences were found in KOOS score between the participants with and participants with-out cartilage defects.

5.1 The results

5.1.1 Study sample

The mean time from injury to surgery was 9.5 ± 10.9 months. Two participants were relative extremes, with 46 and 33 months from injury to surgery. The reasons were for both, initially good function after rehabilitation, but experienced increased instability problems and therefore had surgery. Three other participants had 13, 14, and 17 months between the injury and surgery. Two of them had good function initially but experienced a new injury, and after having instability problems, giving away symptoms and pain. One was studying abroad and wanted to wait with surgery until back in Norway. Excluding these 5 participants, the mean time from injury to surgery was 4.8 months, ranging from 1 to 9 months.

Previous studies on ACL injured individuals have included similar patient groups (ACLR and age group) had listed (mean) 19 months (Ageberg, Forssblad, Herbertsson, & Roos, 2010) from injury to surgery, another only (mean) 8.9 ± 6.2 weeks (Chung et al., 2015) which both are different from the study sample. Since Karlsson et al., (1999) found no difference in outcome for early (2-12 weeks) surgery compared to late (12-24 months) (Karlsson et al., 1999). Frobell et al., (2013) also found no difference between early surgery group (within ten weeks) and late (median 867 days after injury) (R. B. Frobell et al., 2013), it is not relevant for the outcome when the study sample had surgery.

All of the grafts used for the reconstruction were autografts. The majority of the participants had surgery done with the use of the BTB tendon graft, which correlates with findings at www.kvalitetsregistre.no where this tendon is the most used by the surgeons in Norway. Three had surgery with the use of hamstring tendon graft and 3 with a quadriceps tendon graft. The hamstring tendon graft is the second most used tendon, and the quadricep's tendon is not mentioned on the website (*https://www.kvalitetsregistre.no/registers/527/resultater*, 2018). The reason could be that even-though the quadriceps tendon graft has been used as a graft for ACL for over 30 years (Blauth, 1984) it has not been giving much attention until recently, hence therefore also the least studied graft for ACLR (Sheean et al., 2018).

Fourteen participants (66.6%) experienced concomitant injuries compared to 88% in a cohort study of 1145 patients by Olsson et al., (2016) (Olsson, Isacsson, Englund, & Frobell, 2016). The age group was different from the study sample, 10-59 years (mean age: 27.5 ± 12) and when comparing only ACL and meniscal injuries for the same age group (20-29 and 30-39) the result from Olsson et al., is 55% compared to 57% in the study sample.

Most of the concomitant injuries were meniscal injuries (57%), which is in line with other studies (Stephanie R. Filbay & Grindem, 2019)(Olsson et al., 2016).

Lateral meniscus lesions were more common than medial lesions in the study sample, which is similar compared to other articles (Hamrin Senorski et al., 2018). The concomitant injuries in this study were primarily from acute ACL injuries (19 participants). According to the literature, lateral meniscal lesions are more common in this type of injury (Kilcoyne, Dickens, Haniuk, Cameron, & Owens, 2012).

5.1.2 Inter-rater and intra-rater reliability investigation

Both inter-rater and intra-rater reliability investigation showed satisfying results.

Thorborg et al., (2013) have conducted inter-rater reliability study for two of the same hip muscle strength tests as used in the investigation (Kristian Thorborg, Bandholm, & Hölmich, 2013). Healthy athletes (n=21), mean age of 24.8 ± 3.3 years, 15 males and 6 females and two testers (physiotherapy students). The ICC result was higher than our investigation (0.85 and 0.95 respectively).

Another inter-reliability investigation performed by Martins et al., (2017), (26 participants, mean age of 23.5 ± 2.8, 13 females and 13 male), testing both hip and knee isometric muscle strength and for the tests comparable to our study the ICC result was also higher than our investigation ranging from 0.81 – 0.91. The test procedure was different that out study (see methods discussion page 88).

For intra-rater reliability investigation, Thorborg et al., (2009) investigated 9 participants (4 females and 5 male, mean age of 26 ± 4.5), assessing the same HHD tests as presented in this master project except trunk/side-bridge (K. Thorborg, Petersen, Magnusson, & Hölmich, 2009). Here the result was the same as this master project ranging from ICC 0.81 – 0.98.

The biggest difference for the two inter-rater reliability investigations is the number of participants, higher number results in better statistical power (see methods discussion page 88) and thereby better ICC scores. For intra-rater reliability, where the scores between the study sample and the article were similar, the number of participants was almost the same (9 and 10) together with the same HHD and test procedures as the study sample.

5.1.3 Systematic literature search for normative data

The systematic literature search did not reveal an impressive number of articles (5 articles, two were found during hand search) and the attempt to do a systematic search following the guidelines from PRISMA-P was not fully accomplished. The reasons are many. First, a full systematic literature search containing all PRISMA-P items is a too large assignment for this master project. Second, the inclusion and exclusion criteria's may have been too ambitious, especially the inclusion criteria: *"must include both male and female*." The criteria were made due to the small study sample size, where the results had to be presented together because of the statistical power and also since this master projects aim was not to investigate the difference between female and male.
To compare the results, the data from the normative data had to be both male and female, and if presented separately, it would be calculated together as "all." If the study sample had been larger, data could have been presented in male and female separate. Articles, with a large sample as the one from Risberg and colleagues (2018) with 350 female participants tested with an isokinetic dynamometer (May A. Risberg et al., 2018) could then have been used for comparison of isokinetic knee muscle strength for female participants. The article from Zvijac et al. (2014) with normative data from 1252 male American football players (Zvijac, Toriscelli, Merrick, Papp, & Kiebzak, 2014) could have been used for the comparison of the male participants.

5.1.4 Isometric hip and trunk muscle strength, isokinetic knee muscle strength and hop performance

<u>Comparison of the injured and non-injured leg:</u>
There were significant differences for hop performance (both tests) and isokinetic knee extension muscle strength between non-injured and injured leg, where the non-injured leg was significantly stronger than the injured.

Chung et al., (2015) had similar results when comparing the injured versus the non-injured leg 12 months after ACLR, also her were the non-injured leg significant stronger than the injured (Chung et al., 2015) for both isokinetic knee extensor strength and the SLHD test (the side-hop test was not investigated). The participants (n=75) in the study from Chung et al., (2015) had a mean age of 27.9 ± 8.6, and the majority were male, height and weight were similar to the study sample.
The significant differences between the injured and non-injured leg can be because of testing 12 months after ACLR. According to Risberg et. Al., (1999) it may take up to two years before strength is fully regained after ACLR (M. A. Risberg et al., 1999) and it is suggested that it may take even longer (Chung et al., 2015).
One study found that isokinetic knee extensor strength was associated with hop performance (Barfod, Feller, Hartwig, Devitt, & Webster, 2019). The significant difference in the study sample for isokinetic knee extensor strength and hop performance can be explained by this. According to Barfod et al., (2019) lack of strength affects the hop performance.

Isometric hip muscle strength:

The study sample scored significantly lower for hip external rotation and hip extension for both the injured and non-injured leg when compared to normative data from Kemp et al., (2013). Some of the differences can be because rehabilitated after ACLR may take more than 12 months (M. A. Risberg et al., 1999)(Chung et al., 2015). The execution of the tests may also have impacted (see methods discussion page 89).
The importance of hip muscle strength and especially hip external rotation strength have been suggested to be able to predict hop performance (Kline et al., 2018) and weak hip muscle strength have been implicated to affect the risk of ACL injury (Hewett et al., 2005)(Hickey Lucas et al., 2017). Strong hip muscles will there-for reduce the risk for a re-injury or ACL injury to the contralateral knee, and the study sample may be at increased risk because of the weak hip muscle strength. Poor hip muscle strength has also been linked together with other knee issues as patella-femoral pain syndrome and knee pain in general (Ferber et al., 2015)(Boling & Padua, 2013) which also may put the study sample at risk for knee pain not directly related to the ACLR.
Though the data used for comparison was for healthy participants and since it was not possible to detect isometric hip muscle strength data from ACLR patients, it is still

unclear how the study sample scored compared to other ACLR patients.

Isometric trunk muscle strength:

No studies were found for the comparison with normative data or other research data with the same execution as in this master project. It is there for difficult to know if the study sample scores were low or high.

Weak trunk muscle strength may affect hip muscle strength (Powers, 2010) and have also been linked together with an increased risk of ACL injuries (Hickey Lucas et al., 2017). It is there-for important to measure trunk muscle strength for this group of participants.

Isokinetic knee muscle strength:

The result from the study sample was compared to normative data in the article from Danneskiold-Samsøe et al., (2009).

The comparison showed that the study sample had significantly higher scores for both knee extension and knee flexion both injured and non-injured leg except knee flexion for the non-injured leg. Here the result was still higher than the data from Danneskiold-Samsøe et al., (2009) but not significant.

The participants mean age from the article by Danneskiold-Samsøe et al., (2009) was 27 years compared to the study sample mean age of 24.14 years, mean height, weight, and BMI was similar between the two groups. The participants in the Danneskiold-Samsøe study (2009) were included if they were considered healthy (self-reported and clinical) but even though they were asked about their physical activity level during work and pleasure, no result can be found in the data presentation neither the clinical assessment (Danneskiold-Samsøe et al., 2009). They might have been less physical active as the study group thereby giving the study sample better recordings. Additionally, they were not screened for previously knee injury and hence we cannot exclude if the sample in Danneskiold-Samsøe et al. (2009) had any knee conditions, injuries and/or surgery to either knee, that might have affected the result.

Comparing the study sample with other ACLR patients in the same age group, Chung et al., (2015) tested 75 ACLR participants, mean age of 27.9 ± 8.6, 12 months after ACLR (Chung et al., 2015). The involved leg and non-involved leg from the study sample

scored lower than the involved knee in the ACLR group from Chung et al.,(2015). The study by Chung et al., (2015) was performed with Biodex dynamometer and with the same protocol as the study sample.
Why did the study sample score lower compare to a similar ACLR group? Only 10 participants (13.3%) had meniscal injuries in the sample from Chung et al., (2015) and the study sample had 12 out of 21 participants (57%) with meniscal injuries. No articles were found investigating what impact meniscal injuries have on outcomes 12 months after ACLR. The literature is debating about outcomes 2 – 3 years after ACLR, some articles find worse outcomes in patients with concomitant meniscal injuries (Barenius, Forssblad, Engström, & Eriksson, 2013)(Kartus et al., 2002). Other articles do not find any difference in outcomes (Przemysław T. Paradowski, Kęska, & Witoński, 2014).

Hop performance:
Normative data for Hop performance was not found in the systematic literature search and may be an area for future investigations. Data from other studies with ACLR and healthy controls and other studies, including healthy participants for the validation of a test procedure was found and used for the comparison of results from the study sample.

The SLHD test:
In an article by Gustavsson et al., from 2006, 35 ACLR patients were tested with the SLHD test, six months after ACLR (Gustavsson et al., 2006).
Comparing the participant characteristics, the group from Gustavsson et al., (2006) was a few years older, about the same height and weight as the study sample (Gustavsson et al., 2006).
The result from the ACLR group from Gustavsson et al., (2006) for the involved leg was mean 128cm, 7 cm difference (less than the study sample) and for the non-involved leg, the differences were 4 cm (less than the study sample) (Gustavsson et al., 2006).
Gokeler et al., (2017) investigated 52 ACLR patients, 7 months post-surgery (mean age 22.8 ± 3.5, range 17-30) and the results were for the injured leg 143.9 cm (plus 8.9cm difference from the study sample) and 150cm for the non-injured (2 cm less than the study sample) (Alli Gokeler, Welling, Zaffagnini, Seil, & Padua, 2017).

In an article by Kockum & Heijne (2015), healthy participants (n=18) were tested for

the investigation of the reliability of a test battery (Kockum & Heijne, 2015). The age group was similar to the study group (23.4 years) and height and weight also. The participants were all athletes and participated in both recreational and competitive sports.

The differences between the study sample and this group were 8.8cm (study sample scored lower) (Kockum & Heijne, 2015).

The non-injured leg from the study sample scored 8.15cm higher that the group from Kockum & Heijne (2015). This is interesting since Chung et al., (2015) proposed the non-injured leg to have less muscle strength even two years after the ACLR (Chung et al., 2015) and therefor a worse outcome was expected for the study sample for the non-injured leg compared healthy athletes.

The SEM for SLHD test is between 4.61(Ross et al., 2002) and 5.15cm (Kockum & Heijne, 2015) and therefor some of the differences between the study sample and the other groups from Gustavsson et al., (2006), Gokeler et al., (2017) and Kockum & Heijne (2015) can be explained by this. The group from Gokeler et al., (2017) was tested seven months after ACLR compared to the study sample at approximately 12 months after ACLR. When other studies have presented improvement in outcome between 6 and 12 months follow-up (Nawasreh et al., 2017), the difference may be explained by this for this comparison. Regarding the group from Gustavson et al., (2006) their result was lower than the study sample, here the execution of the test can be a reason for the differences in results (see methods discussion page 90).

The Side hop test:

Comparing the result from the study sample to the same group from Gustavsson et al., (2006) the difference for the involved leg is one hop where the group from Gustavsson et al., (2006) scored higher. For the non-involved leg, the study sample scored eight hops lower.

The result from Gokeler et al., (2017) was mean 45 hops, seven hops more than the study sample for the injured leg and seven hops more for the non-injured compared to the study sample as well.

Comparing to the healthy participants in the article by Kockum & Heijne (2015), the injured leg scored lower (9 jumps), and the non-injured leg 6.3 jumps less than the

healthy group.
Some of the differences between the study sample and the groups from Gustavsson et al., (2006), Gokeler et al., (2017) and Kockum & Heijne (2015) can be because of error of measurements (approximately four hops) (Kockum & Heijne, 2015). Some of the difference may also be because of the length of rehabilitation as described previously and also the execution of the tests and fatigue, which is described in the discussion of methods on page 90.

Limb symmetry index:

LSI for hop performance:

Comparing the study sample with the result from a systematic review with a similar patient group (mean age of 26.5 and tested 12 months after ACLR), and close to 5000 participants (Abrams et al., 2014), the study sample had a mean score at 88.0% for the SLHD test where Abrams et al. (2014) had a mean of 92%.
Another article including 52 patients (mean age 22.8 years) and measured approximately seven months after ACLR had LSI scores above 90%, for both hop performance tests (Alli Gokeler et al., 2017). This group scored higher than both the study sample and the group from Abrams et al., (2014). The group from Gokeler et al., (2017) had an isolated ACL tear (A. Gokeler et al., 2017), and there-for all with concomitant injuries were excluded which could have impacted the results.
A recent study by Senorski et al., (2018) found lateral meniscus injury decreased the odds of LSI above 90% for knee extension (Hamrin Senorski et al., 2018) in group (n=263), with 53% male and a mean age of 28 ± 10 years. Could this have impacted hop performance as well? As previously described, knee extension strength affects hop performance (Barfod et al., 2019). Concomitant injury is well known to affect outcome for the long term (May Arna Risberg et al., 2016) and it may also have impacted the result for the study sample 12 months after ACLR. Gokeler et al., (2017) suggests, the significant difference between the injured and non-injured leg, even-though LSI score were above 90%, was because LSI overestimate function and performance. (A. Gokeler et al., 2017) (see also methods discussion on page 91).

LSI for isokinetic knee muscle strength:

LSI scores for the study sample was similar to a group from Abrams et al., (2014). Here

the result for LSI for isokinetic knee extension at 86% and 92% for isokinetic knee flexion (Abrams et al., 2014).
Senorski et al., (2018) found the type of graft, BTB graft, to reduce the odds for achieving 90% LSI for knee extension (Hamrin Senorski et al., 2018). Since 15 participants (71.4%) had surgery with the BTB graft, this may have impacted the result for knee extension.

LSI for isometric hip and trunk muscle strength:
To my knowledge, no LSI data for the isometric hip and trunk muscle strength exist and can be an area for future investigations.

5.1.5 Patient reported outcomes, Tegner Activity Scale, NRS Pain and Global rating of knee function

PROs:
The result from KOOS was lower in all categories when comparing to normative data from 4 different articles, especially subgroups: KOOS Sport and Recreational and KOOS QOL were significantly reduced in the study sample. The study sample scored significantly lower in all subgroup compared to data from Baldwin et al., (2017), Cameron et al., (2013) and both age-groups from Williamson et al., (2015), they scored lower in all subgroups when compared to data from Paradowski et al., (2006) but not significant in KOOS ADL.
The lower scores for QOL could be impacted by the fact that only 11 participants from the study sample had RTS and only 5 to pre-level sport, and since research implicates that RTS have an impact on QOL (S. R. Filbay et al., 2017) this could explain the low score for KOOS QOL.
The low score on KOOS Sport and recreation could be affected by the low number of participants that had RTS and maybe even more so the lack of returning to the same level as pre-injury. For previously athletes with a median Tegner Activity Score at 9, the feeling of satisfaction can be absent (Kocher et al., 2002) until they have returned to the same level as before, which may have affected the score for KOOS Sport and Recreation.

Comparing the study sample with other ACLR patients from a large study (n=4438)

from Ageberg et al., from 2010, who investigated data from the Swedish Knee Ligament Register showed similar results as the study sample. Here the age group was different, ranging from 8 to 67 years old but with a mean age of 27 years (Ageberg et al., 2010). Testing was done 12 months after ACLR, and the finding was similar to the result from the study sample (KOOS Pain: 85.20, KOOS Symptom: 78.90, KOOS ADL: 91.95, KOOS Sport/Rec: 65.25, KOOS QOL: 60.85) (Ageberg et al., 2010). LaPrade et al., (2015) used data from the Norwegian Knee Ligament Registry from 4691 patients with ACLR, KOOS before and two years after ACLR with and with-out meniscal injuries (LaPrade, Dornan, Granan, LaPrade, & Engebretsen, 2015). Mean age was 28.7 ± 10.5 years, 51.3% were male. The result two years after ACLR was (calculated for all groups, with and without meniscal injury together) KOOS Pain: 89.0, KOOS Symptom; 80.0, KOOS ADL: 97.4, KOOS Sport/Rec: 71.8, KOOS QOL: 70.0) (LaPrade et al., 2015) which is higher results than the study sample for all subgroups. The study sample was 4.1 years younger, and all 21 participants from the study sample were very active before the injury according to the Tegner Activity Scale result. In the large sample from LaPrade et al., (2015) the age-group is, according to the Norwegian Knee Ligament Registry website, between 10 and 69 years old (*https://www.kvalitetsregistre.no/registers/527/resultater*, 2018). The age-group is different from the study group, and together with the difference in follow-up time, the comparison should be interpreted with caution.

Tegner Activity Scale:

The result from the Tegner Activity Scale was higher for the study sample, result from before the injury (close to 3 full categories) when compared to the data from Briggs et al., (2009). Twelve months after the injury, the study sample had the same scores as the normative data (mean 5.71 study sample versus 5.7) (Briggs, Steadman, et al., 2009). The study from Briggs et al., (2009) included 488 participants in the age group 18-85, but it was difficult to see what age groups the researcher had divided the group into. The score of 5.7 was the overall score, including participants a lot older than the study group (Briggs, Steadman, et al., 2009) and maybe less active than the study group because of the age.

The higher result before the injury could indicate the study group was very active compared to the group from Briggs et al., (2009).

Comparing the study sample with an ACLR group from Baltaci et al., from 2012, including 30 participants (15 ACLR and 15 controls), tested 18-24 months after ACLR, mean age ACLR group: 29.6 ± 5.9 (range 20-35), height (176.4cm) and weight (77.7kg) was similar to the study sample (Baltaci, Yilmaz, & Atay, 2012). Data was also presented in mean as the data from Briggs et al., (2009). The study sample had an overall higher score *before* the injury (two categories) than the ACLR group from Baltaci et al., (2012), and *after* the ACLR the study sample scored 1 category higher than the group from Baltaci et al., (2012) and were tested approximately 20 months after ACLR (Baltaci et al., 2012).

This difference could, as mention previously, implicate the study sample was very active before the injury. The inclusion criteria to participate in the study from Baltaci et al., (2012) were attending a rehabilitation program between 18 and 24 months before the study (Baltaci et al., 2012). No information about activity participation is presented. According to Hetsroni et al., (2017) higher level on the Tegner Activity Scale before the injury was associated with a higher level after the surgery. Young age at surgery also affected the score after surgery positively (Hetsroni et al., 2017). Since the study sample was 4.5 years younger than the group from Baltaci et al., (2012) and had a higher Tegner Activity Scale before the injury, may explain the difference between the two groups.

NRS Pain and Global rating of knee function:

The participants experienced minor pair, median 0.00 (lower quartile: 0.00 – upper quartile: 1) and calculated into mean and standard deviation: 0.76 ± 1.34 (min: 0 max: 5), meaning some had no pain and others had some pain. The period they were asked about was the time they were tested at NIMI, which mean the same day, approximately a total of 1.5 hours.

Lentz et al., (2012) investigated 94 participants one year after ACLR, 64% male and mean age 22.6 ± 8.6 and found an average pain score of 0.70 ± 0.85, which is similar to the study sample.

Global Rating of knee function the mean score was 6.52, but a very broad range of knee function in the study sample since some had a function at 2 (low function) and other had a function at 10 (same function as before the injury). It was not possible to find other studies rating from 0-10 for comparison.

5.1.6 Associations between patient reported outcomes, Tegner Activity Scale and isokinetic knee and isometric hip and trunk muscle strength and hop performance tests

There was a significant association between isokinetic knee extensor strength of the injured leg and KOOS ADL, KOOS Sport and Recreation and between the non-injured leg and KOOS QOL. For isokinetic knee flexor muscle strength there was a significant association between the injured leg and KOOS Sport and Recreation and the non-injured leg for KOOS QOL.

No other studies were found investigating the association between KOOS and isokinetic knee muscle strength 12 months after ACLR.

One article from Pottkotter et al., (2018) showed data from 12-24 months post ACLR with moderate correlations between quadriceps LSI scores and KOOS Sport and Recreations (Pottkotter et al., 2018).

For hop performance, the SLHD test was significantly associated with KOOS ADL and KOOS Sport and Recreational (both legs), and for the side-hop test there was a significant association between the non-injured leg and KOOS ADL and both legs for KOOS Sport and recreational.

The significant association between the SLHD test and the side hop tests for both legs is similar to the research from Flosasdottir et al., (2016). They found that worse hop performance was associated with worse KOOS scores, especially KOOS Sport and recreational and KOOS QOL, tested in a group of 39 male and 15 female participants with a mean age of 30 years and tested three years after ACL injury or reconstruction (Flosadottir et al., 2016).

Isometric hip- and trunk muscle strength were significantly associated with KOOS Pain and isometric hip extension of the injured leg. A significant association was found between isometric hip external rotation for the injured leg and KOOS ADL.

KOOS Sport and Recreational were associated with; hip external rotation (injured and non-injured leg), the injured leg for hip extension and the non-injured leg for trunk/side-bridge. KOOS QOL was a significant association with hip extension, external rotation for the injured leg and the non-injured leg for hip abduction.

No other studies were found investigating the association between isometric hip muscle

strength and/or isometric trunk muscle strength and KOOS for ACLR patients.

All values were significantly associated with the Tegner Activity Scale except isometric hip extension strength and trunk/side-bridge for the non-injured leg. No other studies were found addressing the impact muscle strength and hop performance have on the Tegner Activity Scale.

5.1.7 Return to Sport

One year after ACLR 11 participants (52%) had returned to sport again and 5 (24%) had returned to pre-level which is equivalent to return to performance according to Ardern et al., (2016) (Clare L Ardern et al., 2016).

These RTS rates are lower than data from a systematic review from Ardern et al., (2014) where 81% had returned to any level of sport, and 65% had returned to pre-injury level (Clare L Ardern et al., 2014). Our study had very similar characteristics as to the study by Ardern et al., (2014) with a mean age of 25.8 years, and 66% were males. The average follow-up rates for studies included in the systematic review was 40 months (range 12 – 156 months) and according to the article, the length of follow-up did not influence the return to sport percentages (Clare L Ardern et al., 2014).

A previously master project by Marie Pedersen investigated RTS after ACLR, one, two, and five years postoperatively (Pedersen, 2017). Included was 60 participants in the age-group 13-39 (median age: 23 years and height and weight were similar to the study group). The participants were included if they participated in level 1 or 2 sports at least twice a week, and all the participants were Norwegian. The result was 50% had RTS after one year, which is a similar result to the study sample.

The articles used in the systematic review from Ardern et al., (2014) included 57 articles for the RTS investigation primarily articles not with data from Norway. Could this influence the higher numbers of participants who RTS in the review? Are we stricter in Norway about who should return and who should not, or are the patients? In the master project from Marie Pedersen (2017), patient-reported knee function was the main reason why they did not return for 76% of the participants.

Ardern et al., (2014) listed several factors that could contribute to RTS; being male, younger age, symmetric LSI for hop performance, normal knee function, lower fear of re-injury and psychological readiness for return to sport (Clare L Ardern et al., 2014).

Others have listed quadriceps strength as an important factor for RTS (Adams et al., 2012)(Myer et al., 2006).
The mean age for the study sample was 21.14 years old, which must be classified as a young sample.
In the study sample 9 participants had LSI ≥ 90% for the SLHD test was, and 15 for the side-hop tests and 7 participants had LSI ≥ 90% for isokinetic quadriceps strength (isokinetic knee extension). Significant differences were found between the injured and non-injured leg for knee extension and hop performance, and all these values are important for subjective knee function. These results could have affected the low number for return to sport as the participants from the master project by Marie Pedersen (2017) and reflects other research data for the RTS (Clare L Ardern et al., 2014), and for the return to pre-injury level (Lentz et al., 2012).
Since RTS affects QOL (Stephanie R. Filbay & Grindem, 2019) and the patients feeling of satisfaction (Sonesson et al., 2017)(Kocher et al., 2002) the low rate of returning to sport may have affected the low scores on KOOS QOL.

5.1.8 Associations between Return to Sport and isokinetic knee and isometric hip and trunk muscle strength and hop performance tests

With a small study sample with only 21 participants, it can be difficult to measure any association since Fischer's exact test must be done due to the low sample size.
Another research article has listed strength and in particular quadriceps strength and performance and skills (including hop performance) (Thomeé et al., 2011)(Clare L Ardern et al., 2016) as important factors that can effect RTS.

5.1.9 Magnetic Resonance Imaging results

There were findings in every subgroup in ACLOAS. No participants were with-out findings. No other published data using ACLOAS except the reliability study was found.

5.1.10 Association between Magnetic Resonance Imaging results and patient-reported outcomes

Nine participants had cartilage defects investigated with ACLOAS, and no significant differences were found between these participants and KOOS. A study by Su et al.,

(2016) in a group of 42 participants (mean age 29.5 ± 8.4 years) one year after ACLR, found significant associations between cartilage defects and KOOS score, in all subscales except KOOS Sport and Recreation (Su et al., 2016).

5.2 The methods

5.2.1 Internal validity

Design

A cross-sectional study can be used to study the prevalence of characteristics and outcomes in a given population in a given time (Laake et al., 2008). The design can be executed fast and are relatively in-expensive (Laake et al., 2008). The cross-sectional study design is information about prevalence with this specific group at that specific time they were tested (Laake et al., 2008).
The limitations of a cross-sectional design are not meant to evaluate the cause and effect or any results of interventions.

The participants were only selected based on the in- and exclusion criteria's, and data were collected at one time; one day for the physical tests and questionnaires and one day for the MRI investigation. The information is there-for limited to the result from the day they were tested. The biggest risk of bias is memory (Laake et al., 2008).

Participants:

Several factors were not investigated regarding the participants that could have impacted their result. Factors as the timing of surgery; was it post-pone until after swelling have emerged, full ROM was achieved and the participant had attained symmetrical (or close to) quadriceps strength (Shelbourne et al., 1991)(Eitzen et al., 2009)(Failla et al., 2016)(Alshewaier et al., 2017). In the study sample, no questions were asked about the timeline (weeks or months) before the surgery, if pre-habilitation was done or the knee condition before or at the surgery. According to the research presented above, this is important questions, for the ACLR outcome.

The assessments

Inter-rater and intra-rater reliability investigation:

Both investigations included ten subjects. Comparing to other inter- and intra-rater reliability projects for assessing e.g., HHD for testing of hip muscle strength, the number of subjects in this master project is small. Thorborg et al., (2013) and Martins et al., (2017) tested inter-rater and intra-rater reliability respectively, both included 21 (Kristian Thorborg et al., 2013) and 26 participants (Martins, da Silva, da Silva;, & Bevilaqua-Grossi, 2017) and thereby had more than 100% increase in participants giving a better statistically power.

A larger number of subjects would have statically strengthened the result for both inter-rater and intra-rater reliability investigations.

The statistical calculations were different compared to our investigation, ICC 2.1 (Kristian Thorborg et al., 2013)(K. Thorborg et al., 2009) and ICC 2.3 (Martins et al., 2017) which may have impacted the result.

The study from Martins et al., (2017) there were difference in the execution since they used a different model HHD (Lafayette) and that was connected to an isokinetic Biodex machine (Martins et al., 2017). The muscles tested were in a different position (except hip extension) than our investigation, which means the comparison must be made with caution (see Isometric hip muscle strength discussion page 89). The study from Thorborg et al., (2013) the same HHD was used as this master project and all the investigation were tested with "make test" and best of 3 repetitions.

The intra-rater reliability included the investigation of HHD tests and leverage measured for the calculation of Nm/kg. This could have included an investigation of all the tests done (including isokinetic and hop performance) for improving the reliability of the results of the study sample. Isometric hip muscle strength tests were chosen because of all the variables in HHD testing the intra-rater have to performed manually (e.g., the pressure made for the "make test," the position of the participant and the handling of the HHD) which increases the chances of errors in-between the tests.

The intra-rater investigation from Thorborg et al., (2009) investigated 3 of the four tests (not the trunk/side-bridge test) in the same positions as the study sample (K. Thorborg et al., 2009). The same HHD was used as this master project and all the investigation was tested with "make test" and best of 3 repetitions.

Isometric hip muscle strength:

Hip external rotation was tested in a sitting position with 90 degrees hip and knee flexion in the article from Kemp et al., (2013) (Kemp et al., 2013), which is different to the study sample. Since Lindsey et al. (1992) concluded that higher peak torque was measured in a sitting position compared to a prone position (Lindsay, Maitland, Lowe, & Kane, 1992), the comparison between the study sample and the result from Kemp et. al., (2013) must there-for be done with caution.

In the study from Kemp et al., (2013), the HHD used was the same as in the study sample (Kemp et al., 2013).

Muscle testing of isometric hip muscle strength with HHD is a valid and reliable method investigated by several authors (Martins et al., 2017)(Kemp et al., 2013)(K. Thorborg et al., 2009)(Kristian Thorborg et al., 2013). For the ACLR patients, it could also have been interesting to investigate hip flexion strength (Karanikas, Arampatzis, & Brüggemann, 2009) and hip adductor muscle strength (Hiemstra, Webber, MacDonald, & Kriellaars, 2007) since these are known to be affected after ACLR.

Isokinetic knee muscle strength:

The use of Biodex isokinetic dynamometer is considered the "gold standard" for measuring isokinetic muscle strength (D. C. Feiring, Ellenbecker, & Derscheid, 1990) and have proven to be valid and reliable for ACLR patients (de Vasconcelos et al., 2009).

The normative data from the article by Danneskiold-Samsøe et al., (2009) was tested with the use of a Lido Active isokinetic dynamometer (Danneskiold-Samsøe et al., 2009). No other studies were found for normative data where both female and male were included and the Biodex isokinetic dynamometer was used for testing. According to a study by Lund et al., (2005) comparing the Biodex isokinetic dynamometer with Lido Active isokinetic dynamometer, no differences in Newton x meter (Nm) was found between the two machines when doing a 60 degrees per second protocol (Lund et al., 2005). The results are there-for safe to compare.

Hop performance:

Why did the participants score lower with six months more of rehabilitation than the group from Gustavsson et al., (2006) for the side-hop test and five months more than the

group from Gokeler et al., (2017) for both hop tests? A possible explanation could be that in these two studies they were only testing hop performance with five hop tests and three hops tests from the respective studies (Gustavsson et al., 2006)(A. Gokeler et al., 2017). The study sample did in contrast to close to 1.5 hours of physical testing, including a maximal strength test for knee extension and flexion and with the side-hop test at the very end, was fatigue the reason why they did not perform well?

Fatigue was tested in an article from Leister et al., (2018). The test battery for the study took 50-70 min and consisted of isometric strength test (hamstring strength), five hop tests and a protocol for fatigue, so similar to the study sample except for the fatigue protocol. They found a decrease in performance in the fatigued leg compared to the non-fatigue (Leister et al., 2018).

The validity and reliability of the two tests used for hop performance for ACLR patients are good, ranging from 0.85 – 0.97 (Gustavsson et al., 2006). Hop tests are and especially the SLHD, often used after ACLR (Abrams et al., 2014) (Powell, Jensen, & Johnson, 2018).

The necessary skills to perform hop tests is a combination of neuro-muscular control, muscle strength and the ability to trust standing and to hop on the ACLR knee (Reid, Birmingham, Stratford, Alcock, & Giffin, 2007) these skills are related to sports activity (Gotlin & Huie, 2000).

Hop performance tests are found to be able to predict who RTS or not (C. L. Ardern et al., 2011) and self-reported knee function (D. Logerstedt et al., 2014). Based on these factors, hop performance testing is useful and necessary after ACLR and rehabilitation. Several other different hop performance tests for ACLR are described throughout the literature; the Cross over test, Trippel hop test, Vertical jump test, and 6-meter timed hop test to mention a few (Abrams et al., 2014)(Powell et al., 2018). Different tests could have been used for the assessment of hop performance and may have impacted the results differently.

The SLHD test:

In the article by Gustavsson et al., (2006), the SLHD test was performed with their hands on the back compared to the study sample who could use the arms for speed and balance. This difference may have a positive impact on the result of the study sample.

In the article from Gokeler et al., (2017) it is not described how the participants had their arms when performing the SLHD tests.

The side-hop test:

The side-hop test is considered physical fatigue or an endurance test. The right leg was tested first regardless of whether it was the injured or non-injured leg. This decision was made to avoid any bias for an increased learning curve (the second leg tested had the advantage).

The participants from the study from Gustavsson et al., (2006) had their hand behind the back while performing the side-hop test, which may affect the result negatively compared to the study sample.

In the study from Kockum & Heijne (2015) the participants had their hands on their hips while jumping, where the study sample could use their arms for balance which would give the study sample an advantage.

In the article from Gokeler et al., (2017) it is not described how the participants had their arms when performing the SLHD tests.

Limb symmetry index:

LSI is designed to evaluate differences between the legs (Noyes, Barber, & Mangine, 1991). LSI was in this master project ≥ 90% or no more than 10% strength difference between the injured and non-injured leg according to the majority of the literature (Fitzgerald, Axe, & Snyder-Mackler, 2000)(Adams et al., 2012).

LSI has been proposed not to be accurate to use since the non-injured leg most likely has strength deficits after ACLR and there-for cannot be used as a reference (Hiemstra et al., 2007)(Wellsandt, Failla, & Snyder-Mackler, 2017)(A. Gokeler et al., 2017).

LSI is still widely used through-out the literature, especially in test batteries for RTS (Alli Gokeler et al., 2017)(Hege Grindem et al., 2016)(Abrams et al., 2014).

If LSI can give a false positive result, the LSI results must be interpreted and used with caution.

Patient-reported outcomes

KOOS has been validated for patients with the risk of developing knee OA which includes ACLR patients and can be used for both short- and long-term investigation (E.

M. Roos, Roos, Lohmander, Ekdahl, & Beynnon, 1998). It has also shown to be valid and reliable for ACLR athletes (Salavati, Akhbari, Mohammadi, Mazaheri, & Khorrami, 2011). KOOS is an extension of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) questionnaire (Ewa M. Roos & Lohmander, 2003) and to my knowledge, no other questionnaire investigate knee OA. Even though it is unlikely to measure any symptomatic knee OA at 12 months post-surgery (Britt Elin Øiestad & Chu, 2018), KOOS still detects many areas that can be affecting the development of knee OA, e.g., knee joint effusion (KOOS SYMPTOM). Results from Palmieri-Smith et al., (2007) shows knee joint effusion inhibits the activation of the quadriceps muscle and there-by impacting knee joint kinematics, which increases the knee joint load and overtime may affect the development of knee OA (Palmieri-Smith, Kreinbrink, Ashton-Miller, & Wojtys, 2007).

For this master project, KOOS was pre-chosen for the baseline testing for the SHIELD cohort. Even-though KOOS is developed for short-term investigations, other questionnaires as the International Committee Subjective Knee Evaluation Form (IKDC) (Irrgang et al., 2001) could have been used for this cross-sectional study 12 months after ACLR.

Tegner Activity Scale:

Other questionnaires addressing physical activity is the Lysholm Knee Scoring Scale and Activity Rating Scale (Natalie J. Collins et al., 2011). Lyshom Knee Scoring Scale is designed to evaluate knee ligament surgery but had limitations in functional scores (Tegner & Lysholm, 1985).

The Activity Rating Scale is developed for the evaluation of activity in the past year and is intended to be used by patients who already participate in sport with various knee conditions (Marx, Stump, Jones, Wickiewicz, & Warren, 2001).

The Tegner Activity Scale was developed for the ACL injured patient, with items likely to be difficult or challenging for the ACL injured patient (Tegner & Lysholm, 1985). It has proven to be both valid and reliable for patients with ACL injury (Briggs, Lysholm, et al., 2009), and was designed to be used in addition to Lysholm Knee Scoring Scale. Though to my knowledge, the Tegner Activity Scale is often used by clinicians alone and not always in addition to the Lysholm Knee Scoring Scale, which is also reflected

in research (Hetsroni et al., 2017)(Chung et al., 2015)(Lentz et al., 2012). The Tegner Activity Scale focuses on activity in work and daily living, recreational, and high level in sports and can be used before and after surgery (Natalie J. Collins et al., 2011).

Pain and Global Rating of knee function:
Others had measured pain as an average from the last 24 hours (Lentz et al., 2012), which is different from the study sample and may have impacted the result.
Other research studies have measures knee function on a scale from 0 to 100 (Global rating of perceived function) (D. Logerstedt et al., 2014), instead of 0 to 10, which gives a more accurate measure of the knee function. This can have affected the overall score of Global Rating of Knee function.

Return to Sport:
The RTS questionnaire was developed in Lund, Sweden and since it was a non-validated questionnaire, the results must be interpreted with caution, all though the questionnaire was designed according to leading experts in this field (Clare L Ardern et al., 2016). The questionnaire was *only* to investigate what type of sport the participants did before the injury, if they had returned to sport or not and at if yes, at what level. It did not contain any questions to determine if they were physical or mentally ready for a return.

Another questionnaire often used for RTS is IKDC. IKDC is a self-reported knee function questionnaire investigating knee function, symptoms and sports activity (Irrgang et al., 2001) and can be used for cut-off points for RTS (Toole et al., 2017). IKDC is often used together with other recommend assessments for RTS testing which should include testing from all ICF categories (C. L. Ardern et al., 2011), and with both open and closed skills (Clare L Ardern et al., 2016). IKDC may have been a better choice for this master project, especially in relation to the RTS evaluation.

ACLOAS:
In this project, ACLOAS was used for the MRI investigation. ACLOAS is a valid and reliable tool for investigating whole joint description of MRI after ACL injury and at later follow-up (Roemer et al., 2014).

Several other scorings systems exist; Boston Leeds Osteoarthritis Knee Score (BLOKS) (Hunter et al., 2008) and MRI Osteoarthritis Knee Score (MOAKS) which is a further development of BLOKS (Hunter et al., 2011). MOAKS use contrast-enhanced MRI (Hunter et al., 2011). Both systems have limitations for the assessment of ACLR patients, and ACLOAS was developed for this specific patient group (Roemer et al., 2014).

ACLOAS is powerful to detect early changes in cartilage and morphology after ACLR and is the only system differentiating trauma caused subchondral bone changes from degenerative bone marrow lesions. ACLOAS is the only tool, including a description of the injury pattern at baseline, which may predict later outcome (Roemer et al., 2014). Further grafts and indirect signs of instability (e.g., anterior tibial shift) are also incorporated in the ACLOAS evaluation (Roemer et al., 2014).

ACLOAS was pre-chosen for this master project since it is part of the SHIELD baseline investigation. Even though cartilage changes can be detected 12 months after ACLR (Theologis et al., 2014), the ACLOAS evaluation at baseline (12 months post-ACLR) may be more relevant for the SHIELD study than this master study.

The machine used in this master project was a Tesla 1.5 and in the study by Su et al., (2016) the machine used was a Tesla 3.0 (Su et al., 2016) which may be even more valid for the investigation of cartilage (Wong et al., 2009). In the study they used a different scoring system; Whole Organ MRI scoring (WORMS) and the amount of participants was more than double compared to our study (Su et al., 2016). The reason why no differences was found in our study can be because of low amount of participants and thereby the risk of type II error.

Bias

Selection bias:

All possible candidates (according to in- and exclusion criteria's) were contacted by mail and telephone. Ten of those did not respond either the telephone call or by mail. Though it was completely voluntary to participate, there is always a risk of selection bias with the participants who chose to participate. Maybe they had problems with their knee and knee-related function and wanted a free MRI and additional tests of the knee? Alternatively, maybe they were doing fine and wanted to have it confirmed in tests and

MRI?

Inspecting the data, especially the RROs, the Tegner Activity Scale and NRS, there is a broad variety of answers, in each direction. Some of the study sample was doing fine, and some had problems, and some were in-between which mirror the reality we see in the clinic.

There-for, the variety of the participants included in this master project, is representative for the population of young and active athletes that sustained an ACL injury and reconstruction which improves the study's external validity (Laake et al., 2008). The small sample size makes it challenging to transfer the results to the general population.

The number of participants in this master project is, as mention, relatively small. The larger the sample size is, the more sufficient and precise the prevalence can be estimated. Since the number of participants was already planned for the Norwegian contribution to SHIELD to be 20, no calculations were made for the sample size. Only 1 participant was added due to the risk of drop-out in the SHIELD cohort. The estimates in this master project will, therefore, be less precise and can be due to chance alone (Laake et al., 2008).

Information bias:

Even though all participants had been screened for their understanding of the Scandinavian language over the telephone, the investigator experienced a few of the youngest participants having problems with reading KOOS and Tegner Activity Scale. Difficult to say if it was a language barrier, nervousness or confusion that may have been the reason.

For especially KOOS, one participant had to ask the investigator several times for an explanation and interpretation of the questions. This could have affected the participant's answer.

Statistical bias:

The risk of a Type I error (reject the hypothesis even though it is true) is relatively small since the significant (p) level was set to be 0.05 and confidence interval to be 95% (Laake et al., 2008). Since the statically power is low due to the small number of

participants, there is a chance of a type II error, meaning accepting the hypothesis even though it is false (Laake et al., 2008).

The Tegner Activity scale is categorized as categorical, ordinal data and should be described with median and quartiles. For the comparison with normative data from Briggs et al., (2009) the data from the article was presented with Mean and no standard deviation (Briggs, Steadman, et al., 2009), which is typically used for continuous data when these are normally distributed (O'Donoghue, 2012). To be able to compare, the result from the study sample is also presented in mean. The difference was between median and mean one full category.

For the binary logistic regression analysis, none of the results was significant either for the RTS and isometric knee and isometric hip and trunk muscle strength and hop performance and the differences between cartilage findings and KOOS score. The reason could be the number of participants in the study sample was too small, and the result may be a type II error.

5.2.2 Limitations in the study

The small sample size gives limitations statically and thereby the external validity. The non-existing knowledge about their knee function before the surgery, if they did pre-habilitation and the content of rehabilitation and their compliance. Did they have any fear for re-injury and how was the metal readiness? These factors are confounders and may have affected the results.

Important outcome after ACLR is the absence of major knee joint effusion and "giving away episodes" (Lynch et al., 2015), no questions or tests, for example, the stroke test for knee joint effusion (Sturgill, Snyder-Mackler, Manal, & Axe, 2009) was done to assess this.

The lack of normative data for hop performance tests and isometric trunk/side-bridge muscle tests, and other studies using ACLOAS is a limitation to the study. Data are collected but cannot be compared to other results, and it is there-for uncertain if the study sample scores are similar to other studies.

5.2.3 External validity

The sample size included 21 young and active adults. This group correlates with the risk group for ACL injury; young and active (Stephanie R. Filbay & Grindem, 2019) and

was doing some sports activity (Moses et al., 2012).
Ninety-five percent of our study sample participated in sports activities when the injury occurred, and soccer was the most common sport. This correlates with the results from www.kvalitetsregistre.no, where soccer is the major contributors to ACL injuries in Norway (*https://www.kvalitetsregistre.no/registers/527/resultater*, 2018).

Eight of the ACL injuries happened during match situations, seven during training and six during other activities as trampoline and/or falling down stairs. The majority of injuries (12 injuries) were non-contact injuries regardless if they happened during a match or in training sessions. This correlates well with the literature where, where according to Wetters et al., (2016), 75% of ACL injuries happens as a non-contact injury (Wetters et al., 2016).
The number of concomitant injuries also correlated with other articles, and the RTS rate was similar to another Norwegian study.

Based on the literature, the study sample was representative of the ACLR patient.

The tests used in this master project, for the evaluation of the participants are representative of the recommendations from Ardern et al., (2011). According to Ardern et al., (2011), the tests should include aspects from every ICF category (C. L. Ardern et al., 2011). Evaluation of strength and pain are categorized as ICF Body function and structures. Tegner Activity Scale, Global rating of knee function and hop performances are categorized under ICF Activities. RTS as ICF participation, and for contextual factors, KOOS was used.
The specific combinations of the tests used in this master project were not found in other studies, but all the tests used in this master projects are found in other studies, investigating similar research questions (Hege Grindem et al., 2016)(Toole et al., 2017) (Ageberg et al., 2010).

The assessments used to evaluate the study sample is representative for the ACLR patient 12 months after reconstruction based on literature.
The small sample size makes it however difficult to transfer the result to the general population, the general ACLR patient, or our rehabilitation practice.

5.3 The clinical implications

Twelve months after ACLR, 52% of the participants had returned to sport. However, RTS is not always safe and without complications. Grindem et al., (2016) presented data where for every month RTS was postponed, until nine months of rehabilitation, reduced the risk for re-injury after ACLR with 51% (Hege Grindem et al., 2016). This study sample is approximately 12 months post ACLR, and based on these findings, the RTS should be safer for the participants. Grindem et al., (2016) also found those who did not pass the RTS criteria (Knee outcome survey – Activities of daily living, global rating of knee function, quadriceps strength and hop performance) with a score >90 on all tests, had 38.2% risk of sustaining a re-injury compared with 5.6% for those who passed the RTS criteria (Hege Grindem et al., 2016). Applying this to the study sample means they are still at risk of re-injury 12 months after ACLR.

Toole et al., (2017) investigated ACLR patients already cleared for RTS and tested them with patient-reported outcomes (IKDC), LSI for knee muscle strength tests, and hop performance tests. From 115 participants participating in the study, only 53% meet the criteria of LSI >90% for the hop performance test and 27.8% for the knee muscle strength tests. 13.9% meet the recommendation of scores >90 for patient reported outcomes (IKDC). Even-though the time from ACLR to RTS only was mean 8.2 ± 2.5 months after ACLR in the study, the numbers are still very low.

The result from the study sample and from the literature listed above implicates that 12 months of rehabilitation may not be enough for a safe return to sport. This correlates well with other studies suggesting that full rehabilitation after ACLR may take years (M. A. Risberg et al., 1999)(Chung et al., 2015).
As a health-care provider, you are obligated to treat the patients according to evidence (*https://fysio.no/Forbundsforsiden/Jus-arbeidsliv/Aktuelle-tema/Etikk/NFFs-yrkesetiske-retningslinjer*, 2019). The area of ACL injury and rehabilitation are well presented in research, with a high level of publications. It is of great importance for the health-care provider to stay updated and not only to plan the rehabilitation but also to execute tests along with rehabilitation to assure progress and make adjustments based

on the results. This gives valuable information for the health-care provider, but is also valuable for the patient, for e.g., motivation. Later in rehabilitation, testing for the return to participation, RTS, and return to performance is of importance (Clare L Ardern et al., 2016).

Even though questions about the rehabilitation and the participant's compliance was not a part of this master project, they are two essential questions to ask. Could some of the poor outcome be a result of no compliance or lack of quality in rehabilitation? To achieve the recommended cut-off scores for a safe return to sport and to reduce the risk of the short-term and long-term outcome, dedication and commitment are crucial for not only the health-care provider and but also the patient.

5.4 The future

Both short- and long-term outcome can have severe consequences for the patient. This young group of athletes can have health issues related to the knee, resulting in a change of preferred carrier, maybe the risk of reduced income, loss of social contact if not returning to sport, loss of confidence and motivation, all of which can and will affect QOL. For the patient, this can be an overwhelming situation, both personal and maybe economic. For the professional, the club loses a player or athlete, which can have devastating consequences with the loss of money and investment. For social economics, there is and will be over time an increase in health-related expenses from the ACL injury and the ACLR patients in the Scandinavian countries, where the health system is government funded. Money that could have been well spent on patient education and rehabilitation to avoid short- and long-term outcomes.

6.0 Conclusion

The evaluation of 21 young adults one year after ACLR showed significant differences between the injured and non-injured leg for isokinetic knee extension and both hop

performance tests, where the non-injured leg was stronger. Significant association were found between PROs and isokinetic knee and isometric hip and trunk muscle strength and hop performance. All values (isokinetic knee- and iso isometric hip and trunk muscle strength and hop performance) were significantly associated with Tegner Activity Scale except for isometric hip extension and trunk/side-bridge for the non-injured leg. 52% of the participants had returned to sport and 24% to the previous level. 9 participants had cartilages defects found with the use of ACLOAS evaluation system. No association between the ACLOAS cartilage score and KOOS were found.

References

Abrams, G. D., Harris, J. D., Gupta, A. K., McCormick, F. M., Bush-Joseph, C. A., Verma, N. N., … Bach, B. R. (2014). Functional Performance Testing After Anterior Cruciate Ligament Reconstruction: A Systematic Review. *Orthopaedic Journal of Sports Medicine*, *2*(1), 232596711351830. https://doi.org/10.1177/2325967113518305

Adams, D., Logerstedt, D., Hunter-Giordano, A., Axe, M. J., & Snyder-Mackler, L. (2012). Current Concepts for Anterior Cruciate Ligament Reconstruction: A Criterion-Based Rehabilitation Progression. *Journal of Orthopaedic & Sports Physical Therapy*, *42*(7), 601–614. https://doi.org/10.2519/jospt.2012.3871

Ageberg, E., Forssblad, M., Herbertsson, P., & Roos, E. M. (2010). Sex Differences in Patient-Reported Outcomes After Anterior Cruciate Ligament Reconstruction: Data From the Swedish Knee Ligament Register. *The American Journal of Sports Medicine*, *38*(7), 1334–1342. https://doi.org/10.1177/0363546510361218

Ageberg, E., Thomeé, R., Neeter, C., Silbernagel, K. G., & Roos, E. M. (2008). Muscle strength and functional performance in patients with anterior cruciate ligament injury treated with training and surgical reconstruction or training only: A two to five-year followup. *Arthritis & Rheumatism*, *59*(12), 1773–1779. https://doi.org/10.1002/art.24066

Alentorn-Geli, E., Mendiguchía, J., Samuelsson, K., Musahl, V., Karlsson, J., Cugat, R., & Myer, G. D. (2014). Prevention of anterior cruciate ligament injuries in sports—Part I: Systematic review of risk factors in male athletes. *Knee Surgery, Sports Traumatology, Arthroscopy*, *22*(1), 3–15. https://doi.org/10.1007/s00167-013-2725-3

Alshewaier, S., Yeowell, G., & Fatoye, F. (2017). The effectiveness of pre-operative exercise physiotherapy rehabilitation on the outcomes of treatment following anterior cruciate ligament injury: a systematic review. *Clinical Rehabilitation*, *31*(1), 34–44. https://doi.org/10.1177/0269215516628617

Andernord, D., Desai, N., Björnsson, H., Gillén, S., Karlsson, J., & Samuelsson, K. (2015). Predictors of Contralateral Anterior Cruciate Ligament Reconstruction: A Cohort Study of 9061 Patients With 5-Year Follow-up. *The American Journal of Sports Medicine*, *43*(2), 295–302. https://doi.org/10.1177/0363546514557245

Ardern, C. L., Webster, K. E., Taylor, N. F., & Feller, J. A. (2011). Return to sport following anterior cruciate ligament reconstruction surgery: a systematic review and meta-analysis of the state of play. *British Journal of Sports Medicine*, *45*(7), 596–606. https://doi.org/10.1136/bjsm.2010.076364

Ardern, Clare L, Glasgow, P., Schneiders, A., Witvrouw, E., Clarsen, B., Cools, A., … Bizzini, M. (2016). 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern. *British Journal of Sports Medicine*, *50*(14), 853–864. https://doi.org/10.1136/bjsports-2016-096278

Ardern, Clare L, Taylor, N. F., Feller, J. A., & Webster, K. E. (2014). Fifty-five per cent return to competitive sport following anterior cruciate ligament reconstruction surgery: an updated systematic review and meta-analysis including aspects of physical functioning and contextual factors. *British Journal of Sports Medicine*, *48*(21), 1543–1552. https://doi.org/10.1136/bjsports-2013-093398

Ardern, Clare L., Taylor, N. F., Feller, J. A., Whitehead, T. S., & Webster, K. E. (2013). Psychological responses matter in returning to preinjury level of sport after anterior cruciate ligament reconstruction surgery. *The American Journal of Sports Medicine*, *41*(7), 1549–1558. https://doi.org/10.1177/0363546513489284

Bahr, R. (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. *British Journal of Sports Medicine*, *39*(6), 324–329. https://doi.org/10.1136/bjsm.2005.018341

Baldwin, J. N., McKay, M. J., Simic, M., Hiller, C. E., Moloney, N., Nightingale, E. J., … Quinlan, K. (2017). Self-reported knee pain and disability among healthy individuals: reference data and factors associated with the Knee injury and Osteoarthritis Outcome Score (KOOS) and KOOS-Child. *Osteoarthritis and Cartilage*, *25*(8), 1282–1290. https://doi.org/10.1016/j.joca.2017.03.007

Baltaci, G., Yilmaz, G., & Atay, A. O. (2012). The outcomes of anterior cruciate ligament reconstructed and rehabilitated knees versus healthy knees: a functional comparison. *Acta Orthopaedica Et Traumatologica Turcica*, *46*(3), 186–195.

Barber-Westin, S. D., & Noyes, F. R. (2011). Objective criteria for return to athletics after anterior cruciate ligament reconstruction and subsequent reinjury rates: a systematic review. *The Physician and Sportsmedicine*, *39*(3), 100–110. https://doi.org/10.3810/psm.2011.09.1926

Barenius, B., Forssblad, M., Engström, B., & Eriksson, K. (2013). Functional recovery after anterior cruciate ligament reconstruction, a study of health-related quality of life based on the Swedish National Knee Ligament Register. *Knee Surgery, Sports Traumatology, Arthroscopy*, *21*(4), 914–927. https://doi.org/10.1007/s00167-012-2162-8

Barfod, K. W., Feller, J. A., Hartwig, T., Devitt, B. M., & Webster, K. E. (2019). Knee extensor strength and hop test performance following anterior cruciate ligament reconstruction. *The Knee*, *26*(1), 149–154. https://doi.org/10.1016/j.knee.2018.11.004

Benjaminse, A., Gokeler, A., & van der Schans, C. P. (2006). Clinical Diagnosis of an Anterior Cruciate Ligament Rupture: A Meta-analysis. *Journal of Orthopaedic & Sports Physical Therapy*, *36*(5), 267–288. https://doi.org/10.2519/jospt.2006.2011

Bennell, K. L., Wrigley, T. V., Hunt, M. A., Lim, B.-W., & Hinman, R. S. (2013). Update on the role of muscle in the genesis and management of knee

osteoarthritis. *Rheumatic Diseases Clinics of North America*, *39*(1), 145–176. https://doi.org/10.1016/j.rdc.2012.11.003

Blauth, W. (1984). [2-strip substitution-plasty of the anterior cruciate ligament with the quadriceps tendon]. *Unfallheilkunde*, *87*(2), 45–51.

Boden, B. P., Dean, G. S., Feagin, J. A., & Garrett, W. E. (2000). Mechanisms of anterior cruciate ligament injury. *Orthopedics*, *23*(6), 573–578.

Boling, M., & Padua, D. (2013). Relationship between hip strength and trunk, hip, and knee kinematics during a jump-landing task in individuals with patellofemoral pain. *International Journal of Sports Physical Therapy*, *8*(5), 661–669.

Briggs, K. K., Lysholm, J., Tegner, Y., Rodkey, W. G., Kocher, M. S., & Steadman, J. R. (2009). The Reliability, Validity, and Responsiveness of the Lysholm Score and Tegner Activity Scale for Anterior Cruciate Ligament Injuries of the Knee: 25 Years Later. *The American Journal of Sports Medicine*, *37*(5), 890–897. https://doi.org/10.1177/0363546508330143

Briggs, K. K., Steadman, J. R., Hay, C. J., & Hines, S. L. (2009). Lysholm Score and Tegner Activity Level in Individuals with Normal Knees. *The American Journal of Sports Medicine*, *37*(5), 898–901. https://doi.org/10.1177/0363546508330149

Butler, D. L., Noyes, F. R., & Grood, E. S. (1980). Ligamentous restraints to anterior-posterior drawer in the human knee. A biomechanical study. *The Journal of Bone and Joint Surgery. American Volume*, *62*(2), 259–270.

Cameron, K. L., Thompson, B. S., Peck, K. Y., Owens, B. D., Marshall, S. W., & Svoboda, S. J. (2013). Normative values for the KOOS and WOMAC in a young athletic population: history of knee ligament injury is associated with lower scores. *The American Journal of Sports Medicine*, *41*(3), 582–589. https://doi.org/10.1177/0363546512472330

Cavanaugh, J. T., & Powers, M. (2017). ACL Rehabilitation Progression: Where Are We Now? *Current Reviews in Musculoskeletal Medicine*, *10*(3), 289–296. https://doi.org/10.1007/s12178-017-9426-3

Chung, K. S., Ha, J. K., Yeom, C. H., Ra, H. J., Lim, J. W., Kwon, M. S., & Kim, J. G. (2015). Are Muscle Strength and Function of the Uninjured Lower Limb Weakened After Anterior Cruciate Ligament Injury?: Two-Year Follow-up After Reconstruction. *The American Journal of Sports Medicine*, *43*(12), 3013–3021. https://doi.org/10.1177/0363546515606126

Cieza, A., Brockow, T., Ewert, T., Amman, E., Kollerits, B., Chatterji, S., … Stucki, G. (2002). Linking health-status measurements to the international classification of functioning, disability and health. *Journal of Rehabilitation Medicine*, *34*(5), 205–210.

Cinque, M. E., Dornan, G. J., Chahla, J., Moatshe, G., & LaPrade, R. F. (2018). High Rates of Osteoarthritis Develop After Anterior Cruciate Ligament Surgery: An Analysis of 4108 Patients. *The American Journal of Sports Medicine*, *46*(8), 2011–2019. https://doi.org/10.1177/0363546517730072

Collins, Natalie J., Misra, D., Felson, D. T., Crossley, K. M., & Roos, E. M. (2011). Measures of knee function: International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form, Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form (KOOS-PS), Knee Ou. *Arthritis Care & Research*, *63*(S11), S208–S228. https://doi.org/10.1002/acr.20632

Collins, N.J., Prinsen, C. A. C., Christensen, R., Bartels, E. M., Terwee, C. B., & Roos, E. M. (2016). Knee Injury and Osteoarthritis Outcome Score (KOOS): systematic review and meta-analysis of measurement properties. *Osteoarthritis and Cartilage*, *24*(8), 1317–1329. https://doi.org/10.1016/j.joca.2016.03.010

Csintalan, R. P., Inacio, M. C. S., & Funahashi, T. T. (2008). Incidence rate of anterior cruciate ligament reconstructions. *The Permanente Journal*, *12*(3), 17–21.

Czuppon, S., Racette, B. A., Klein, S. E., & Harris-Hayes, M. (2014). Variables associated with return to sport following anterior cruciate ligament reconstruction: a systematic review. *British Journal of Sports Medicine*, *48*(5), 356–364. https://doi.org/10.1136/bjsports-2012-091786

Danneskiold-Samsøe, B., Bartels, E. M., Bülow, P. M., Lund, H., Stockmarr, A., Holm, C. C., … Bliddal, H. (2009). Isokinetic and isometric muscle strength in a healthy population with special reference to age and gender. *Acta Physiologica*, *197*, 1–68. https://doi.org/10.1111/j.1748-1716.2009.02022.x

Davarinos, N., O'Neill, B. J., & Curtin, W. (2014). A Brief History of Anterior Cruciate Ligament Reconstruction. *Advances in Orthopedic Surgery*, *2014*, 1–6. https://doi.org/10.1155/2014/706042

Davies, G. J., McCarty, E., Provencher, M., & Manske, R. C. (2017). ACL Return to Sport Guidelines and Criteria. *Current Reviews in Musculoskeletal Medicine*, *10*(3), 307–314. https://doi.org/10.1007/s12178-017-9420-9

de Fontenay, B. P., Argaud, S., Blache, Y., & Monteil, K. (2014). Motion alterations after anterior cruciate ligament reconstruction: comparison of the injured and uninjured lower limbs during a single-legged jump. *Journal of Athletic Training*, *49*(3), 311–316. https://doi.org/10.4085/1062-6050-49.3.11

de Vasconcelos, R. A., Bevilaqua-Grossi, D., Shimano, A. C., Paccola, C. J., Salvini, T. F., Prado, C. L., & Junior, W. A. M. (2009). RELIABILITY AND VALIDITY OF A MODIFIED ISOMETRIC DYNAMOMETER IN THE ASSESSMENT OF MUSCULAR PERFORMANCE IN INDIVIDUALS WITH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION. *Revista Brasileira de*

Ortopedia (English Edition), *44*(3), 214–224. https://doi.org/10.1016/S2255-4971(15)30071-9

Dhanda, S. (2010). Case Series: Cyclops lesion - extension loss after ACL reconstruction. *Indian Journal of Radiology and Imaging*, *20*(3), 208. https://doi.org/10.4103/0971-3026.69361

Downes, M. J., Brennan, M. L., Williams, H. C., & Dean, R. S. (2016). Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS). *BMJ Open*, *6*(12), e011458. https://doi.org/10.1136/bmjopen-2016-011458

Duthon, V. B., Barea, C., Abrassart, S., Fasel, J. H., Fritschy, D., & Ménétrey, J. (2006). Anatomy of the anterior cruciate ligament. *Knee Surgery, Sports Traumatology, Arthroscopy*, *14*(3), 204–213. https://doi.org/10.1007/s00167-005-0679-9

Eckenrode, B. J., Carey, J. L., Sennett, B. J., & Zgonis, M. H. (2017). Prevention and Management of Post-operative Complications Following ACL Reconstruction. *Current Reviews in Musculoskeletal Medicine*, *10*(3), 315–321. https://doi.org/10.1007/s12178-017-9427-2

Eckstein, F., Hitzl, W., Duryea, J., Kent Kwoh, C., & Wirth, W. (2013). Baseline and longitudinal change in isometric muscle strength prior to radiographic progression in osteoarthritic and pre-osteoarthritic knees – data from the Osteoarthritis Initiative. *Osteoarthritis and Cartilage*, *21*(5), 682–690. https://doi.org/10.1016/j.joca.2013.02.658

Eitzen, I., Holm, I., & Risberg, M. A. (2009). Preoperative quadriceps strength is a significant predictor of knee function two years after anterior cruciate ligament reconstruction. *British Journal of Sports Medicine*, *43*(5), 371–376. https://doi.org/10.1136/bjsm.2008.057059

Englund, M. (2008). The Role of the Meniscus in Osteoarthritis Genesis. *Rheumatic Disease Clinics of North America*, *34*(3), 573–579. https://doi.org/10.1016/j.rdc.2008.05.009

Failla, M. J., Arundale, A. J. H., Logerstedt, D. S., & Snyder-Mackler, L. (2015). Controversies in Knee Rehabilitation. *Clinics in Sports Medicine*, *34*(2), 301–312. https://doi.org/10.1016/j.csm.2014.12.008

Failla, M. J., Logerstedt, D. S., Grindem, H., Axe, M. J., Risberg, M. A., Engebretsen, L., … Snyder-Mackler, L. (2016). Does Extended Preoperative Rehabilitation Influence Outcomes 2 Years After ACL Reconstruction?: A Comparative Effectiveness Study Between the MOON and Delaware-Oslo ACL Cohorts. *The American Journal of Sports Medicine*, *44*(10), 2608–2614. https://doi.org/10.1177/0363546516652594

Feiring, David C., Ellenbecker, T. S., & Derscheid, G. L. (1990). Test-Retest Reliability of the Biodex Isokinetic Dynamometer. *Journal of Orthopaedic & Sports Physical Therapy*, *11*(7), 298–300. https://doi.org/10.2519/jospt.1990.11.7.298

Ferber, R., Bolgla, L., Earl-Boehm, J. E., Emery, C., & Hamstra-Wright, K. (2015). Strengthening of the hip and core versus knee muscles for the treatment of patellofemoral pain: a multicenter randomized controlled trial. *Journal of Athletic Training*, *50*(4), 366–377. https://doi.org/10.4085/1062-6050-49.3.70

Filbay, S. R., Ackerman, I. N., Russell, T. G., & Crossley, K. M. (2017). Return to sport matters-longer-term quality of life after ACL reconstruction in people with knee difficulties. *Scandinavian Journal of Medicine & Science in Sports*, *27*(5), 514–524. https://doi.org/10.1111/sms.12698

Filbay, Stephanie R., & Grindem, H. (2019). Evidence-based recommendations for the management of anterior cruciate ligament (ACL) rupture. *Best Practice & Research Clinical Rheumatology*. https://doi.org/10.1016/j.berh.2019.01.018

Fitzgerald, G. K., Axe, M. J., & Snyder-Mackler, L. (2000). A decision-making scheme for returning patients to high-level activity with nonoperative treatment after anterior cruciate ligament rupture. *Knee Surgery, Sports Traumatology, Arthroscopy*, *8*(2), 76–82. https://doi.org/10.1007/s001670050190

Flosadottir, V., Roos, E. M., & Ageberg, E. (2016). Muscle function is associated with future patient-reported outcomes in young adults with ACL injury. *BMJ Open Sport & Exercise Medicine*, *2*(1), e000154. https://doi.org/10.1136/bmjsem-2016-000154

Flynn, R. K., Pedersen, C. L., Birmingham, T. B., Kirkley, A., Jackowski, D., & Fowler, P. J. (2005). The Familial Predisposition toward Tearing the Anterior Cruciate Ligament: A Case Control Study. *The American Journal of Sports Medicine*, *33*(1), 23–28. https://doi.org/10.1177/0363546504265678

Frobell, R. B., Roos, H. P., Roos, E. M., Roemer, F. W., Ranstam, J., & Lohmander, L. S. (2013). Treatment for acute anterior cruciate ligament tear: five year outcome of randomised trial. *BMJ*, *346*(jan24 1), f232–f232. https://doi.org/10.1136/bmj.f232

Frobell, Richard B., Roos, E. M., Roos, H. P., Ranstam, J., & Lohmander, L. S. (2010). A Randomized Trial of Treatment for Acute Anterior Cruciate Ligament Tears. *New England Journal of Medicine*, *363*(4), 331–342. https://doi.org/10.1056/NEJMoa0907797

George, M. S., Dunn, W. R., & Spindler, K. P. (2006). Current Concepts Review: Revision Anterior Cruciate Ligament Reconstruction. *The American Journal of Sports Medicine*, *34*(12), 2026–2037. https://doi.org/10.1177/0363546506295026

Girgis, F. G., Marshall, J. L., & Monajem, A. (1975). The cruciate ligaments of the knee joint. Anatomical, functional and experimental analysis. *Clinical Orthopaedics and Related Research*, (106), 216–231.

Gokeler, A., Welling, W., Benjaminse, A., Lemmink, K., Seil, R., & Zaffagnini, S. (2017). A critical analysis of limb symmetry indices of hop tests in athletes after anterior cruciate ligament reconstruction: A case control study. *Orthopaedics & Traumatology: Surgery & Research*, *103*(6), 947–951. https://doi.org/10.1016/j.otsr.2017.02.015

Gokeler, Alli, Welling, W., Zaffagnini, S., Seil, R., & Padua, D. (2017). Development of a test battery to enhance safe return to sports after anterior cruciate ligament reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy*, *25*(1), 192–199. https://doi.org/10.1007/s00167-016-4246-3

Gotlin, R. S., & Huie, G. (2000). Anterior Cruciate Ligament Injuries: Operative and Rehabilitative Options. *Physical Medicine and Rehabilitation Clinics of North America*, *11*(4), 895–915. https://doi.org/10.1016/S1047-9651(18)30107-4

Grindem, H, Granan, L. P., Risberg, M. A., Engebretsen, L., Snyder-Mackler, L., & Eitzen, I. (2015). How does a combined preoperative and postoperative rehabilitation programme influence the outcome of ACL reconstruction 2 years after surgery? A comparison between patients in the Delaware-Oslo ACL Cohort and the Norwegian National Knee Ligament Registry. *British Journal of Sports Medicine*, *49*(6), 385–389. https://doi.org/10.1136/bjsports-2014-093891

Grindem, Hege, Eitzen, I., Engebretsen, L., Snyder-Mackler, L., & Risberg, M. A. (2014). Nonsurgical or Surgical Treatment of ACL Injuries: Knee Function, Sports Participation, and Knee Reinjury. *The Journal of Bone and Joint Surgery*, *96*(15), 1233–1241. https://doi.org/10.2106/JBJS.M.01054

Grindem, Hege, Snyder-Mackler, L., Moksnes, H., Engebretsen, L., & Risberg, M. A. (2016). Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: the Delaware-Oslo ACL cohort study. *British Journal of Sports Medicine*, *50*(13), 804–808. https://doi.org/10.1136/bjsports-2016-096031

Gustavsson, A., Neeter, C., Thomeé, P., Grävare Silbernagel, K., Augustsson, J., Thomeé, R., & Karlsson, J. (2006). A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy*, *14*(8), 778–788. https://doi.org/10.1007/s00167-006-0045-6

Hamrin Senorski, E., Svantesson, E., Beischer, S., Thomeé, C., Grassi, A., Krupic, F., … Samuelsson, K. (2018). Concomitant injuries may not reduce the likelihood of achieving symmetrical muscle function one year after anterior cruciate ligament reconstruction: a prospective observational study based on 263 patients. *Knee Surgery, Sports Traumatology, Arthroscopy*, *26*(10), 2966–2977. https://doi.org/10.1007/s00167-018-4845-2

Hardy, A., Casabianca, L., Andrieu, K., Baverel, L., & Noailles, T. (2017). Complications following harvesting of patellar tendon or hamstring tendon grafts for anterior cruciate ligament reconstruction: Systematic review of

literature. *Orthopaedics & Traumatology: Surgery & Research*, *103*(8), S245–S248. https://doi.org/10.1016/j.otsr.2017.09.002

Hetsroni, I., van-Stee, M., Marom, N., Koch, J. E. J., Dolev, E., Maoz, G., … Mann, G. (2017). Factors Associated With Improved Function and Maintenance of Sports Activities at 5 to 10 Years After Autologous Hamstring ACL Reconstruction in Young Men. *Orthopaedic Journal of Sports Medicine*, *5*(4), 232596711770084. https://doi.org/10.1177/2325967117700841

Hewett, T. E., Di Stasi, S. L., & Myer, G. D. (2013). Current Concepts for Injury Prevention in Athletes After Anterior Cruciate Ligament Reconstruction. *The American Journal of Sports Medicine*, *41*(1), 216–224. https://doi.org/10.1177/0363546512459638

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S., Colosimo, A. J., McLean, S. G., … Succop, P. (2005). Biomechanical Measures of Neuromuscular Control and Valgus Loading of the Knee Predict Anterior Cruciate Ligament Injury Risk in Female Athletes: A Prospective Study. *The American Journal of Sports Medicine*, *33*(4), 492–501. https://doi.org/10.1177/0363546504269591

Hickey Lucas, K. C., Kline, P. W., Ireland, M. L., & Noehren, B. (2017). Hip and trunk muscle dysfunction: implications for anterior cruciate ligament injury prevention. *Annals of Joint*, *2*, 18–18. https://doi.org/10.21037/aoj.2017.05.07

Hiemstra, L. A., Webber, S., MacDonald, P. B., & Kriellaars, D. J. (2007). Contralateral limb strength deficits after anterior cruciate ligament reconstruction using a hamstring tendon graft. *Clinical Biomechanics*, *22*(5), 543–550. https://doi.org/10.1016/j.clinbiomech.2007.01.009

Hinterwimmer, S., Engelschalk, M., Sauerland, S., Eitel, F., & Mutschler, W. (2003). Operative vs. konservative Therapie der vorderen Kreuzbandruptur: eine systematische Literatur﷯bersicht. *Der Unfallchirurg*, *106*(5), 374–379. https://doi.org/10.1007/s00113-003-0596-7

http://koos.nu. (2018, February 11).

https://casp-uk.net. (2018). *Casp appraisal tools*.

https://en.oxforddictionaries.com. (2019).

https://euroqol.org/eq-5d-instruments/population-norms/. (2019).

https://fysio.no/Forbundsforsiden/Jus-arbeidsliv/Aktuelle-tema/Etikk/NFFs-yrkesetiske-retningslinjer. (2019).

https://www.kvalitetsregistre.no/registers/527/resultater. (2018).

https://www.qualityforum.org/Projects/n-r/Patient-Reported_Outcomes/Patient-Reported_Outcomes.aspx. (2019, December 3).

https://www.uvm.edu/~dhowell/methods9/Supplements/icc/More%20on%20ICCs.pdf. (2019, December 5).

https://www.who.int/classifications/icf/en/. (2019).

https://www.yourdictionary.com/normative. (2019).

http://www.businessdictionary.com/definition/normative.html. (2019).

http://www.equator-network.org/reporting-guidelines/prisma-protocols/. (2019).

Hunter, D. J., Guermazi, A., Lo, G. H., Grainger, A. J., Conaghan, P. G., Boudreau, R. M., & Roemer, F. W. (2011). Evolution of semi-quantitative whole joint assessment of knee OA: MOAKS (MRI Osteoarthritis Knee Score). *Osteoarthritis and Cartilage*, *19*(8), 990–1002. https://doi.org/10.1016/j.joca.2011.05.004

Hunter, D. J., Lo, G. H., Gale, D., Grainger, A. J., Guermazi, A., & Conaghan, P. G. (2008). The reliability of a new scoring system for knee osteoarthritis MRI and the validity of bone marrow lesion assessment: BLOKS (Boston–Leeds Osteoarthritis Knee Score). *Annals of the Rheumatic Diseases*, *67*(2), 206–211. https://doi.org/10.1136/ard.2006.066183

Hunter, D. J., Lohmander, L. S., Makovey, J., Tamez-Peña, J., Totterman, S., Schreyer, E., & Frobell, R. B. (2014). The effect of anterior cruciate ligament injury on bone curvature: exploratory analysis in the KANON trial. *Osteoarthritis and Cartilage*, *22*(7), 959–968. https://doi.org/10.1016/j.joca.2014.05.014

Irrgang, J. J., Anderson, A. F., Boland, A. L., Harner, C. D., Kurosaka, M., Neyret, P., … Shelborne, K. D. (2001). Development and Validation of the International Knee Documentation Committee Subjective Knee Form <sup/>. *The American Journal of Sports Medicine*, *29*(5), 600–613. https://doi.org/10.1177/03635465010290051301

Kaeding, C. C., Léger-St-Jean, B., & Magnussen, R. A. (2017). Epidemiology and Diagnosis of Anterior Cruciate Ligament Injuries. *Clinics in Sports Medicine*, *36*(1), 1–8. https://doi.org/10.1016/j.csm.2016.08.001

Karanikas, K., Arampatzis, A., & Brüggemann, G. P. (2009). Motor task and muscle strength followed different adaptation patterns after anterior cruciate ligament reconstruction. *European Journal of Physical and Rehabilitation Medicine*, *45*(1), 37–45.

Karcioglu, O., Topacoglu, H., Dikme, O., & Dikme, O. (2018). A systematic review of the pain scales in adults: Which to use? *The American Journal of Emergency Medicine*, *36*(4), 707–714. https://doi.org/10.1016/j.ajem.2018.01.008

Karlsson, J., Kartus, J., Magnusson, L., Larsson, J., Brandsson, S., & Eriksson, B. I. (1999). Subacute versus delayed reconstruction of the anterior cruciate ligament in the competitive athlete. *Knee Surgery, Sports Traumatology, Arthroscopy*, *7*(3), 146–151. https://doi.org/10.1007/s001670050139

Kartus, J. T., Russell, V. J., Salmon, L. J., Magnusson, L. C., Brandsson, S., Pehrsson, N. G., & Pinczewski, L. A. (2002). Concomitant partial meniscectomy worsens outcome after arthroscopic anterior cruciate ligament reconstruction. *Acta Orthopaedica Scandinavica*, *73*(2), 179–185. https://doi.org/10.1080/000164702753671777

Kemp, J. L., Schache, A. G., Makdissi, M., Sims, K. J., & Crossley, K. M. (2013). Greater understanding of normal hip physical function may guide clinicians in

providing targeted rehabilitation programmes. *Journal of Science and Medicine in Sport*, *16*(4), 292–296. https://doi.org/10.1016/j.jsams.2012.11.887

Kilcoyne, K. G., Dickens, J. F., Haniuk, E., Cameron, K. L., & Owens, B. D. (2012). Epidemiology of Meniscal Injury Associated With ACL Tears in Young Athletes. *Orthopedics*, *35*(3), 208–212. https://doi.org/10.3928/01477447-20120222-07

Kline, P. W., Burnham, J., Yonz, M., Johnson, D., Ireland, M. L., & Noehren, B. (2018). Hip external rotation strength predicts hop performance after anterior cruciate ligament reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA*, *26*(4), 1137–1144. https://doi.org/10.1007/s00167-017-4534-6

Kobayashi, H., Kanamura, T., Koshida, S., Miyashita, K., Okado, T., Shimizu, T., & Yokoe, K. (2010). Mechanisms of the anterior cruciate ligament injury in sports activities: a twenty-year clinical research of 1,700 athletes. *Journal of Sports Science & Medicine*, *9*(4), 669–675.

Kocher, M. S., Steadman, J. R., Briggs, K., Zurakowski, D., Sterett, W. I., & Hawkins, R. J. (2002). Determinants of patient satisfaction with outcome after anterior cruciate ligament reconstruction. *The Journal of Bone and Joint Surgery. American Volume*, *84-A*(9), 1560–1572.

Kockum, B., & Heijne, A. I.-L. M. (2015). Hop performance and leg muscle power in athletes: Reliability of a test battery. *Physical Therapy in Sport*, *16*(3), 222–227. https://doi.org/10.1016/j.ptsp.2014.09.002

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine*, *15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Kyritsis, P., Bahr, R., Landreau, P., Miladi, R., & Witvrouw, E. (2016). Likelihood of ACL graft rupture: not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture. *British Journal of Sports Medicine*, *50*(15), 946–951. https://doi.org/10.1136/bjsports-2015-095908

Laake, P., Olsen, B. R., & Benestad, H. B. (2008). *Forskning i medisin og biofag*. Oslo: Gyldendal.

Lambson, R. B., Barnhill, B. S., & Higgins, R. W. (1996). Football Cleat Design and Its Effect on Anterior Cruciate Ligament Injuries: A Three-Year Prospective Study. *The American Journal of Sports Medicine*, *24*(2), 155–159. https://doi.org/10.1177/036354659602400206

LaPrade, C. M., Dornan, G., Granan, L.-P., LaPrade, R. F., & Engebretsen, L. (2015). Outcomes after Anterior Cruciate Ligament Reconstruction using the Norwegian Knee Ligament Registry of 14,142 Patients: How does Meniscal Repair or

Resection Affect Short-Term Outcomes? *Orthopaedic Journal of Sports Medicine*, *3*(7_suppl2), 2325967115S0006. https://doi.org/10.1177/2325967115S00064

Leister, I., Mattiassich, G., Kindermann, H., Ortmaier, R., Barthofer, J., Vasvary, I., … Kulnik, S. T. (2018). Reference values for fatigued versus non-fatigued limb symmetry index measured by a newly designed single-leg hop test battery in healthy subjects: a pilot study. *Sport Sciences for Health*, *14*(1), 105–113. https://doi.org/10.1007/s11332-017-0410-5

Lentz, T. A., Zeppieri, G., Tillman, S. M., Indelicato, P. A., Moser, M. W., George, S. Z., & Chmielewski, T. L. (2012). Return to Preinjury Sports Participation Following Anterior Cruciate Ligament Reconstruction: Contributions of Demographic, Knee Impairment, and Self-report Measures. *Journal of Orthopaedic & Sports Physical Therapy*, *42*(11), 893–901. https://doi.org/10.2519/jospt.2012.4077

Lepley, L. K., Lepley, A. S., Onate, J. A., & Grooms, D. R. (2017). Eccentric Exercise to Enhance Neuromuscular Control. *Sports Health: A Multidisciplinary Approach*, *9*(4), 333–340. https://doi.org/10.1177/1941738117710913

Leys, T., Salmon, L., Waller, A., Linklater, J., & Pinczewski, L. (2012). Clinical Results and Risk Factors for Reinjury 15 Years After Anterior Cruciate Ligament Reconstruction: A Prospective Study of Hamstring and Patellar Tendon Grafts. *The American Journal of Sports Medicine*, *40*(3), 595–605. https://doi.org/10.1177/0363546511430375

Liechti, D. J., Chahla, J., Dean, C. S., Mitchell, J. J., Slette, E., Menge, T. J., & LaPrade, R. F. (2016). Outcomes and Risk Factors of Rerevision Anterior Cruciate Ligament Reconstruction: A Systematic Review. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, *32*(10), 2151–2159. https://doi.org/10.1016/j.arthro.2016.04.017

Lindsay, D. M., Maitland, M. E., Lowe, R. C., & Kane, T. J. (1992). Comparison of Isokinetic Internal and External Hip Rotation Torques Using Different Testing Positions. *Journal of Orthopaedic & Sports Physical Therapy*, *16*(1), 43–50. https://doi.org/10.2519/jospt.1992.16.1.43

Logerstedt, D., Di Stasi, S., Grindem, H., Lynch, A., Eitzen, I., Engebretsen, L., … Snyder-Mackler, L. (2014). Self-reported knee function can identify athletes who fail return-to-activity criteria up to 1 year after anterior cruciate ligament reconstruction: a delaware-oslo ACL cohort study. *The Journal of Orthopaedic and Sports Physical Therapy*, *44*(12), 914–923. https://doi.org/10.2519/jospt.2014.4852

Logerstedt, D. S., Snyder-Mackler, L., Ritter, R. C., Axe, M. J., & Godges, J. J. (2010). Knee Stability and Movement Coordination Impairments: Knee Ligament Sprain: Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the

American Physical Therapy Association. *Journal of Orthopaedic & Sports Physical Therapy*, *40*(4), A1–A37. https://doi.org/10.2519/jospt.2010.0303

Lohmander, L. S., Englund, P. M., Dahl, L. L., & Roos, E. M. (2007). The Long-term Consequence of Anterior Cruciate Ligament and Meniscus Injuries: Osteoarthritis. *The American Journal of Sports Medicine*, *35*(10), 1756–1769. https://doi.org/10.1177/0363546507307396

Lund, H., Sondergaard, K., Zachariassen, T., Christensen, R., Bulow, P., Henriksen, M., … Bliddal, H. (2005). Learning effect of isokinetic measurements in healthy subjects, and reliability and comparability of Biodex and Lido dynamometers. *Clinical Physiology and Functional Imaging*, *25*(2), 75–82. https://doi.org/10.1111/j.1475-097X.2004.00593.x

Lynch, A. D., Logerstedt, D. S., Grindem, H., Eitzen, I., Hicks, G. E., Axe, M. J., … Snyder-Mackler, L. (2015). Consensus criteria for defining 'successful outcome' after ACL injury and reconstruction: a Delaware-Oslo ACL cohort investigation. *British Journal of Sports Medicine*, *49*(5), 335–342. https://doi.org/10.1136/bjsports-2013-092299

Macías-Hernández, S. I., Miranda-Duarte, A., Ramírez-Mora, I., Cortés-González, S., Morones-Alba, J. D., Olascoaga-Gómez, A., … Cruz-Medina, E. (2016). Knee muscle strength correlates with joint cartilage T2 relaxation time in young participants with risk factors for osteoarthritis. *Clinical Rheumatology*, *35*(8), 2087–2092. https://doi.org/10.1007/s10067-016-3333-7

Martins, J., da Silva, J. R., da Silva;, M. R. B., & Bevilaqua-Grossi, D. (2017). Reliability and Validity of the Belt-Stabilized Handheld Dynamometer in Hip- and Knee-Strength Tests. *Journal of Athletic Training*, *52*(9), 809–819. https://doi.org/10.4085/1062-6050-52.6.04

Marx, R. G., Stump, T. J., Jones, E. C., Wickiewicz, T. L., & Warren, R. F. (2001). Development and Evaluation of an Activity Rating Scale for Disorders of the Knee. *The American Journal of Sports Medicine*, *29*(2), 213–218. https://doi.org/10.1177/03635465010290021601

Mayr, H. O., Weig, T. G., & Plitz, W. (2004). Arthrofibrosis following ACL reconstruction?reasons and outcome. *Archives of Orthopaedic and Trauma Surgery*, *124*(8), 518–522. https://doi.org/10.1007/s00402-004-0718-x

Moses, B., Orchard, J., & Orchard, J. (2012). Systematic Review: Annual Incidence of ACL Injury and Surgery in Various Populations. *Research in Sports Medicine*, *20*(3–4), 157–179. https://doi.org/10.1080/15438627.2012.680633

Myer, G. D., Ford, K. R., Paterno, M. V., Nick, T. G., & Hewett, T. E. (2008). The Effects of Generalized Joint Laxity on Risk of Anterior Cruciate Ligament Injury in Young Female Athletes. *The American Journal of Sports Medicine*, *36*(6), 1073–1080. https://doi.org/10.1177/0363546507313572

Myer, G. D., Paterno, M. V., Ford, K. R., Quatman, C. E., & Hewett, T. E. (2006). Rehabilitation After Anterior Cruciate Ligament Reconstruction: Criteria-Based Progression Through the Return-to-Sport Phase. *Journal of Orthopaedic & Sports Physical Therapy*, *36*(6), 385–402. https://doi.org/10.2519/jospt.2006.2222

Nae, J., Creaby, M. W., Nilsson, G., Crossley, K. M., & Ageberg, E. (2017). Measurement Properties of a Test Battery to Assess Postural Orientation During Functional Tasks in Patients Undergoing ACL Injury Rehabilitation. *Journal of Orthopaedic & Sports Physical Therapy*, 1–42. https://doi.org/10.2519/jospt.2017.7270

Nakagawa, T. H., Maciel, C. D., & Serrão, F. V. (2015). Trunk biomechanics and its association with hip and knee kinematics in patients with and without patellofemoral pain. *Manual Therapy*, *20*(1), 189–193. https://doi.org/10.1016/j.math.2014.08.013

Nawasreh, Z., Logerstedt, D., Cummer, K., Axe, M. J., Risberg, M. A., & Snyder-Mackler, L. (2017). Do Patients Failing Return-to-Activity Criteria at 6 Months After Anterior Cruciate Ligament Reconstruction Continue Demonstrating Deficits at 2 Years? *The American Journal of Sports Medicine*, *45*(5), 1037–1048. https://doi.org/10.1177/0363546516680619

Nessler, T., Denney, L., & Sampley, J. (2017). ACL Injury Prevention: What Does Research Tell Us? *Current Reviews in Musculoskeletal Medicine*, *10*(3), 281–288. https://doi.org/10.1007/s12178-017-9416-5

Noyes, F. R., Barber, S. D., & Mangine, R. E. (1991). Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *The American Journal of Sports Medicine*, *19*(5), 513–518. https://doi.org/10.1177/036354659101900518

O'Connor, P. J. (1990). Normative data: their definition, interpretation, and importance for primary care physicians. *Family Medicine*, *22*(4), 307–311.

O'Donoghue, P. (Ed.). (2012). *Statistics for sport and exercise studies: an introduction*. London ; New York: Routledge.

ØIestad, B. E., Holm, I., Gunderson, R., Myklebust, G., & Risberg, M. A. (2010). Quadriceps muscle weakness after anterior cruciate ligament reconstruction: A risk factor for knee osteoarthritis? *Arthritis Care & Research*, *62*(12), 1706–1714. https://doi.org/10.1002/acr.20299

Øiestad, B.E., Juhl, C. B., Eitzen, I., & Thorlund, J. B. (2015). Knee extensor muscle weakness is a risk factor for development of knee osteoarthritis. A systematic review and meta-analysis. *Osteoarthritis and Cartilage*, *23*(2), 171–177. https://doi.org/10.1016/j.joca.2014.10.008

Øiestad, Britt Elin, & Chu, C. R. (2018). Early clinical findings may predict long-term development of radiographic knee osteoarthritis in patients with anterior cruciate ligament reconstruction. *Annals of Joint*, *3*, 72–72. https://doi.org/10.21037/aoj.2018.09.01

Øiestad, Britt Elin, Engebretsen, L., Storheim, K., & Risberg, M. A. (2009). Winner of the 2008 Systematic Review Competition: Knee Osteoarthritis after Anterior Cruciate Ligament Injury. *The American Journal of Sports Medicine*, *37*(7), 1434–1443. https://doi.org/10.1177/0363546509338827

Øiestad, Britt Elin, Holm, I., Aune, A. K., Gunderson, R., Myklebust, G., Engebretsen, L., … Risberg, M. A. (2010). Knee Function and Prevalence of Knee Osteoarthritis after Anterior Cruciate Ligament Reconstruction: A Prospective Study with 10 to 15 Years of Follow-up. *The American Journal of Sports Medicine*, *38*(11), 2201–2210. https://doi.org/10.1177/0363546510373876

Øiestad, Britt Elin, Holm, I., & Risberg, M. A. (2018). Return to pivoting sport after ACL reconstruction: association with osteoarthritis and knee function at the 15-year follow-up. *British Journal of Sports Medicine*, *52*(18), 1199–1204. https://doi.org/10.1136/bjsports-2017-097718

Olsen, O. E., Myklebust, G., Engebretsen, L., Holme, I., & Bahr, R. (2003). Relationship between floor type and risk of ACL injury in team handball. *Scandinavian Journal of Medicine & Science in Sports*, *13*(5), 299–304.

Olsson, O., Isacsson, A., Englund, M., & Frobell, R. B. (2016). Epidemiology of intra- and peri-articular structural injuries in traumatic knee joint hemarthrosis – data from 1145 consecutive knees with subacute MRI. *Osteoarthritis and Cartilage*, *24*(11), 1890–1897. https://doi.org/10.1016/j.joca.2016.06.006

Orchard, J., Seward, H., McGivern, J., & Hood, S. (1999). Rainfall, evaporation and the risk of non-contact anterior cruciate ligament injury in the Australian Football League. *The Medical Journal of Australia*, *170*(7), 304–306.

Orchard, John, Seward, H., McGivern, J., & Hood, S. (2001). Intrinsic and Extrinsic Risk Factors for Anterior Cruciate Ligament Injury in Australian Footballers <sup/>. *The American Journal of Sports Medicine*, *29*(2), 196–200. https://doi.org/10.1177/03635465010290021301

Palmieri-Smith, R. M., Kreinbrink, J., Ashton-Miller, J. A., & Wojtys, E. M. (2007). Quadriceps Inhibition Induced by an Experimental Knee Joint Effusion Affects Knee Joint Mechanics during a Single-Legged Drop Landing. *The American Journal of Sports Medicine*, *35*(8), 1269–1275. https://doi.org/10.1177/0363546506296417

Palmieri-Smith, R. M., Villwock, M., Downie, B., Hecht, G., & Zernicke, R. (2013). Pain and Effusion and Quadriceps Activation and Strength. *Journal of Athletic Training*, *48*(2), 186–191. https://doi.org/10.4085/1062-6050-48.2.10

Paradowski, Przemyslaw T, Bergman, S., Sundén-Lundius, A., Lohmander, L. S., & Roos, E. M. (2006). Knee complaints vary with age and gender in the adult population. Population-based reference data for the Knee injury and Osteoarthritis Outcome Score (KOOS). *BMC Musculoskeletal Disorders*, *7*(1). https://doi.org/10.1186/1471-2474-7-38

Paradowski, Przemysław T., Kęska, R., & Witoński, D. (2014). Does concomitant meniscectomy affect medium-term outcome of anterior cruciate ligament reconstruction? A preliminary report. *Archives of Medical Science: AMS*, *10*(5), 992–998. https://doi.org/10.5114/aoms.2014.46219

Paterno, M. V. (2015). Incidence and Predictors of Second Anterior Cruciate Ligament Injury After Primary Reconstruction and Return to Sport. *Journal of Athletic Training*, *50*(10), 1097–1099. https://doi.org/10.4085/1062-6050-50.10.07

Paterno, M. V., Flynn, K., Thomas, S., & Schmitt, L. C. (2018). Self-Reported Fear Predicts Functional Performance and Second ACL Injury After ACL Reconstruction and Return to Sport: A Pilot Study. *Sports Health: A Multidisciplinary Approach*, *10*(3), 228–233. https://doi.org/10.1177/1941738117745806

Paterno, M. V., Rauh, M. J., Schmitt, L. C., Ford, K. R., & Hewett, T. E. (2014). Incidence of Second ACL Injuries 2 Years After Primary ACL Reconstruction and Return to Sport. *The American Journal of Sports Medicine*, *42*(7), 1567–1573. https://doi.org/10.1177/0363546514530088

Paterno, M. V., Schmitt, L. C., Ford, K. R., Rauh, M. J., Myer, G. D., Huang, B., & Hewett, T. E. (2010). Biomechanical Measures during Landing and Postural Stability Predict Second Anterior Cruciate Ligament Injury after Anterior Cruciate Ligament Reconstruction and Return to Sport. *The American Journal of Sports Medicine*, *38*(10), 1968–1978. https://doi.org/10.1177/0363546510376053

Pedersen, M. (2017, January 7). *Retur til idrett etter rekonstruksjon av fremre korsbånd blant utøvere med intensjon om å returnere til nivå 1 idrett: oppfølging ett, to og fem år postoperativt*. Retrieved from https://nih.brage.unit.no/nih-xmlui/handle/11250/2447628

Petersen, W., Taheri, P., Forkel, P., & Zantop, T. (2014). Return to play following ACL reconstruction: a systematic review about strength deficits. *Archives of Orthopaedic and Trauma Surgery*, *134*(10), 1417–1428. https://doi.org/10.1007/s00402-014-1992-x

Petersen, W., & Zantop, T. (2007). Anatomy of the Anterior Cruciate Ligament with Regard to Its Two Bundles: *Clinical Orthopaedics and Related Research*, *454*, 35–47. https://doi.org/10.1097/BLO.0b013e31802b4a59

Pottkotter, K. A., Di Stasi, S. L., Schmitt, L. C., Magnussen, R. A., Paterno, M. V., Flanigan, D. C., … Hewett, T. E. (2018). Improvements in Thigh Strength

Symmetry Are Modestly Correlated With Changes in Self-Reported Function After Anterior Cruciate Ligament Reconstruction. *Orthopaedic Journal of Sports Medicine*, *6*(11), 232596711880745. https://doi.org/10.1177/2325967118807459

Powell, C., Jensen, J., & Johnson, S. (2018). Functional Performance Measures Used for Return-to-Sport Criteria in Youth Following Lower-Extremity Injury. *Journal of Sport Rehabilitation*, *27*(6), 581–590. https://doi.org/10.1123/jsr.2017-0061

Powers, C. M. (2010). The Influence of Abnormal Hip Mechanics on Knee Injury: A Biomechanical Perspective. *Journal of Orthopaedic & Sports Physical Therapy*, *40*(2), 42–51. https://doi.org/10.2519/jospt.2010.3337

Reid, A., Birmingham, T. B., Stratford, P. W., Alcock, G. K., & Giffin, J. R. (2007). Hop Testing Provides a Reliable and Valid Outcome Measure During Rehabilitation After Anterior Cruciate Ligament Reconstruction. *Physical Therapy*, *87*(3), 337–349. https://doi.org/10.2522/ptj.20060143

Risberg, M. A., Holm, I., Tjomsland, O., Ljunggren, E., & Ekeland, A. (1999). Prospective study of changes in impairments and disabilities after anterior cruciate ligament reconstruction. *The Journal of Orthopaedic and Sports Physical Therapy*, *29*(7), 400–412. https://doi.org/10.2519/jospt.1999.29.7.400

Risberg, May A., Steffen, K., Nilstad, A., Myklebust, G., Kristianslund, E., Moltubakk, M. M., & Krosshaug, T. (2018). Normative Quadriceps and Hamstring Muscle Strength Values for Female, Healthy, Elite Handball and Football Players: *Journal of Strength and Conditioning Research*, 1. https://doi.org/10.1519/JSC.0000000000002579

Risberg, May Arna, Oiestad, B. E., Gunderson, R., Aune, A. K., Engebretsen, L., Culvenor, A., & Holm, I. (2016). Changes in Knee Osteoarthritis, Symptoms, and Function After Anterior Cruciate Ligament Reconstruction: A 20-Year Prospective Follow-up Study. *The American Journal of Sports Medicine*, *44*(5), 1215–1224. https://doi.org/10.1177/0363546515626539

Roemer, F. W., Frobell, R., Lohmander, L. S., Niu, J., & Guermazi, A. (2014). Anterior Cruciate Ligament OsteoArthritis Score (ACLOAS): Longitudinal MRI-based whole joint assessment of anterior cruciate ligament injury. *Osteoarthritis and Cartilage*, *22*(5), 668–682. https://doi.org/10.1016/j.joca.2014.03.006

Roos, E. M., Roos, H. P., Lohmander, L. S., Ekdahl, C., & Beynnon, B. D. (1998). Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. *The Journal of Orthopaedic and Sports Physical Therapy*, *28*(2), 88–96. https://doi.org/10.2519/jospt.1998.28.2.88

Roos, Ewa M., & Arden, N. K. (2015). Strategies for the prevention of knee osteoarthritis. *Nature Reviews Rheumatology*, *12*, 92.

Roos, Ewa M., Herzog, W., Block, J. A., & Bennell, K. L. (2011). Muscle weakness, afferent sensory dysfunction and exercise in knee osteoarthritis. *Nature Reviews. Rheumatology*, *7*(1), 57–63. https://doi.org/10.1038/nrrheum.2010.195

Roos, Ewa M., & Lohmander, L. S. (2003). The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. *Health and Quality of Life Outcomes*, *1*, 64. https://doi.org/10.1186/1477-7525-1-64

Ross, M. D., Langford, B., & Whelan, P. J. (2002). Test-retest reliability of 4 single-leg horizontal hop tests. *Journal of Strength and Conditioning Research*, *16*(4), 617–622.

Salavati, M., Akhbari, B., Mohammadi, F., Mazaheri, M., & Khorrami, M. (2011). Knee injury and Osteoarthritis Outcome Score (KOOS); reliability and validity in competitive athletes after anterior cruciate ligament reconstruction. *Osteoarthritis and Cartilage*, *19*(4), 406–410. https://doi.org/10.1016/j.joca.2011.01.010

Salmon, L. J., Russell, V. J., Refshauge, K., Kader, D., Connolly, C., Linklater, J., & Pinczewski, L. A. (2006). Long-term Outcome of Endoscopic Anterior Cruciate Ligament Reconstruction with Patellar Tendon Autograft: Minimum 13-Year Review. *The American Journal of Sports Medicine*, *34*(5), 721–732. https://doi.org/10.1177/0363546505282626

Sheean, A. J., Musahl, V., Slone, H. S., Xerogeanes, J. W., Milinkovic, D., Fink, C., & Hoser, C. (2018). Quadriceps tendon autograft for arthroscopic knee ligament reconstruction: use it now, use it often. *British Journal of Sports Medicine*, *52*(11), 698–701. https://doi.org/10.1136/bjsports-2017-098769

Shelbourne, K. D., Benner, R. W., & Gray, T. (2017). Results of Anterior Cruciate Ligament Reconstruction With Patellar Tendon Autografts: Objective Factors Associated With the Development of Osteoarthritis at 20 to 33 Years After Surgery. *The American Journal of Sports Medicine*, *45*(12), 2730–2738. https://doi.org/10.1177/0363546517718827

Shelbourne, K. D., Freeman, H., & Gray, T. (2012). Osteoarthritis After Anterior Cruciate Ligament Reconstruction: The Importance of Regaining and Maintaining Full Range of Motion. *Sports Health: A Multidisciplinary Approach*, *4*(1), 79–85. https://doi.org/10.1177/1941738111430201

Shelbourne, K. D., Urch, S. E., Gray, T., & Freeman, H. (2012). Loss of Normal Knee Motion After Anterior Cruciate Ligament Reconstruction Is Associated With Radiographic Arthritic Changes After Surgery. *The American Journal of Sports Medicine*, *40*(1), 108–113. https://doi.org/10.1177/0363546517718827

Shelbourne, K. D., Wilckens, J. H., Mollabashy, A., & DeCarlo, M. (1991). Arthrofibrosis in acute anterior cruciate ligament reconstruction: The effect of timing of reconstruction and rehabilitation. *The American Journal of Sports Medicine*, *19*(4), 332–336. https://doi.org/10.1177/036354659101900402

Shim, J.-K., Choi, H.-S., & Shin, J.-H. (2015). Effects of neuromuscular training on knee joint stability after anterior cruciate ligament reconstruction. *Journal of Physical Therapy Science*, *27*(12), 3613–3617. https://doi.org/10.1589/jpts.27.3613

Singh, N. (2018). International Epidemiology of Anterior Cruciate Ligament Injuries. *Orthopedic Research Online Journal*, *1*(5). https://doi.org/10.31031/OPROJ.2018.01.000525

Smith, H. C., Vacek, P., Johnson, R. J., Slauterbeck, J. R., Hashemi, J., Shultz, S., & Beynnon, B. D. (2012a). Risk Factors for Anterior Cruciate Ligament Injury: A Review of the Literature — Part 1: Neuromuscular and Anatomic Risk. *Sports Health: A Multidisciplinary Approach*, *4*(1), 69–78. https://doi.org/10.1177/1941738111428281

Smith, H. C., Vacek, P., Johnson, R. J., Slauterbeck, J. R., Hashemi, J., Shultz, S., & Beynnon, B. D. (2012b). Risk Factors for Anterior Cruciate Ligament Injury: A Review of the Literature—Part 2: Hormonal, Genetic, Cognitive Function, Previous Injury, and Extrinsic Risk Factors. *Sports Health: A Multidisciplinary Approach*, *4*(2), 155–161. https://doi.org/10.1177/1941738111428282

Smith, T. O., Postle, K., Penny, F., McNamara, I., & Mann, C. J. V. (2014). Is reconstruction the best management strategy for anterior cruciate ligament rupture? A systematic review and meta-analysis comparing anterior cruciate ligament reconstruction versus non-operative treatment. *The Knee*, *21*(2), 462–470. https://doi.org/10.1016/j.knee.2013.10.009

Sonesson, S., Kvist, J., Ardern, C., Österberg, A., & Silbernagel, K. G. (2017). Psychological factors are important to return to pre-injury sport activity after anterior cruciate ligament reconstruction: expect and motivate to satisfy. *Knee Surgery, Sports Traumatology, Arthroscopy*, *25*(5), 1375–1384. https://doi.org/10.1007/s00167-016-4294-8

Sturgill, L. P., Snyder-Mackler, L., Manal, T. J., & Axe, M. J. (2009). Interrater reliability of a clinical scale to assess knee joint effusion. *The Journal of Orthopaedic and Sports Physical Therapy*, *39*(12), 845–849. https://doi.org/10.2519/jospt.2009.3143

Su, F., Pedoia, V., Teng, H.-L., Kretzschmar, M., Lau, B. C., McCulloch, C. E., … Li, X. (2016). The association between MR T1ρ and T2 of cartilage and patient-reported outcomes after ACL injury and reconstruction. *Osteoarthritis and Cartilage*, *24*(7), 1180–1189. https://doi.org/10.1016/j.joca.2016.01.985

Tegner, Y., & Lysholm, J. (1985). Rating systems in the evaluation of knee ligament injuries. *Clinical Orthopaedics and Related Research*, (198), 43–49.

The MARS Group, Wright, R. W., Huston, L. J., Spindler, K. P., Dunn, W. R., Haas, A. K., … Stuart, M. J. (2010). Descriptive Epidemiology of the Multicenter ACL

Revision Study (MARS) Cohort. *The American Journal of Sports Medicine*, *38*(10), 1979–1986. https://doi.org/10.1177/0363546510378645

Theologis, A. A., Haughom, B., Liang, F., Zhang, Y., Majumdar, S., Link, T. M., … Li, X. (2014). Comparison of T1rho relaxation times between ACL-reconstructed knees and contralateral uninjured knees. *Knee Surgery, Sports Traumatology, Arthroscopy*, *22*(2), 298–307. https://doi.org/10.1007/s00167-013-2397-z

Thomeé, R., Kaplan, Y., Kvist, J., Myklebust, G., Risberg, M. A., Theisen, D., … Witvrouw, E. (2011). Muscle strength and hop performance criteria prior to return to sports after ACL reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy*, *19*(11), 1798–1805. https://doi.org/10.1007/s00167-011-1669-8

Thomeé, R., Neeter, C., Gustavsson, A., Thomeé, P., Augustsson, J., Eriksson, B., & Karlsson, J. (2012). Variability in leg muscle power and hop performance after anterior cruciate ligament reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy*, *20*(6), 1143–1151. https://doi.org/10.1007/s00167-012-1912-y

Thorborg, K., Petersen, J., Magnusson, S. P., & Hölmich, P. (2009). Clinical assessment of hip strength using a hand-held dynamometer is reliable: Clinical assessment of hip strength. *Scandinavian Journal of Medicine & Science in Sports*, *20*(3), 493–501. https://doi.org/10.1111/j.1600-0838.2009.00958.x

Thorborg, Kristian, Bandholm, T., & Hölmich, P. (2013). Hip- and knee-strength assessments using a hand-held dynamometer with external belt-fixation are inter-tester reliable. *Knee Surgery, Sports Traumatology, Arthroscopy*, *21*(3), 550–555. https://doi.org/10.1007/s00167-012-2115-2

Thorborg, Kristian, Serner, A., Petersen, J., Madsen, T. M., Magnusson, P., & Hölmich, P. (2011). Hip Adduction and Abduction Strength Profiles in Elite Soccer Players: Implications for Clinical Evaluation of Hip Adductor Muscle Recovery After Injury. *The American Journal of Sports Medicine*, *39*(1), 121–126. https://doi.org/10.1177/0363546510378081

Toole, A. R., Ithurburn, M. P., Rauh, M. J., Hewett, T. E., Paterno, M. V., & Schmitt, L. C. (2017). Young Athletes After Anterior Cruciate Ligament Reconstruction Cleared for Sports Participation: How Many Actually Meet Recommended Return-to-Sport Criteria Cutoffs? *Journal of Orthopaedic & Sports Physical Therapy*, 1–27. https://doi.org/10.2519/jospt.2017.7227

Tsoukas, D., Fotopoulos, V., Basdekis, G., & Makridis, K. G. (2016). No difference in osteoarthritis after surgical and non-surgical treatment of ACL-injured knees after 10 years. *Knee Surgery, Sports Traumatology, Arthroscopy*, *24*(9), 2953–2959. https://doi.org/10.1007/s00167-015-3593-9

Turkington, C., & Anan, R. (2007). *The encyclopedia of autism spectrum disorders*. New York, NY: Facts On File.

Uhorchak, J. M., Scoville, C. R., Williams, G. N., Arciero, R. A., Pierre, P. St., & Taylor, D. C. (2003). Risk Factors Associated with Noncontact Injury of the Anterior Cruciate Ligament. *The American Journal of Sports Medicine*, *31*(6), 831–842. https://doi.org/10.1177/03635465030310061801

Üstün, T. B., Chatterji, S., Bickenbach, J., Kostanjsek, N., & Schneider, M. (2003). The International Classification of Functioning, Disability and Health: a new tool for understanding disability and health. *Disability and Rehabilitation*, *25*(11–12), 565–571. https://doi.org/10.1080/0963828031000137063

Van Ginckel, A., Verdonk, P., & Witvrouw, E. (2013). Cartilage adaptation after anterior cruciate ligament injury and reconstruction: implications for clinical management and research? A systematic review of longitudinal MRI studies. *Osteoarthritis and Cartilage*, *21*(8), 1009–1024. https://doi.org/10.1016/j.joca.2013.04.015

van Melick, N., van Cingel, R. E. H., Brooijmans, F., Neeter, C., van Tienen, T., Hullegie, W., & Nijhuis-van der Sanden, M. W. G. (2016). Evidence-based clinical practice update: practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus. *British Journal of Sports Medicine*, *50*(24), 1506–1515. https://doi.org/10.1136/bjsports-2015-095898

van Yperen, D. T., Reijman, M., van Es, E. M., Bierma-Zeinstra, S. M. A., & Meuffels, D. E. (2018). Twenty-Year Follow-up Study Comparing Operative Versus Nonoperative Treatment of Anterior Cruciate Ligament Ruptures in High-Level Athletes. *The American Journal of Sports Medicine*, *46*(5), 1129–1136. https://doi.org/10.1177/0363546517751683

Wagemakers, H. P., Luijsterburg, P. A., Boks, S. S., Heintjes, E. M., Berger, M. Y., Verhaar, J. A., … Bierma-Zeinstra, S. M. (2010). Diagnostic Accuracy of History Taking and Physical Examination for Assessing Anterior Cruciate Ligament Lesions of the Knee in Primary Care. *Archives of Physical Medicine and Rehabilitation*, *91*(9), 1452–1459. https://doi.org/10.1016/j.apmr.2010.06.012

Wang, D., Jones, M. H., Khair, M. M., & Miniaci, A. (2010). Patient-reported outcome measures for the knee. *The Journal of Knee Surgery*, *23*(3), 137–151.

Weldring, T., & Smith, S. M. S. (2013). Article Commentary: Patient-Reported Outcomes (PROs) and Patient-Reported Outcome Measures (PROMs). *Health Services Insights*, *6*, HSI.S11093. https://doi.org/10.4137/HSI.S11093

Wellsandt, E., Failla, M. J., & Snyder-Mackler, L. (2017). Limb Symmetry Indexes Can Overestimate Knee Function After Anterior Cruciate Ligament Injury. *Journal of Orthopaedic & Sports Physical Therapy*, *47*(5), 334–338. https://doi.org/10.2519/jospt.2017.7285

Wetters, N., Weber, A. E., Wuerz, T. H., Schub, D. L., & Mandelbaum, B. R. (2016). Mechanism of Injury and Risk Factors for Anterior Cruciate Ligament Injury. *Operative Techniques in Sports Medicine*, *24*(1), 2–6. https://doi.org/10.1053/j.otsm.2015.09.001

Wilk, K. E., & Arrigo, C. A. (2017). Rehabilitation Principles of the Anterior Cruciate Ligament Reconstructed Knee. *Clinics in Sports Medicine*, *36*(1), 189–232. https://doi.org/10.1016/j.csm.2016.08.012

Williamson, T., Sikka, R., Tompkins, M., & Nelson, B. J. (2016). Use of the Knee Injury and Osteoarthritis Outcome Score in a Healthy United States Population. *The American Journal of Sports Medicine*, *44*(2), 440–446. https://doi.org/10.1177/0363546515616812

Wong, S., Steinbach, L., Zhao, J., Stehling, C., Ma, C. B., & Link, T. M. (2009). Comparative study of imaging at 3.0 T versus 1.5 T of the knee. *Skeletal Radiology*, *38*(8), 761–769. https://doi.org/10.1007/s00256-009-0683-0

Wylie, J. D., Marchand, L. S., & Burks, R. T. (2017). Etiologic Factors That Lead to Failure After Primary Anterior Cruciate Ligament Surgery. *Clinics in Sports Medicine*, *36*(1), 155–172. https://doi.org/10.1016/j.csm.2016.08.007

Zimmerman, M. E. (2011). Normative Data. In J. S. Kreutzer, J. DeLuca, & B. Caplan (Eds.), *Encyclopedia of Clinical Neuropsychology* (pp. 1795–1795). https://doi.org/10.1007/978-0-387-79948-3_1227

Zvijac, J. E., Toriscelli, T. A., Merrick, W. S., Papp, D. F., & Kiebzak, G. M. (2014). Isokinetic Concentric Quadriceps and Hamstring Normative Data for Elite Collegiate American Football Players Participating in the NFL Scouting Combine: *Journal of Strength and Conditioning Research*, *28*(4), 875–883. https://doi.org/10.1519/JSC.0b013e3182a20f19

Zysk, S. P., & Refior, H. J. (2000). Operative or conservative treatment of the acutely torn anterior cruciate ligament in middle-aged patients: A follow-up study of 133 patients between the ages of 40 and 59 years. *Archives of Orthopaedic and Trauma Surgery*, *120*(1–2), 59–64. https://doi.org/10.1007/PL00021217

Abbreviations

ACL:	Anterior Cruciate Ligament
ACLR:	Anterior Cruciate Ligament Reconstruction
QOL:	Quality of Life
LSI:	Limb Symmetry Index
MCL:	Medial Collateral Ligament
PCL:	Posterior Cruciate Ligament
ROM:	Range of Motion
OA:	Osteoarthritis
1RM:	One Repetition Max
MRI:	Magnetic Resonance Imaging
KT-1000:	KT-1000 knee arthrometer
SLHD:	Single Leg Hop for Distance
PROs:	Patient reported outcomes
KOOS:	Knee injury and Osteoarthritis Outcome Score
RTS:	Return to Sport
BTB:	Bone-patella Tendon-Bone graft
ACLOAS:	Anterior Cruciate Ligament OsteoArthritis Score
WHO:	World Health Organization
ICF:	International Classification of Functioning, Disabilities, and Health,
OUS:	Oslo University Hospital
SEM:	Standard Error of Measurements
MDC:	Minimal Detective Change
HHD:	Hand-held Dynamometer
ICC:	Intraclass Correlation Doefficient
NRS:	Numeric Rating Scale
NIMI:	Norwegian Institute for Sports Medicine in Oslo
DS:	Dorthe Strauss
AC:	Anna Cronström
PRISMA-P:	Preferred Reporting Items for Systematic review and Meta-Analysis Protocols
AXIS:	The Appraisal tool for Cross-sectional Studies

CASP:	Critical Appraisal Skills Programme
N:	Newton
SD:	Standard Deviation
CI:	Confidence Interval
BMI:	Body Mass Index
Nm:	Newton x meter
Nm/Kg:	Newton x meter divided by bodyweight
IKDC:	International Committee Subjective Knee Evaluation Form

List of Tables

List of Figures

Appendix

I: Revised exclusion criteria´s

II: ACLOAS scoring

III: AXIS and CASP: Critical appraisal of 7 articles

IV: Approval from the Regional committees for medical and health research ethics

V: "DATA behandler avtale OUS" /Secure data handling at OUS

VI: Information Letter and Written consent

VII: "Reiseregning" /Travel expenses for the patient

VIII: AIM 5a

IX: AIM 5c

Appendix I: Revised exclusion criteria's

(Exclusion criteria in English and explanations in Norwegian/Danish)

Eksklusjons kriterier mars 2016	**Eksklusjons kriterier oktober 2016**
	1. Less 9 months after ACLR,
1. More than 30 months after ACLR	2. More than 18 months after ACLR
2. Additional surgery to the index knee between the time point of ACLR and inclusion	3. Previous knee surgery in either knee (e.g., ACL, meniscal),
3. ACL injury to the contralateral knee	
4. Serious injury to the index knee (e.g., giving-way episode(s)) resulting in pain, swelling, and/or requiring inpatient or outpatient health care between the time point of ACLR and inclusion	4. Previous serious knee injury resulting in pain, swelling, and/or requiring inpatient or outpatient health care (e.g., ACL, meniscus, patella luxation, jumper's knee),
5. Diseases or disorders overriding the knee condition	5. Diseases or disorders overriding the knee condition (e.g., neurological disease),
6. Contraindicators for MRI	6. Contraindicators for MRI
7. Not understanding the languages of interest (Swedish, Norwegian, or English).	7. Not understanding the languages of interest (Scandinavian or English).

UDDYBENDE FORKLARING OG SAMMENFATNING:
Inklusjons kriterier er endret fra to år etter korsbånds rekonstruksjon til et år samt en uddybning av hvilke andre skader der kan være i kneet.

Eksklusjons kriteriene er endret til:
Mindre end 9 måneder etter korsbånds rekonstruksjon og ikke mere end 18 måneder etter korsbåndsoperasjonen.
Punkt 2 og 3 fra mars 2016 er nu sammenfattet i punkt 2 (oktober 2016).
Punkt 4 er omskrevet og omfatter nu ikke kun andre skader i kneet der trenger behandling fra korsbånds-operasjonen til inklusjonsdatoen, til at omfatte behandling av andre skader både tidligere og aktuelt i forløbet.
Punkt 5 er uddybet i utgaven fra oktober 2016.
Punkt 7 er omskrevet men betydningen er den samme.

Appendix II: Detailed description for ACLOAS scoring

ACLOAS	SCORING
CARTILAGE	Al available sequences are used. Scored in every sub-region; patella, femur and tibia Focal defects are differentiated from more diffuse damage and depth of cartilage is taken into account. Scored according to worst grade within sub-region. *Scoring:* 0 = normal cartilage 2.0 Focal partial-thickness defect (≤10% of sub-regional area affected) 2.5 = Focal full-thickness defect (≥10% of sub-regional area affected) 3 = Multiple areas of partial-thickness (grade 2) defects and areas of normal thickness in sub-region, or a grade 2.0 defect ≥10% but <75% of the sub-region. 4 = Diffuse partial-thickness loss (≥75% of sub-region) 5 = Multiple areas of full-thickness loss (grade 2.5) or a grade 2.5 lesion ≥10% but <75% of the sub-region 6 = Diffuse full-thickness loss (≥75% of sub-region)
TRAUMATIC BONE MARROW OSTEOCHONDRAL SURFACE DAMAGE (traumatic articular surface damage and traumatic and degenerative subchondral bone marrow lesions) *BML = Bone marrow lesion*	Assessed using fat suppressed water sensitive sequences such as STIR, proton density or T2 weighted sequences. Osteochondral surface damage ONLY at baseline. *Type of injury scoring:* 0 = normal articular surface, subchondral traumatic BML only 1 = Subchondral fracture 2 = Osteochondral depression with intact articular surface 3 = Osteochondral depression with disrupted articular surface 4 = Detached osteochondral fracture *Injury size scoring:* 0 = absent 1 = Mild; <33% of sub-regional volume involved 2 = Moderate; 33–66% of sub-regional volume involved 3 = Severe; >66% of sub-regional volume involved

DEGENERATIVE BONE MARROW LESIONS	ONLY at follow-up Pre-existing subchondral cysts are ignored BML´s that are evolving into cysts without an ill-defined component are also considered BML´s in ACLOAS *Injury size scoring:* 0 = absent 1 = Mild; <33% of sub-regional volume involved 2 = Moderate; 33–66% of sub-regional volume involved 3 = Severe; >66% of sub-regional volume involved
LIGAMENTS AND ACL GRAFT	Collateral ligaments: Baseline visit *Scoring:* 0 = Continuous ligament with normal signal, no surrounding hyperintensity/edema 1 = Continuous ligament with normal signal, surrounding hyperintensity reflecting edema and/or hematoma 2 = Partial rupture/discontinuity with some preserved fibers 3 = Complete disruption ACL: All visits following the baseline visit *Scoring:* 0 = Normal ligament with hypointense signal and regular thickness and continuity 1 = Thickened ligament and/or high intra ligamentous signal with normal course and continuity 2 = Thinned or elongated but continuous ligament 3 = Absent ligament or complete discontinuity ACL graft: according to signal and continuity. *Scoring:* 0 = Hypointense, regular thickness 1 = Hyperintense, regular thickness 2 = Thinned or elongated graft 3 = Graft failure, complete discontinuity PCL: *Scoring:* 0 = Normal ligament with hypointense signal and regular thickness and continuity 1 = Thickened ligament and/or high intraligamentous signal with normal course and continuity 2 = Thinned or elongated but continuous ligament 3 = Absent ligament or complete discontinuity + Tibia and femoral tunnels are assessed in regard to adjacent bone marrow edema and cysts

	Scoring: Absent or present
MENISCHIAL MORPHOLOGY AND EXTRUSION	Morphology: Medial and lateral meniscus at the anterior, body and posterior horn. Anterior and posterior horn are scored using the sagittal sequences, body is scored using the coronal sequences. *Scoring:* 0 = Normal meniscus with absence of tear, maceration and hypointense signal 1 = Intra-meniscal hyperintensity not extending to meniscal surface 2 = Horizontal tear 3 = Radial and vertical tear 4 = Bucket-handle tear, displaced tear (including root tears) and complex tears 5 = Meniscal repair 6 = Partial meniscectomy and partial maceration 7 = Progressive partial maceration or re-partial meniscectomy (i.e., loss of morphological substance of the meniscus) as compared to the previous visit 8 = Complete maceration or resection. Extrusion: Medial and lateral meniscal scored on a mid-coronal slice. *Scoring:* 0 = No extrusion 1 = Extrusion <50% of meniscal coronal length 2 = ≥50% of meniscal coronal length
EFFUSION- AND HOFFAS SYNOVITIS	Joint effusion: Suprapatellar recess will be used for reference and scored on sagittal images in a mid-line slice. *Scoring:* 0 = <2 mm 1 = ≥2 and <5 mm 2 = ≥5 and <10 mm 3 = ≥10 mm Hoffas synovitis: Scored in a mid-line sagittal image as one single score for assessment of degrees of hyperintensity in hoffa´s fat pad. *Scoring:* 0 = Normal, only small physiologic vascular structures visible 1 = Mild hyperintensity signal changes 2 = Moderate hyperintensity signal changes 3 = Severe hyperintensity signal changes

OSTEOPHYTES	T1 weighted non-fat suppressed or gradients-echo sequences are used for evaluation. Assessed at following locations: Anterior medial and lateral femur (sagittal plane) Anterior and posterior tibial plateau (sagittal plane) Superior and inferior patella pole (sagittal plane) Medial and lateral femur (mid-coronal slice) Medial and lateral tibia (mid-coronal slice) *Scoring:* 0 = Absent 1 = Equivocal or questionable osteophyte 2 = Small beak-like definite osteophyte 3 = Small-moderate osteophyte 4 = Moderate osteophyte 5 = Moderate-large osteophyte 6 = Large osteophyte 7 = Very large osteophyte

Appendix III: AXIS and CASP Critical appraisal of 7 articles

Critical Appraisal tool AXIS used for the article:
"Isokinetic and isometric muscle strength in a healthy population with special reference to age and gender"

Author(s): B. Danneskiold-Samsøe, E.M. Bartels, P.M. Bu¨low, H. Lund, A. Stockmarr, C. C. Holm, W¨atjen, M. Appleyard and H. Bliddal

(The answer is bold and italic)

Introduction:

1.	Were the aims/objective of the study clear?	***Yes***	No	Do not know

Methods:

2.	Was the study design appropriate for the stated aim(s)?	***Yes***	No	Do not know
3.	Was the sample size justified?	Yes	***No***	Do not know
4.	Was the target/reference population clearly defined?	***Yes***	No	Do not know
5.	Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	***Yes***	No	Do not know
6.	Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	***Yes***	No	Do not know
7.	Were measures undertaken to address and categories non-responders?	Yes	***No***	Do not know
8.	Were the risk factor and outcome variables measured appropriate to the aims of the study?	***Yes***	No	Do not know
9.	Were the risk factor and outcome measured correctly using instruments/measurements that had been trialed, piloted or published previously?	***Yes***	No	Do not know
10.	It is clear what was used to determined statistical significance and/or precision estimates?	***Yes***	No	Do not know
11.	Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	***Yes***	No	Do not know

Results:

12.	Were the basic data adequately described?	***Yes***	No	Do not know
13.	Does the response rate raise concerns about non-response bias?	Yes	***No***	Do not know
14.	If appropriate, was the information about the non-responders described?	Yes	***No***	Do not know
15.	Were the results internally consistent?	***Yes***	No	Do not know
16.	Were the results for the analyses described in methods, presented?	***Yes***	No	Do not know

Discussion:

17.	Were the authors discussion and conclusion justified by the results?	***Yes***	No	Do not know
18.	Were the limitations of the study discussed?	***Yes***	No	Do not know

Other:

19.	Were there any funding sources or conflicts of interest that may affect the authors interpretation of the results?	Yes	***No***	Do not know
20.	Was ethical approval or consent of participants attained?	***Yes***	No	Do not know

Critical Appraisal tool AXIS used for the article:

"Greater understanding of normal hip physical function may guide clinicians in providing targeted rehabilitation programmes"

Author(s): Joanne L. Kemp, Anthony G. Schache, Michael Makdissi, Kevin J. Sims, Kay M. Crossley

(The answer is bold and italic)

Introduction:

1.	Were the aims/objective of the study clear?	***Yes***	No	Do not know

Methods:

2.	Was the study design appropriate for the stated aim(s)?	***Yes***	No	Do not know
3.	Was the sample size justified?	Yes	***No***	Do not know
4.	Was the target/reference population clearly defined?	***Yes***	No	Do not know
5.	Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	Yes	No	***Do not know***
6.	Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	Yes	No	***Do not know***
7.	Were measures undertaken to address and categories non-responders?	Yes	No	***Do not know***
8.	Were the risk factor and outcome variables measured appropriate to the aims of the study?	Yes	No	***Do not know***
9.	Were the risk factor and outcome measured correctly using instruments/measurements that had been trialed, piloted or published previously?	***Yes***	No	Do not know
10.	It is clear what was used to determined statistical significance and/or precision estimates?	***Yes***	No	Do not know
11.	Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	***Yes***	No	Do not know

Results:

12.	Were the basic data adequately described?	***Yes***	No	Do not know
13.	Does the response rate raise concerns about non-response bias?	Yes	No	***Do not know***
14.	If appropriate, was the information about the non-responders described?	Yes	No	***Do not know***
15.	Were the results internally consistent?	***Yes***	No	Do not know
16.	Were the results for the analyses described in methods, presented?	***Yes***	No	Do not know

Discussion:

17.	Were the authors discussion and conclusion justified by the results?	***Yes***	No	Do not know
18.	Were the limitations of the study discussed?	***Yes***	No	Do not know

Other:

19.	Were there any funding sources or conflicts of interest that may affect the authors interpretation of the results?	Yes	***No***	Do not know
20.	Was ethical approval or consent of participants attained?	***Yes***	No	Do not know

Critical Appraisal tool AXIS used for the article:
"Normative Values for the KOOS and WOMAC in a Young Athletic Population"

Author(s): Kenneth L. Cameron, Brandon S. Thompson, Karen Y. Peck, Brett D. Owens, Stephen W. Marshall, Steven J. Svoboda.

(The answer is bold and italic)

Introduction:

1.	Were the aims/objective of the study clear?	***Yes***	No	Do not know

Methods:

2.	Was the study design appropriate for the stated aim(s)?	***Yes***	No	Do not know
3.	Was the sample size justified?	Yes	***No***	Do not know
4.	Was the target/reference population clearly defined?	***Yes***	No	Do not know
5.	Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	***Yes***	No	Do not know
6.	Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	***Yes***	No	Do not know
7.	Were measures undertaken to address and categories non-responders?	Yes	***No***	Do not know
8.	Were the risk factor and outcome variables measured appropriate to the aims of the study?	***Yes***	No	Do not know
9.	Were the risk factor and outcome measured correctly using instruments/measurements that had been trialed, piloted or published previously?	***Yes***	No	Do not know
10.	It is clear what was used to determined statistical significance and/or precision estimates?	***Yes***	No	Do not know
11.	Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	***Yes***	No	Do not know

Results:

12.	Were the basic data adequately described?	***Yes***	No	Do not know
13.	Does the response rate raise concerns about non-response bias?	Yes	***No***	Do not know
14.	If appropriate, was the information about the non-responders described?	Yes	***No***	Do not know
15.	Were the results internally consistent?	***Yes***	No	Do not know
16.	Were the results for the analyses described in methods, presented?	***Yes***	No	Do not know

Discussion:

17.	Were the authors discussion and conclusion justified by the results?	***Yes***	No	Do not know
18.	Were the limitations of the study discussed?	***Yes***	No	Do not know

Other:

19.	Were there any funding sources or conflicts of interest that may affect the authors interpretation of the results?	Yes	***No***	Do not know
20.	Was ethical approval or consent of participants attained?	***Yes***	No	Do not know

Critical Appraisal tool AXIS used for the article:

"Knee complaints vary with age and gender in the adult population. Population-based reference data for the Knee injury and Osteoarthritis Outcome Score (KOOS)"

Author(s): Przemyslaw T. Paradowski, Stefan Bergman, Anne Sundén-Lundius, L. Stefan Lohmander, Eva M. Roos

(The answer is bold and italic)

Introduction:

1.	Were the aims/objective of the study clear?	***Yes***	No	Do not know

Methods:

2.	Was the study design appropriate for the stated aim(s)?	***Yes***	No	Do not know
3.	Was the sample size justified?	***Yes***	No	Do not know
4.	Was the target/reference population clearly defined	***Yes***	No	Do not know
5.	Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	***Yes***	No	Do not know
6.	Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	***Yes***	No	Do not know
7.	Were measures undertaken to address and categories non-responders?	***Yes***	No	Do not know
8.	Were the risk factor and outcome variables measured appropriate to the aims of the study?	***Yes***	No	Do not know
9.	Were the risk factor and outcome measured correctly using instruments/measurements that had been trialed, piloted or published previously?	***Yes***	No	Do not know
10.	It is clear what was used to determined statistical significance and/or precision estimates?	Yes	***No***	Do not know
11.	Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	Yes	***No***	Do not know

Results:

12.	Were the basic data adequately described?	Yes	***No***	Do not know
13.	Does the response rate raise concerns about non-response bias?	***Yes***	No	Do not know
14.	If appropriate, was the information about the non-responders described?	Yes	***No***	Do not know
15.	Were the results internally consistent?	***Yes***	No	Do not know
16.	Were the results for the analyses described in methods, presented?	***Yes***	No	Do not know

Discussion:

17.	Were the authors discussion and conclusion justified by the results?	***Yes***	No	Do not know
18.	Were the limitations of the study discussed?	Yes	***No***	Do not know

Other:

19.	Were there any funding sources or conflicts of interest that may affect the authors interpretation of the results?	Yes	***No***	Do not know
20.	Was ethical approval or consent of participants attained?	***Yes***	No	Do not know

Critical Appraisal tool: CASP used for Observational Study:

"Self-reported knee pain and disability among healthy individuals: reference data and factors associated with the Knee injury and Osteoarthritis Outcome Score (KOOS) and KOOS-Child"

Author(s): J.N. Baldwin, M.J. McKay, M. Simic, C.E. Hiller, N. Moloney, E.J. Nightingale, J. Burns

(The answer is bold and italic)

Section A: Are the results of the trial valid:

1.	Did the study address a clearly focused issue?	***Yes***	Can´t tell	No
2.	Did the authors use an appropriate method to answer their question?	***Yes***	Can´t tell	No
3.	Were the cases recruited in an acceptable way?	***Yes***	Can´t tell	No
4.	Were the controls selected in an acceptable way?	Yes	***Can´t tell***	No
5.	Was the exposure accurately measured to minimize bias?	***Yes***	Can´t tell	No
6.	(a) A side from the experimental intervention, were the groups treated equally?	***Yes***	Can´t tell	No
	Comment: Only one group			
	(b)Have the authors taken account of the potential confounding factors of the design and/or in their analysis?	Yes	***Can´t tell***	No

Section B: What are the results?

7. How large was the treatment effect?
   Only reference data, no treatment effect

8. How precise was the estimate of the treatment effect?
   Only reference data, no estimates for treatment

9.	Do you believe the result?	***Yes***	No

Section C: Will the results help locally?

10.	Can the results be applied to the local population	***Yes***	Can´t tell	No
11.	Do the results of this study fit with other available evidence?	***Yes***	Can´t tell	No

Critical Appraisal tool AXIS used for the article:
"Use of the Knee Injury and Osteoarthritis Outcome Score in a Healthy United States Population"

Author(s): Tyler Williamson, Robby Sikka, Marc Tompkins, Bradley J. Nelson

(The answer is bold and italic)

Introduction:

1.	Were the aims/objective of the study clear?	***Yes***	No	Do not know

Methods:

2.	Was the study design appropriate for the stated aim(s)?	***Yes***	No	Do not know
3.	Was the sample size justified?	Yes	***No***	Do not know
4.	Was the target/reference population clearly defined?	***Yes***	No	Do not know
5.	Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	***Yes***	No	Do not know
6.	Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	***Yes***	No	Do not know
7.	Were measures undertaken to address and categories non-responders?	***Yes***	No	Do not know
8.	Were the risk factor and outcome variables measured appropriate to the aims of the study?	***Yes***	No	Do not know
9.	Were the risk factor and outcome measured correctly using instruments/measurements that had been trialed, piloted or published previously?	***Yes***	No	Do not know
10.	It is clear what was used to determined statistical significance and/or precision estimates?	***Yes***	No	Do not know
11.	Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	***Yes***	No	Do not know

Results:

12.	Were the basic data adequately described?	***Yes***	No	Do not know
13.	Does the response rate raise concerns about non-response bias?	Yes	***No***	Do not know
14.	If appropriate, was the information about the non-responders described?	***Yes***	No	Do not know
15.	Were the results internally consistent?	Yes	No	***Do not know***
16.	Were the results for the analyses described in methods, presented?	***Yes***	No	Do not know

Discussion:

17.	Were the authors discussion and conclusion justified by the results?	***Yes***	No	Do not know
18.	Were the limitations of the study discussed?	***Yes***	No	Do not know

Other:

19.	Were there any funding sources or conflicts of interest that may affect the authors interpretation of the results?	Yes	***No***	Do not know
20.	Was ethical approval or consent of participants attained?	***Yes***	No	Do not know

Critical Appraisal tool AXIS used for the article:
"Lysholm Score and Tegner Activity Level in Individuals With Normal Knees"

Author(s): Karen K. Briggs, J. Richard Steadman, Connor J. Hay and Sophia L. Hines

(The answer is bold and italic)

Introduction:

1.	Were the aims/objective of the study clear?	***Yes***	No	Do not know

Methods:

2.	Was the study design appropriate for the stated aim(s)?	***Yes***	No	Do not know
3.	Was the sample size justified?	Yes	***No***	Do not know
4.	Was the target/reference population clearly defined?	Yes	***No***	Do not know
5.	Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	Yes	No	***Do not know***
6.	Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	Yes	No	***Do not know***
7.	Were measures undertaken to address and categories non-responders?	Yes	***No***	Do not know
8.	Were the risk factor and outcome variables measured appropriate to the aims of the study?	Yes	No	***Do not know***
9.	Were the risk factor and outcome measured correctly using instruments/measurements that had been trialed, piloted or published previously?	Yes	No	***Do not know***
10.	It is clear what was used to determined statistical significance and/or precision estimates?	***Yes***	No	Do not know
11.	Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	***Yes***	No	Do not know

Results:

12.	Were the basic data adequately described?	***Yes***	No	Do not know
13.	Does the response rate raise concerns about non-response bias?	Yes	***No***	Do not know
14.	If appropriate, was the information about the non-responders described?	Yes	***No***	Do not know
15.	Were the results internally consistent?	Yes	No	***Do not know***
16.	Were the results for the analyses described in methods, presented?	***Yes***	No	Do not know

Discussion:

17.	Were the authors discussion and conclusion justified by the results?	***Yes***	No	Do not know
18.	Were the limitations of the study discussed?	***Yes***	No	Do not know

Other:

19.	Were there any funding sources or conflicts of interest that may affect the authors interpretation of the results?	Yes	***No***	Do not know
20.	Was ethical approval or consent of participants attained?	***Yes***	No	Do not know

Appendix IV: Approval from the Regional committees for medical and health research ethics

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst	Leena Heinonen	22845529	09.09.2016	2016/1128 REK sør-øst D
			Deres dato:	Deres referanse:
			14.06.2016	

Vår referanse må oppgis ved alle henvendelser

May Arna Risberg
Norges Idrettshøgskole

2016/1128 God muskelfunksjon -forebyggende for artrose etter fremre korsbåndoperasjon?

Forskningsansvarlig: Oslo universitetssykehus HF
Prosjektleder: May Arna Risberg

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK sør-øst D) i møtet 17.08.2016. Vurderingen er gjort med hjemmel i helseforskningsloven (hfl.) § 10, jf. forskningsetikkloven § 4.

Prosjektleders prosjektbeskrivelse
Denne prospektive kohortestudien skal undersøke om muskelfunksjon har en forebyggende rolle og/eller kan bremse progresjonen av tidlig artrose i kneet etter fremre korsbåndoperasjon. Hovedstudien utgår fra Universitetet i Lund, Sverige. I Norge skal vi inkludere 20 pasienter og dette skal være data til et masterprosjekt. Forskning har vist at individer med tidligere kneskade har 4 gange større risiko for utviklingen av kne artrose. Det er også påvist fra tidligere korsbånds studier at svak muskulatur på forsiden av kneet, nedsatt hop funksjon og balanse har betydning for utvikling av kne smerte. Studien vil undersøke om nedsatt knemuskelstyrke og nedsatt funksjon har en sammenheng med tidlige artrose evaluert med MR og biomarkører i blod. Resultatet av denne studien vil ha betydning for individer med risiko for artrose og samfunnsøkonomisk da det har fokus på forebygging av kneartrose.

Vurdering
Prosjektet er en multisenterstudie sammen med Universitetet i Lund, Sverige. Det skal inkluderes 20 pasienter på 18-35 år i Norge. Studien vil undersøke om nedsatt knemuskelstyrke og nedsatt funksjon har en sammenheng med tidlige artrose evaluert med MR og biomarkører i blod.

Prosjektet ønsker å koble informasjon om disse pasientene mot Nasjonalt korsbåndsregister og Leddproteseregisteret. Nasjonalt korsbåndregister ligger inn under Leddproteseregisteret (Nasjonalt kompetansesenter for leddproteser og hoftebrudd, Helse Bergen HF). Fra disse registre ønskes det data om funksjon (KOOS spørreskjema), operasjonsdata, og andre baseline karakteristika, samt evt. leddproteseinformasjon.

Det ønskes også tillatelse til å hente data fra pasientjournal. Fra journalen ønskes det å innhente operasjonsbeskrivelse fra korsbåndsoperasjonen, informasjon om andre skader og/eller inngrep i underekstremitetene i tiden fra korsbåndsoperasjonen til inkluderingstidspunktet, 2 år etter operasjonen og inntil 4 år etter rekonstruksjonen. Opplysninger om inngrep vil bli hentet både fra operert og ikke-operert side.

Besøksadresse: Gullhaugveien 1-3, 0484 Oslo
Telefon: 22845511
E-post: post@helseforskning.etikkom.no
Web: http://helseforskning.etikkom.no/

Det skal utføres ulike tester, samt MR undersøkelse, røntgen undersøkelse i tillegg at det tas blodprøve. Det informeres i e-poster datert 02.09.2016 at det skal opprettes en spesifikk forskningsbiobank for lagring av prøvene. Navn på biobanken er «God muskelfunksjon -forebyggende for artrose etter fremre korsbåndoperasjon?» og ansvarshavende er Lars Engebretsen. Informasjon om dette er nå inkludert i informasjonsskrivet. Da biobanken er spesifikk og kun knyttet til prosjektet, ber komiteen om at det legges til i informasjonsskrivet at biobanken opphører etter prosjektslutt.

Det fremgår av søknaden at det er ønskelig å lagre avidentifiserte data i 20 år for eventuelt senere bruk, men det er ikke skissert noen konkret oppfølgingsstudie. REK kan derfor ikke gi forlenget oppbevaring utover 5 års oppbevaring av dokumentasjonshensyn etter prosjektslutt. Dersom det er behov for forlengelse utover dette, må det søkes REK om prosjektendring.

Komiteens helhetlige vurdering av prosjektet, er at det kan være til nytte for fremtidige pasienter, og at deltagelse er forbundet med liten risiko. Komiteen anser det dermed som forsvarlig å gjennomføre prosjektet slik det er beskrevet i søknad og protokoll.

På denne bakgrunn godkjennes prosjektet på følgende vilkår:
- Det må fremkomme i informasjonsskrivet at biobanken opphører etter prosjektslutt.
- Årstall for sletting av opplysninger må endres til 2025.
- Revidert informasjonsskriv skal ettersendes komiteen til orientering.

Vedtak
Med hjemmel i helseforskningsloven § 9 jf. 33 godkjenner komiteen at prosjektet gjennomføres under forutsetning av at ovennevnte vilkår oppfylles.

I tillegg til vilkår som fremgår av dette vedtaket, er godkjenningen gitt under forutsetning av at prosjektet gjennomføres slik det er beskrevet i søknad og protokoll, og de bestemmelser som følger av helseforskningsloven med forskrifter.

Komiteen godkjenner opprettelse av en spesifikk forskningsbiobank, i tråd med det som er oppgitt i søknaden. Biobankregisteret vil få kopi av dette brev. Hvis forskningsbiobanken opphører, nedlegges eller overtas av andre, skal det søkes REK om tillatelse, jf. helseforskningsloven § 30.

Tillatelsen gjelder til 01.08.2020. Av dokumentasjonshensyn skal opplysningene likevel bevares inntil 01.09.2025. Forskningsfilen skal oppbevares atskilt i en nøkkel- og en opplysningsfil. Opplysningene skal deretter slettes eller anonymiseres, senest innen et halvt år fra denne dato.

Forskningsprosjektets data skal oppbevares forsvarlig, se personopplysningsforskriften kapittel 2, og Helsedirektoratets veileder for «Personvern og informasjonssikkerhet i forskningsprosjekter innenfor helse og omsorgssektoren».

Dersom det skal gjøres vesentlige endringer i prosjektet i forhold til de opplysninger som er gitt i søknaden, må prosjektleder sende endringsmelding til REK.

Prosjektet skal sende sluttmelding på eget skjema, senest et halvt år etter prosjektslutt.

Komiteens avgjørelse var enstemmig.

Klageadgang
REKs vedtak kan påklages, jf. forvaltningslovens § 28 flg. Klagen sendes til REK sør-øst D. Klagefristen er tre uker fra du mottar dette brevet. Dersom vedtaket opprettholdes av REK sør-øst D, sendes klagen videre til Den nasjonale forskningsetiske komité for medisin og helsefag for endelig vurdering.

Vi ber om at alle henvendelser sendes inn på korrekt skjema via vår saksportal:
http://helseforskning.etikkom.no. Dersom det ikke finnes passende skjema kan henvendelsen rettes på e-post

til: post@helseforskning.etikkom.no.

Vennligst oppgi vårt referansenummer i korrespondansen.

Med vennlig hilsen

Finn Wisløff
Professor em. dr. med.
Leder

Leena Heinonen
rådgiver

Kopi til: lars.engebretsen@medisin.uio.no
Oslo universitetssykehus HF ved øverste administrative ledelse: oushfdlgodkjenning@ous-hf.no

Appendix V: ”DATA behandler avtale OUS”

Oslo universitetssykehus

Skjema for behandling av helseforskningsdata

Dette skjemaet er nødvendig for behandling av helseforskningsdata ved Oslo universitetssykehus, i tillegg til de opplysninger som fremkommer i REK-søknaden. Skjemaet sendes til godkjenning@oslo-universitetssykehus.no sammen med kopi av REK-søknaden, forskningsprotokollen og informasjonsskrivet til deltagerne. Dette må senest gjøres samtidig med at REK søkes.

Dersom prosjektleder kan bekrefte ved avkrysning at punktene på denne siden stemmer overens med studieprotokollen og søknaden som er forelagt REK, er det kun side 4 som er nødvendig å fylle ut. Prosjektleder trenger da ikke å avvente tilbakemelding fra personvernombudet. **Dersom prosjektleder ikke kan gi slik bekreftelse, må side 2 – 4 fylles ut, og man må avvente både REKs godkjenning og personvernombudets interne tilbakemelding før studien kan starte.**

Dersom REK avviser søknaden under henvisning til at studien ikke er helseforskning, men for eksempel kvalitetssikring, og det behandles opplysninger som kan knyttes til enkeltpersoner, så må studien tilrådes av personvernombudet. Se egne rutiner. Ved spørsmål; ta kontakt med personvernombudet v/ seksjon for personvern og informasjonssikkerhet.

Prosjekter som ikke må avvente personvernombudets interne tilbakemelding:

Oppstart

1. Oppstart avventes til REK har godkjent studien.
    a. Dersom REK vurderer studien til å være kvalitetssikring eller annen forskning enn helseforskning, vil oppstart avventes til personvernombudet ved OUS har tilrådd studien.

Samtykke

2. Alle inkluderte i studien forhåndssamtykker til deltagelse
3. REKs mal for informasjonsskriv/samtykke benyttes uavkortet, inklusive følgende informasjon:
    a. retten til å kreve innsyn, retting og sletting av opplysningene, samt tidspunkt (årstall) for når data vil bli slettet/anonymisert

Taushetsplikten og tilgang til journal

4. Deltagerne rekrutteres av behandlende personell.
5. Opplysninger hentes ut av pasientjournalen (hvis relevant for studien) av ansatte ved OUS med egen brukertilgang.

Registrering, kobling, lagring og sletting

6. Det er uaktuelt å innhente opplysninger fra Reseptregisteret, NOIS, IPLOS (krever konsesjon i tillegg til REK).
7. Det er uaktuelt å samle opplysninger fra interne kvalitetsregistre eller konsesjonsbelagte registre.
8. Opplysninger samles inn uten bruk av elektroniske spørreskjemaer, iPad, smarttelefoner, skjermbrett, video o.l..
9. Ved OUS lagres opplysningene utelukkende på forskningsserver (K:\Forskning, MEDInsight eller Forskernett)
    a. Punktet gjelder ikke prosjekter som utelukkende samler inn og utleverer opplysninger til ekstern virksomhet, uten lokal lagring av dataene ved OUS. Se avsnitt om utlevering nedenfor.
10. Kode/navnelisten lagres utelukkende i papirform eller på godkjent minnepenn, nedlåst ved sykehuset.
11. Data som kan knyttes til enkeltpersoner slettes på et forhåndsdefinert tidspunkt (ref. varighet i samtykke og REK-godkjenning).

Utlevering til eksterne virksomheter (hvis aktuelt)

12. Utlevering av opplysninger (inkl. avidentifiserte) skjer kun til virksomheter som har REK-godkjenning og eget formål med å motta opplysningene.
13. Utleveringen er beskrevet i samtykket, inkl. navn på virksomhet som mottar opplysningene.
14. Ved multisenterstudier og behov for lokal kopi av studiedatabase og de utleverte opplysningene:
    a. Dette er beskrevet i godkjent studieprotokoll.
15. Opplysningene utleveres uten bruk av elektroniske hjelpemidler.
    a. Unntak for utlevering til legemiddelfirma med adresse i Norge, som benytter passordbeskyttet kryptert forbindelse over internett, og som ikke krever installasjon av egen programvare i sykehusnettet.

Endringer

16. Dersom det i løpet av studien blir nødvendig å endre på noen av ovenstående punkter, vil prosjektleder ta kontakt med personvernombudet før endringen trer i kraft.

Jeg er prosjektleder for studien, og bekrefter ved avkrysning at punktene ovenfor stemmer overens med studieprotokollen og søknaden som er forelagt REK: ☐

Prosjektleders navn: May Arna Risberg Avdeling som har ansvaret for studien: Ortopedisk Klinikk, Forskningsavdelingen

Prosjektets navn: God muskelfunksjon -forebyggende for artrose etter fremre korsbåndoperasjon?

Hvis det er krysset av for ”ja”, gå til side 4. Hvis ikke, fyll ut sidene 2 – 4 og avvent personvernombudets tilbakemelding.

Skjema for behandling av helseforskningsdata

1. Informasjon om søker og prosjekttittel

Prosjektleders navn:	May Arna Risberg		
Telefonnummer:	41312776	Epost:	m.a.risberg@nih.no
Klinikk:	Ortopedisk	Avdeling:	Forskningsavdelingen
Avdelingsleders navn:	Lars Nordsletten		
Studiens navn/tittel:	God muskelfunksjon -forebyggende for artrose etter fremre korsbåndoperasjon?		

2. Tilgang og utlevering av helseopplysninger fra OUS journalsystem og andre helseregistre

Personopplysninger som skal hentes fra journal/andre helseregistre, forutsetter at den som henter opplysninger har et ansettelsesforhold til OUS, eller på annen måte er under OUS instruksjonsmyndighet. Videre må det være gyldig grunnlag for oppslag og uthenting av person- og helseopplysninger.

Dersom studien/prosjektet krever uthenting av journalopplysninger, må følgende avklares:

Oppslag i journal gjøres av ansatt som har lovlig grunnlag for oppslag og uthenting av studiens opplysninger: ☒ Ja ☐ Nei

- Dersom ja, angi hva som gir lovlig grunnlag for de oppslag i journal som skal gjøres:
  Lars Engebretsen, overlege og professor ved Klinikken eller Kristin Bølstad som er forskningskoordinator tar ut operasojnsbeskrivelse og skadeadata slik det er beskrevet i søknaden til REK
- Dersom nei, hvordan skal journalopplysninger hentes ut og utleveres, (beskriv hvem som lovlig kan gjøre oppslag i journal og utlevere data):

3. Tilgang og kobling med andre helseregistre ved OUS

A) **Skal det hentes/brukes data fra journalsystem, labsystem, eller spesialistsystem**? ☒ Ja ☐ Nei
Angi hvilke(t): Operasjonsbeskrivelse fra journal og informasjon fra journal om andre skader og kneskader fra begge ben.

B) **Skal det hentes/brukes data fra internt kvalitetsregister?** ☐ Ja ☒ Nei
Angi hvilke(t):

C) **Skal det hentes/brukes data fra register med tematisk konsesjon eller kvalitetsregister med konsesjon/tilrådning fra PVO?** ☒ Ja ☐ Nei
Angi hvilke: Nasjonalt Korsbåndsregister,
Nasjonalt Register for leddproteser,
Helse Bergen HF

4. Bruk av humant biologisk materiale/biobank og personopplysninger fra helseregister/tematisk register

Ved bruk av eksisterende tematisk register/helseregister med konsesjon og/eller godkjent biobank, skal det foreligge godkjenning fra ansvarshavende av denne. Bekreftelse fra ansvarshavende for tematisk register/helseregister og biobank sendes pr. epost, oppgi navn på denne ansvarshavende: Lars Engebretsen

5. Opprettelse av biobank / Utførsel av materiale

A) Ved opprettelse og bruk av prosjektspesifikk biobank, oppgi:

Oppbevaringstid:	01.08.2020	Antall givere:	20
Type materiale:	fullblod		

B) Utførsel av biologisk materiale til annen institusjon? ☐ Ja ☒ Nei

Institusjon:	Oslo Universitetssykehus
Kontaktperson:	Lars Engebretsen

Skjema for behandling av helseforskningsdata

6. Utlevering av forskningsdata til eksterne samarbeidspartnere

A) Vil forskningsdata bli gjort tilgjengelig/utlevert til ekstern samarbeidspartner(e)? ☒ Ja ☐ Nei
Institusjon: Lunds Universitet, Sverige Kontaktperson: Eva Ageberg

B) Er virksomheten innenfor EU/EØS? ☒ Ja ☐ Nei

C) Vil den eksterne virksomheten brukes som ressurs/laboratorium/annet for studien? ☐ Ja ☒ Nei

D) Vil mottakeren ha eget formål/studie? ☐ Ja ☒ Nei

E) Hva blir overført?
☐ Informasjon med navn, fødselsnummer eller annet som entydig angir det enkelte individ
☒ Anonymisert informasjon
☐ Avidentifisert informasjon. Forklar i så fall hvordan kryssreferanseliste beskyttes dersom dette ikke er likt som i punkt 7:

F) Hvordan oversendes informasjonen?
☒ Personlig overlevering
☐ Legges ut på sikret område for nedlasting av mottaker
☒ CD sendt med rekommandert post
☐ Registreres på sikret web-side hos mottaker, som ikke krever installasjon av programvare i OUS-nettet
☐ Annet, nærmere beskrivelse:

7. Lagring og behandling av opplysninger

Lagring og behandling av forskningsdata skal samsvare med hva som er angitt i REK-søknad pkt 5a, b og h. Risikovurdering for lagring og databehandleravtale må være håndtert, inkludert godkjent av Personvernombud, før opplysninger eventuelt kan lagres utenfor foretakets forskningsservere og hos eksterne.

A) Hvordan lagres opplysningene (se søknad om tilgang på siste side)?
☒ Sykehusnettet under **K:\Forskning\Forskningsstudier** (for forskningsstudier)
☐ Forskernett under **R:\Research** (for en forsknings- eller kvalitetsstudie, kun tilgjengelig i RH/DnR-nettet)
☐ **MEDinsight**

☒ På papir. Forklar hvordan dette sikres mot uvedkommende:
Alle data lagres i låsbare skap
☒ På video, tape eller annet opptak. Beskriv hvordan dette er sikret og om personen kan identifiseres:
Iht REK søknad skal funksjonstestene videofilmes og scores av prosjektmedarbeidere. Alle video legges på K for scoring og ingen ansikt skal vises på videoene.
☐ Annet (for eksempel andre virksomheters nettverk). Forklar:

8. Gjenfinning av opplysningene

A) Hvordan gjenfinnes opplysningene? (Bruk av direkte identifisering som fødselsnummer og navn skal forsøkes unngått)
☐ Opplysningene lagres med navn, fødselsnummer eller annet som entydig angir det enkelte individ
☒ Opplysningene lagres avidentifisert (ved bruk av krysslister, kodelister, løpenummer eller lignende)

B) Hvordan er krysslister/kodelister beskyttet/lagret?
Forklar: Krysslister/kodelister lagres i låsbare safe

9. Sletting / anonymisering

A) Angi tidspunkt for sletting/anonymisering av data: 2025
B) Beskriv hvordan data vil bli slettet/anonymisert: alle krysslister vil bli makulert og ID nummer vil bli slettet

Oslo universitetssykehus

Skjema for behandling av helseforskningsdata

Bestilling av lagringsplass for studiedata på K:\Sensitivt\Forskning

De som skal ha tilgang (navn):	Brukernavn:	Angi lese- eller skrivetilgang
Lars Engebretsen		☒ Lese ☒ Skrive
Kristin Bølstad	krboel	☒ Lese ☒ Skrive
Dorthe Strauss		☒ Lese ☒ Skrive
May Arna Risberg	marisb	☒ Lese ☒ Skrive
		☐ Lese ☐ Skrive
		☐ Lese ☐ Skrive
		☐ Lese ☐ Skrive
		☐ Lese ☐ Skrive
		☐ Lese ☐ Skrive
Ved behov for flere, legges disse til i nytt skjema.		

Ønsket navn på mappe: Quadfunk_ACL_Artrose

Dataene slettes eller anonymiseres (årstall): 2025

Mappenavnet vil bestå av det interne saksnummeret i ePhorte + eget valgt navn (F.eks. "*12-341_Studienavn*"). Prosjektleder får beskjed om at mappen er opprettet. Purring skal skje til personvernombudet.

VIKTIG:
Helse- og personopplysninger skal normalt lagres avidentifisert (kodet) dersom ikke annet er godkjent av REK. Kodeliste/navneliste/koblingsnøkkel skal normalt ikke lagres i sykehusnettet uten egen godkjenning.

Skjemaet skal sendes per e-post til godkjenning@oslo-universitetssykehus.no.

For spørsmål, kontakt personvernombudet

Appendix VI: Information letter and written consent

Oslo universitetssykehus

Forespørsel til deg som har

gjennomgått en fremre korsbåndsoperasjon,

om deltakelse i et forskingsprosjekt som inkluderer forespørsel om å avgi biologisk materiale (blodprøver):

«Kan musklene beskytte kneet og forhindre og/eller bremse artrose etter fremre korsbåndoperasjon?»

Bakgrunn

Hvis du har hatt en stor kneskade har du en økt risiko for utvikling av artrose i kneet etter 10-15 år (før kalte man dette slitasjegikt). Aktiv rehabilitering inngår som en viktig behandling etter en fremre korsbåndskader og er også svært sentralt i behandlingen av pasienter med tidlig artrose. Riktige øvelser og trening bedrer fysisk funksjon; musklene blir sterkere og det er lettere å utføre de oppgaver som du gjør i hverdagen og ved trening /sportsaktiviteter. Det antas at musklene kan være viktige bidragsytere til å beskytte kneet for utvikling av artrose, men her har vi foreløpig for lite kunnskap.

Det tar lang tid før man kan se artrose på et røntgenbilde, men man har i dag kunnskap om at denne utviklingen antagelig starter tidlig etter skade. Vi trenger derfor å benytte oss av andre undersøkelser enn vanlige røntgen bilder for å vurdere om artroseprosesser har startet i kneet på et tidlig tidspunkt (1-2 år etter skade). Til dette brukes ofte MR (magnetisk resonans) undersøkelser og blodprøver. MR og blodprøver brukes som markører for å vurdere status og endringer i brusken i kneet.

Denne studien er del av en større studie i samarbeid med Universitetet i Lund, Sverige.

Mål

Vi ønsker å undersøke om musklene kan beskytte kneet og forhindre og/eller bremse utviklingen av artrose i kneet. For å undersøke dette må vi benytte forskjellige muskeltester, MR undersøkelser og blodprøver. Videre trenger vi å samle inn data fra operasjonsbeskrivelsen etter fremre korsbåndskaden og om du eventuelt har hatt andre skader/operasjoner i kneet.

Hvem kan delta?

Pasienter som har vært igjennom en fremre operert korsbåndoperasjon og er i alderen 18-35 år kan vurderes for deltakelse i studien.

Hva dette innebærer for deg?
Ved første gangs test skal du svare på noen spørreskjema, måle muskelstyrken i begge lår-, hoftemuskulatur samt muskulatur i bolen(truncus). Videre skal du gjennomføre noen funksjonelle tester og balansetester. Noen av testene vil vi også filme for å kunne vurdere dem i etterkant. Men ingen vil se ansiktet ditt under filmene og du vil da selvsagt ikke kunne identifiseres. Alle disse testene blir gjort på samme dag og kommer til å ta ca. 1,5 time. Undersøkelse av muskelstyrke og funksjonelle testr vil foregå på Norsk Idrettsmedisinsk Institutt (NIMI), Sognsveien 75D, Ullevål Stadion, Oslo. På testdagen skal du møte i joggesko, shorts og lett genser eller t-skjorte.
MR og røntgen bilder av knærne og blodprøver vil bli gjennomført på Oslo Universitetssykehus og blir gjort 2 ganger, med ca. 2 års mellomrom. I tillegg vil du 2 år etter første testene få tilsendt spørreskjema der du skal svare på hvordan du opplever knefunksjonen din. Alle blodprøver vil bli studert i vårt laboratorium på Oslo Universitetssykehus og lagret i en spesifikk biobank for forskning på bruskceller. Det vil benyttes såkalt fullblod som innhentes gjennom blodprøvetaking for å undersøke markører for brusk degenerasjon i serum i blodet (COMP). Blodprøvetakingen vil ikke medfører noen helseskade.

Mulige ulemper?
Undersøkelsene innebærer ingen større risiko. De funksjonelle testene ligner hverdagsaktiviteter eller aktiviteter du gjør ved idrett eller mosjon. Eksempler disse på test kan være: et bens knebøy og ett bens hink. Test av muskelstyrke og funksjon kan eventuelt gi deg noe opplevelse av ømhet i muskulaturen dagen etter og blodprøven kan oppleves kortvarig ubehagelig, men er helt ufarlig. I visse tilfeller (for eksempel hvis man har pacemaker) skal man ikke gjennomføre MR undersøkelse. Dette vil vi spørre deg om når vi kontakter deg.
Dersom du har reiseutgifter til undersøkelsene får du refundert de på vanlig måte dersom du leverer regninger og fyller ut de nødvendige skjema for refusjon.

Mulige fordeler
Etter testdagen vil du kunne ta med deg viktig informasjon om muskelstyrke og funksjon knyttet til det korsbåndopererte kneet ditt. Dette vil være nyttig informasjon som du kan benytte for å fortsette trening og/eller få råd og veiledning om hvordan du bør trene videre.

Hva skjer med informasjonen om deg?
Informasjon om operasjonen og eventuelt senere kneoperasjoner, samt data fra de ulike undersøkelsene om muskelstyrke, balansetestet og andre funksjonelle tester, videoopptak og blodprøver samt MR beskrivelser vil bli lagret på forskriftsmessig måte, etter alle dagens regler for datalagring.

Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert.
Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kode knytter deg til dine opplysninger gjennom en navneliste.
All data vil bli behandlet konfidensielt, og benyttet kun i forskningsøyemed. Forskere som benytter dataene er underlagt taushetsplikt.
Opplysningene blir slettet/fullstendig anonymisert i løpet av 2025. Alle blodprøver lagret i biobanken blir slettet innen prosjektslutt, anslått prosjektslutt innen 01.08.2020. Studien er godkjent av Regional Etisk Komité.

Hvordan får jeg informasjon om resultatet av studien?
Helt ferdigstilte resultater fra hele undersøkelsen vil publiseres i vitenskapelige tidsskrift 2019-2020. Vi sender deg en epost med hovedresultatene når disse foreligger i 2019 – 2020. Vi er da selvsagt avhengig av at vi har en epost adresse til deg.

Forsikring
Du omfattes av pasientskadeforsikringen som ved enhver annen behandling hos lege eller fysioterapeut. Dette er ingen intervensjonsstudie (ingen behandlingsstudie), men kun en studie der vi følger dere med fremre korsbåndoperasjon over 2 år.

Frivillig deltakelse
Det er frivillig å delta i prosjektet. Du har rett til å trekke deg fra prosjektet/undersøkelsen når som helst, og du har rett til å kreve dataene slettet. Du har nøyaktig de samme rettighetene og forsikringsvilkårene som du ville hatt dersom du ikke deltok i dette prosjekt.
Dersom du ikke ønsker å delta i prosjektet, send vennligst en mail til dorthe.strauss@nimi.no. Da vil vi ikke kontakte deg pr. telefon.

Forsknings ansvarlig:
Har du noen spørsmål ta gjerne kontakt med:
forskningskoordinator/masterstudent Dorthe Strauss, prosjektleder professor May Arna Risberg (m.a.risberg@nih.no), eller forskningsansvarlige:
Lars Engebretsen, professor og ortoped/overlege, Ortopedisk klinikk, Oslo Universitetssykehus (lars.engebretsen@medisin.uio.no)

Med vennlig hilsen

Dorthe Bro Strauss, Fysioterapeut master student
Norsk Idretts Medisinsk Institutt (NIMI)
Sognsveien 75D,
E-post: dorthe.strauss@nimi.no, Mobil: 466 34 367

SAMTYKKEERKLÆRING:

Jeg har lest og blitt forklart informasjonen i dette informasjonsskrivet og sier meg villig til at alle operasjonsbeskrivelser fra korsbåndsoperasjonen og eventuelt senere kneoperasjoner kan hentes fra min journal på det/de sykehus jeg ble operert.
Jeg sier meg villig til at utfylle spørreskjema, møte til kliniske tester, blodprøver samt MR ved henholdsvis NIMI og Ullevål universitetssykehus.
Jeg har forstått at deltakelse er frivillig og at jeg kan trekke med på et hvilket som helst tidspunkt.

Dato og sted.....

.....
Underskrift

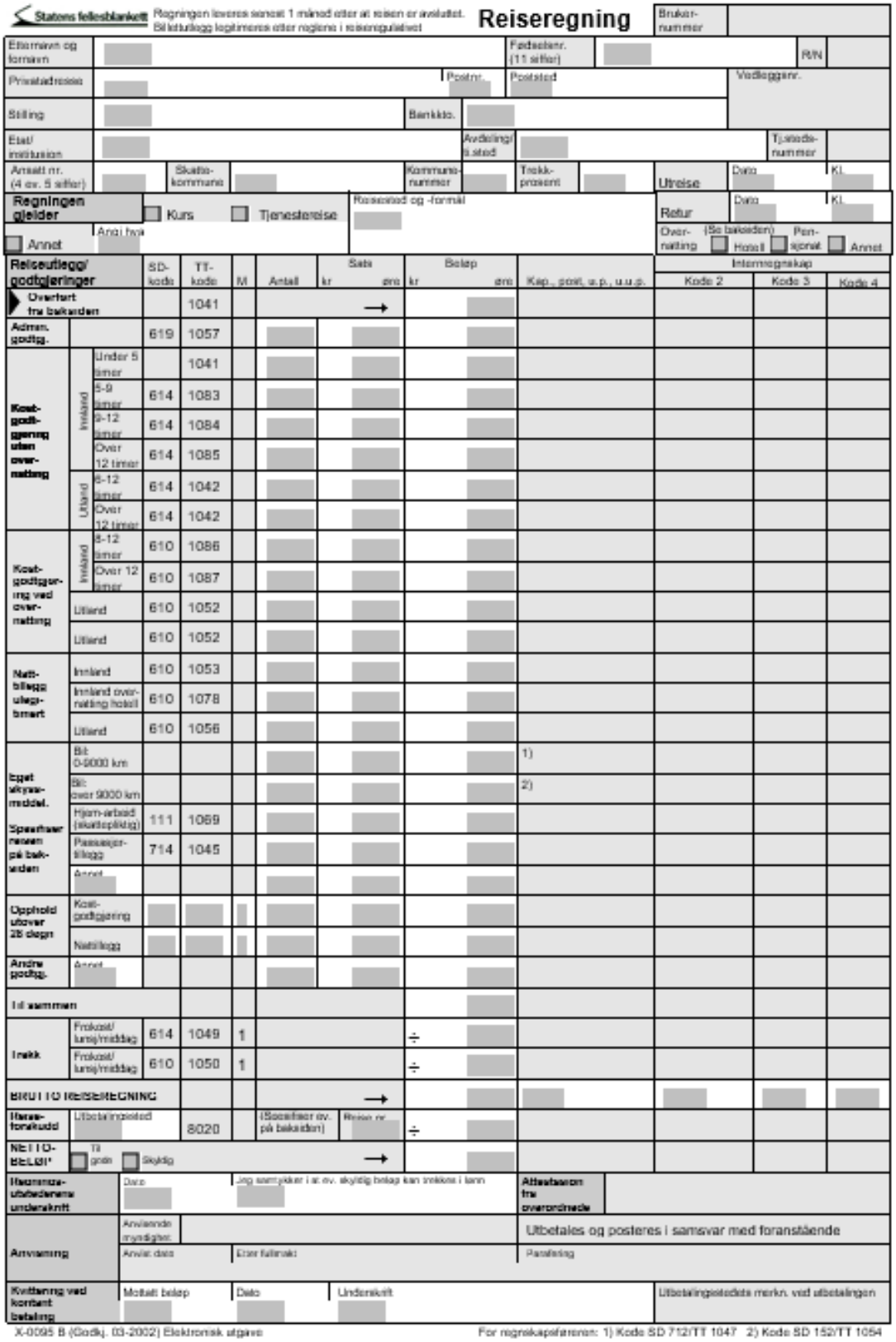
.....
Navn med blokkbokstaver

.....
Fødselsnummer (11 siffer)

.....
Telefonnummer/Mobil

.....
E-post adresse

Appendix VII: “Reiseregning”



Statens fellesblankett

Regningen leveres senest 1 måned etter at reisen er avsluttet.
Billettutlegg legitimeres etter reglene i reiseregulativet

Reiseregning

Bruker-nummer

Etternavn og fornavn | Fødselsnr. (11 siffer) | R/N

Privatadresse | Postnr. | Poststed | Vedleggsnr.

Stilling | Bankkto.

Etat/ institusjon | Avdeling/ sted | Tjeneste-nummer

Ansatt nr. (4 av. 5 siffer) | Skatte-kommune | Kommune-nummer | Trekk-prosent | Utreise: Dato, Kl.

Regningen gjelder: ☐ Kurs ☐ Tjenestereise ☐ Annet (Angi hva) | Reisested og -formål | Retur: Dato, Kl.

Over-natting (Se bakside): ☐ Hotell ☐ Pensjonat ☐ Annet

Reiseutlegg/ godtgjørelser			SD-kode	TT-kode	M	Antall	Sats kr	Sats øre	Beløp kr	Beløp øre	Kjøp, post, u.p., u.u.p.	Internregnskap Kode 2	Kode 3	Kode 4
Overført fra baksiden				1041			→							
Admin. godtgj.			619	1057										
Kost-godtgjørelse uten overnatting	Innland	Under 5 timer		1041										
		5-9 timer	614	1083										
		9-12 timer	614	1084										
		Over 12 timer	614	1085										
	Utland	6-12 timer	614	1042										
		Over 12 timer	614	1042										
Kost-godtgjørelse ved overnatting	Innland	6-12 timer	610	1086										
		Over 12 timer	610	1087										
	Utland		610	1052										
	Utland		610	1052										
Natt-tillegg ulegitimert	Innland		610	1053										
	Innland overnatting hotell		610	1078										
	Utland		610	1056										
Eget skyss-middel. Spesifiser reisen på baksiden	Bil: 0-9000 km										1)			
	Bil: over 9000 km										2)			
	Hjem-arbeid (skattepliktig)		111	1069										
	Passasjer-tillegg		714	1045										
	Annet													
Opphold utover 28 dager	Kost-godtgjørelse													
	Nattillegg													
Andre godtgj.	Annet													
Til sammen														
Trekk	Frokost/ lunsj/middag		614	1049	1				÷					
	Frokost/ lunsj/middag		610	1050	1				÷					
BRUTTO REISEREGNING							→							
Hase-forskudd	Utbetalingssted			8020		(Spesifiser ev. på baksiden)	Reise nr.		÷					
NETTO-BELØP	☐ Til gode ☐ Skyldig						→							

Hasonnize-utbetalerens underskrift: Dato | Jeg samtykker i at ev. skyldig beløp kan trekkes i lønn

Attestasjon fra overordnede

Anvisning: Anvisende myndighet: Utbetales og posteres i samsvar med foranstående

Anvist dato | Etter fullmakt | Påsetning

Kvittering ved kontant betaling: Mottatt beløp | Dato | Underskrift | Utbetalingsstedets merkn. ved utbetalingen

X-0095 B (Godkj. 03-2002) Elektronisk utgave

For regnskapsføreren: 1) Kode SD 712/TT 1047 2) Kode SD 152/TT 1054

Navn								Fødselsnr.			
Reisespesifikasjon								**Reiseutlegg**			
Dato	FRA		TIL		Skyssmiddel *		Fremmed valuta		Kurs	Beløp
	Kl.	Sted	Sted	Kl.	Type	km, eget	Kode	Beløp		

Hjemmel for bruk av bil	Dato		Sum km denne reisen, overføres egot skyssmiddel (bil) på forsiden		☐ Kryss av ved overføring av km	Sum	
	Gitt av		+ tidligere godtgjort i år (km)				
			= sum km i år				

*** For bruk av egen bil skal du ha med:**
reiseruten - kjørt distanse for hver tjenestereise, oppgitt etappervis og avrundet på kilometertelleren - årsak til omkjøringer - lokal kjøring på oppdragsstedet.

Beregning av kostgodtgjøring
For kurs slutter reisen ved kursstart. Ny reise skal regnes fra kursslutt.

Dersom regelen om 6 timer eller mer skal brukes ved utregning av kostgodtgjøringen, skal disse dagnene føres på forsiden under kostgodtgjøring ved overnatting - TT-kode 1086/1087/1052.

Kost og overnatting etter regning
På denne siden fører du kost og opphold som blir dekket etter regning. Hvis du i tillegg til dekning av utleggene får kursgodtgjøring, skriver du antall dagn under kode 1057 på forsiden. Samlet kursgodtgjøring skal stå i beløpsrubrikken.

Utlegg til hotell, mat o.l.

Dato	Spesifikasjon	Fremmed valuta		Kurs	
		Kode	Beløp		
Reiseutlegg - overføres til forsiden, TT-kode 1041					

Overnatting	
Navn og adresse på hotell pensjonat e.a. (ikke privat)	

Merknader

Appendix VIII: research aim 5a

Simple Linear regression analysis between KOOS PAIN and isokinetic knee and isometric hip and trunk muscle strength and hop performance

KOOS PAIN (**Bold** indicates significant association)	Sig.*	R^2	95% CI*	B*	Constant (95% CI)		Residuals:		
						Durbin-Watson	Shapiro-Wilk	H*	Btw* +3 and -3
Knee extension: (Nm/kg)									
Injured	0.582	0.016	-0.06 - 0.1	0.023	80.443	2.152	0.038	Y	-2.7-1.3
Non-injured	0.553	0.019	-0.06 – 0.1	0.024	78.765	2.108	0.043	Y	-2.7-1.3
Knee flexion:									
Injured	0.179	0.093	-0.05 – 0.3	0.103	72.375	2.043	0.023	Y	-2.8-1.3
Non-injured	0.273	0.063	-0.07 – 0.2	0.083	74.314	2.059	0.067	Y	-2.8-1.3
SLHD: (cm)									
Injured	0.139	0.112	-0.03-0.2	0.097	72.250	2.284	0.027	Y	-2.8-1.5
Non-injured	0.190	0.088	-0.5-0.3	0.102	69.813	2.231	0.084	Y	-2.7-1.5
Side hop: (n)									
Injured	0.407	0.036	-0.2-0.4	0.124	80.670	2.267	0.025	Y	-2.9-1.3
Non-injured	0.313	0.054	-0.2-0.5	0.153	79.114	2.230	0.038	Y	-2.8-1.3
Hip extension (Nm/kg)									
Injured	**0.020**	**0.252**	**3.9-40.9**	**22.39**	**62.938**	**1.693**	**0.182**	**Y**	**-2.6-1.4**
Non-injured	0.138	0.112	-5.2-34.9	14.85	70.829	2.386	0.419	Y	-2.5-1.6
Hip external rotation									
Injured	0.280	0.061	-12.9-42.0	14.57	75.973	2.078	0.015	N	-2.7-1.2
Non-injured	0.148	0.107	-9.0-55.8	23.36	70.072	2.046	0.179	Y	-2.5-1.4
Hip abduction									
Injured	0.124	0.120	-2.2-16.9	7.350	72.544	2.252	0.256	Y	-2.5-1.5
Non-injured	0.218	0.079	-4.4-17.9	6.815	73.147	2.119	0.068	N	-2.5-1.4
Trunk									
Injured	0.185	0.091	-0.8-3.9	1.558	77.457	2.225	0.198	Y	-2.6-1.4
Non-injured	0.142	0.110	-0.7-4.5	1.900	75.938	2.165	0.111	Y	-2.6-1.3

*Sig: Significance, *CI: Confidence Interval, *B: Slope of the line *H: Homoscedatic, Btw*: Between,

Simple Linear regression analysis between KOOS SYMPTOM and isokinetic knee and isometric hip and trunk muscle strength and hop performance

KOOS SYMPTOM (**Bold** indicates significant association)	Sig.*	R^2	95% CI*	B*	Constant (95% CI)		Residuals:		
						Durbin-Watson	Shapiro-Wilk	H*	Btw* +3 and -3
Knee extension: (Nm/kg)									
Injured	0.615	0.014	-0.1 – 0.2	0.033	70.560	1.654	0.008	Y	-2.8 - 1.1
Non-injured	0.863	0.002	-0.1 – 0.1	0.011	74.6	1.643	0.013	N	-2.8 - 1.2
Knee flexion:									
Injured	0.668	0.010	-0.2 – 0.3	0.053	70.953	1.665	0.008	N	-2.8 - 1.2
Non-injured	0.835	0.002	-0.2 – 0.3	0.026	74.285	1.650	0.014	N	-2.8 - 1.2
SLHD: (cm)									
Injured	0.254	0.068	-0.9 – 0.3	0.120	61.432	1.741	0.015	N	-2.8 -1.1
Non-injured	0.185	0.090	-0.9 – 0.4	0.164	52.717	1.643	0.010	N	-2.8 -1.1
Side hop: (n)									
Injured	0.743	0.006	-0.4 – 0.6	0.078	74.716	1.691	0.010	N	-2.9 - 1.2
Non-injured	0.771	0.005	-0.4 – 0.6	0.071	74.776	1.665	0.010	N	-2.9 -1.2
Hip extension (Nm/kg)									
Injured	0.460	0.029	-21.5 – 45.6	12.073	65.592	1.539	0.010	N	-2.7 -1.3
Non-injured	0.389	0.039	-19.2 – 47.2	13.974	64.017	1.670	0.014	N	-2.7 -1.2
Hip external rotation									
Injured	0.241	0.072			61.540	1.705	0.031	Y	-2.7 -1.4
Non-injured	0.141	0.111	-18.3 – 68.5	25.098	53.011	1.644	0.063	Y	-2.5 -1.2
Hip abduction									
Injured	0.445	0.031	-13.7 – 89.1	37.736	67.316	1.619	0.010	Y	-2.7 -1.2
Non-injured	0.631	0.012			69.999	1.627	0.014	N	-2.7 -1.2
			-10.0 – 21.9	5.949					
			-14.1 – 22.7	4.288					
Trunk									
Injured	0.364	0.044	-2.1 – 5.6	1.717	68.987	1.736	0.015	N	-2.7 -1.2
Non-injured	0.228	0.075	-1.7 – 6.7	2.503	65.290	1.670	0.012	N	-2.7 -1.1

*Sig: Significance, *CI: Confidence Interval, *B: Slope of the line *H: Homoscedatic, Btw*: Between

Simple Linear regression analysis between KOOS ADL and isokinetic knee and isometric hip and trunk muscle strength and hop performance

KOOS ADL (**Bold** indicates significant association)	Sig.*	R^2	95% CI*	B*	Constant (95% CI)		Residuals:		
						Durbin-Watson	Shapiro-Wilk	H*	Btw* +3 and -3
Knee extension: (Nm/kg)									
Injured	**0.036**	**0.211**	**0.004 – 0.1**	**0.060**	**79.161**	**2.283**	**0.431**	**Y**	**-2.7 -1.6**
Non-injured	0.223	0.077	-0.02 – 0.1	0.036	82.289	2.205	0.630	Y	-2.4 -1.5
Knee flexion:									
Injured	0.116	0.125	-0.02 – 0.2	0.086	81.051	2.343	0.162	Y	-2.6 -1.4
Non-injured	0.405	0.037	-0.07 – 0.2	0.046	85.806	2.251	0.165	Y	-2.4 -1.2
SLHD: (cm)									
Injured	**0.028**	**0.229**	**0.01 – 0.19**	**0.100**	**78.326**	**2.236**	**0.331**	**Y**	**-2.5 -1.4**
Non-injured	**0.028**	**0.229**	**0.01 – 0.2**	**0.119**	**73.831**	**2.360**	**0.480**	**Y**	**-2.5 -1.5**
Side hop: (n)									
Injured	0.074	0.158	-0.02 – 0.4	0.187	84.877	2.322	0.194	Y	-2.8 -1.5
Non-injured	**0.027**	**0.233**	**0.03 – 0.4**	**0.231**	**82.515**	**2.283**	**0.380**	**Y**	**-2.7 -1.7**
Hip extension (Nm/kg)									
Injured	0.075	0.157	-1.4 – 27.0	12.795	79.109	2.032	0.637	Y	-2.2 -1.5
Non-injured	0.143	0.109	-3.9 – 25.2	10.612	81.538	2.295	0.325	Y	-2.2 -1.3
Hip external rotation									
Injured	**0.023**	**0.242**	**3.2 – 38.9**	**21.008**	**78.406**	**2.294**	**0.280**	**Y**	**-2.4 -1.3**
Non-injured	0.054	0.182	-0.4 – 44.5	22.061	77.491	2.245	0.573	Y	-2.1 -1.5
Hip abduction									
Injured	0.117	0.124	-1.5 – 12.3	5.416	82.481	2.320	0.326	Y	-2.2 -1.3
Non-injured	0.159	0.101	-2.4 – 13.6	5.597	81.898	2.288	0.317	Y	-2.2 -1.4
Trunk									
Injured	0.175	0.094	-0.6 – 2.9	1.150	86.088	2.413	0.331	Y	-2.3 -1.3
Non-injured	0.306	0.055	-1.0 – 2.9	0.973	87.093	2.314	0.90	N	-2.3 -1.2

*Sig: Significance, *CI: Confidence Interval, *B: Slope of the line *H: Homoscedatic, Btw*: Between,

Simple Linear regression analysis between KOOS SPORT AND RECREATION and isokinetic knee and isometric hip and trunk muscle strength and hop performance

KOOS SPORT/ RECREATION (**Bold** indicates significant association)	Sig.*	R^2	95% CI*	B*	Constant		Residuals:		
						Durbin-Watson	Shapiro-Wilk	H*	Btw* +3 and -3
Knee extension: (Nm/kg)									
Injured	**0.007**	**0.325**	**0.06 - 0.34**	**0.200**	**20.901**	**2.510**	**0.143**	**Y**	**-1.6 -1.6**
Non-injured	0.080	0.153	-0.02 – 0.29	0.135	27.014	2.272	0.749	Y	-1.9 -1.7
Knee flexion:									
Injured	**0.002**	**0.391**	**0.17 – 0.66**	**0.413**	**11.683**	**2.421**	**0.693**	**Y**	**-2.0 -1.6**
Non-injured	0.053	0.183	-0.00 – 0.6	0.278	26.860	2.280	0.904	Y	-1.7 -1.9
SLHD: (cm)									
Injured	**0.004**	**0.365**	**0.13 – 0.56**	**0.341**	**17.355**	**2.762**	**0.110**	**Y**	**-1.4 -2.0**
Non-injured	**0.003**	**0.371**	**0.15 – 0.67**	**0.409**	**1.445**	**2.630**	**0.204**	**Y**	**-1.5 -2.3**
Side hop: (n)									
Injured	**0.043**	**0.199**	**0.20 – 1.1**	**0.565**	**42.307**	**2.665**	**0.397**	**Y**	**-1.9 -1.6**
Non-injured	**0.030**	**0.224**	**0.07 – 1.2**	**0.612**	**38.703**	**2.381**	**0.666**	**Y**	**-2.2 -1.6**
Hip extension (Nm/kg)									
Injured	**0.022**	**0.248**	**7.1 – 79.6**	**43.350**	**20.217**	**1.885**	**0.881**	**Y**	**-2.0 -2.0**
Non-injured	0.349	0.046	-22.0 -59.3	18.645	45.359	2.223	0.671	Y	-1.9 -1.6
Hip external rotation									
Injured	**0.008**	**0.320**	**19.5 - 110.8**	**65.162**	**21.700**	**2.627**	**0.244**	**Y**	**-1.3 -2.2**
Non-injured	**0.031**	**0.222**	**6.6 – 124.8**	**65.699**	**20.645**	**2.376**	**0.297**	**Y**	**-1.5 -1.8**
Hip abduction									
Injured	0.059	0.176	-0.7 – 35.5	17.380	33.329	2.307	0.398	Y	-1.6 -1.8
Non-injured	0.110	0.129	-4.2 – 38.3	17.017	33.145	2.315	0.273	Y	-1.5 -1.7
Trunk									
Injured	0.073	0.159	-0.4 – 8.5	4.029	43.197	2.607	0.179	Y	-1.5 -1.7
Non-injured	**0.026**	**0.234**	**0.7 – 10.1**	**5.414**	**36.797**	**2.484**	**0.083**	**Y**	**-1.4 -1.5**

*Sig: Significance, *CI: Confidence Interval, *B: Slope of the line *H: Homoscedatic, Btw*: Between,

Simple Linear regression analysis between KOOS QUALITY OF LIFE (QOL) and isokinetic knee and isometric hip and trunk muscle strength and hop performance

KOOS QOL (**Bold** indicates significant association)	Sig.*	R^2	95% CI*	B*	Constant		Residuals:		
						Durbin-Watson	Shapiro-Wilk	H*	Btw* +3 and -3
Knee extension: (Nm/kg)									
Injured	0.08	0.153	-0.2 – 0.3	0.129	32.410	2.643	0.097	Y	-2.4 -1.6
Non-injured	**0.012**	**0.228**	**0.04 – 0.3**	**0.175**	**12.647**	**2.380**	**0.441**	**Y**	**-2.2 -1.5**
Knee flexion:									
Injured	0.071	0.161	-0.02 – 0.5	0.250	28.561	2.480	0.020	N	-2.4 -1.3
Non-injured	**0.050**	**0.188**	**0.001 – 0.5**	**0.266**	**24.880**	**2.544**	**0.530**	**Y**	**-2.2 -1.6**
SLHD: (cm)									
Injured	0.184	0.091	-0.08 – 0.4	0.161	38.235	2.505	0.096	Y	-2.8 -1.6
Non-injured	0.096	0.139	-0.05 – 0.5	0.236	24.189	2.503	0.210	Y	-2.6 -1.4
Side hop: (n)									
Injured	0.313	0.054	-0.3 – 0.8	0.276	49.594	2.460	0.054	N	-2.7 -1.3
Non-injured	0.214	0.080	-0.2 – 0.9	0.345	45.992	2.405	0.058	N	-2.6 -1.3
Hip extension (Nm/kg)									
Injured	**0.027**	**0.233**	**5.1 – 74.2**	**39.605**	**20.392**	**2.616**	**0.222**	**Y**	**-1.9 -1.8**
Non-injured	0.138	0.112	-9.6 – 64.3	27.357	33.277	2.334	0.597	Y	-1.9 -1.6
Hip external rotation									
Injured	**0.028**	**0.229**	**6.1 – 97.8**	**51.960**	**26.612**	**2.821**	**0.292**	**Y**	**-2.4 -1.7**
Non-injured	0.103	0.134	-10.7- 106.9	48.117	28.562	2.287	0.217	Y	-2.0 -1.3
Hip abduction									
Injured	0.084	0.149	-2.2 – 32.4	15.084	33.753	2.465	0.831	Y	-2.0 -1.6
Non-injured	**0.022**	**0.246**	**3.6 – 40.8**	**22.188**	**20.327**	**2.534**	**0.347**	**Y**	**-1.8 -1.5**
Trunk									
Injured	0.684	0.009	-3.7 – 5.5	0.900	55.450	2.444	0.682	Y	-2.2 -1.6
Non-injured	0.385	0.040	-2.9 -7.1	2.111	49.559	2.349	0.798	Y	-2.2 -1.7

*Sig: Significance, *CI: Confidence Interval, *B: Slope of the line *H: Homoscedatic, Btw*: Between

Simple Linear regression analysis between Tegner Activity Scale and isokinetic knee and isometric hip and trunk muscle strength and hop performance

TEGNER ACTIVITY SCALE NOW (**Bold** indicates significant association)	Sig.*	R^2	95% CI*	B*	Constant		Residuals:		
						Durbin-Watson	Shapiro-Wilk	H*	Btw* +3 and -3
Knee extension: (Nm/kg)									
Injured	**0.005**	**0.344**	**0.01-0.04**	**0.022**	**1.09**	**2.25**	**0.931**	**Y**	**-2.1-1.9**
Non-injured	**0.022**	**0.247**	**0.003-0.03**	**0.018**	**0.82**	**2.49**	**0.750**	**Y**	**-1.9-1.9**
Knee flexion:									
Injured	**0.000**	**0.493**	**0.03-0.07**	**0.049**	**-0.423**	**2.22**	**0.134**	**Y**	**-2.0-2.4**
Non-injured	**0.001**	**0.436**	**0.02-0.07**	**0.012**	**-0.257**	**2.42**	**0.711**	**Y**	**-2.0-2.0**
SLHD: (cm)									
Injured	**0.006**	**0.339**	**0.11-0.58**	**0.035**	**1.02**	**2.06**	**0.273**	**Y**	**-1.6-1.7**
Non-injured	**0.003**	**0.354**	**0.02-0.07**	**0.044**	**-0.96**	**2.42**	**0.637**	**Y**	**-1.8-1.7**
Side hop: (n)									
Injured	**0.011**	**0.294**	**0.02-0.13**	**0.072**	**2.99**	**2.09**	**0.531**	**Y**	**-1.4-2.1**
Non-injured	**0.004**	**0.363**	**0-03-0.13**	**0.082**	**2.38**	**2.15**	**0.299**	**Y**	**-1.4-1.7**
Hip extension (Nm/kg)									
Injured	**0.003**	**0.374**	**2.1-0.1**	**5.609**	**0.105**	**2.66**	**0.285**	**Y**	**-1.9-1.4**
Non-injured	0.097	0.138	-0.7-7.5	3.395	2.398	2.564	0.047	Y	-1.8-1.3
Hip external rotation									
Injured	**0.000**	**0.567**	**5.3-12.97**	**9.144**	**-0.16**	**2.35**	**0.856**	**Y**	**-2.0-2.2**
Non-injured	**0.041**	**0.202**	**0.3-12.9**	**6.606**	**1.398**	**2.53**	**0.619**	**Y**	**-2.3-1.7**
Hip abduction									
Injured	**0.008**	**0.317**	**0.7-4.2**	**2.461**	**1.432**	**3.016**	**0.273**	**Y**	**-2.1-1.5**
Non-injured	**0.041**	**0.202**	**0.1-4.4**	**2.245**	**1.701**	**2.617**	**0.184**	**Y**	**-2.1-1.4**
Trunk									
Injured	**0.023**	**0.243**	**0.08-0.97**	**0.525**	**3.059**	**2.665**	**0.947**	**Y**	**-2.3-1.9**
Non-injured	0.110	0.129	-0.1-0.95	0.424	3.619	2.340	0.514	Y	-2.1-1.7

*Sig: Significance, *CI: Confidence Interval, *B: Slope of the line *H: Homoscedatic, Btw*: Between

Appendix IX: research aim 5c

Logistic regression analysis between returning to sport and isokinetic knee and isometric hip and trunk muscle strength and hop performance

Return to sport: YES/NO	Sig.*	Exp. (B)*	95% CI*	Fisher´s Exact test: (Exact Sig)
Knee extension: (Nm/kg)				
Injured	0.027	1.033	1.004 – 1.063	1.000
Non-injured	0.106	1.014	0.997 – 1.031	1.000
Knee flexion:				
Injured	0.026	1.053	1.006 – 1.103	1.000
Non-injured	0.273	1.016	0.988 – 1.045	1.000
SLHD: (cm)				
Injured	0.133	1.021	0.994 – 1.050	1.000
Non-injured	0.256	1.017	0.988 – 1.047	0.214
Side hop: (n)				
Injured	0.040	1.075	1.003 – 1.152	0.280
Non-injured	0.039	1.079	1.004 – 1.160	1.000
Hip extension: (Nm/kg)				
Injured	0.215	1.011	0.994 – 1.027	1.000
Non-injured	0.545	0.995	0.980 – 1.011	1.000
Hip external rotation:				
Injured	0.186	1.013	0.994 - 1.032	1.000
Non-injured	0.789	1.003	0.984 – 1.022	1.000
Hip abduction:				
Injured	0.495	1.007	0.987 –1.027	1.000
Non-injured	0.295	1.010	0.991 – 1.029	0.476
Trunk:				
Injured	0.467	1.003	0.995 – 1.010	1.000
Non-injured	0.964	1.000	0.992 – 1.009	1.000

*Sig: Significance, *Exp(B): Odds Ratio *CI: Confidence Interval

Logistic regression analysis between returning to same level of sport and isokinetic knee and isometric hip and trunk muscle strength and hop performance

Returned to same level of sport: YES/NO	Sig.*	Exp. (B)*	95% CI*	Fisher´s Exact test: (Exact Sig)
Knee extension: (Nm/kg)				
Injured	0.027	1.038	1.004 – 1.073	1.000
Non-injured	0.186	1.010	0.995 – 1.024	1.000
Knee flexion:				
Injured	0.032	1.086	1.007 – 1.175	1.000
Non-injured	0.030	1.068	1.006 – 1.133	1.000
SLHD: (cm)				
Injured	0.116	1.028	0.993 – 1.065	0.429
Non-injured	0.179	1.026	0.988 – 1.066	1.000
Side hop: (n)				
Injured	0.076	1.072	0.993 – 1.157	0.498
Non-injured	0.109	1.071	0.985 – 1.164	0.866
Hip extension: (Nm/kg)				
Injured	0.036	1.024	1.001– 1.047	1.000
Non-injured	0.436	1.007	0.990– 1.024	1.000
Hip external rotation:				
Injured	0.740	1.019	0.998– 1.040	1.000
Non-injured	0.312	1.011	0.989 – 1.034	1.000
Hip abduction:				
Injured	0.265	1.012	0.991 – 1.034	1.000
Non-injured	0.327	1.010	0.990 – 1.031	0.619
Trunk:				
Injured	0.043	1.011	1.000 – 1.022	1.000
Non-injured	0.227	1.007	0.996 – 1.018	1.000

*Sig: Significance, *Exp(B): Odds Ratio *CI: Confidence Interval