NORGES
IDRETTSHØGSKOLE

Anne Inger Mørtvedt

Sports medicine professionals cannot predict ACL injury risk in elite female players

A ROC analysis of visual assessment of the vertical drop jump test

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ABSTRACT

Background: The vertical drop jump (VDJ) test has been suggested as a screening tool for assessing anterior cruciate ligament (ACL) injury risk. Except from one smaller cohort study, no study has so far reported that individuals or computerized methods can identify high-risk players based on the VDJ test when ACL injury is used as the outcome.

Objectives: To examine if sports and sports medicine professionals have the ability to identify players at increased risk of sustaining an ACL injury by assessing the players' performance of a vertical drop jump (VDJ) test.

Methods: One hundred and ten video clips of elite female handball and football players performing the VDJ test were uploaded in an online survey. Sports and sports medicine professionals were invited to assess their performance and rate each clip with a number between 1 and 10 (1 representing low risk of sustaining an ACL injury and 10 representing high risk). Receiver operating characteristic (ROC) analysis was used to assess classification accuracy level for each assessor and between-group differences were analysed using One-way ANOVA.

Results: Two hundred and thirty seven participants completed the survey. Area under the curve (AUC) values ranged from 0.37 to 0.61, with a mean score of 0.48. There were no significant differences between groups (e.g. physicians, coaches, certified athletic trainers, researchers or physical therapists).

Conclusion: AUC values revealed assessors have poor predictive ability, indicating that visual assessment of the VDJ test is a poor test for assessing ACL injury risk in elite female handball and football players.

Keywords: ACL; injury risk; visual assessment; VDJ test; female; elite; handball; football

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1. THEORY

1.1. Background and purpose of the master thesis

Anterior cruciate ligament (ACL) injuries are a costly problem in sports, especially within female athletes participating in contact or landing and pivoting sports (Arendt, Agel, & Dick, 1999; Joseph et al., 2013; Walden, Hagglund, Werner, & Ekstrand, 2011). An ACL injury causes severe consequences for the player regarding time lost from sports, decreased performance and increased risk of re-injury. In a long-term perspective the injury also increases the risk of early osteoarthritis, pain and reduced knee function (Li et al., 2011; Struewer et al., 2012). The injury mechanism appears to be multifactorial (Koga et al., 2011; Koga et al., 2010; Matsumoto et al., 2001; Meyer & Haut, 2008), and several factors are suggested to be associated with increased ACL injury risk. The different risk factors will be further discussed in the theory section.

An athlete's movement patterns may reveal important information associated with ACL injury risk, and assessing the performance of a vertical drop jump (VDJ) test is hypothesised to identify several risk factors associated with ACL injuries (Redler, Watling, Dennis, Swart, & Ahmad, 2016), especially the frontal plane knee motion (Ford, Myer, & Hewett, 2003; McLean et al., 2005; Nilstad et al., 2014). The use of the VDJ test as a screening tool for assessing ACL injury risk has been investigated with the use of three-dimensional (3D) motion analyses, but results are inconsistent when ACL injury is the outcome (Hewett et al., 2005; Krosshaug et al., 2016; Leppanen et al., 2017). 3D motion analysis is reported as the "gold standard" for assessing risk factors for ACL injuries (Stensrud, Myklebust, Kristianslund, Bahr, & Krosshaug, 2011), but it is well known that substantial errors in estimates may occur using this analysis method (Cappozzo, Catani, Leardini, Benedetti, & Croce, 1996; Reinschmidt, van den Bogert, Nigg, Lundberg, & Murphy, 1997). Compared to 3D motion analyses, humans may have the ability to visually integrate more movement information at one time by assessing several reported risk factors in one jump. This may be beneficial considering the multifactorial injury mechanism.

Thus, the purpose of this exploratory study was to examine sports and sports medicine professionals' ability to visually identify female elite football and handball players with increased risk for ACL injury based on the performance on a VDJ test.

1.2. Anatomy and function of the anterior cruciate ligament (ACL)

There are two cruciate ligaments intraarticularly located in the knee called the anterior and posterior cruciate ligament based on their site of attachment to the tibia (Woo, Abramowitch, Kilger, & Liang, 2006). They help maintain smooth movement of joints under normal, physiologic circumstances and restrain excessive joint displacements under different loads. A synovial layer surrounds the ligaments and both ligaments consist of two bundles. The ACL is attached to the anterior part of the intercondylar eminentia of the tibia and extends posterolateral to the intercondylar fossa of the femur. The anteromedial bundle of the ACL is thought to be important for restraining the anterior-posterior translation of the knee while the posterolateral bundle restrain rotational moments about the knee (Woo et al., 2006).

Ligaments consist of closely packed collagen fibre bundles oriented in a parallel way to provide stability of the joint. Type I collagen is the major constituent of the dry weight (70-80 %) and is responsible for the tensile strength of the ligament (Woo et al., 2006). The ACL also contains different sets of mechanoreceptors that provide information about the joint position to the central nervous system (Andersson, Samuelsson, & Karlsson, 2009; Ingersoll, Grindstaff, Pietrosimone, & Hart, 2008). These proprioceptive properties of the ligament are essential for knee control during jump tasks and rapid changes in direction (Brukner & Khan, 2012).

1.3. Incidence of ACL injuries in female elite football and handball players

It has been reported an annual incidence of ACL injuries in Scandinavia of 81-85 per 100 000 in the at-risk population aged between 16 and 39 (Frobell, Lohmander, & Roos, 2007; Granan, Bahr, Steindal, Furnes, & Engebretsen, 2008). Females are reported to have 2 to 6 times higher risk of sustaining an ACL injury compared to men (Arendt et al., 1999; Joseph et al., 2013; Walden et al., 2011). The highest incidence of ACL injuries is reported in the age before 20 among females (Johnsen et al., 2016; Nordenvall et al., 2012; Sanders et al., 2016; Walden et al., 2011). The injury rate seem to decrease in the age between 19 and 25 and are relatively stable in the next decades among females, compared to men, which have the highest injury rate in the age between 19 and 25 (Sanders et al., 2016). One reason for the decrease in incidence of ACL injuries among female after age 20 may be the decrease of female participation in sports (Sanders et al., 2016). ACL injuries most often occur when people are performing sports, and the Norwegian registry of ACL injuries reports that injuries most frequently occur performing football (52%) and handball (39%) among young Norwegian females (Johnsen et al., 2016). The risk of sustaining an ACL injury is increased during competition compared to practice, and for female handball players it has been reported 30 times higher injury risk during competition (Myklebust, Maehlum, Holm, & Bahr, 1998).

1.4. Consequences of sustaining an ACL injury for elite female athletes

The injury itself causes severe consequences for the athlete regarding time lost from sports, decreased performance, and increased risk of re-injury. Proprioception in the knee is decreased following an ACL injury, also after surgical reconstruction of the ligament (Ingersoll et al., 2008; Krogsgaard, Dyhre-Poulsen, & Fischer-Rasmussen, 2002). It is uncertain whether this property, together with reflex activity between afferent nerves in the ligament and muscles surrounding the knee and biomechanical changes are reversible after an ACL injury (Anderson, Browning, Urband, Kluczynski, & Bisson, 2016; Ingersoll et al., 2008; Krogsgaard et al., 2002). Studies also report that muscle strength and performance in functional tests are decreased years after the injury (Ageberg, Thomee, Neeter, Silbernagel, & Roos, 2008; Grindem, Eitzen, Engebretsen, Snyder-Mackler, & Risberg, 2014). The risk of re-injury is severe, and a systematic review and meta-analysis by Wiggins et al. (2016) report that 1 in 4 young athletes who have sustained an ACL injury and return to high-risk sports will sustain a new ACL injury at some point in their career.

In a long-term perspective the injury also increases the risk of early osteoarthritis (OA), pain and reduced knee function (Li et al., 2011; Struewer et al., 2012). Over five years after injury, people report reduced health related quality of life, which also seem to be associated with symptomatic knee OA (Anderson et al., 2016; Filbay, Ackerman, Russell, Macri, & Crossley, 2014). The reported prevalence of knee OA following an ACL injury varies from less than 10 % to over 90 % in different studies, but a meta-analysis shows that studies with the highest methodological quality reported a prevalence up to 13 % more than 10 years after the injury (Oiestad, Engebretsen, Storheim, & Risberg, 2009). Symptomatic radiographic OA was revealed in 41 % of the patients in a prospective cohort study with 10 to 15 years follow-up (Oiestad et al., 2010).

1.5. Injury mechanism

The fundamental basis of this research field is that ACL injuries do not occur randomly, but in patterns that reflect the underlying causes (risk factors) (Renstrom et al., 2008). van Mechelen explains research of injury prevention through four different steps: "the sequence of prevention" (Figure 1) (van Mechelen, Hlobil, & Kemper, 1992). First, an identification of the extent of the injury problem has to be explored. Secondly, risk factors associated with the injury mechanism must be identified. Thirdly, development of an intervention programme based on the findings in step two must take place. And last, but not least, the fourth step includes an evaluation of the effect of the intervention from step three by identifying the extent of the injury problem again (step one). This thesis will focus on the second step in the sequence of preventing ACL injuries in elite female athletes.

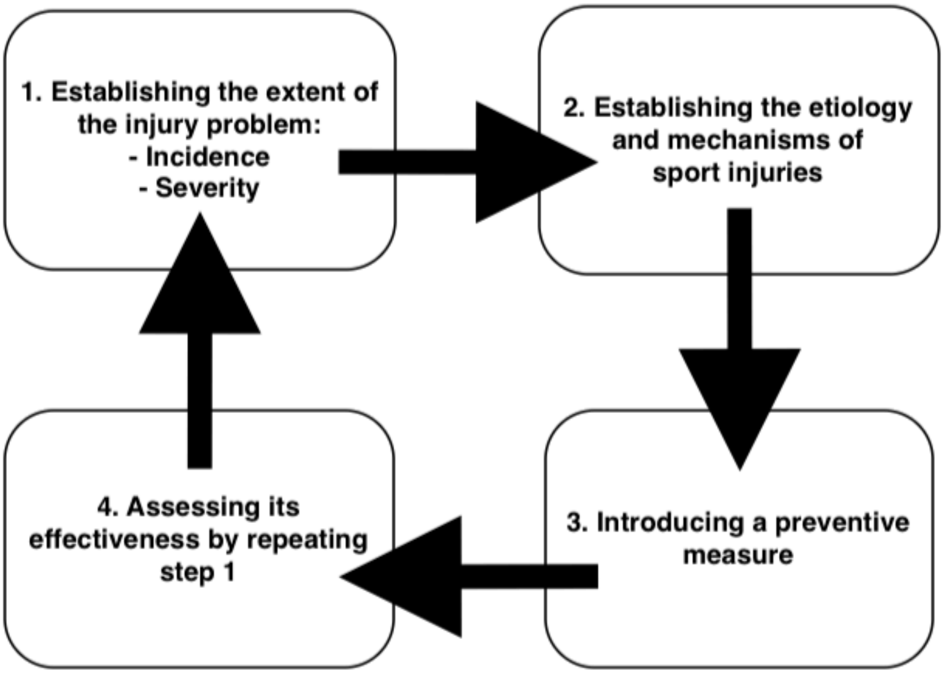


Figure 1: The 4-step sequence of prevention research (based on the work of van Mechelen et al. (1992))

The loading mechanisms associated with ACL injuries are multifactorial and to what extent different factors contribute to higher injury risk is still unclear. Several studies report that the injury mechanism involves landing stiffness with increased ground reaction force (GRF) and decreased knee flexion combined with a rapid valgus development and rotation of the tibia (Kiapour et al., 2016; Koga et al., 2010); Yu and Garrett (2007) describe the great posterior GRF and great quadriceps muscle force to both being associated with ACL injuries. Results from a recently published cadaver study show that, in the presence of an impulsive axial compression, combined anterior tibial shear force, knee abduction, and internal tibial rotation moments increase ACL strain significantly (Kiapour et al., 2016).

Several authors have suggested poor frontal plane knee control as a key feature of the injury mechanism (Brophy, Stepan, Silvers, & Mandelbaum, 2015; Cochrane, Lloyd, Buttfield, Seward, & McGivern, 2007; Ebstrup & Bojsen-Moller, 2000; Koga et al., 2010; Krosshaug et al., 2016). Results from a number of studies show that ACL ruptures when knee valgus loading and lateral compression at initial contact (IC) generate internal rotation of the tibia and anterior tibial translation (Koga et al., 2011; Koga et al., 2010; Matsumoto et al., 2001; Meyer & Haut, 2008). Several studies have also shown that the injury risk is higher with decreased knee flexion angle (Cochrane et al., 2007; Hewett et al., 2005; Koga et al., 2010; Leppanen et al., 2017; Renstrom et al., 2008; Yu & Garrett, 2007).

Weinhandl et al. (2013) calculated three-dimensional (3D) kinematics and kinetics during anticipated and unanticipated sidestep cutting. Their results showed that sagittal plane loading within the first 30 milliseconds after IC contributed to 62-67% of the peak ACL loading in a sidestep cutting manoeuvre while transverse and frontal plane components contributed to the remaining 38 %. The results also showed that unanticipated movements such as sidestep cutting increased the ACL loading compared to anticipated movements (Weinhandl et al., 2013).

1.6. Risk factors

Risk factors are often divided into extrinsic (external) and intrinsic (internal) factors (Bahr & Holme, 2003; Bahr & Krosshaug, 2005; Renstrom et al., 2008). Figure 2 depicts a summary of risk factors that may predispose and make an athlete susceptible for injury.

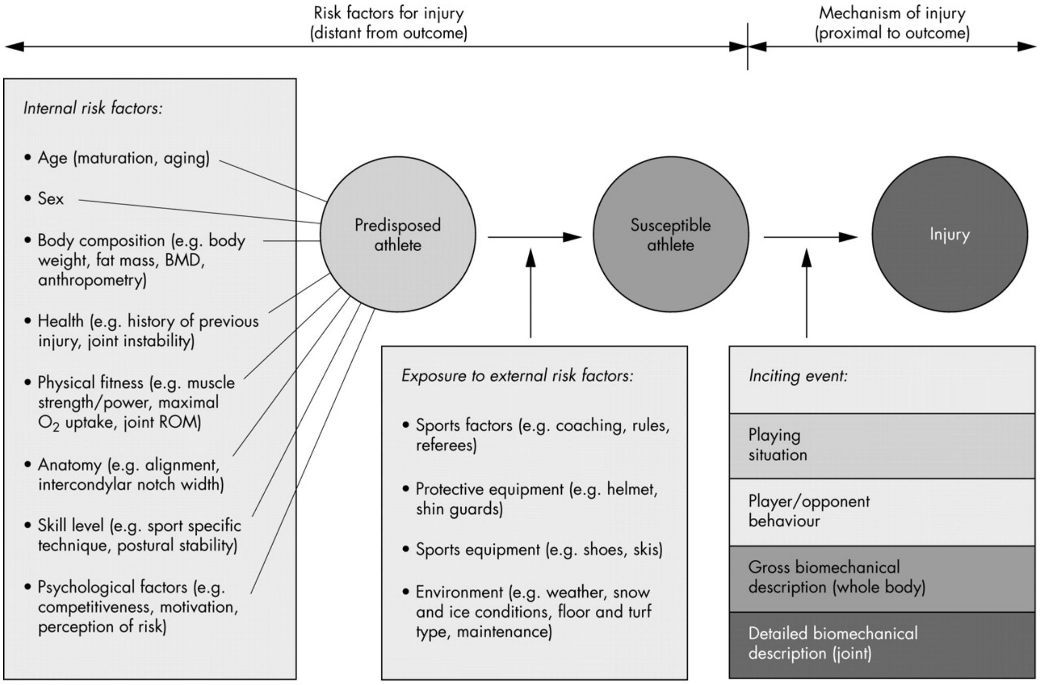


Figure 2: A model of injury causation (reproduced with permission from Bahr and Krosshaug (2005))

Several anatomical, hormonal and neuromuscular factors have been investigated and are summarized in an article by Shultz et al. (2015). In their consensus statement they reported that lower extremity alignment, size of the intercondylar femoral notch, tibial plateau geometry and ligament geometrics are anatomical factors that influences the risk of sustaining an ACL injury. In a review by Posthumus, Collins, September, and Schwellnus (2011), published articles that focused on intrinsic risk factors for ACL injuries were studied and the level of evidence of each study and level of certainty for each risk factor were determined. Only femoral notch geometry was given a high level of certainty based on reported results from studies with high level of evidence. Tibial plateau geometry, ACL geometry (for women), foot pronation, increased anterior pelvic tilt and anterior knee laxity (for women) were anatomical factors given a moderate level of certainty (Posthumus et al., 2011).

Hormonal factors include the structural and mechanical properties of the ACL, muscle performance and menstrual cycle (Renstrom et al., 2008; Shultz et al., 2012). Sex hormone concentrations vary across the menstrual cycle and seem to have an influence on collagen metabolism and production, knee joint laxity and muscle stiffness (Shultz et al., 2012). Some women are more influenced by these hormonal variations in concentration during the cycle than others. Menstrual cycle phase was given a moderate level of certainty by Posthumus et al. (2011).

The neuromuscular and neuromechanical factors include analyses of kinetics, kinematics, muscular activation and force production (Shultz et al., 2012). These factors are mainly modifiable risk factors and are important in the preventative work. A prospective study has reported a decreased preactivation in knee flexor muscles and an increased preactivation in knee extensor muscles during landings in subjects that subsequently sustained an ACL injury (Zebis, Andersen, Bencke, Kjaer, & Aagaard, 2009). However, this finding is based on a single study with only five injured cases, and the level of evidence is considered to be moderate at best (Posthumus et al., 2011). Isometric abduction and external hip rotation strength has been reported to independently predict ACL injuries (Khayambashi, Ghoddosi, Straub, & Powers, 2016), indicating that weakness in hip abductor and external rotator muscles is a modifiable risk factor. Excessive knee valgus collapse during landing is reported to increase injury risk in young female athletes (Hewett et al., 2005). Also, decreased knee flexion and hip flexion in landing seem to increase injury risk (Chappell, Creighton, Giuliani, Yu, & Garrett, 2007; Leppanen et al., 2017). A more upright posture is associated with increased vertical ground reaction forces, leading to increased demands on the quadriceps muscles and increased anterior tibial translation during the early stages of deceleration at IC (Shultz et al., 2012). Hewett, Ford, Hoogenboom, and Myer (2010) have also reported excessive trunk motion as a risk factor. Although research has lead to identifying different risk factors for ACL injury, there are still a lot of unanswered questions with regard to how these factors influence and to what extent they influence individually and combined with other factors.

The gender differences in injury risk may be explained by anatomical, hormonal and neuromuscular factors (Renstrom et al., 2008; Shultz et al., 2012). Neuromuscular factors are reported to be the most important reason for the higher injury rate in females compared to males (Griffin et al., 2000). Females have demonstrated more anterior tibial laxity and less muscle strength and endurance. Recruitment and generation of maximum hamstrings torque have been reported to be delayed in response to anterior tibial translation (Wojtys, Huston, Taylor, & Bastian, 1996). The female ligament is reported to have lower tensile linear stiffness, greater elongation and greater strain (Shultz et al., 2012). Greater tibiofemoral joint laxity and lower joint resistance to translation and rotation is also reported in women when compared to men (Posthumus et al., 2011; Renstrom et al., 2008; Shultz et al., 2012). Women appear to have a smaller and weaker ACL, but no significant differences in ACL volume between gender are reported when adjusted for weight (Chaudhari, Zelman, Flanigan, Kaeding, & Nagaraja, 2009).

There is strong evidence that performing preventative neuromuscular exercise programs reduce the risk of sustaining ACL injuries (Sugimoto et al., 2016; Sugimoto, Myer, McKeon, & Hewett, 2012; Taylor, Waxman, Richter, & Shultz, 2015). Implementing prevention and intervention programs targeting modifiable risk factors for ACL injury have resulted in improved movement pattern and landing technique with decreased knee valgus and increased knee flexion (Sugimoto et al., 2016; Thompson et al., 2017). The incidence of ACL injuries has also been reported to decrease by 40 to 80 % after implementation of exercise programs targeting these risk factors (Myer, Sugimoto, Thomas, & Hewett, 2013; Myklebust et al., 2003; Taylor et al., 2015; Walden, Atroshi, Magnusson, Wagner, & Hagglund, 2012). Preventive neuromuscular training programmes are reported to reduce ACL injury risk by 61 % when plyometric exercises are incorporated, 68 % when strengthening exercises are incorporated and 67 % when proximal control exercises are incorporated in young female athletes (Sugimoto et al., 2016). There are studies reporting that implementation of preventative exercise programs have no or minimal effect for reducing ACL injury risk, but these studies often reported poor compliance as well. Since implementation of preventative exercise programs is reported to reduce the risk of ACL injuries, there is still a need for investigating modifiable risk factors for ACL injuries to improve suggested prevention programs.

1.7. The value of performing screening tests

The purpose and intention of screening is to detect a disease or risk of injury in individuals without signs or symptoms of that disease/injury (Bahr, 2016). The objective of screening in sports injury prevention is to initiate intervention as early as possible to minimise risk factors before injury occurs. Potentially, screening could then reduce costs with regard to operations, medical care, rehabilitation, insurance and time lost from sports and other commitments. A screening test, with the purpose of predicting who will get injured, should have a high sensitivity and specificity. These properties are related, meaning that if you want to capture all injured players (100% sensitivity), the specificity becomes weaker since a higher number of non-injured players will be classified as high-risk athletes. Establishing a proper cut-off value for classifying high-risk and low-risk athletes could be both difficult. If the recommended intervention is easy and has no documented side effects, choosing a cut-off value representing high sensitivity would seem reasonable (Bahr, 2016). The recommended intervention for preventing ACL injuries is performing neuromuscular exercise, and the cut-off value of a screening test should therefore represent high sensitivity.

Development of a valid screening test is a challenging task and attempts with regard to this have repeatedly seemed to be failing. Bahr (2016) recently published a critical review about why screening tests to predict injury do not work and probably never will. He is pointing at three steps that need to be fulfilled. It has to be a strong relationship between the predictor (marker) and the injury risk (1). Properties of the test needs to be examined using appropriate statistical tools and with a sample drawn from relevant populations (2). If these two steps are done in an adequate way, the third step will be to document that screening-based intervention programs are more beneficial compared to intervention alone. Bahr (2016) concludes in his review that no example of a screening test for sports injuries with adequate test properties has yet been documented.

Although screening tests may not be able to predict injury with sufficient accuracy, they may have other potential positive outcomes. The tests can be useful for detecting significant associations and risk factors when they are systematically investigated as part of a large prospective cohort study (Bahr, 2016). Further, these risk factors may be helpful in the work of developing efficient preventative exercise programs where biomechanical technique correction or feedback is emphasized (Bahr & Krosshaug, 2005; Sugimoto et al., 2012). Compliance of preventative exercise programs for sports injuries seem to be a critical component for injury risk reduction, where higher compliance is reported to have a higher effect on injury risk reduction (Hägglund, Atroshi, Wagner, & Waldén, 2013; Soligard et al., 2010; Sugimoto et al., 2016; Sugimoto et al., 2012). Numbers-needed-to-treat analyses show that a relatively high amount of athletes need to undergo preventative training to prevent one ACL injury (Sugimoto et al., 2012). If a screening test has the ability to discriminate between high and low risk athletes, athletes classified as high risk athletes would potentially get more motivated to perform preventative training. One the other hand, this classification of athletes could lead to lack of motivation for low risk athletes to perform preventative training. These athletes will also have a risk of sustaining an ACL injury, and would therefore potentially benefit from performing preventative training.

1.8. The vertical drop jump test

The vertical drop jump (VDJ) test has been used as a screening test for predicting ACL injuries. The test has shown good inter- and intra-rater reliability and high sensitivity for identifying athletes with lower extremity biomechanics associated with increased risk of sustaining an ACL injury (Redler et al., 2016). The VDJ test has also shown good to excellent within-session and between-session reliability for knee biomechanical measures when testing both elite athletes and young athletes (Ford, Myer, & Hewett, 2007; Mok, Petushek, & Krosshaug, 2016). Using a real-time visual observation method of the test could reduce prevention time and increase effectiveness without the use of additional tools (Hewett et al., 2005). The VDJ test requires no expensive equipment and test only takes a few seconds to conduct. Using this test would potentially reduce time and costs significantly compared to the current use of biomechanical instrument-based methods (Hewett et al., 2005; Myer, Ford, Khoury, Succop, & Hewett, 2010).

Hewett et al. (2005) were the first to introduce the VDJ test as a screening tool for ACL injury risk estimation. This cohort study included 205 female athletes participating in high-risk sports and the athletes were measured prospectively for neuromuscular control using 3D kinematics and kinetics during the VDJ test. They used analysis of variance and logistic and linear regression to isolate predictors of risk in athletes who subsequently ruptured their ACL (n=9). The results showed that these nine injured athletes had significantly different knee posture and loading compared to those who did not get injured. The differences identified in the injured athletes were greater knee abduction moment and higher GRF.

Results from other injury risk factor studies indicate that the VDJ test is a poor screening tool for assessing ACL injury risk (Krosshaug et al., 2016; Leppanen et al., 2017; Smith et al., 2012), and contradicts the findings by Hewett et al. (2005). Leppanen et al. (2017) also reported that landing stiffness, with less knee flexion angle and greater vertical GRF (vGRF) in a VDJ test, were associated with increased risk of ACL injury in their sample of young female basketball and floorball players (n=171). However, the receiver operating characteristic (ROC) curve analysis based on knee flexion angle and vGRF revealed poor accuracy (area under the curve (AUC) 0.6 and 0.7, respectively). Krosshaug et al. (2016) assessed the VDJ performance of over 700 elite female football and handball players with marker-based 3D motion analyses. They studied five variables considered to give increased risk of injury: knee valgus angle at initial contact, peak knee abduction moment, peak knee flexion angle, peak vertical ground-reaction force and medial knee displacement. The corrected results showed that none of the five variables were associated with increased risk for ACL injuries for players with or without a history of previous ACL injury ("Corrigendum," 2017). Moreover, only a history of previous ACL injury was reported to increase risk of sustaining a new ACL injury.

1.9. Observational analysis methods

Three-dimensional motion analyses have been reported as the "gold standard" for assessing risk factors for ACL injuries (Stensrud et al., 2011). However, movements and skills acquired during ball and team sports are complex and therefore also challenging to analyse using instrument-based methods. Performing this type of analysis method in the environment athletes usually contest and train in can be difficult and results may lack validity. The use of visual assessment can give a number of advantages since it can be performed in the right context and without the use of any expensive, complex equipment (Savage & McIntosh, 2016). However, there are some concerns about the accuracy, objectivity and reliability using these methods.

The rating and judgement may be influenced by the observer's education level, skill and experience. Human behaviour highly adapts to the environmental demands (Ericsson & Lehmann, 1996), but research on how experience influences performance of a task shows inconsistent results. Ericsson and Lehmann (1996) define expert performance as "*consistently superior performance on a specified set of representative tasks for a domain.*" It is generally assumed that outstanding human performances reflect a varying balance between nurture (training and experience) and innate differences in nature (capacity and talent) (Ericsson & Lehmann, 1996).

Performance has been shown to decrease in environments' with large number of cues/variables (Karelaia & Hogarth, 2008). Since ACL injury mechanisms are associated with different movements, assessing risk during a VDJ test may involve observing multiple variables at a time. Bays and Husain (2008) reports that the demand on short-term memory and perceptual dynamics may be greater when observing multiple variables. This could again influence performance in observational movement assessment.

In 1956, Egon Brunswik developed The Lens Model, a conceptual framework for understanding ”achievement” or judgement performance by comparing the relationship between the human and an idealized (normative) judgement process (Brunswik, 1956). The judge uses ”proximal” variables or cues (i.e. knee valgus motion, landing symmetry, weight) in the uncertain environment to infer the current state (ACL injury risk status). These cues can be thought of as predictors in a regression model, whereas the ability of the judge to correctly assess these cues is considered the utilization coefficient. Some cues may be related or correlated with one another and the judge must choose the cue(s) that relate or correlate best with the current state. Ecological validities are by Brunswik (1956) considered to be the relationship between the cues and the actual state. Using this conceptual framework when looking at current literature on ACL injury risk estimation may lead to significant insights. Petushek (2014) has made a modified model based on the results reported from different studies (Figure 1).

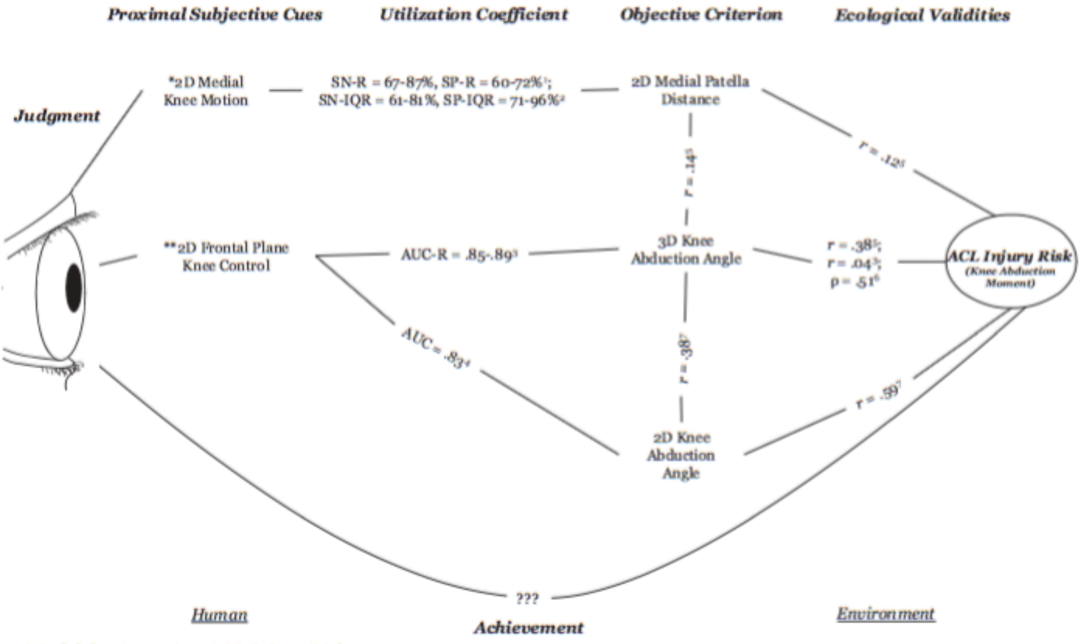


Figure 3: Lens Model for assessing ACL injury risk. Reproduced with permission from Petushek (2014)

Note. SN-R = Sensitivity Range; SP-R = Specificity Range; SN-IQR = Sensitivity Inter-quartile Range; SP-IQR = Specificity Inter-quartile Range; AUC-R = Area Under ROC curve Range; AUC = Area Under ROC; *(Patella medial to the toe; 2pt Scale); **(Knee Valgus Motion/Stability; 3pt Scale); [1]Ekegren, Miller, Celebrini, Eng, and Macintyre (2009) (n = 40 measurements; N = 3 Judges); [2]Whatman, Hume, and Hing (2013) (n = 23 measurements; n = 66 Judges); [3]Nilstad et al. (2014) (n = 60 measurements; N = 3 Judges); [4]Stensrud et al. (2011) (n =186 measurement; n= 1 Judge); [5]Unpublished data (n = 100 measurements); [6]Kristianslund and Krosshaug (2013) (n = 120 measurements); [7]Mizner, Chmielewski, Toepke, and Tofte (2012) (n = 36 measurements)

Some studies have reported results implying that physical therapists may have the ability to assess the movement and loadings of the knee joint associated with ACL injury risk during a VDJ test (Ekegren et al., 2009; Nilstad et al., 2014; Rabin, Levi, Abramowitz, & Kozol, 2016; Stensrud et al., 2011; Whatman, Hing, & Hume, 2012; Whatman et al., 2013). Results of these studies are based on assessment done by a small number of physical therapists. The assessors were also given specific cues to assess and the results are only valid for assessment of this cue. Results also lack generalizability to other individuals who would benefit from assessing ACL injury risk (Petushek, Ward, Cokely, & Myer, 2015).

1.10. Visual assessment of the VDJ test

Visual analysis of athletes performing the vertical drop jump test has shown that visual assessment may be sufficient for identifying potential risk factors associated with ACL injury (Ekegren et al., 2009; Nilstad et al., 2014; Petushek, Ward, et al., 2015). These studies have hypothesised that one or several variables in the movement analysis increase the risk of sustaining an ACL injury. Scores from the visual assessment of these variables have then been compared to 3D motion analysis of the same variable. Results from visual assessment of the VDJ test show that some individuals may have the ability to assess frontal plane knee motion (Ekegren et al., 2009; Nilstad et al., 2014; Petushek, Cokely, et al., 2015).

In the study of Nilstad et al. (2014) three physiotherapists independently viewed the performance of 60 players performing the VDJ test. The observational screening test scores were compared with frontal plane knee motion kinematics and kinetics measured through 3D motion analysis. They reported high accuracy for assessment of knee valgus angles (AUC 0.85-0.89), but poor accuracy for knee abduction moments (AUC 0.56-0.57) based on ROC analysis. Spearman rank correlation coefficient showed a moderate association between the observational test scores and knee valgus angles measured with 3D analysis (0.54-0.60). The results in their study indicate that visual assessment of the VDJ test may be useful for identifying players with poor or reduced knee control. Ekegren et al. (2009) studied the validity of observational risk screening using the VDJ test. Physiotherapists visually assessed dynamic knee valgus during a drop jump and their scores were compared to 3D motion analysis. The results showed that the sensitivity values of the observational ratings ranged from 67-87 %. This means that the assessors failed to detect about one third of the athletes with assumed high risk of sustaining an ACL injury when compared to the gold standard.

To examine the ability to estimate risk between individuals with different background, Petushek, Cokely, et al. (2015) developed a valid psychometric assessment for the estimation of knee abduction moment associated with ACL injury: the ACL Injury Risk Estimation Quiz (ACL-IQ). The test was intended to measure an individual's ability to visually estimate an athlete's potential risk of sustaining an ACL injury by assessing videos of young athletes performing VDJ's. The responses were compared with concurrent 3D biomechanical measurement of the knee abduction moment. In a following study by Petushek, Ward, et al. (2015) the test were made available online and assessors with different backgrounds (coaches, parents, players, physiotherapist, exercise science researchers etc.) conducted the test. The results from this study implied that physical therapists, athletic trainers, strength and conditioning coaches and exercise science students exhibited consistently superior ACL injury risk estimation ability compared with sport coaches, parents of athletes, and members of the general public (Petushek, Ward, et al., 2015). Based on these results, it can be hypothesised that some individuals may have an ability to identify players with increased risk of sustaining an ACL injury.

Both the studies of Ekegren et al. (2009) and Nilstad et al. (2014) have compared knee valgus motion with 3D motion analysis. A rapid knee valgus motion after initial contact during a landing is considered a key factor in the mechanism of an ACL injury (Koga et al., 2010). However, since the injury mechanism seems to be multifactorial, knee valgus motion alone may not be sufficient to predict high-risk athletes. As mentioned earlier, Krosshaug et al. (2016) reported in their study that knee valgus motion did not predict injury risk when measured with 3D motion analysis. Krosshaug et al. (2016) also reported that the knee flexion motion and the peak vertical ground reaction force not were associated with ACL injury risk. Since 3D motion analysis studies haven't been able to identify athletes at risk in this population either, the results from the visual assessment studies so far may lack clinical relevance due to this. However, visual assessment of the test may give individuals the ability to capture a bigger picture of the athlete's movement when no specific assessment instructions or cues are given in advance. No study has yet proven that visual assessment of the VDJ test is directly associated with ACL injury.

1.11. Confidence in visually assessing movement performance

Predicting injury through visual assessment of the VDJ test is a challenging task for the assessors and it would be interesting to know how confident assessors are in their decision-making. Kruger & Dunning presented in 1999 the unskilled and unaware phenomenon, which is based on the ability to know how well one is performing (Kruger & Dunning, 1999). According to literature people tend to overestimate their abilities and lack the ability to evaluate how well on is performing. This overestimation seem more miscalibrated when people are facing difficult tasks (Kruger & Dunning, 1999). The authors argue that it is the same knowledge or skill that underlies the ability to know when one is right and when one is wrong. Therefore, unskilled people suffer a dual burden: *"Not only do they perform poorly, but they fail to realize it"* (Kruger & Dunning, 1999). Assessment of people's confidence level for performing a risk rating assignment can further be compared to their accuracy level of the same assignment. Results from this comparison could indicate if the assessors should be more or less confident for performing this task.

1.12. Methodological considerations

There are mainly three designs available for studying injury risk factors: cohort studies, case control studies and intervention studies. The sample included in the current study is drawn from a large cohort study, which is the design most often preferred (Bahr & Holme, 2003). With this design, data can be collected standardised and prospectively for a long period of time. It is also an appropriate design for assessing several risk factors. In the current study, specific risk factors will not be measured and analysed, but movement patterns associated with injury risk will be assessed and can potentially detect significant associations and other risk factors (Bahr, 2016).

1.1.1 Sample size

A critical issue for this design is the need of a large number of athletes included and an exceedingly long study period, especially if the injury of interest occurs less frequently (Bahr & Holme, 2003). The number of athletes included in a risk factor study need to be carefully considered. A small number of athletes and total amount of injury cases seem to be a persistent problem in literature published so far. This means that the studies may lack power: the ability to identify an association between risk factors and reported injuries (Bahr & Holme, 2003). The power is affected by the strength of the true association between the risk factor and injury risk, the injury frequency and the significance level. In general, the more frequent the injury occur and the stronger the association between the risk factor and injury is, the smaller sample size is needed to maintain a proper power. Bahr and Holme (2003) report that a sample size of 20 to 50 injury cases is needed to detect a moderate to strong associations.

1.1.2 Pilot testing

The term pilot study refers to a small scale-test or trial run of the methods and procedures to be used in the major study (van Teijlingen, 2001). It is also called a ”feasibility study” (Leon, Davis, & Kraemer, 2011; van Teijlingen, 2001), and can be used to test research protocols, data collection instruments, sample recruitment and other research techniques before conducting the main study (Hassan, Schattner, & Mazza, 2006). Statistical analyses can be done with data material from the pilot study to make sure these are appropriate to use based on the purpose of the study.

1.1.3 Measuring accuracy of the assessment of the VDJ test

The ROC curve is a graphical plot that illustrates the performance of a binary classifier system as its discrimination threshold is varied (Hajian-Tilaki, 2013). There are four possible outcomes of a diagnostic test: a true positive test, false positive test, true negative test and false negative test. A ROC curve is a plot of the sensitivity (true positive) versus 1-specifisity (false positive) (Kiesel, Plisky, & Voight, 2007; Metz, 1978), and only the true positive rate (TPR) and the false positive rate (FPR) are needed to draw the curve. The TPR defines how many correct positive results occur among all positive samples available during the test (benefits), and the FPR defines how many incorrect results occur (costs) (Hajian-Tilaki, 2013). Using the VDJ test as an example: in the present study we can use the ROC curve to determine a cut-off score for assessment of the VDJ test when classifying athletes as low risk- or high risk-athletes for sustaining an ACL injury. Each prediction result represents one point in the ROC space. The best possible prediction method would yield a point in the upper left corner or coordinate (0,1) of the ROC space, representing 100% sensitivity (no false negatives) and 100% specificity (no false positives). This point is also called a perfect classification. If a point from a prediction result ends up along the diagonal line (0.5,0.5), this result would be similar to a random guess (Obuchowski, 2003). The longer distance from the diagonal line indicates a greater predictive power of the method (Hajian-Tilaki, 2013). The level of accuracy is often classified as excellent (0.9-1), good (0.8-0.9), fair (0.7-0.8), poor

(0.6-0.7) or fail (0.5-0.6), and is measured by the area under the ROC curve (AUC) (Lüdemann, Grieger, Wurm, Wust, & Zimmer, 2006). The AUC represents the probability that a classifier will rank a randomly chosen positive instance higher than a randomly chosen negative one, and is closely related to the Mann-Whitney U test and Wilcoxon test of ranks (Hajian-Tilaki, 2013).

2. REFERENCE LIST

Ageberg, E., Thomee, 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 Rheum, 59*(12), 1773-1779. doi:10.1002/art.24066

Anderson, M. J., Browning, W. M., 3rd, Urband, C. E., Kluczynski, M. A., & Bisson, L. J. (2016). A Systematic Summary of Systematic Reviews on the Topic of the Anterior Cruciate Ligament. *Orthop J Sports Med, 4*(3), 2325967116634074. doi:10.1177/2325967116634074

Andersson, D., Samuelsson, K., & Karlsson, J. (2009). Treatment of anterior cruciate ligament injuries with special reference to surgical technique and rehabilitation: an assessment of randomized controlled trials. *Arthroscopy, 25*(6), 653-685. doi:10.1016/j.arthro.2009.04.066

Arendt, E., Agel, J., & Dick, R. (1999). Anterior cruciate ligament injury patterns among collegiate men and women. *J Athl Train, 34*(2), 86-92.

Arendt, E., & Dick, R. (1995). Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature. *Am J Sports Med, 23*(6), 694-701.

Bahr, R. (2016). Why screening tests to predict injury do not work-and probably never will...: a critical review. *Br J Sports Med*. doi:10.1136/bjsports-2016-096256

Bahr, R., & Holme, I. (2003). Risk factors for sports injuries--a methodological approach. *Br J Sports Med, 37*(5), 384-392.

Bahr, R., & Krosshaug, T. (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. *Br J Sports Med, 39*(6), 324-329. doi:10.1136/bjsm.2005.018341

Bays, P. M., & Husain, M. (2008). Dynamic shifts of limited working memory resources in human vision. *Science, 321*(5890), 851-854. doi:10.1126/science.1158023

Brophy, R. H., Stepan, J. G., Silvers, H. J., & Mandelbaum, B. R. (2015). Defending Puts the Anterior Cruciate Ligament at Risk During Soccer: A Gender-Based Analysis. *Sports Health, 7*(3), 244-249. doi:10.1177/1941738114535184

Brukner, P., & Khan, K. A. A. (2012). *Brukner & Khan's clinical sports medicine* (4 ed.). Sydney: Mc Graw-Hill.

Brunswik, E. (1956). *Perception and the Representative Design of Psychological Experiments*: University of California Press.

Cappozzo, A., Catani, F., Leardini, A., Benedetti, M. G., & Croce, U. D. (1996). Position and orientation in space of bones during movement: experimental artefacts. *Clin Biomech (Bristol, Avon), 11*(2), 90-100.

Chappell, J. D., Creighton, R. A., Giuliani, C., Yu, B., & Garrett, W. E. (2007). Kinematics and electromyography of landing preparation in vertical stop-jump: risks for noncontact anterior cruciate ligament injury. *Am J Sports Med, 35*(2), 235-241. doi:10.1177/0363546506294077

Chaudhari, A. M. W., Zelman, E. A., Flanigan, D. C., Kaeding, C. C., & Nagaraja, H. N. (2009). ACL-Injured Subjects Have Smaller ACLs Than Matched Controls: An MRI Study. *Am J Sports Med, 37*(7), 1282-1287. doi:10.1177/0363546509332256

Cochrane, J. L., Lloyd, D. G., Buttfield, A., Seward, H., & McGivern, J. (2007). Characteristics of anterior cruciate ligament injuries in Australian football. *J Sci Med Sport, 10*(2), 96-104. doi:10.1016/j.jsams.2006.05.015

Corrigendum. (2017). *Am J Sports Med, 45*(9), NP28-NP29. doi:10.1177/0363546517716155

Ebstrup, J. F., & Bojsen-Moller, F. (2000). Anterior cruciate ligament injury in indoor ball games. *Scand J Med Sci Sports, 10*(2), 114-116.

Ekegren, C. L., Miller, W. C., Celebrini, R. G., Eng, J. J., & Macintyre, D. L. (2009). Reliability and validity of observational risk screening in evaluating dynamic knee valgus. *J Orthop Sports Phys Ther, 39*(9), 665-674. doi:10.2519/jospt.2009.3004

Ericsson, K. A., & Lehmann, A. C. (1996). Expert and exceptional performance: evidence of maximal adaptation to task constraints. *Annu Rev Psychol, 47*, 273-305. doi:10.1146/annurev.psych.47.1.273

Fagenbaum, R., & Darling, W. G. (2003). Jump landing strategies in male and female college athletes and the implications of such strategies for anterior cruciate ligament injury. *Am J Sports Med, 31*(2), 233-240. doi:10.1177/03635465030310021301

Filbay, S. R., Ackerman, I. N., Russell, T. G., Macri, E. M., & Crossley, K. M. (2014). Health-related quality of life after anterior cruciate ligament reconstruction: a systematic review. *Am J Sports Med, 42*(5), 1247-1255. doi:10.1177/0363546513512774

Ford, K. R., Myer, G. D., & Hewett, T. E. (2003). Valgus knee motion during landing in high school female and male basketball players. *Med Sci Sports Exerc, 35*(10), 1745-1750. doi:10.1249/01.mss.0000089346.85744.d9

Ford, K. R., Myer, G. D., & Hewett, T. E. (2007). Reliability of Landing 3D Motion Analysis. *39*, 2021-2028. doi:10.1249/mss.0b013e318149332d

Frobell, R. B., Lohmander, L. S., & Roos, H. P. (2007). Acute rotational trauma to the knee: poor agreement between clinical assessment and magnetic resonance imaging findings. *Scand J Med Sci Sports, 17*(2), 109-114. doi:10.1111/j.1600-0838.2006.00559.x

Granan, L. P., Bahr, R., Steindal, K., Furnes, O., & Engebretsen, L. (2008). Development of a national cruciate ligament surgery registry: the Norwegian National Knee Ligament Registry. *Am J Sports Med, 36*(2), 308-315. doi:10.1177/0363546507308939

Griffin, L. Y., Agel, J., Albohm, M. J., Arendt, E. A., Dick, R. W., Garrett, W. E., . . . Wojtys, E. M. (2000). Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. *J Am Acad Orthop Surg, 8*(3), 141-150.

Grindem, H., 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 Delaware-Oslo ACL Cohort Study. *J Bone Joint Surg Am, 96*(15), 1233-1241. doi:10.2106/jbjs.m.01054

Hajian-Tilaki, K. (2013). Receiver Operating Characteristic (ROC) Curve Analysis for Medical Diagnostic Test Evaluation. *Caspian Journal of Internal Medicine, 4*(2), 627-635.

Hassan, Z. A., Schattner, P., & Mazza, D. (2006). Doing A Pilot Study: Why Is It Essential? *Malaysian Family Physician : the Official Journal of the Academy of Family Physicians of Malaysia, 1*(2-3), 70-73.

Hewett, T. E., Ford, K. R., Hoogenboom, B. J., & Myer, G. D. (2010). Understanding and preventing ACL injuries: current biomechanical and epidemiologic considerations - update 2010. *North American Journal of Sports Physical Therapy : NAJSPT, 5*(4), 234-251.

Hewett, T. E., Myer, G., Ford, K., Heidt, R., Colosimo, A., McLean, S., . . . 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. *Am J Sports Med, 33*(4), 492-501. doi:10.1177/0363546504269591

Hägglund, M., Atroshi, I., Wagner, P., & Waldén, M. (2013). Superior compliance with a neuromuscular training programme is associated with fewer ACL injuries and fewer acute knee injuries in female adolescent football players: secondary analysis of an RCT. *Br J Sports Med, 47*(15), 974-979. doi:10.1136/bjsports-2013-092644

Ingersoll, C. D., Grindstaff, T. L., Pietrosimone, B. G., & Hart, J. M. (2008). Neuromuscular Consequences of Anterior Cruciate Ligament Injury. *Clinics in Sports Medicine, 27*(3), 383-404.

Johnsen, M. B., Guddal, M. H., Smastuen, M. C., Moksnes, H., Engebretsen, L., Storheim, K., & Zwart, J. A. (2016). Sport Participation and the Risk of Anterior Cruciate Ligament Reconstruction in Adolescents: A Population-based Prospective Cohort Study (The Young-HUNT Study). *Am J Sports Med, 44*(11), 2917-2924. doi:10.1177/0363546516643807

Joseph, A. M., Collins, C. L., Henke, N. M., Yard, E. E., Fields, S. K., & Comstock, R. D. (2013). A Multisport Epidemiologic Comparison of Anterior Cruciate Ligament Injuries in High School Athletics. *Journal of Athletic Training, 48*(6), 810-817. doi:10.4085/1062-6050-48.6.03

Karelaia, N., & Hogarth, R. M. (2008). Determinants of linear judgment: a meta-analysis of lens model studies. *Psychol Bull, 134*(3), 404-426. doi:10.1037/0033-2909.134.3.404

Khayambashi, K., Ghoddosi, N., Straub, R. K., & Powers, C. M. (2016). Hip Muscle Strength Predicts Noncontact Anterior Cruciate Ligament Injury in Male and Female Athletes:

A Prospective Study. *Am J Sports Med, 44*(2), 355-361. doi:10.1177/0363546515616237

Kiapour, A. M., Demetropoulos, C. K., Kiapour, A., Quatman, C. E., Wordeman, S. C., Goel, V. K., & Hewett, T. E. (2016). Strain Response of the Anterior Cruciate Ligament to Uniplanar and Multiplanar Loads During Simulated Landings: Implications for Injury Mechanism. *Am J Sports Med*. doi:10.1177/0363546516640499

Kiesel, K., Plisky, P. J., & Voight, M. L. (2007). Can Serious Injury in Professional Football be Predicted by a Preseason Functional Movement Screen? *North American Journal of Sports Physical Therapy : NAJSPT, 2*(3), 147-158.

Koga, H., Bahr, R., Myklebust, G., Engebretsen, L., Grund, T., & Krosshaug, T. (2011). Estimating anterior tibial translation from model-based image-matching of a noncontact anterior cruciate ligament injury in professional football: a case report. *Clin J Sport Med, 21*(3), 271-274. doi:10.1097/JSM.0b013e31821899ec

Koga, H., Nakamae, A., Shima, Y., Iwasa, J., Myklebust, G., Engebretsen, L., . . . Krosshaug, T. (2010). Mechanisms for noncontact anterior cruciate ligament injuries: knee joint kinematics in 10 injury situations from female team handball and basketball. *Am J Sports Med, 38*(11), 2218-2225. doi:10.1177/0363546510373570

Kristianslund, E., & Krosshaug, T. (2013). Comparison of Drop Jumps and Sport-Specific Sidestep Cutting. *Am J Sports Med, 41*(3), 684-688. doi:10.1177/0363546512472043

Krogsgaard, M. R., Dyhre-Poulsen, P., & Fischer-Rasmussen, T. (2002). Cruciate ligament reflexes. *J Electromyogr Kinesiol, 12*(3), 177-182.

Krosshaug, T., Nakamae, A., Boden, B. P., Engebretsen, L., Smith, G., Slauterbeck, J. R., . . . Bahr, R. (2007). Mechanisms of anterior cruciate ligament injury in basketball: video analysis of 39 cases. *Am J Sports Med, 35*(3), 359-367. doi:10.1177/0363546506293899

Krosshaug, T., Steffen, K., Kristianslund, E., Nilstad, A., Mok, K. M., Myklebust, G., . . . Bahr, R. (2016). The Vertical Drop Jump Is a Poor Screening Test for ACL Injuries in Female Elite Soccer and Handball Players: A Prospective Cohort Study of 710 Athletes. *Am J Sports Med, 44*(4), 874-883. doi:10.1177/0363546515625048

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. *J Pers Soc Psychol, 77*(6), 1121-1134.

Leon, A. C., Davis, L. L., & Kraemer, H. C. (2011). The Role and Interpretation of Pilot Studies in Clinical Research. *Journal of psychiatric research, 45*(5), 626-629. doi:10.1016/j.jpsychires.2010.10.008

Leppanen, M., Pasanen, K., Kujala, U. M., Vasankari, T., Kannus, P., Ayramo, S., . . . Parkkari, J. (2017). Stiff Landings Are Associated With Increased ACL Injury Risk in Young Female Basketball and Floorball Players. *Am J Sports Med, 45*(2), 386-393. doi:10.1177/0363546516665810

Li, R. T., Lorenz, S., Xu, Y., Harner, C. D., Fu, F. H., & Irrgang, J. J. (2011). Predictors of radiographic knee osteoarthritis after anterior cruciate ligament reconstruction. *Am J Sports Med, 39*(12), 2595-2603. doi:10.1177/0363546511424720

Lüdemann, L., Grieger, W., Wurm, R., Wust, P., & Zimmer, C. (2006). Glioma Assessment Using Quantitative Blood Volume Maps Generated by T1-Weighted Dynamic Contrast-Enhanced Magnetic Resonance Imaging: A Receiver Operating Characteristic Study. *Acta Radiologica, 47*(3), 303-310. doi:10.1080/02841850500539033

Matsumoto, H., Suda, Y., Otani, T., Niki, Y., Seedhom, B. B., & Fujikawa, K. (2001). Roles of the anterior cruciate ligament and the medial collateral ligament in preventing valgus instability. *J Orthop Sci, 6*(1), 28-32.

McLean, S. G., Walker, K., Ford, K. R., Myer, G. D., Hewett, T. E., & van den Bogert, A. J. (2005). Evaluation of a two dimensional analysis method as a screening and evaluation tool for anterior cruciate ligament injury. *Br J Sports Med, 39*(6), 355-362. doi:10.1136/bjsm.2005.018598

Metz, C. E. (1978). Basic principles of ROC analysis. *Semin Nucl Med, 8*(4), 283-298.

Meyer, E. G., & Haut, R. C. (2008). Anterior cruciate ligament injury induced by internal tibial torsion or tibiofemoral compression. *J Biomech, 41*(16), 3377-3383. doi:10.1016/j.jbiomech.2008.09.023

Mihata, L. C., Beutler, A. I., & Boden, B. P. (2006). Comparing the incidence of anterior cruciate ligament injury in collegiate lacrosse, soccer, and basketball players: implications for anterior cruciate ligament mechanism and prevention. *Am J Sports Med, 34*(6), 899-904. doi:10.1177/0363546505285582

Mizner, R. L., Chmielewski, T. L., Toepke, J. J., & Tofte, K. B. (2012). Comparison of 2-dimensional measurement techniques for predicting knee angle and moment during a drop vertical jump. *Clin J Sport Med, 22*(3), 221-227. doi:10.1097/JSM.0b013e31823a46ce

Mok, K. M., Petushek, E., & Krosshaug, T. (2016). Reliability of knee biomechanics during a vertical drop jump in elite female athletes. *Gait Posture, 46*, 173-178. doi:10.1016/j.gaitpost.2016.03.003

Myer, G. D., Ford, K. R., Khoury, J., Succop, P., & Hewett, T. E. (2010). Development and validation of a clinic-based prediction tool to identify female athletes at high risk for anterior cruciate ligament injury. *Am J Sports Med, 38*(10), 2025-2033. doi:10.1177/0363546510370933

Myer, G. D., Sugimoto, D., Thomas, S., & Hewett, T. E. (2013). The influence of age on the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: a meta-analysis. *Am J Sports Med, 41*(1), 203-215. doi:10.1177/0363546512460637

Myklebust, G., Engebretsen, L., Braekken, I. H., Skjolberg, A., Olsen, O. E., & Bahr, R. (2003). Prevention of anterior cruciate ligament injuries in female team handball players: a prospective intervention study over three seasons. *Clin J Sport Med, 13*(2), 71-78.

Myklebust, G., Maehlum, S., Holm, I., & Bahr, R. (1998). A prospective cohort study of anterior cruciate ligament injuries in elite Norwegian team handball. *Scand J Med Sci Sports, 8*(3), 149-153.

Nilstad, A., Andersen, T. E., Kristianslund, E., Bahr, R., Myklebust, G., Steffen, K., & Krosshaug, T. (2014). Physiotherapists can identify female football players with high knee valgus angles during vertical drop jumps using real-time observational screening. *J Orthop Sports Phys Ther, 44*(5), 358-365. doi:10.2519/jospt.2014.4969

Nordenvall, R., Bahmanyar, S., Adami, J., Stenros, C., Wredmark, T., & Fellander-Tsai, L. (2012). A population-based nationwide study of cruciate ligament injury in Sweden, 2001-2009: incidence, treatment, and sex differences. *Am J Sports Med, 40*(8), 1808-1813. doi:10.1177/0363546512449306

Numata, H., Nakase, J., Kitaoka, K., Shima, Y., Oshima, T., Takata, Y., . . . Tsuchiya, H. (2017). Two-dimensional motion analysis of dynamic knee valgus identifies female high school athletes at risk of non-contact anterior cruciate ligament injury. *Knee Surg Sports Traumatol Arthrosc*. doi:10.1007/s00167-017-4681-9

Obuchowski, N. A. (2003). Receiver operating characteristic curves and their use in radiology. *Radiology, 229*(1), 3-8. doi:10.1148/radiol.2291010898

Oiestad, B. E., Engebretsen, L., Storheim, K., & Risberg, M. A. (2009). Knee osteoarthritis after anterior cruciate ligament injury: a systematic review. *Am J Sports Med, 37*(7), 1434-1443. doi:10.1177/0363546509338827

Oiestad, B. E., 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. *Am J Sports Med, 38*(11), 2201-2210. doi:10.1177/0363546510373876

Olsen, O. E., Myklebust, G., Engebretsen, L., & Bahr, R. (2004). Injury mechanisms for anterior cruciate ligament injuries in team handball: a systematic video analysis. *Am J Sports Med, 32*(4), 1002-1012.

Petushek, E. J. (2014). Development and validation of the anterior cruciate ligament injury-risk-estimation quiz (ACL-IQ). *Michigan Techological University*. doi:http://digitalcommons.mtu.edu/etds/794

Petushek, E. J., Cokely, E. T., Ward, P., Durocher, J. J., Wallace, S. J., & Myer, G. D. (2015). Injury Risk Estimation Expertise: Assessing the ACL Injury Risk Estimation Quiz. *Am J Sports Med, 43*(7), 1640-1647. doi:10.1177/0363546515580791

Petushek, E. J., Ward, P., Cokely, E. T., & Myer, G. D. (2015). Injury Risk Estimation Expertise: Interdisciplinary Differences in Performance on the ACL Injury Risk Estimation Quiz. *Orthopaedic Journal of Sports Medicine, 3*(11), 2325967115614799. doi:10.1177/2325967115614799

Posthumus, M., Collins, M., September, A., & Schwellnus, M. (2011). *The Intrinsic Risk Factors for ACL Ruptures: An Evidence-Based Review* (Vol. 39).

Rabin, A., Levi, R., Abramowitz, S., & Kozol, Z. (2016). A new real-time visual assessment method for faulty movement patterns during a jump-landing task. *Physical Therapy in Sport, 20*, 7-12.

Redler, L. H., Watling, J. P., Dennis, E. R., Swart, E., & Ahmad, C. S. (2016). Reliability of a field-based drop vertical jump screening test for ACL injury risk assessment. *Phys Sportsmed, 44*(1), 46-52. doi:10.1080/00913847.2016.1131107

Reinschmidt, C., van den Bogert, A. J., Nigg, B. M., Lundberg, A., & Murphy, N. (1997). Effect of skin movement on the analysis of skeletal knee joint motion during running. *J Biomech, 30*(7), 729-732.

Renstrom, P., Ljungqvist, A., Arendt, E., Beynnon, B., Fukubayashi, T., Garrett, W., . . . Engebretsen, L. (2008). Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. *Br J Sports Med, 42*(6), 394-412. doi:10.1136/bjsm.2008.048934

Sanders, T. L., Maradit Kremers, H., Bryan, A. J., Larson, D. R., Dahm, D. L., Levy, B. A., . . . Krych, A. J. (2016). Incidence of Anterior Cruciate Ligament Tears and Reconstruction. *Am J Sports Med, 44*(6), 1502-1507. doi:10.1177/0363546516629944

Savage, T. N., & McIntosh, A. S. (2016). Tackling reliability and construct validity: the systematic development of a qualitative protocol for skill and incident analysis. *J Sports Sci*, 1-8. doi:10.1080/02640414.2016.1172722

Shultz, S. J., Schmitz, R. J., Benjaminse, A., Chaudhari, A. M., Collins, M., & Padua, D. A. (2012). ACL Research Retreat VI: An Update on ACL Injury Risk and Prevention: March 22–24, 2012; Greensboro, NC. *Journal of Athletic Training, 47*(5), 591-603.

Shultz, S. J., Schmitz, R. J., Benjaminse, A., Collins, M., Ford, K., & Kulas, A. S. (2015). ACL Research Retreat VII: An Update on Anterior Cruciate Ligament Injury Risk Factor Identification, Screening, and Prevention. *J Athl Train, 50*(10), 1076-1093. doi:10.4085/1062-6050-50.10.06

Smith, H. C., Johnson, R. J., Shultz, S. J., Tourville, T., Holterman, L. A., Slauterbeck, J., . . . Beynnon, B. D. (2012). A prospective evaluation of the Landing Error Scoring System (LESS) as a screening tool for anterior cruciate ligament injury risk. *Am J Sports Med, 40*(3), 521-526. doi:10.1177/0363546511429776

Soligard, T., Nilstad, A., Steffen, K., Myklebust, G., Holme, I., Dvorak, J., . . . Andersen, T. E. (2010). Compliance with a comprehensive warm-up programme to prevent injuries in youth football. *Br J Sports Med, 44*(11), 787-793. doi:10.1136/bjsm.2009.070672

Stensrud, S., Myklebust, G., Kristianslund, E., Bahr, R., & Krosshaug, T. (2011). Correlation between two-dimensional video analysis and subjective assessment in evaluating knee control among elite female team handball players. *Br J Sports Med, 45*(7), 589-595. doi:10.1136/bjsm.2010.078287

Struewer, J., Frangen, T. M., Ishaque, B., Bliemel, C., Efe, T., Ruchholtz, S., & Ziring, E. (2012). Knee function and prevalence of osteoarthritis after isolated anterior cruciate ligament reconstruction using bone-patellar tendon-bone graft: long-term follow-up. *Int Orthop, 36*(1), 171-177. doi:10.1007/s00264-011-1345-0

Sugimoto, D., Myer, G. D., Barber Foss, K. D., Pepin, M. J., Micheli, L. J., & Hewett, T. E. (2016). Critical components of neuromuscular training to reduce ACL injury risk in female athletes: meta-regression analysis. *Br J Sports Med, 50*(20), 1259-1266. doi:10.1136/bjsports-2015-095596

Sugimoto, D., Myer, G. D., McKeon, J. M., & Hewett, T. E. (2012). Evaluation of the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: a critical review of relative risk reduction and numbers-needed-to-treat analyses. *Br J Sports Med, 46*(14), 979-988. doi:10.1136/bjsports-2011-090895

Taylor, J. B., Waxman, J. P., Richter, S. J., & Shultz, S. J. (2015). Evaluation of the effectiveness of anterior cruciate ligament injury prevention programme training components: a systematic review and meta-analysis. *Br J Sports Med, 49*(2), 79-87. doi:10.1136/bjsports-2013-092358

Thompson, J. A., Tran, A. A., Gatewood, C. T., Shultz, R., Silder, A., Delp, S. L., & Dragoo, J. L. (2017). Biomechanical Effects of an Injury Prevention Program in Preadolescent Female Soccer Athletes. *Am J Sports Med, 45*(2), 294-301. doi:10.1177/0363546516669326 van Mechelen, W., Hlobil, H., & Kemper, H. C. (1992). Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med, 14*(2), 82-99.

van Teijlingen, E., Hundley, V. (2001). The importance of pilot studies. *Social Research Update, 35*.

Walden, M., Atroshi, I., Magnusson, H., Wagner, P., & Hagglund, M. (2012). Prevention of acute knee injuries in adolescent female football players: cluster randomised controlled trial. *Bmj, 344*, e3042. doi:10.1136/bmj.e3042

Walden, M., Hagglund, M., Werner, J., & Ekstrand, J. (2011). The epidemiology of anterior cruciate ligament injury in football (soccer): a review of the literature from a gender-related perspective. *Knee Surg Sports Traumatol Arthrosc, 19*(1), 3-10. doi:10.1007/s00167-010-1172-7

Walden, M., Krosshaug, T., Bjorneboe, J., Andersen, T. E., Faul, O., & Hagglund, M. (2015). Three distinct mechanisms predominate in non-contact anterior cruciate ligament injuries in male professional football players: a systematic video analysis of 39 cases. *Br J Sports Med, 49*(22), 1452-1460. doi:10.1136/bjsports-2014-094573

Weinhandl, J. T., Earl-Boehm, J. E., Ebersole, K. T., Huddleston, W. E., Armstrong, B. S., & O'Connor, K. M. (2013). Anticipatory effects on anterior cruciate ligament loading during sidestep cutting. *Clin Biomech (Bristol, Avon), 28*(6), 655-663. doi:10.1016/j.clinbiomech.2013.06.001

Whatman, C., Hing, W., & Hume, P. (2012). Physiotherapist agreement when visually rating movement quality during lower extremity functional screening tests. *Phys Ther Sport, 13*(2), 87-96. doi:10.1016/j.ptsp.2011.07.001

Whatman, C., Hume, P., & Hing, W. (2013). The reliability and validity of physiotherapist visual rating of dynamic pelvis and knee alignment in young athletes. *Phys Ther Sport, 14*(3), 168-174. doi:10.1016/j.ptsp.2012.07.001

Wiggins, A. J., Grandhi, R. K., Schneider, D. K., Stanfield, D., Webster, K. E., & Myer, G. D. (2016). Risk of Secondary Injury in Younger Athletes After Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-analysis. *Am J Sports Med, 44*(7), 1861-1876. doi:10.1177/0363546515621554

Wojtys, E. M., Huston, L. J., Taylor, P. D., & Bastian, S. D. (1996). Neuromuscular adaptations in isokinetic, isotonic, and agility training programs. *Am J Sports Med, 24*(2), 187-192. doi:10.1177/036354659602400212

Woo, S. L., Abramowitch, S. D., Kilger, R., & Liang, R. (2006). Biomechanics of knee ligaments: injury, healing, and repair. *J Biomech, 39*(1), 1-20. doi:10.1016/j.jbiomech.2004.10.025

Yu, B., & Garrett, W. E. (2007). Mechanisms of non-contact ACL injuries. *Br J Sports Med, 41 Suppl 1*, i47-51. doi:10.1136/bjsm.2007.037192

Zebis, M. K., Andersen, L. L., Bencke, J., Kjaer, M., & Aagaard, P. (2009). Identification of athletes at future risk of anterior cruciate ligament ruptures by neuromuscular screening. *Am J Sports Med, 37*(10), 1967-1973. doi:10.1177/0363546509335000

3. ARTICLE

Date

October 30, 2017

Title

Sports medicine professionals cannot predict ACL injury risk in elite female players: A ROC analysis of visual assessment of the vertical drop jump test.

Author list

Anne Inger Mørtvedt, PT, Tron Krosshaug, PhD[1], Erich Petushek, PhD, CSCS[2]

Affiliations

[1]Oslo Sports Trauma Research Center, Department of Sports Medicine, Norwegian School of Sport Sciences, Oslo, Norway
[2]College of Human Medicine, Michigan State University, East Lansing, Michigan, USA.; Department of Health and Human Performance, Northern Michigan University, Marquette, Michigan, USA

Correspondence to:

Anne Inger Mørtvedt, Oslo Sports Trauma Research Center,
Department of Sports Medicine, Norwegian School of Sport Sciences, PB 4014 Ullevål Stadion, Oslo 0806, Norway, Phone: + 47 95816015, E-mail: aim_@hotmail.com

Keywords: ACL; injury risk; visual assessment; VDJ test; female; elite; handball; football

Word count: 3972

3.1. Abstract

Background: The vertical drop jump (VDJ) test has been suggested as a screening tool for assessing anterior cruciate ligament (ACL) injury risk. Except from one smaller cohort study, no study has so far reported that individuals or computerized methods can identify high-risk players based on the VDJ test when ACL injury is used as the outcome.

Objectives: To examine if sports and sports medicine professionals have the ability to identify players at risk of sustaining an ACL injury by assessing the players' performance of a VDJ test.

Methods: One hundred and ten video clips of elite female handball and football players performing the VDJ test were uploaded in an online survey. Sports and sports medicine professionals were invited to assess their performance and rate each clip with a number between 1 and 10 (1 representing low risk of sustaining an ACL injury and 10 representing high risk). Receiver operating characteristic (ROC) analysis was used to assess classification accuracy level for each assessor and between-group differences were analysed using One-way ANOVA.

Results: Two hundred and thirty seven participants completed the survey. Area under the curve (AUC) values ranged from 0.37 to 0.61, with a mean score of 0.48. There were no significant differences between groups (e.g. physicians, coaches, certified athletic trainers, researchers or physical therapists).

Conclusion: AUC values revealed assessors have poor predictive ability (and no better than guessing or chance), indicating that visual assessment of the VDJ test is a poor test for assessing ACL injury risk in elite female handball and football players.

Keywords: ACL; injury risk; visual assessment; VDJ test; female; elite; handball; football

3.2. Introduction

Anterior cruciate ligament (ACL) injuries are a costly problem in sports, especially within athletes participating in contact or landing and pivoting sports. The reported incidence of ACL injuries in pivoting sports is up to 2 to 6 times higher in female compared to male athletes (Arendt, Agel, & Dick, 1999; Joseph et al., 2013; Walden, Hagglund, Werner, & Ekstrand, 2011). The incidence of ACL injuries in female athletes is 0.28-0.32 per 1000 athletic exposures compared to 0.09-0.12 among male athletes (Arendt & Dick, 1995; Mihata, Beutler, & Boden, 2006; Renstrom et al., 2008), but the ratio seem to decrease as females mature and the level of play increases (Renstrom et al., 2008). The injury itself causes severe consequences for the player regarding time lost from sports, decreased performance and increased risk of re-injury. In a long-term perspective the injury also increase the risk of early osteoarthritis, pain and reduced knee function (Li et al., 2011; Struewer et al., 2012).

An athlete's movement patterns may reveal important information associated with ACL injury risk. The injury mechanism appears to be multifactorial and it's been hypothesized that the ACL ruptures by knee valgus loading and lateral compression at initial contact (IC) generating internal rotation of the tibia and anterior tibial translation (Koga et al., 2011; Koga et al., 2010; Matsumoto et al., 2001; Meyer & Haut, 2008). Increased ground reaction force (GRF) (Hewett et al., 2005; Leppanen et al., 2017; Yu & Garrett, 2007), decreased knee flexion angle (Cochrane, Lloyd, Buttfield, Seward, & McGivern, 2007; Koga et al., 2010; Leppanen et al., 2017; Renstrom et al., 2008; Yu & Garrett, 2007), femorotibial translation (Koga et al., 2011), knee valgus (Ebstrup & Bojsen-Moller, 2000; Koga et al., 2010; Krosshaug et al., 2007; Renstrom et al., 2008), knee abduction moment (Hewett et al., 2005; Kiapour et al., 2016) and tibial rotations (Ebstrup & Bojsen-Moller, 2000; Kiapour et al., 2016; Koga et al., 2010; Renstrom et al., 2008) are all factors seen when analysing injury situations, and could therefore be associated with increased risk of ACL injury. To what extent the different factors contribute to higher injury risk remains unclear.

Screening of athletes for injury prediction purposes have been an area of debate in the literature lately, and according to Bahr (2016), to date, no screening test with adequate sensitivity and specificity for predicting injury has been developed for sports injuries. Anyway, associations reported from prospective cohort studies and intervention studies (based on screening) can be helpful in understanding causative factors (Bahr, 2016).

Decisions on whether a prevention program should be introduced, and who may benefit from it, can easier be made based on the results of these studies (Bahr, 2016).

The use of vertical drop jump (VDJ) test as a screening tool for assessing ACL injury risk has been investigated, but the results are inconsistent. Hewett et al. (2005) reported that increased knee abduction moment and GRF increases injury risk. On the other hand, Leppanen et al. (2017) reported that GRF could be associated with, but not predict injury, while Krosshaug et al. (2016) reported that neither GRF or knee abduction moment could predict ACL injury. These results are based on three different cohorts, which may be a possible reason for the different findings. Assessing the performance of a VDJ is hypothesised to identify several risk factors associated with ACL injuries (Redler, Watling, Dennis, Swart, & Ahmad, 2016), especially the frontal plane knee motion (Ford, Myer, & Hewett, 2003; McLean et al., 2005; Nilstad et al., 2014; Stensrud, Myklebust, Kristianslund, Bahr, & Krosshaug, 2011). There are studies reporting that physiotherapists may have the ability to visually identify different risk factors during a drop jump based on a comparison with the results of three-dimensional (3D) motion analyses (Ekegren, Miller, Celebrini, Eng, & Macintyre, 2009; Nilstad et al., 2014; Petushek, Cokely, et al., 2015; Rabin, Levi, Abramowitz, & Kozol, 2016; Stensrud et al., 2011; Whatman, Hing, & Hume, 2012; Whatman, Hume, & Hing, 2013). 3D motion analysis is reported as the “gold standard” for assessing risk factors for ACL injuries (Stensrud et al., 2011), but it is well known that substantial errors may occur using this analysis method. Current technology is both time-consuming and expensive, and evidence seems inconsistent when the VDJ test are analysed for predicting injury. Compared to 3D motion analyses, humans may have the ability to integrate more movement information at one time. Several reported risk factors, e.g. knee valgus motion, trunk motion and landing stiffness can be directly observed and assessed in one jump. This may be beneficial considering the multifactorial injury mechanism. Visual assessment will also be a more time-efficient method for assessing the VDJ test

The purpose of this exploratory study was to examine sports and sports medicine professionals’ ability to visually identify female elite football and handball players with increased risk for ACL injury based on the performance on a VDJ test. Furthermore, we examined if any differences in ability to assess ACL injury risk were present for various groups within sports medicine.

3.3. Methods

3.3.1. Study design

The present study explored if there are visually observable differences in the VDJ performance between female athletes who subsequently did or did not sustain an ACL injury. The baseline tests and injury registration material were collected through a large prospective cohort study from the Oslo Sports Trauma and Research Center (OSTRC) investigating risk factors for ACL injury. Sports medicine professionals were invited through email and social media platforms to assess the VDJ test performance of 110 players and rate the risk of each player with a number between 1 (low risk) and 10 (high risk). The risk assessment was conducted anonymous in an online survey.

3.3.2. Data material

The video clips of the VDJ test were randomly sampled from the prospective cohort study where all teams in the Norwegian female handball and football premier league were invited to a preseason baseline screening including videotaping of the VDJ test (See Appendix A for test protocol) (Krosshaug et al., 2016; Stensrud et al., 2011). The data collection and testing happened between August 2007 and February 2014. Players signed a written consent form before inclusion and the Regional Committee for Medical Research Ethics, the South Eastern Norway Regional Health Authority and the Norwegian Social Science Data Services approved the study (see Appendix D). All complete ACL injuries among the tested players were recorded throughout May 2015. Magnetic resonance imaging (MRI) and/or arthroscopy verified all injuries. The 110 video clips included in the survey, were randomly selected from the 700 available video clips of players tested between 2009-2013. Out of these 700, 50 players were registered with ACL injury subsequently. Among the 110 players included in the survey, 20 players were registered with a subsequent ACL injury. The ratio of injured to non-injured players in the survey (2:9) is higher than reported in the prospective cohort study with the original data material (1:13). The data material from 2009-2013 was chosen due to video quality of the remaining testing years. Each player was tested until three valid test jumps was recorded, and by choosing the player's last test jump clip, we ensured a valid test. After identification of the randomised players, the video was clipped and blurred to ensure anonymity. Both clipping and blurring of the video clips were done in Adobe After Effects CC (2015.2 Release, Version 13.7.2.3) and further rendered to mp4 files in Adobe Media Encoder CC (2015.2 Release, Build 9.2.0.26). Five clips from the ACL Injury Risk

Estimation Quiz (ACL-IQ) developed by Petushek, Cokely, et al. (2015) was also included in the survey.

3.3.3. Pilot testing

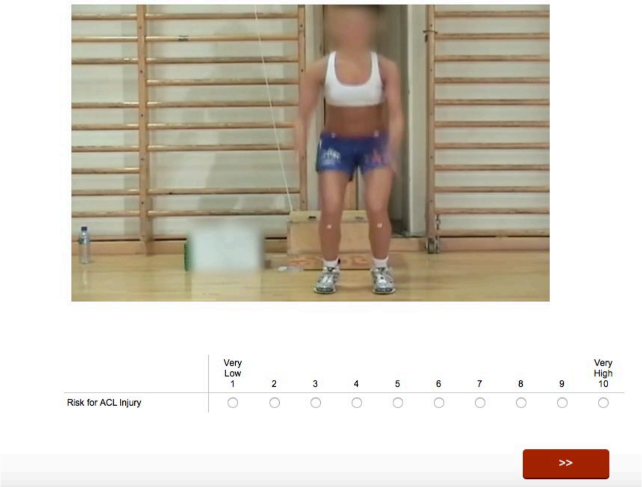
A pilot study was conducted before inviting assessors to the present study. Over 10 sports and sports medicine professionals took part in this pilot testing, and technical issues were detected and corrected before recruitment of assessors began.

3.3.4. Recruitment of assessors

Recruitment of assessors happened in a period between March 22nd and April 27th 2017. The invitations were sent through email with a direct link to the online survey (See Appendix B). Email addresses were collected through email lists from different academies, conferences, universities, workplaces, courses etc. The survey link was also distributed on social media platforms like Facebook and Twitter. Colleagues nationally and abroad helped recruit assessors. We aimed to invite various groups within sports medicine, including experts among coaches, strength and conditioning coaches, athletic trainers, physicians, physiotherapists and researchers both nationally and internationally. No incentives for participation were given.

3.3.5. Online survey

The videos were embed within Qualtrics (® 2017 Qualtrics LCC) in March 2017. Instructions on how to conduct the survey, followed by one test clip, were given in the beginning. The assessors then watched each clip following a 3-2-1 countdown. One clip lasted for two or three seconds (excluding the countdown), and the assessors could watch each clip several times if needed. Assessors were asked to rate the clip with a number between 1 and 10, where 1 represented very low risk and 10 represented very high risk (Figure 1). The first five clips were from ACL-IQ test developed by Petushek, Cokely, et al. (2015). At the end they were asked what they generally based their rating on, to rate the importance of different cues when assessing ACL injury risk, confidence level when assessing and different demographic questions.



	Very Low 1	2	3	4	5	6	7	8	9	Very High 10
Risk for ACL Injury	○	○	○	○	○	○	○	○	○	○

Figure 1: Screen shot of a risk rating assessment in the survey

3.3.6. Statistical analysis

Receiver operating characteristic (ROC) curves and subsequent area (AUC) with 95 % confidence intervals (CI) was calculated for each assessor to describe the diagnostic ability of the assessor for using the VDJ test for identifying players with increased ACL injury risk. The level of accuracy was classified as excellent (AUC 0.9-1), good (AUC 0.8-0.9), fair (AUC 0.7-0.8), poor (AUC 0.6-0.7) or fail (AUC 0.5-0.6). Differences between groups was analysed using one-way ANOVA with Bonferroni post hoc corrections. Pairwise comparisons were calculated between the two groups with the biggest difference using independent samples t-test. The significance level was set to $p<0.5$. Differences between the group with highest and lowest confidence level were analysed using independent samples t-test. Effect sizes are presented by Cohen's *d.*

The sample size of video clips included is based on a study by Bahr and Holme (2003). The number of injured cases is a bit over-represented to reduce the number of videos to assess and to give the assessors the best advantage for success. Thus, ROC curve analyses were also calculated with a reduced number of injured cases. Ten injured cases were randomly excluded before processing these ROC curves. This procedure was repeated five times.

3.4. Results

3.4.1. Assessors

The survey was open from March 22nd to May 1st. Over 1700 people opened the survey using the distributed link, but the majority did not complete it. Two hundred and thirty seven assessors (32.5 % women and 67.5% male, mean age 36.2, ±10.6) completed the online survey. About one half of the respondents were physiotherapists (n=110, 46 %). Seventy one percent of the participants reported that they were currently working with athletes, and 55 % of the participants reported that they have assessed performance of the VDJ test before (Table 1).

Table 1: Demographic data

Occupation	N = 237	Gender (n=236)		Age (n=237)	Working with athletes (%) (n=233)				Years of experience in current occupation (%) (n=236)					Assessed VDJ test before (%) (n=237)	
		Male	Female	Mean (SD*)	Yes	Within the last 5 years	Within the last 10 years	No	0-2	3-5	5-8	8-12	12+	Yes	No
Physician[2]	20	13	7	43.8 (11.9)	81[1]	6[1]	0[1]	13[1]	10	25	10	10	45	25	75
Certified Athletic Trainer	15	11	4	40.2 (8.3)	87	13	0	0	0	20	0	27	47	53	47
Coach	20	14	6	40.8 (11.4)	85	0	5	10	5	25	30	10	30	45	55
Strength/Con Coach	12	10	2	31.5 (8.0)	83	17	0	0	8	33	33	17	8	75	25
Physical Therapist[4]	110	71	38	35.3 (9.8)	76	11	1	12	11	27	22	14	26	66	34
Researcher[3]	34	24	10	38.0 (10.7)	47	41	6	6	18	12	21	15	35	53	47
Student	19	11	8	25.4 (4.3)	47	37	5	11	63	21	16	0	0	21	79
Other	7	5	2	33.9 (9.9)	86	0	0	14	29	14	14	29	14	71	29
Total	**237**	**159**	**77**	**36.2**	**168**	**38**	**5**	**22**	**36**	**56**	**47**	**32**	**66**	**131**	**106**

Footnote: [1]Based on the 16 respondents [2]Working within General Practice (n=4), Sports Medicine (n=12) and Orthopaedics (n=4) [3]Working with ACL related research (n=14) [4]Working in private clinic (n=72), Hospital inpatient/outpatient (n=16), Municipality physiotherapist (n=5), Rehabilitation Clinic (n=15) *SD = standard deviation

3.4.2. Recoded values

Recorded responses with completion less than 95% were not processed. In twelve of the 110 clips, only 236 assessors had recorded a risk rating score. For these clips, the average risk rating score was calculated and inserted in the dataset where the risk rating score was missing. Two assessors checked “Other” for the occupation question because they were both physical therapists and researchers. Before doing analysis, both cases were recoded to “Physical Therapist”.

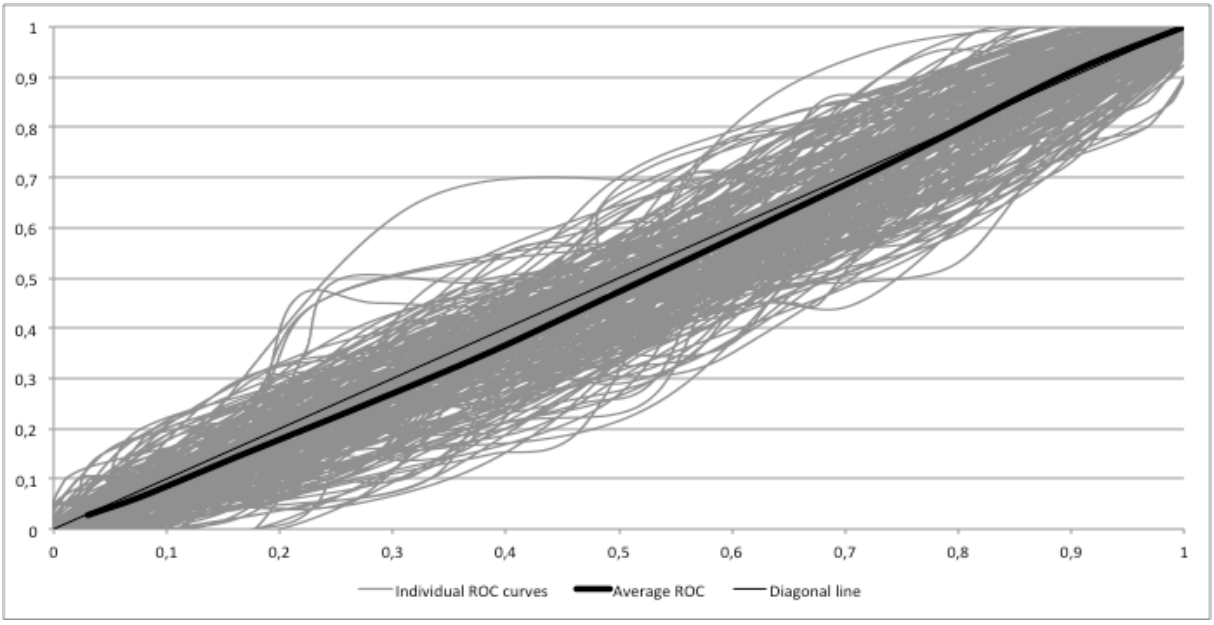


Figure 2: Individual receiver operating characteristic (ROC) curve for all 237 assessors

3.4.3. Receiver Operating Curve

Receiver operating curves are presented in Figure 1. Area under the curve (AUC) values ranged from 0.37 to 0.61. Average AUC score was 0.48. Average AUC for each group ranged from 0.46 to 0.48 (mean difference = .23, 95 % CI: -.01 to .05, p = .113, *d* = .47) (Table 2). There were no significant differences between groups (p =.706). The mean rating score of the injured players was 4.48 (±1.67) whereas the mean score of the non-injured players was 4.67 (±1.73). Correlation between ACL-IQ score and AUC was *r* (235) = -.13 with Bootstrapped 95% CI (-.27, .032) *p* = .046.

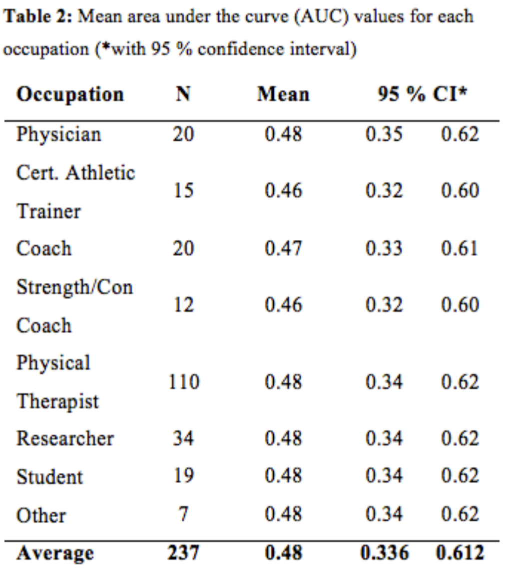


Table 2: Mean area under the curve (AUC) values for each occupation (*with 95 % confidence interval)

Occupation	N	Mean	95 % CI*	
Physician	20	0.48	0.35	0.62
Cert. Athletic Trainer	15	0.46	0.32	0.60
Coach	20	0.47	0.33	0.61
Strength/Con Coach	12	0.46	0.32	0.60
Physical Therapist	110	0.48	0.34	0.62
Researcher	34	0.48	0.34	0.62
Student	19	0.48	0.34	0.62
Other	7	0.48	0.34	0.62
Average	**237**	**0.48**	**0.336**	**0.612**

3.4.4. Confidence level

Participants reported an overall confidence score of 6.0 (out of 10) for performing this injury risk assessment (Table 3). Certified athletic trainers and physicians reported the highest and lowest average confidence score (mean difference = 2.83, 95 % CI: 1.02 to 3.54, *d* = 1.4).

Table 3: Confidence level (ranging from 1 (low) to 10 (high) when assessing ACL injury

Occupation	Mean (±SD*)
Physician	5.3 (2.4)
Cert. Athletic Trainer	7.5 (1.1)
Coach	6.4 (2.1)
Strength/Con Coach	6.9 (1.2)
Physical Therapist	5.8 (2.0)
Researcher	6.2 (1.6)
Student	5.9 (1.7)
Other	5.7 (2.1)
Total	6.0 (1.9)

Footnote: *SD = standard deviation

3.4.5. Use of cues

Inward/outward knee motion, knee position in landing and landing symmetry were the three cues the participants most frequently reported that they used for injury risk assessment, 99.2 %, 99.6 % and 98.7 % respectively. Participants also rated the importance of these factors when assessing ACL injury risk with 8.8 (95% CI 8.65-9.04), 9.0 (95% CI 8.8-9,1) and 8.1 (95% CI 7.85-8.30) on a scale ranging from 1 to 10 (see Figure 3). Jump alignment and landing stiffness were also factors the participants frequently reported that they used in the assessment, 96.6 % and 95.8 % respectively.

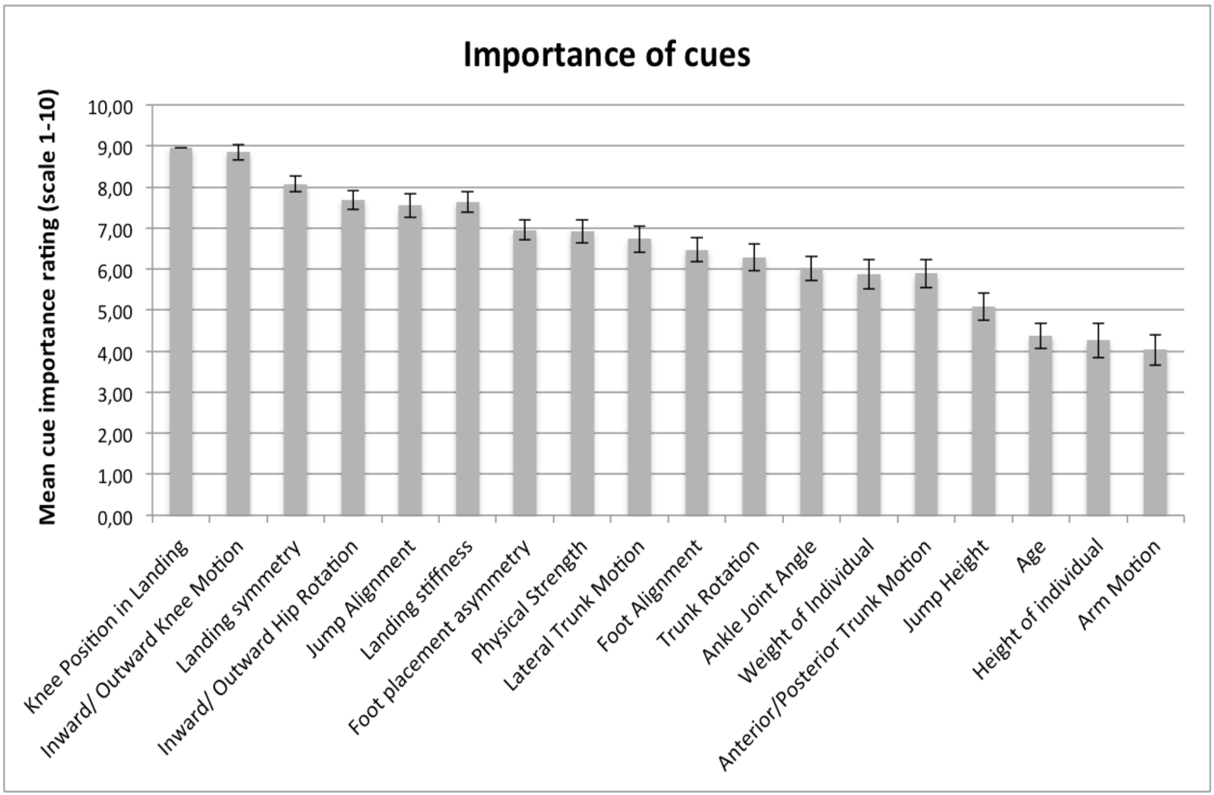


Figure 3: Importance of cues (with 95 % confidence intervals)

3.5. Discussion

This exploratory study revealed that observational assessment of the VDJ test cannot be used to assess ACL injury risk in this population of elite female handball and football players. In this study we had the opportunity to compare the visually assessed injury risk of players who have and have not sustained an ACL injury after testing. The results from ROC curve analysis showed that all 237 individual curves are lying close to the diagonal line of 0.5, meaning that the individuals' risk rating ability is no better than guessing. AUC values ranged from 0.37 to 0.61 (mean 0.48, 95 % CI 0.336-0.612), revealing a poor combined sensitivity and specificity of the test. ROC curve analyses calculated with adjusted ratio of injured and non-injured players showed no different results than the original ROC curve analysis. No differences were identified between groups with different occupational background. Inward/outward knee motion, knee position in landing and landing symmetry were all cues used by nearly 100 % of the assessors and rated as cues with high importance (over 8/10) for assessing ACL injury risk.

The results of the present study support the findings of Krosshaug et al. (2016) and Leppanen et al. (2017), indicating that the VDJ test is a poor screening tool for assessing ACL injury risk. None of the respondents displayed a ROC curve showing fair, good or excellent accuracy, and only one respondent achieved an accuracy score classified as poor (AUC 0.61). The rest of the respondents achieved results no better than random guessing (AUC <0.6). Despite the low accuracy, the assessors reported high levels of confidence in their risk rating assignment (mean 6.0 ± 1.9). This indicates poor judgment calibration and adds data to support the unskilled and unaware phenomena (Kruger & Dunning, 1999), saying people tend to overestimate their abilities and lack competence to evaluate how well they are performing. Based on our results it's important to acknowledge that individuals should not be confident when screening ACL injury risk through visual assessment of the VDJ test in this population.

Frontal plane knee motion is reported to be associated with ACL injury risk (Brophy, Stepan, Silvers, & Mandelbaum, 2015; Cochrane et al., 2007; Ebstrup & Bojsen-Moller, 2000; Kiapour et al., 2016; Koga et al., 2010). In the present study, the assessors were not given any specific cues in advance. However, the assessors reported that they especially focused on frontal plane knee motion (knee placement in landing + inward/outward knee motion) in their assessment and considered it to be an important factor (9/10) for assessing ACL injury risk. Krosshaug et al. (2016) performed 3D motion analyses of the VDJ test based on data material from the same prospective cohort study as the present study. Their results implied that frontal plane knee motion were not associated with increased ACL injury risk ("Corrigendum," 2017). Our hypothesis was that the human eye might be able to capture more information than what would be registered during 3D motion analyses of specific variables. Given that athletes with increased risk of ACL injury actually are possible to identify, results from the ROC curve analysis in the present study imply that visual assessment of the VDJ test cannot identify players at risk of sustaining an ACL injury no better than 3D motion analyses, even though frontal plane knee motion apparently were given superior attention by the assessors in this survey.

A critical question is whether this drop jump test is challenging enough for these elite players and similar enough to detect factors that are thought to increase ACL injury risk. The test does not demand any rapid lateral changes in direction, which is often seen in the moment of injury. The load is distributed in both legs during landing in a VDJ test. In contrast, ACL injuries typically occur in one-legged landings (Krosshaug et al., 2007; Olsen, Myklebust, Engebretsen, & Bahr, 2004; Walden et al., 2015). Even though injuries may happen without contact from any other player, the environment surrounding the player would potentially influence which movement the player will perform next. The player will have to react and decide quickly. In a VDJ test, the player is told what to do and does it without any outer interference. The results of this study support the need of a test that could increase the validity of a risk assessment test. For ethical reason players cannot be exposed to and assessed in situations where they potentially could rupture their ACL, and development of an adequate screening test is challenging.

The present study has limitations that should be taken into consideration when interpreting these results. First, the video clips differed in quality and distance between the camera and the player. However, participants were given the opportunity to watch the clips several times giving them a better chance of succeeding as well as increasing the clinical relevance of the results. Second, we do not know if any of the players in the survey have been or will become injured after making the online survey, or if anyone has quit playing or reduced her competition level and activity load. The injury mechanism are as known multifactorial. Uninjured players may not have been exposed to a similar situation in which the injured players ruptured their ligament regarding external factors and inciting events.

Looking at a player’s three valid test attempts, the jump performance seem to vary in all three. Choosing the third valid test, may not give the right picture of the “normal” performance of this player. However, according to the previous work of Mok, Petushek, and Krosshaug (2016), the knee biomechanical variables of the vertical drop jump test are reliable for both within- and between-session analyses for elite female handball and football players. Therefore, we don’t find these methodological limitations crucial for the outcome presented in this study.

The assessors only assessed the player’s movements from a frontal plane view. Based on the multifactorial injury mechanism one can discuss if the drop jump should be assessed from a sagittal plane view as well. As presented in the introduction of this article, decreased knee flexion angle (Cochrane et al., 2007; Fagenbaum & Darling, 2003; Ford et al., 2003; Koga et al., 2010; Krosshaug et al., 2007; Leppanen et al., 2017; Renstrom et al., 2008; Yu & Garrett, 2007) and femorotibial translation (Koga et al., 2011) during landing is reported to be associated with increased ACL injury risk. These factors would have been better to assess from a sagittal plane view. Still, landing stiffness could be evaluated from a frontal plane view based on how deep an athlete goes when landing. Increased GRF (Hewett et al., 2005; Leppanen et al., 2017; Yu & Garrett, 2007) is also a reported risk factor that would have been better to assess live where noise level also can be assessed and evaluated. However, frontal plane knee motion is a reported risk factor that seem consistent based on risk factor studies, and are by most authors reported to be an important factor in the ACL injury mechanism (Brophy et al., 2015; Cochrane et al., 2007; Ebstrup & Bojsen-Moller, 2000; Kiapour et al., 2016; Koga et al., 2010; Krosshaug et al., 2016; Numata et al., 2017). Based on the current knowledge of injury mechanism and risk factors, one could hypothesise that it would be favourable assessing movement patterns for identifying players at risk from a frontal plane view, if this identification even is possible through this kind of assessment.

In the present study we included 20 injury cases. According to Bahr and Holme (2003), including 20 injury cases makes a risk factor study feasible to detect moderate to strong associations between a risk factor and injury. If results from the present ROC curve analysis had revealed that sports and sports medicine professionals could accurately identify players with increased risk of ACL injury through assessment of the VDJ test, associations between risk factors and injury could potentially be identified. However, this was not possible based on the result in the present study. Due to the need of including 20 injury cases and to maintain an appropriate ratio between injured and non-injured cases, the survey contained a robust number of video clips showing players perform the VDJ test. The number of clips makes the power of the study more robust. On the other hand, it may result in a gradually lack of motivation and concentration for doing the risk assessment. This was also feedback given from some of the participants after conducting the survey. However, the video clips were presented in a random order. Therefore, fatigue or vigilance effects would be mitigated.

We know from current literature that some individuals have the ability to identify risk factors associated with ACL injury (Ekegren et al., 2009; Nilstad et al., 2014; Petushek, Ward, Cokely, & Myer, 2015), and that targeting these risk factors in preventative exercise programs reduce the incidence and risk of sustaining an ACL injury (Sugimoto, Myer, McKeon, & Hewett, 2012; Taylor, Waxman, Richter, & Shultz, 2015). However, except from the original study of Hewett et al. (2005), no study has so far reported that individuals or computerized methods can identify high-risk players based on the VDJ test when ACL injury is used as the outcome. The relatively rare number of injuries, combined with inappropriate measurement methods or the type of task or environment players are tested in, makes prospective risk factors studies a possible recipe for failure. To date there is strong evidence saying we should keep encourage athletes to engage in preventative exercise programs providing feedback on knee alignment, soft landings etc., even though we might never be able to predict which athletes will have higher risk of sustaining a future ACL injury with a sufficient level of accuracy. The VDJ test may provide information about movement patterns and modifiable risk factors, but should not be used as a screening test for predicting ACL injuries in elite athletes with a high level of certainty.

3.6. Conclusion

The present study imply that sports and sports medicine professionals do not have the ability to identify players at risk by visually assessing their performance of the VDJ test.
ROC curve analysis and subsequent AUC values reveal a predictive ability no better than guessing. Sports and sports medicine professionals should not feel confident when assessing ACL injury risk in this population of elite female athletes.

3.7. Implications

Sports and sports medicine professionals should be cautious interpreting results from their visual assessment of the VDJ test when screening elite female athletes for ACL injury risk purposes.

4. REFERENCE LIST

Arendt, E., Agel, J., & Dick, R. (1999). Anterior cruciate ligament injury patterns among collegiate men and women. *J Athl Train, 34*(2), 86-92.

Arendt, E., & Dick, R. (1995). Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature. *Am J Sports Med, 23*(6), 694-701.

Bahr, R. (2016). Why screening tests to predict injury do not work-and probably never will...: a critical review. *Br J Sports Med*. doi:10.1136/bjsports-2016-096256

Bahr, R., & Holme, I. (2003). Risk factors for sports injuries--a methodological approach. *Br J Sports Med, 37*(5), 384-392.

Brophy, R. H., Stepan, J. G., Silvers, H. J., & Mandelbaum, B. R. (2015). Defending Puts the Anterior Cruciate Ligament at Risk During Soccer: A Gender-Based Analysis. *Sports Health, 7*(3), 244-249. doi:10.1177/1941738114535184

Cochrane, J. L., Lloyd, D. G., Buttfield, A., Seward, H., & McGivern, J. (2007). Characteristics of anterior cruciate ligament injuries in Australian football. *J Sci Med Sport, 10*(2), 96-104. doi:10.1016/j.jsams.2006.05.015

Corrigendum. (2017). *Am J Sports Med, 45*(9), NP28-NP29. doi:10.1177/0363546517716155

Ebstrup, J. F., & Bojsen-Moller, F. (2000). Anterior cruciate ligament injury in indoor ball games. *Scand J Med Sci Sports, 10*(2), 114-116.

Ekegren, C. L., Miller, W. C., Celebrini, R. G., Eng, J. J., & Macintyre, D. L. (2009). Reliability and validity of observational risk screening in evaluating dynamic knee valgus. *J Orthop Sports Phys Ther, 39*(9), 665-674. doi:10.2519/jospt.2009.3004

Fagenbaum, R., & Darling, W. G. (2003). Jump landing strategies in male and female college athletes and the implications of such strategies for anterior cruciate ligament injury. *Am J Sports Med, 31*(2), 233-240. doi:10.1177/03635465030310021301

Ford, K. R., Myer, G. D., & Hewett, T. E. (2003). Valgus knee motion during landing in high school female and male basketball players. *Med Sci Sports Exerc, 35*(10), 1745-1750. doi:10.1249/01.mss.0000089346.85744.d9

Hewett, T. E., Myer, G., Ford, K., Heidt, R., Colosimo, A., McLean, S., . . . 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. *Am J Sports Med, 33*(4), 492-501. doi:10.1177/0363546504269591

Joseph, A. M., Collins, C. L., Henke, N. M., Yard, E. E., Fields, S. K., & Comstock, R. D. (2013). A Multisport Epidemiologic Comparison of Anterior Cruciate Ligament Injuries in High School Athletics. *Journal of Athletic Training, 48*(6), 810-817. doi:10.4085/1062-6050-48.6.03

Kiapour, A. M., Demetropoulos, C. K., Kiapour, A., Quatman, C. E., Wordeman, S. C., Goel, V. K., & Hewett, T. E. (2016). Strain Response of the Anterior Cruciate Ligament to Uniplanar and Multiplanar Loads During Simulated Landings: Implications for Injury Mechanism. *Am J Sports Med*. doi:10.1177/0363546516640499

Koga, H., Bahr, R., Myklebust, G., Engebretsen, L., Grund, T., & Krosshaug, T. (2011). Estimating anterior tibial translation from model-based image-matching of a noncontact anterior cruciate ligament injury in professional football: a case report. *Clin J Sport Med, 21*(3), 271-274. doi:10.1097/JSM.0b013e31821899ec

Koga, H., Nakamae, A., Shima, Y., Iwasa, J., Myklebust, G., Engebretsen, L., . . . Krosshaug, T. (2010). Mechanisms for noncontact anterior cruciate ligament injuries: knee joint kinematics in 10 injury situations from female team handball and basketball. *Am J Sports Med, 38*(11), 2218-2225. doi:10.1177/0363546510373570

Krosshaug, T., Nakamae, A., Boden, B. P., Engebretsen, L., Smith, G., Slauterbeck, J. R., . . . Bahr, R. (2007). Mechanisms of anterior cruciate ligament injury in basketball: video analysis of 39 cases. *Am J Sports Med, 35*(3), 359-367. doi:10.1177/0363546506293899

Krosshaug, T., Steffen, K., Kristianslund, E., Nilstad, A., Mok, K. M., Myklebust, G., . . . Bahr, R. (2016). The Vertical Drop Jump Is a Poor Screening Test for ACL Injuries in Female Elite Soccer and Handball Players: A Prospective Cohort Study of 710 Athletes. *Am J Sports Med, 44*(4), 874-883. doi:10.1177/0363546515625048

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. *J Pers Soc Psychol, 77*(6), 1121-1134.

Leppanen, M., Pasanen, K., Kujala, U. M., Vasankari, T., Kannus, P., Ayramo, S., . . . Parkkari, J. (2017). Stiff Landings Are Associated With Increased ACL Injury Risk in

Young Female Basketball and Floorball Players. *Am J Sports Med, 45*(2), 386-393. doi:10.1177/0363546516665810

Li, R. T., Lorenz, S., Xu, Y., Harner, C. D., Fu, F. H., & Irrgang, J. J. (2011). Predictors of radiographic knee osteoarthritis after anterior cruciate ligament reconstruction. *Am J Sports Med, 39*(12), 2595-2603. doi:10.1177/0363546511424720

Matsumoto, H., Suda, Y., Otani, T., Niki, Y., Seedhom, B. B., & Fujikawa, K. (2001). Roles of the anterior cruciate ligament and the medial collateral ligament in preventing valgus instability. *J Orthop Sci, 6*(1), 28-32.

McLean, S. G., Walker, K., Ford, K. R., Myer, G. D., Hewett, T. E., & van den Bogert, A. J. (2005). Evaluation of a two dimensional analysis method as a screening and evaluation tool for anterior cruciate ligament injury. *Br J Sports Med, 39*(6), 355-362. doi:10.1136/bjsm.2005.018598

Meyer, E. G., & Haut, R. C. (2008). Anterior cruciate ligament injury induced by internal tibial torsion or tibiofemoral compression. *J Biomech, 41*(16), 3377-3383. doi:10.1016/j.jbiomech.2008.09.023

Mihata, L. C., Beutler, A. I., & Boden, B. P. (2006). Comparing the incidence of anterior cruciate ligament injury in collegiate lacrosse, soccer, and basketball players: implications for anterior cruciate ligament mechanism and prevention. *Am J Sports Med, 34*(6), 899-904. doi:10.1177/0363546505285582

Mok, K. M., Petushek, E., & Krosshaug, T. (2016). Reliability of knee biomechanics during a vertical drop jump in elite female athletes. *Gait Posture, 46*, 173-178. doi:10.1016/j.gaitpost.2016.03.003

Nilstad, A., Andersen, T. E., Kristianslund, E., Bahr, R., Myklebust, G., Steffen, K., & Krosshaug, T. (2014). Physiotherapists can identify female football players with high knee valgus angles during vertical drop jumps using real-time observational screening. *J Orthop Sports Phys Ther, 44*(5), 358-365. doi:10.2519/jospt.2014.4969

Numata, H., Nakase, J., Kitaoka, K., Shima, Y., Oshima, T., Takata, Y., . . . Tsuchiya, H. (2017). Two-dimensional motion analysis of dynamic knee valgus identifies female high school athletes at risk of non-contact anterior cruciate ligament injury. *Knee Surg Sports Traumatol Arthrosc*. doi:10.1007/s00167-017-4681-9

Olsen, O. E., Myklebust, G., Engebretsen, L., & Bahr, R. (2004). Injury mechanisms for anterior cruciate ligament injuries in team handball: a systematic video analysis. *Am J Sports Med, 32*(4), 1002-1012.

Petushek, E. J., Cokely, E. T., Ward, P., Durocher, J. J., Wallace, S. J., & Myer, G. D. (2015). Injury Risk Estimation Expertise: Assessing the ACL Injury Risk Estimation Quiz. *Am J Sports Med, 43*(7), 1640-1647. doi:10.1177/0363546515580791

Petushek, E. J., Ward, P., Cokely, E. T., & Myer, G. D. (2015). Injury Risk Estimation Expertise: Interdisciplinary Differences in Performance on the ACL Injury Risk Estimation Quiz. *Orthopaedic Journal of Sports Medicine, 3*(11), 2325967115614799. doi:10.1177/2325967115614799

Rabin, A., Levi, R., Abramowitz, S., & Kozol, Z. (2016). A new real-time visual assessment method for faulty movement patterns during a jump-landing task. *Physical Therapy in Sport, 20*, 7-12.

Redler, L. H., Watling, J. P., Dennis, E. R., Swart, E., & Ahmad, C. S. (2016). Reliability of a field-based drop vertical jump screening test for ACL injury risk assessment. *Phys Sportsmed, 44*(1), 46-52. doi:10.1080/00913847.2016.1131107

Renstrom, P., Ljungqvist, A., Arendt, E., Beynnon, B., Fukubayashi, T., Garrett, W., . . . Engebretsen, L. (2008). Non-contact ACL injuries in female athletes: an International Olympic Committee current concepts statement. *Br J Sports Med, 42*(6), 394-412. doi:10.1136/bjsm.2008.048934

Stensrud, S., Myklebust, G., Kristianslund, E., Bahr, R., & Krosshaug, T. (2011). Correlation between two-dimensional video analysis and subjective assessment in evaluating knee control among elite female team handball players. *Br J Sports Med, 45*(7), 589-595. doi:10.1136/bjsm.2010.078287

Struewer, J., Frangen, T. M., Ishaque, B., Bliemel, C., Efe, T., Ruchholtz, S., & Ziring, E. (2012). Knee function and prevalence of osteoarthritis after isolated anterior cruciate ligament reconstruction using bone-patellar tendon-bone graft: long-term follow-up. *Int Orthop, 36*(1), 171-177. doi:10.1007/s00264-011-1345-0

Sugimoto, D., Myer, G. D., McKeon, J. M., & Hewett, T. E. (2012). Evaluation of the effectiveness of neuromuscular training to reduce anterior cruciate ligament injury in female athletes: a critical review of relative risk reduction and numbers-needed-to-treat analyses. *Br J Sports Med, 46*(14), 979-988. doi:10.1136/bjsports-2011-090895

Taylor, J. B., Waxman, J. P., Richter, S. J., & Shultz, S. J. (2015). Evaluation of the effectiveness of anterior cruciate ligament injury prevention programme training components: a systematic review and meta-analysis. *Br J Sports Med, 49*(2), 79-87. doi:10.1136/bjsports-2013-092358

Walden, M., Hagglund, M., Werner, J., & Ekstrand, J. (2011). The epidemiology of anterior cruciate ligament injury in football (soccer): a review of the literature from a gender-related perspective. *Knee Surg Sports Traumatol Arthrosc, 19*(1), 3-10. doi:10.1007/s00167-010-1172-7

Walden, M., Krosshaug, T., Bjorneboe, J., Andersen, T. E., Faul, O., & Hagglund, M. (2015). Three distinct mechanisms predominate in non-contact anterior cruciate ligament injuries in male professional football players: a systematic video analysis of 39 cases. *Br J Sports Med, 49*(22), 1452-1460. doi:10.1136/bjsports-2014-094573

Whatman, C., Hing, W., & Hume, P. (2012). Physiotherapist agreement when visually rating movement quality during lower extremity functional screening tests. *Phys Ther Sport, 13*(2), 87-96. doi:10.1016/j.ptsp.2011.07.001

Whatman, C., Hume, P., & Hing, W. (2013). The reliability and validity of physiotherapist visual rating of dynamic pelvis and knee alignment in young athletes. *Phys Ther Sport, 14*(3), 168-174. doi:10.1016/j.ptsp.2012.07.001

Yu, B., & Garrett, W. E. (2007). Mechanisms of non-contact ACL injuries. *Br J Sports Med, 41 Suppl 1*, i47-51. doi:10.1136/bjsm.2007.037192

5. TABLES

ARTICLE

Table 1: Demographic data

Table 2: Mean area under the curve values

Table 3: Confidence level

6. FIGURES

THEORY

Figure 1: The 4-step sequence of prevention research

Figure 2: Model for injury causation

Figure 3: Lens Model for assessing ACL injury risk

ARTICLE

Figure 1: Risk rating assessment

Figure 2: Individual receiver operating characteristic (ROC) curve for all 237 assessors

Figure 3: Importance of cues (with 95 % CI)

7. ABBREVIATIONS

7.1. Theory

ACL	anterior cruciate ligament
OA	osteoarthritis
GRF	ground reaction force
IC	initial contact
3D	3-dimensional
VDJ	vertical drop jump
vGRF	vertical ground reaction force
ROC	receiver operating characteristic
AUC	area under the curve
ACL-IQ	ACL Injury Risk Estimation Quiz
TPR	true positive rate
FPR	false positive rate

7.2. Article

ACL	anterior cruciate ligament
IC	initial contact
GRF	ground reaction force
VDJ	vertical drop jump
3D	3-dimensional
OSTRC	Oslo Sports Trauma and Research Center
MRI	magnetic resonance imaging
ROC	receiver operating characteristic
AUC	area under the curve
ANOVA	analysis of variance
CI	confidence interval
SD	standard deviation

8. APPENDIX

- **Appendix A:** VDJ test protocol
- **Appendix B:** Survey protocol
- **Appendix C:** Email invitation
- **Appendix D:** Ethical committee and National Social Science Data Services approval schemes

8.1. Appendix A

SUBJECTIVE ASSESSMENT OF SINGLE LEG SQUATS AND VERTICAL DROP JUMPS

Preparations

Players wore a sports bra or a rolled up t-shirt and shorts or short tight. They were all using their own handball shoes. To simplify the 2D analyses, small pieces of sports tape were attached to the left and right anterior superior iliac spine and tuberositas tibiae. All players executed a standardized warm up program prior to the tests. The program consisted of series of two-legged squats (2x 8 repetitions), two-legged maximum jumps (2x 5 repetitions), followed by stretching of the muscles in the calf, with straight and bent knee, holding each position for 30 seconds to 1 min. To familiarize with the tests, the players were allowed to perform one to three practise repetitions ahead of each test.

Tests

The players completed three tests; single leg squat (SLS), single leg vertical drop jump (SLVDJ) and two-legged vertical drop jump (VDJ). All players performed two or three valid trials on each test, the number were set by the consistent of the performance during the first two trials. Three players did even do four trials on one or two tests, as they were difficult to assess on the first three trials.

Two-legged vertical drop jump

The VDJ test was performed similar tothe test of Hewett (2005). The players started on top of a 30cm high box with the feet 30cm apart (distance measured between to markers on top of the box), and were instructed to drop off the box and directly perform a maximum vertical jump (fig. 1). To ensure that the players performed the jump with maximum effort, a regular handball was attached 260cm above the ground, allowing some of the players to reach it. The players were instructed to try touching the ball with bothhands. An extrinsic motivator, such as an overhead goal has been shown to alter lower-extremity biomechanics, and increase performance (Ford *et al.*, 2005). A trial was not valid if the player reached for the ball with only one hand or the player lost balance or fell during the performance.

***Figure 1**. Two-legged vertical drop jump.*

8.2. Appendix B

Survey Protocol: Optimized ACL-IQ OSTRC

Q355 ACL injury risk survey
In this anonymous survey you will rate the risk for ACL injury of players performing vertical drop jumps. Following the judgements of the clips you will be asked a series of additional questions. The survey will take approximately 30 minutes to complete.
TEST INSTRUCTIONS
The video clips will be presented following a 3-2-1 countdown. You will be able to see the clip again if needed by clicking on the video. After viewing the clip you will be asked to rate the players' degree of risk for sustaining a future ACL injury using a number between 1 and 10 (1 being low risk of injury and 10 being high). Please do not press the "Back" or "Refresh" button at any point. Maximize your browser window size now to optimize viewing. The 6 first videos will be from the ACL-IQ and the rest are from the OSTRC.

Q220 The first video will be practice. The video will automatically begin playing when it is fully buffered.

Q221

	Very Low 1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	6 (6)	7 (7)	8 (8)	9 (9)	Very High 10 (10)
Risk for ACL Injury (1)	○	○	○	○	○	○	○	○	○	○

Q357 The test will now begin. Remember, you can replay each clip if needed.

Q333

	Very Low 1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	6 (6)	7 (7)	8 (8)	9 (9)	Very High 10 (10)
Risk for ACL Injury (1)	○	○	○	○	○	○	○	○	○	○

(Q333 was repeated for all 100 + 5 video clips)

Q352 Overall, how confident were you when rating the players' risk?

	Very Low 1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	6 (6)	7 (7)	8 (8)	9 (9)	Very High 10 (10)
Overall Confidence in Risk Assessment (1)	○	○	○	○	○	○	○	○	○	○

Q353 What information (cues) did you use for rating ACL injury risk in this survey?

Q354 Rate the importance of the following cues for assessing ACL injury risk

	Importance (1 = not important - 10 = very important)										I did not use this cue	I am not sure
	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)	6 (6)	7 (7)	8 (8)	9 (9)	10 (10)	-------- (1)	-------- (1)
Height of Individual (1)	○	○	○	○	○	○	○	○	○	○	☐	☐
Weight of Individual (2)	○	○	○	○	○	○	○	○	○	○	☐	☐
Inward/Outward Knee Motion (3)	○	○	○	○	○	○	○	○	○	○	☐	☐
Knee Position in Landing (5)	○	○	○	○	○	○	○	○	○	○	☐	☐
Jump Height (6)	○	○	○	○	○	○	○	○	○	○	☐	☐
Jump Alignment (7)	○	○	○	○	○	○	○	○	○	○	☐	☐
Inward/Outward Hip Rotation (8)	○	○	○	○	○	○	○	○	○	○	☐	☐
Ankle Joint Angle (9)	○	○	○	○	○	○	○	○	○	○	☐	☐
Landing Stiffness (10)	○	○	○	○	○	○	○	○	○	○	☐	☐
Landing Symmetry (11)	○	○	○	○	○	○	○	○	○	○	☐	☐
Foot Placement Asymmetry (12)	○	○	○	○	○	○	○	○	○	○	☐	☐
Foot Alignment (13)	○	○	○	○	○	○	○	○	○	○	☐	☐
Lateral Trunk Motion (14)	○	○	○	○	○	○	○	○	○	○	☐	☐

Anterior/Posterior Trunk Motion (15)	○	○	○	○	○	○	○	○	○	○	☐	☐
Trunk Rotation (16)	○	○	○	○	○	○	○	○	○	○	☐	☐
Arm Motion (17)	○	○	○	○	○	○	○	○	○	○	☐	☐
Age of Individual (18)	○	○	○	○	○	○	○	○	○	○	☐	☐
Physical Strength of Individual (19)	○	○	○	○	○	○	○	○	○	○	☐	☐

Q338 Gender

○ Male (1)
○ Female (2)

Q339 Age

Q340 Region?

○ Oceania (1)
○ Asia (2)
○ North America (3)
○ Africa (4)
○ Europe (5)
○ South America (6)

Q341 Highest degree obtained

☐ Bachelor's degree (1)
☐ Masters (2)
☐ Ph.D. (3)
☐ M.D. (4)
☐ D.P.T. (5)
☐ Other: Please type here (6) ____________________

Q342 Current occupation (If several, pick the one most relevant for movement assessment)

- ○ Physician (1)
- ○ Physical Therapist (7)
- ○ Certified Athletic Trainer (3)
- ○ Coach (4)
- ○ Strength and Conditioning Coach (5)
- ○ Researcher (14)
- ○ Student (13)
- ○ Other: Please type here (6) ____________________

If Other: Please type here Is Selected, Then Skip To Are you currently working with athletes?If Student Is Selected, Then Skip To Studying to become aIf Researcher Is Selected, Then Skip To Field of researchIf Certified Athletic Trainer Is Selected, Then Skip To Are you currently working with athletes?If Strength and Conditioning C... Is Selected, Then Skip To Are you currently working with athletes?If Coach Is Selected, Then Skip To Are you currently working with athletes?

Display This Question:
If Current occupation (If several, pick the one most relevant for movement assessment) Physical Therapist Is Selected

Q343 Working in

- ☐ Hospital inpatient/outpatient (1)
- ☐ Municipality physiotherapist (2)
- ☐ Rehabilitation Clinic (6)
- ☐ Private Clinic (3)
- ☐ Other: Please type here (4) ____________________

If Hospital inpatient/outpatient Is Selected, Then Skip To Are you currently working with athletes?If Municipality physiotherapist Is Selected, Then Skip To Are you currently working with athletes?If Private Clinic Is Selected, Then Skip To Are you currently working with athletes?If Other: Please type here Is Selected, Then Skip To Are you currently working with athletes?If Rehabilitation Clinic Is Selected, Then Skip To Are you currently working with athletes?

Display This Question:
If Current occupation (If several, pick the one most relevant for movement assessment) Physician Is Selected

Q344 Working within

- ☐ General Practice (1)
- ☐ Sports Medicine (2)
- ☐ Orthopaedics (3)
- ☐ Other: Please type here (4) ____________________

If General Practice Is Selected, Then Skip To Years of experience in current occupa...If Sports Medicine Is Selected, Then Skip To Are you currently working with athletes?If Orthopaedics Is Selected, Then Skip To Are you currently working with athletes?If Other: Please type here Is Selected, Then Skip To Are you currently working with athletes?

Q345 Studying to become a

○ Physician (1)
○ Physiotherapist with MSc (2)
○ Athletic Trainer (3)
○ Coach (4)
○ Physical Therapist (5)
○ Strength and Conditioning Coach (6)
○ Other: Please type here (7) ____________________

If Physician Is Selected, Then Skip To Are you currently working with athletes?If Physiotherapist with MSc Is Selected, Then Skip To Are you currently working with athletes?If Athletic Trainer Is Selected, Then Skip To Are you currently working with athletes?If Coach Is Selected, Then Skip To Are you currently working with athletes?If Physical Therapist Is Selected, Then Skip To Are you currently working with athletes?If Strength and Conditioning C... Is Selected, Then Skip To Are you currently working with athletes?If Other: Please type here Is Selected, Then Skip To Are you currently working with athletes?

Q346 Field of research

○ ACL related research (1)
○ Other: Please type here (2) ____________________

If Other: Please type here Is Selected, Then Skip To Are you currently working with athletes?If ACL related research Is Selected, Then Skip To Are you currently working with athletes?

Q347 Are you currently working with athletes?

○ Yes (1)
○ Not at the moment, but I've worked with athletes within the last 5 years (3)
○ Not at the moment, but I've worked with athletes within the last 15 years (4)
○ No (2)

If Yes Is Selected, Then Skip To SportsIf Not at the moment, but I've... Is Selected, Then Skip To SportsIf Not at the moment, but I've... Is Selected, Then Skip To SportsIf No Is Selected, Then Skip To Years of experience in current occupa...

Q348 Sports

☐ Soccer (1)
☐ Handball (2)
☐ Basketball (3)
☐ Volleyball (5)
☐ Other: Please type here (4) ____________________

Display This Question:
If Sports Soccer Is Selected
Or Sports Handball Is Selected
Or Sports Basketball Is Selected
Or Sports Volleyball Is Selected
Or Sports Other: Please type here Is Selected

Q349 Level

☐ High School (1)
☐ College (2)
☐ Proffesional (3)
☐ Amateurs (4)
☐ Other: Please type here (5) ____________________

Q350 Years of experience in current occupation

○ 0-2 (1)
○ 3-5 (2)
○ 5-8 (3)
○ 8-12 (4)
○ 12 + (5)

Q351 Have you ever assessed the performance of a vertical drop jump test?

○ Yes, and have been doing this for how many years (1) ____________________
○ No (2)

Q356 Congratulations!

You have now completed the survey.

We are truly grateful for your participation!

Any comments regarding this survey:

8.3. Appendix C

Oslo Sports Trauma
RESEARCH CENTER

Can you identify players with increased risk of ACL injury?

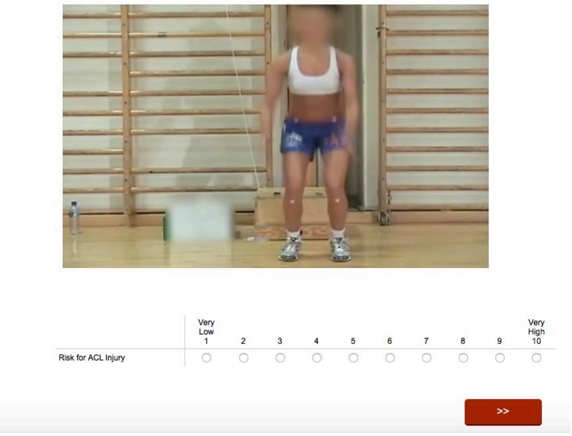
The aim of this study is to examine whether individuals with different backgrounds have the ability to identify players with higher risk of sustaining an ACL injury through visual assessment of the vertical drop jump test (VDJ test).

Although the VDJ test has been investigated using standardized biomechanical measurements, it is possible that the human brain has the ability to better estimate injury risk. We would therefore like you to participate in a study where you will visually assess the risk for injury of approximately 100 female athletes, where the majority took part in the prospective cohort study of the Oslo Sports Trauma Research Center (OSTRC). The assessment will take approximately 45 minutes.

The following link will lead you to the web-based survey: http://goo.gl/wdxrAs

We are looking for individuals in each of these categories:

- Coaches (handball, soccer, basketball, volleyball)
- Physicians
- Certified Athletic Trainers
- Strength and Conditioning Coaches
- Physical Therapists



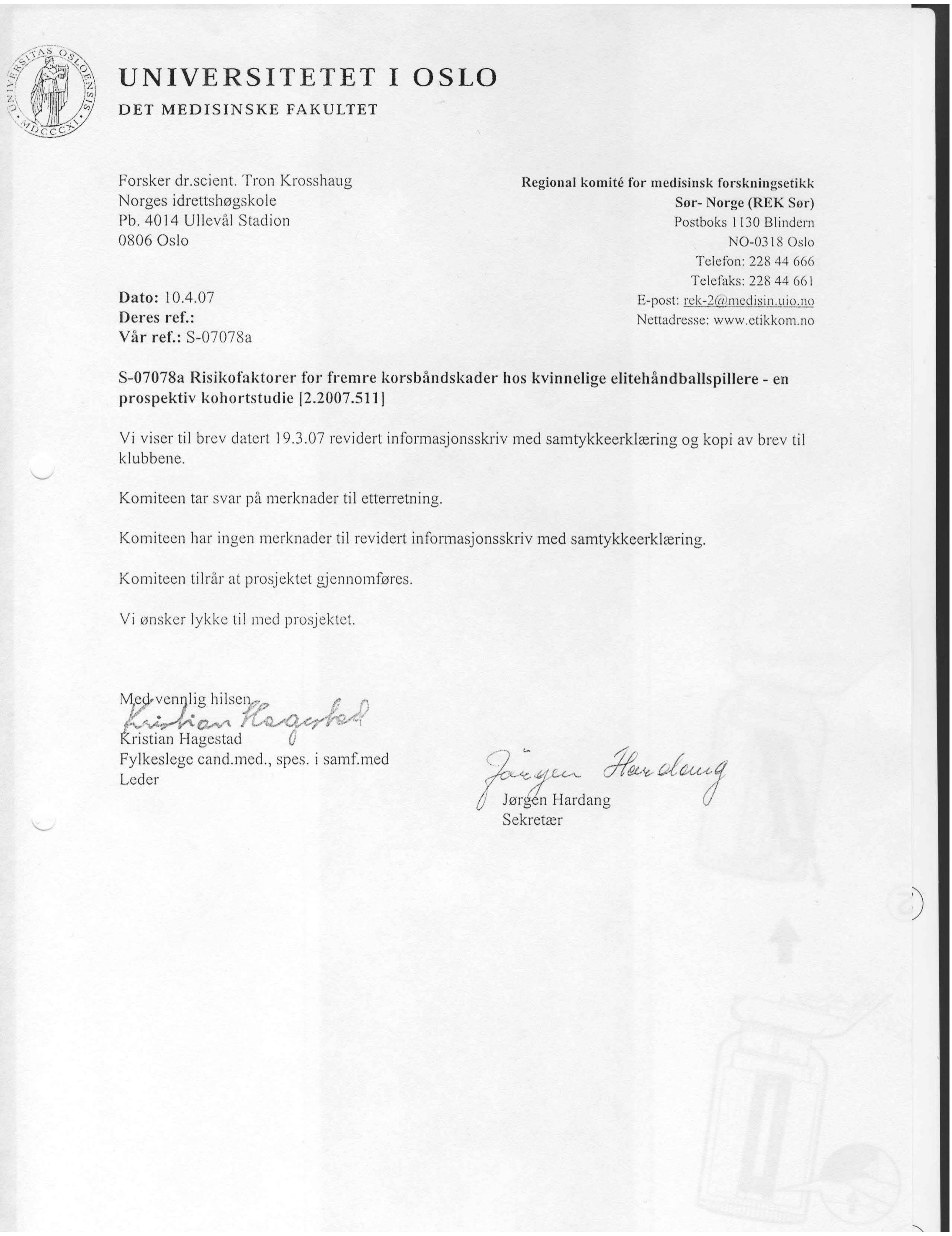
	Very Low 1	2	3	4	5	6	7	8	9	Very High 10
Risk for ACL Injury	○	○	○	○	○	○	○	○	○	○

The survey is **fully online**, **anonymous** and is intended to be completed on a **laptop or desktop computer** and will not work on a mobile device. A summary of results will be sent to you upon request after the study is completed.

If you have any questions, please contact Tron Krosshaug, Associate Professor at OSTRC or Erich Petushek, Assistant Professor at Michigan State University, on ACLinjuryrisk@nih.no

Oslo Sports Trauma
RESEARCH CENTER

8.4. Appendix D



UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

Forsker dr.scient. Tron Krosshaug
Norges idrettshøgskole
Pb. 4014 Ullevål Stadion
0806 Oslo

Regional komité for medisinsk forskningsetikk
Sør- Norge (REK Sør)
Postboks 1130 Blindern
NO-0318 Oslo
Telefon: 228 44 666
Telefaks: 228 44 661
E-post: rek-2@medisin.uio.no
Nettadresse: www.etikkom.no

Dato: 10.4.07
Deres ref.:
Vår ref.: S-07078a

S-07078a Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndballspillere - en prospektiv kohortstudie [2.2007.511]

Vi viser til brev datert 19.3.07 revidert informasjonsskriv med samtykkeerklæring og kopi av brev til klubbene.

Komiteen tar svar på merknader til etterretning.

Komiteen har ingen merknader til revidert informasjonsskriv med samtykkeerklæring.

Komiteen tilrår at prosjektet gjennomføres.

Vi ønsker lykke til med prosjektet.

Med vennlig hilsen
Kristian Hagestad
Kristian Hagestad
Fylkeslege cand.med., spes. i samf.med
Leder

Jørgen Hardang
Jørgen Hardang
Sekretær

UNIVERSITETET I OSLO
DET MEDISINSKE FAKULTET

Forsker dr.scient. Tron Krosshaug
Norges idrettshøgskole
Pb. 4014 Ullevål Stadion
0806 Oslo

Regional komité for medisinsk og helsefaglig forskningsetikk Sør-Øst A (REK Sør-Øst A)
Postboks 1130 Blindern
NO-0318 Oslo

Telefon: 22 84 46 66
Telefaks: 22 85 05 90
E-post: jorgen.hardang@medisin.uio.no

Dato: 15.12.08
Deres ref.:
Vår ref.: S-07078a

S-07078a Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndballspillere - en prospektiv kohortstudie [2.2007.511]

Vi viser til skjema for protokolltillegg og endringer datert 3.12.08 vedlagt revidert informasjonsskriv.

Prosjektleder ønsker å utvide prosjektpopulasjonen til kvinnelige elitefotballspillere fra Toppserien i Norge (ca 240 spillere).

Komiteen godkjenner endringen slik den er beskrevet i skjema for protokolltillegg og endringer og videresender kopi av informasjonsskriv, endringsskjema samt komiteens vedtak til Helsedirektoratet for behandling av endring av biobanken.

Med vennlig hilsen
Kristian Hagestad
Kristian Hagestad
Fylkeslege cand.med., spes. i samf.med
Leder

Jørgen Hardang
Jørgen Hardang
Sekretær

Kopi: Helsedirektoratet, Postboks 7000, St. Olavs plass, 0130 Oslo

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	**Saksbehandler:**	**Telefon:**	**Vår dato:**	**Vår referanse:**
REK sør-øst	Anette Solli Karlsen	22845522	13.12.2016	2010/3153/REK sør-øst A
			Deres dato:	**Deres referanse:**
			28.11.2016	

Vår referanse må oppgis ved alle henvendelser

Tron Krosshaug
Norgens Idrettshøgskole

2010/3153 Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndballspillere - en prospektiv kohortstudie

Forskningsansvarlig: Norgens idrettshøgskole
Prosjektleder: Eirik Kristianslund

Vi viser til søknad om prosjektendring datert 28.11.2016 for ovennevnte forskningsprosjekt. Søknaden er behandlet av leder for REK sør-øst på fullmakt, med hjemmel i helseforskningsloven § 11.

Vurdering

REK har vurdert følgende endringer i prosjektet:
-Oppføgling av deltakere i ACL-risikofaktorstudien, med tanke på mulig fremre korsbåndskade.

Komiteens leder har vurdert søknaden og har ingen innvendinger til de endringer som er beskrevet.

Vedtak

Komiteen godkjenner med hjemmel i helseforskningsloven § 11 annet ledd at prosjektet videreføres i samsvar med det som fremgår av søknaden om prosjektendring og i samsvar med de bestemmelser som følger av helseforskningsloven med forskrifter.

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

Av dokumentasjonshensyn skal opplysningene oppbevares i 15 år etter prosjektslutt. Opplysningene skal deretter slettes eller anonymiseres.

Opplysningene skal oppbevares avidentifisert, dvs. atskilt i en nøkkel- og en datafil. Forskningsprosjektets data skal oppbevares forsvarlig, se personopplysningsforskriften kapittel 2, og Helsedirektoratets veileder for «Personvern og informasjonssikkerhet i forskningsprosjekter innenfor helse- og omsorgssektoren».

Prosjektet skal sende sluttmelding til REK, se helseforskningsloven § 12, senest 6 måneder etter at prosjektet er avsluttet.

Klageadgang

Komiteens vedtak kan påklages til Den nasjonale forskningsetiske komité for medisin og helsefag, jf.

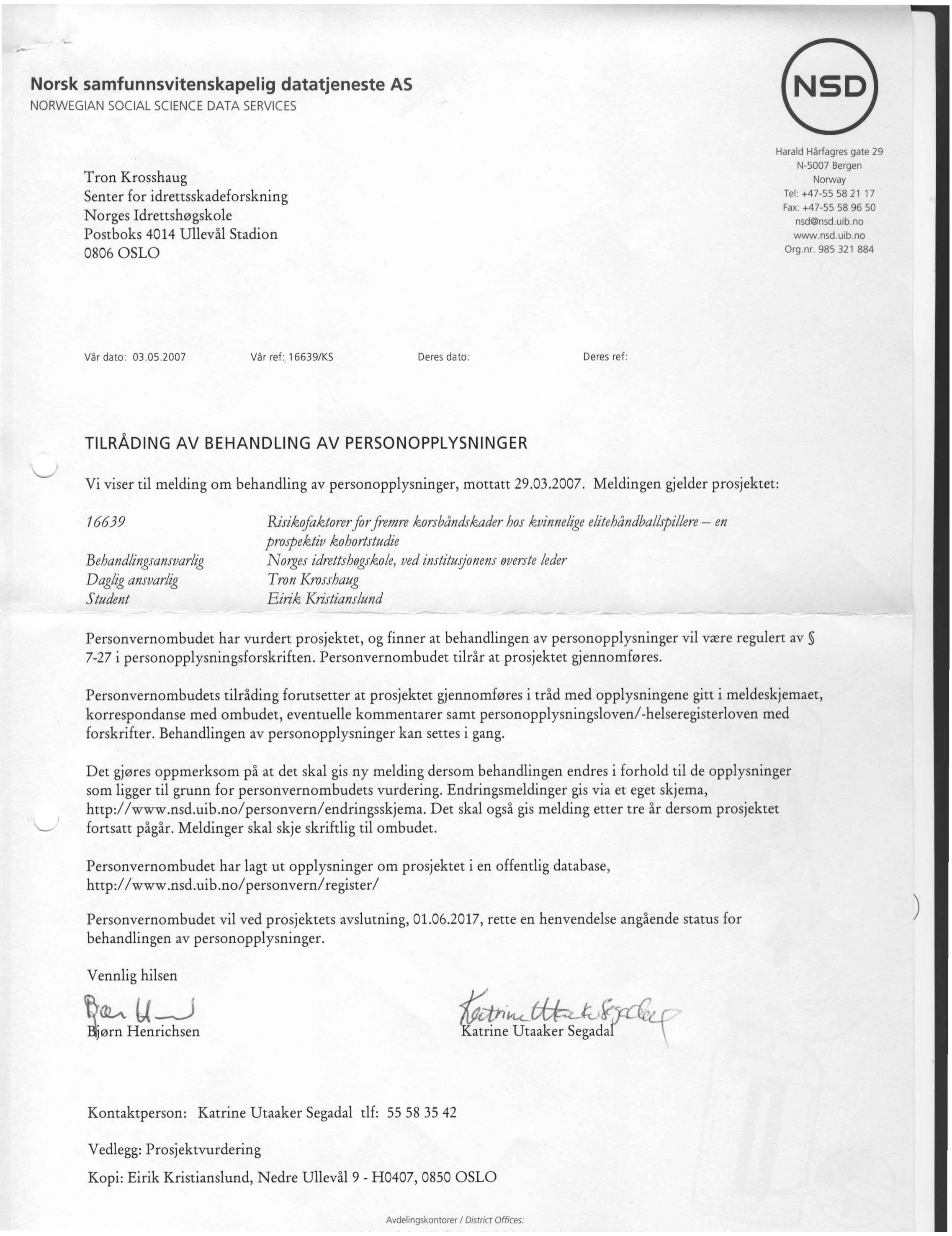
helseforskningsloven § 10 tredje ledd og forvaltningsloven § 28. En eventuell klage sendes til REK sør-øst A. Klagefristen er tre uker fra mottak av dette brevet, jf. forvaltningsloven § 29.

Med vennlig hilsen

Knut Engedal
Professor dr. med.
Leder

Anette Solli Karlsen
Komitesekretær

Kopi til: *postmottak@nih.no*



Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

NSD

Harald Hårfagres gate 29
N-5007 Bergen
Norway
Tel: +47-55 58 21 17
Fax: +47-55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org.nr. 985 321 884

Tron Krosshaug
Senter for idrettsskadeforskning
Norges Idrettshøgskole
Postboks 4014 Ullevål Stadion
0806 OSLO

Vår dato: 03.05.2007 Vår ref: 16639/KS Deres dato: Deres ref:

TILRÅDING AV BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 29.03.2007. Meldingen gjelder prosjektet:

16639	*Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndballspillere – en prospektiv kohortstudie*
Behandlingsansvarlig	*Norges idrettshøgskole, ved institusjonens øverste leder*
Daglig ansvarlig	*Tron Krosshaug*
Student	*Eirik Kristianslund*

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, eventuelle kommentarer samt personopplysningsloven/-helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/endringsskjema. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://www.nsd.uib.no/personvern/register/

Personvernombudet vil ved prosjektets avslutning, 01.06.2017, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Bjørn Henrichsen
Katrine Utaaker Segadal

Kontaktperson: Katrine Utaaker Segadal tlf: 55 58 35 42

Vedlegg: Prosjektvurdering

Kopi: Eirik Kristianslund, Nedre Ullevål 9 - H0407, 0850 OSLO

Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

NSD

Harald Hårfagres gate 29
N-5007 Bergen
Norway
Tel: +47-55 58 21 17
Fax: +47-55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org.nr. 985 321 884

Tron Krosshaug
Senter for idrettsskadeforskning
Norges idrettshøgskole
Pb 4014 Ullevål Stadion
0806 OSLO

Dato: 16.02.2009 Vår ref: 16639 PB/LR Deres dato: Deres ref:

ENDRING AV FORSKNINGSPROSJEKT

Vi viser til endringsmelding mottatt 28.12.2008, samt påfølgende e-postkorrespondanse med daglig ansvarlig (senest 13.02.2009), gjeldende prosjektet

16639 Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndball- og elitefotballspillere – en prospektiv kohortstudie

I endringsskjema opplyses det om at man ønsker å utvide prosjektpopulasjonen til å også omfatte kvinnelige elitefotballspillere fra toppserien i Norge (ca. 240 individer). Tittelen på prosjektet endres dermed fra *Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndballspillere – en prospektiv kohortstudie* til *Risikofaktorer for fremre korsbåndskader hos kvinnelige elitehåndball- og elitefotballspillere – en prospektiv kohortstudie.*

For hele utvalget ønsker man videre å se på genetiske faktorer som risikofaktorer for fremre korsbåndskader. Man skal ta blodprøve (5 ml. venøs prøve) av deltagerne for å studere genvarianter som kan bidra til å lage et svakere ligament. Kollagen er en viktig substans i ligamenter, og man vil i første omgang se på gener som er ansvarlige for kvaliteten mht. kollagenfibre. Prøven sendes til avidentifisert (med kobling til navneliste som oppbevares ved NIH) til Ullevål Universitetssykehus for å ekstrahere DNA. Ekstrahert DNA vil bli sendt til samarbeidspartner i Sør-Afrika, Exercise Science and Sports Medicine Research Unit (ESSM) for videre analyse. Det vil på grunnlag av analysene gjøres sammenligninger mellom skadede og ikke skadede spillere. Resultatene av testene vil kun være tilgjengelig for dette forskningsformålet. Biobanken opprettes ved Ullevål Universitetssykehus.

En ytterligere endring av prosjektet består i at ombudet etter avtale med daglig ansvarlig Tron Krosshaug, registrerer prosjektet som forskerprosjekt i stedet for som studentprosjekt. Studenten ved NIH Eirik Kristianslund er fortsatt å regne som medarbeider i prosjektet, men registreringsendringen foretas på bakgrunn av at prosjektets tidsperspektiv (planlagt avslutning i 2017) gjør det lite hensiktsmessig å la studenten bli stående som kontaktperson for ombudet. Videre registreres stipendiaten ved NIH Agnethe Nilstad som medarbeider i prosjektet sammen med Dr. Scient. Kathrin Steffen og Dr. Med. Thor Einar Andersen.

Ombudet mottok 13.02.2009 reviderte informasjonsskriv for rekruttering av deltagere til prosjektet og finner begge skrivene meget tilfredsstillende.

Ombudet legger til grunn at endringen, inkludert opprettelsen av forskningsbiobank, godkjennes av REK. Det bes om at kopi av tilråding ettersendes.

Ombudet anbefaler at det opprettes en databehandleravtale med Ullevål og med ESSM, jf. personopplysningsloven § 15.

Endringene medfører ingen endring av ombudets opprinnelige vurdering og tilråding av prosjektet (se brev datert 03.05.2007) mht. behandlings- eller hjemmelsgrunnlag.

Ombudet minner om at bruk av videoopptak i undervisnings- eller formidlingsøyemed kan medføre meldeplikt overfor Datatilsynet. Dette bør avklares direkte med tilsynet.

Ta gjerne kontakt dersom noe er uklart.

Vennlig hilsen

Bjørn Henrichsen

Pernilla Bollman

Kontaktperson: Pernilla Bollman 55 58 24 10