Knee kinematics during a novel hop test with an unanticipated change of direction for female floorball athletes and controls

Evaluation of within-session and test-retest reliability and assessment of knee function

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Idrottsmedicin: Examensarbete för magisterexamen
Examensarbete, 30 hp
Vt-2016
Magisterprogrammet i Idrottsmedicin
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**Title:** Knee kinematics during a novel hop test with an unanticipated change of direction for female elite floorball athletes and controls - Evaluation of within-session and test-retest reliability and assessment of knee function  

**Year:** 2016

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**Keywords:** Floorball, reliability, anterior cruciate ligament, knee, kinematics, unanticipated

**Introduction:** The incidence of anterior cruciate ligament (ACL) injuries in female floorball is relatively high, and the risk for sustaining a second ACL injury is greater compared to previously uninjured. Existing evaluation tests in rehabilitation may not be discriminative enough to guide decisions on return to sport.

**Aim:** To evaluate the within-session and test-retest reliability of knee kinematics in floorball athletes and controls during a hop encompassing a sudden unanticipated change of direction. A second aim was to investigate the discriminative validity by comparing the test outcomes between the athletes and a control group of non-athletes.

**Method:** 11 elite floorball athletes and 8 controls were tested on two occasions separated by one to three weeks. Knee kinematics, ground contact time and number of successful hops were analyzed. Relative reliability was quantified by Intraclass correlation coefficient (ICC) and absolute reliability by standard error of measurement (SEM).

**Results:** ICCs for knee kinematics within-session reliability were excellent (0.83-0.96) for athletes and poor to excellent (0.40-0.94) for the controls. For the test-retest reliability, the athletes had good to excellent (0.56-0.96) reliability and the controls had poor to excellent (0.26-0.93) reliability. Only two measured kinematic variables were significantly different between the groups.

**Conclusion:** This pilot study indicate good to excellent reliability for the majority of the kinematic variables tested and, therefore, it could be assumed to be adequately reliable. Discriminative validity needs to be further evaluated in a larger material.
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Introduction

Floorball is an indoor sport that contains a great deal of pivoting, landings, accelerations, decelerations and change of directions, which implies risks of suffering an injury of the anterior cruciate ligament (1). In 2014, the International Floorball Federation reported that there were 300,133 registered players in the world (2). Of these players Sweden had the most, approximately 123,000 (3), second came Finland with 51,000 and thereafter the Czech Republic with 38,000 (4). Few studies investigate the injury spectrum in floorball, but there are some (5). A study by Löfgren et al. (6) showed that floorball is a sport in which the knee and ankle being was the most frequently injured structure, 11% and 30% respectively. Another study included 374 licensed female floorball players from the Finnish top league and followed them prospectively during one season. The researchers could conclude that the incidence for an anterior cruciate ligament (ACL) injury was 5.4 per 100 players per year (1). Also, a new report from Swedish researchers who studied the injury profile of elite floorball athletes pointed out the higher risk for females since the incidence rate of ACL injury between male and females, which was 1% and 6% respectively (7).

The risk of sustaining such an injury is multifactorial and results from a multifaceted interaction between intrinsic factors, such as cognition, physical fitness, anatomy or neuromuscular function, and extrinsic factors, e.g. environment, sport exposure or equipment (8). Intrinsic factors affect reactive situations where there is a short period of time before the joint is loaded and sensory and complex motor planning must correctly anticipate the coming joint loads with the biomechanical demands of the fast changing physical environment (9). If the conscious decision-making function does not cope with the rapidly changing environment, then the movement planning could be disturbed and task uncertainty follows. Consequently contributing to a loss of neuromuscular control and failure to optimally control the knee joint (10), and this loss of control can lead to uncontrolled movements, which is often associated with non-contact ACL injuries (11).

Floorball is a sport which involve landing and cutting in response to extrinsic factors, and the understanding of external stimuli as a risk factor has lead researchers to look at the effect of different tasks anticipation status in relation to the mechanism of the lower extremity. Studies have looked at the combination of different features such as
anticipation (12), decision making (13) as well as the effect of external targets (14), and presented how they can decrease neuromuscular control in comparison to situations without such components. These studies together shows that situations where the attention is distracted from the movement can lead to an altered outcome in hop performance and biomechanics. The combination of intrinsic and extrinsic factors implies that a person will be more or less susceptible to injury (8). Several authors have mentioned specific biomechanical and neuromuscular risk factors associated with the increased risk. Among other, they have described that females exhibit decreased knee and hip flexion angles and increased knee abduction angle, valgus moment and quadriceps activation compared to males when performing hop-landing movements (15-17). These factors together are thought to place a greater load on the ACL. One more reason why so much emphasis has been placed on these biomechanical variables is that they can be influenced by well-targeted training interventions and therefore reduce the risk of ACL injury (18).

An ACL injury can lead to difficult consequences such as high treatment costs (19), time away from the sporting activity (20), pain (21), decreased knee function in the form of loss of motor control (22) and muscle strength (23). Also the physical activity and knee-related quality of life can diminish. Psychological factors have also been recognized as an issue following ACL injury, with feelings of instability which may generate in a fear of movement (24, 25). Long-term studies further show that about 50% of those who suffered an ACL injury are more likely to have radiographic osteoarthritic changes in the knee joint 10-20 years after injury, regardless of whether they have surgery or not (26-28). There is no consent if these changes are due to a meniscus injury at the time of the injury, a secondary meniscus injury, meniscectomy or anything else causing the osteoarthritis development (26). Overall, an ACL injury has a substantial influence on the individual, both in short and long-term.

One challenge for medical professionals is that it is difficult to distinguish which factors that lead to a successful rehabilitation after an ACL injury. The restoration of knee function varies among different individuals depending on ambitions and expectations, but if return to sports is the ambition, one or more tests are required to evaluate knee function. These difficulties are due to a lack of consensus of how knee function during
rehabilitation should be evaluated. There are a number of factors that should be taken into account when assessing the knee function after an ACL injury. Earlier studies have evaluated knee function by using hop performances, muscle strength tests of quadriceps and hamstring, and with questionnaires (29, 30). Hop tests are especially interesting to use before returning to sports since they are functional and the performance will be influenced by numerous factors such as muscle strength, flexibility, neuromuscular ability, balance and endurance (during repeated hops/tests) (31). These tests challenge the knee and require a good knee function during push-off and landing phases, which is similar to conditions occurring during sport situations. There is however no consensus of which hop test that best evaluates knee function before returning to sport. There are various tests described in the literature and most of them have been shown to be valid and reliable (32). The current recommendation is to use a battery of tests to evaluate different aspects of knee function (33, 34). However, when comparing the results of test performance and the patient's self-reflected knee function there is a clear discrepancy since self-reported knee function during sports as well as knee related quality of life is poor, even with >90% muscle function capacity in their injured leg compared with their non-injured leg (35, 36). This problem is emphasized in a review by Adern et al. (20) in which it is stated that only 63% had returned to pre-injury level participation three years after injury. One reason for this was that many did not trust that their knee would be able to cope with the demands of return to sport.

It has further been shown that the risk of a re-rupture on the ipsilateral leg or a second ACL injury on the contralateral leg is higher in persons who have already sustained an ACL injury, compared with uninjured persons (37, 38). A recent study showed that athletes between the ages of 10 and 25 years who returned to a pivoting or cutting sport after ACL reconstruction was 15 times more likely to sustain an ACL injury in the first 12 months compared to a previously uninjured athlete (38). The same authors also showed that about 30% of the patients who sustained a second ACL injury had it in less than 20 athletic-exposures after being cleared to return to their sport (39). Another study concluded that young athletes (<20-25 years old) have a 30 to 40 times greater overall risk of sustaining a second ACL injury when compared with their uninjured teammates if they return to high-risk sports. In other terms approximately 1 of 4 young athletes with a primary ACL injury will sustain a secondary injury, and it will likely occur early after
return to play (40). This high re-injury rate could be an indication that several ACL injured patients have not been rehabilitated enough when they return to their sport, despite approved test scores.

To evaluate the rehabilitation of an ACL injury a ratio of the difference between the injured and un-injured leg is often calculated during hop and strength tests, this is referred to as the limb symmetry index (LSI). The existing recommendations for LSI vary slightly, however the latest proposal for LSI is ≥90% during hop tests and ≥100% for muscle strength tests, to be able to reassure a safe return to knee demanding sports (33). Nevertheless, the use of LSI is controversial since studies have shown that an ACL injury on one leg can lead to a cross-over effect on the contralateral leg with decreased function, strength and proprioception due to changes in e.g. biomechanics and neuromuscular control (41, 42). To then compare the injured leg with the non-injured leg could lead to an overestimation of the rehabilitation and test results. Also, quantitative and absolute measures such as height, length and number of accomplished hops, which today are used during the evaluation of knee function in hop tests, does not give adequate information about the movement quality (30). A recently performed study where the quality of knee movement was addressed, showed that both ACL reconstructed and ACL deficient patients presented lower extremity kinematics that increased the risk of an ACL injury even after they had fulfilled their rehabilitation program (43). Information of landing technique, knee and hip kinematics, and their moments can give more valuable information to be able to separate ACL injured patients with inappropriate movement patterns to those with optimally restored movement patterns. If these biomechanical variables are included in relation to absolute measures of hop performances, then hop tests could be an even better predictor to establish the evaluation of rehabilitation.

As mentioned above, a movement in floorball does not always happen with the knowledge of how it will be executed, but rather as a reaction to e.g something external, such as an opponent who needs to be avoided, or when running after a ball in an unanticipated direction. The majority of hop test are performed with the subject having knowledge of what movement is going to be executed even before the test begins. This awareness leads to planning of how to execute the movement before the test is
performed and does not reflect the loading that occur during the sporting activity, where persons have to react without previous information about the movement (44). Knowledge of how unanticipated movements could contribute to potentially unsafe knee movements is therefore essential to e.g. reduce the incidence of ACL injuries. A previous study showed that movement patterns are planned and implemented before a cutting task is performed, by adjusting the direction of foot and abdomen in advance to correct the body towards the new direction and maintaining appropriate posture (45). Researchers who have investigated if there is a difference in knee kinematics between anticipated and unanticipated hop tests shows that there are significant differences between them. There is an increased risk for the knee to end up in a position with higher risk of an ACL injury, such as smaller hip flexion angle, knee flexion angle and greater flexion and valgus moments during unanticipated movement (44, 46, 47). Furthermore, it has been demonstrated that the external varus/valgus and internal/external rotation moments applied to the knee joint during unanticipated cutting maneuvers are up to two times higher compared to anticipated conditions (12). This stress can significantly increase the load on the ACL, especially if the muscles around the knee are not sufficiently activated to counter the load (48). A sport specific and challenging hop test with demands of reaction and cutting components can therefore present important information about knee function.

Three-dimensional motion analysis of different hop tests to evaluate the knee function has become increasingly common within the research of ACL injuries (49-51). When performing such tests on repeated occasions there will always be some variation due to the participant, tester or the instrument being used. So, when a new test is being developed it should be tested for reliability before the validity, since good reliability is a requirement for the validity (52). Two frequently used statistical methods for calculating the reliability is the Intraclass correlation coefficient (ICC) and the standard error of measurement (SEM). Both measures are related; however, they describe distinctly different properties. The ICC is a form of relative reliability that varies between zero (no reliability) to one (perfect reliability). The SEM has been used to decide the absolute reliability and is a quantified value from the test and provides an indication of the dispersion, in the same unit of measurement as the test, of the measurement errors for the true value of the participant score. Thus it gives an
indication for how accurate the test is (53), and may provide a good estimation to predict the minimal clinically important difference.

The reliability of kinematics for lower limb biomechanical measurements during a single-leg cutting task have been investigated by a few authors. DiCesare et al. (54) investigated the reliability between three different institutions and showed coefficient of multiple correlations (CMC) values for the right and left knee during knee flexion (0.93 and 0.96, respectively), knee abduction (0.79 and 0.76, respectively), and knee internal rotation (0.62 and 0.78, respectively). Sigwards and Powers (55) presented between day reliability for a cutting maneuver and showed CMC values for flexion-extension, abduction-adduction and internal-external rotation (0.98, 0.63, and 0.61, respectively). However these results should be interpreted with caution since the CMC has been mentioned to be unsuitable for assessing the reliability of kinematic data. The range of motion (ROM) will affect the outcome and therefore CMC will have different values for each joint and plane, and can consequently not be compared with other joints and planes (56). In 2005 Ford et al. (57) presented ICC values for within-session reliability from three trials for knee abduction-adduction angles from an unanticipated cutting maneuver at initial contact (0.93), maximum abduction (0.94) and maximum adduction (0.95). However, they did not examine the test-retest reliability. To the authors knowledge, the study by Ford et al. (57) is the only study which have examined the reliability of a cutting task in combination with an unanticipated component. So there is limited information concerning such a task, which could be more complex and varied than a regular cutting maneuver and therefore result in lower reliability. However, it could still provide additional information when evaluation the dynamic knee function.

To sum up, there is an obvious need to improve the evaluation of knee function in dynamical and functional movements. The tests used today are not sensitive enough to find impairments in motor control and function, which are considered important parameters for an optimally functioning knee. In order to support the use of a newly developed hop tests with focus on the knee function, further information concerning its measurement characteristics should be provided. Specially, further information regarding the reliability of these hop tests is needed to more accurately plan for the
future use of it. It is also unclear what impact the athletic experience has on knee joint movement patterns, which is an other issue that this study aims to adress.

The main aim of this paper was thus to investigate the within-session and test-retest reliability of a new knee-demanding hop test with an unanticipated change of direction among female floorball elite athletes and a matched control group. The hypothesis was that kinematic variables quantified from the hop test would be reliable within and between sessions, for both groups. A second aim was to measure and compare the kinematics of the knee during a part of the loading phase in the unanticipated hop test with a change of direction. It was hypothesized that during the unanticipated hop test the athletes, which is more experienced in such complex tasks, would display movement patterns with greater knee flexion and smaller knee abduction compared to the control group. Based on the existing literature, no benchmark for kinematic values could be set as an increased risk of ACL injury. However, it is likely that a combination of lower flexion, larger knee abduction and tibial rotation are deleterious movement patterns for the knee joint in relation to non-contact ACL injury.

Methods

Participants
There were 11 female elite athlete floorball players and eight female controls recruited to participate in this study (see Table 1). The participants were recruited by convenience through a research coordinator, relatives, colleagues and other contacts. Ads were also set up around the Umeå university campus. Inclusion criterias for both groups were: age 17 – 34, no musculoskeletal injuries or neurological diseases and no history of knee or ankle injuries the last six months. An experienced physiotherapist examined the participants knees prior to the to the test session to ensure that the participants had no problems with their knees. The participants in the athletic group were included if they were active in the highest or second highest national floorball league and regularly performed specific knee demanding exercises which stresses the knee in all three planes (frontal, sagittal and transversal). The control group was excluded if they performed any such knee demanding activities (exercise such as strength training or participating in various group training was considered acceptable). The groups were matched based on age, gender and body mass index (BMI). All
participants were required to wear shorts and a sports bra, and to be barefoot during the test.

**TABLE 1.** Descriptive data for athletes and control (Mean and SD).

<table>
<thead>
<tr>
<th></th>
<th>Athletes (N=11)</th>
<th>Controls (N=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>21.3 ± 2.5</td>
<td>23.0 ± 4.0</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.70 ± 0.05</td>
<td>1.70 ± 0.03</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>63.3 ± 7.8</td>
<td>62.8 ± 7.4</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.0 ± 2.0</td>
<td>21.8 ± 1.9</td>
</tr>
<tr>
<td>One leg hop distance (m)</td>
<td>1.28 ± 0.17</td>
<td>1.18 ± 0.15</td>
</tr>
<tr>
<td>Isometric hamstring strength (Nm/kg), 65° flexion</td>
<td>0.7 ± 0.1</td>
<td>0.6 ± 0.2</td>
</tr>
<tr>
<td>Isometric quadriceps strength (Nm/kg), 65° flexion</td>
<td>1.6 ± 0.3</td>
<td>1.4 ± 0.4</td>
</tr>
</tbody>
</table>

**Length and strength measures**

Data from tests of the common one leg hop for distance (OLHD) and isometric strength for knee flexion and extension was collected for descriptives of the participants. The OLHD was performed prior to the unanticipated hop test. The participant was informed to hop as far as possible with requirement of stabilization in the landing. The length of the hop was calculated via a motion analysis system used in this study (see below), and was based on the horizontal movement of a reflective marker on the head of the 5th metatarsal. A maximum of five attempts were allowed in the OLHD, however if three succesfull landings were accomplished it was considered to be enough. A strength test was performed seated in a Kin-Com (Kinetic communicator 125 Auto Positioning, Chattanooga Group Inc.; Hixson, TN, USA) with the backrest set at an angle of 78° and seat angle of 10°. Straps were set around the chest, waist and tigh to limit body motion and prevent compensation of other muscles than the quadriceps and hamstring. The angle of the knee was set to 65° (for both flexion and extension) using the lever. The buckle from the lever was attached around the foot, it was approximately 10 centimeters high with the lower part just above the medial malleolus. Three trials of maximum voluntary isometric contractions (MVIC) was performed for quadriceps and hamstrings. For each trial the participant was instructed to produce a maximal force against the resistance lever for five seconds and then rest five to seven seconds before the next MVIC. A moving average window of 60 ms was applied to the raw data for
smoothing, and the maximum moment was then multiplied with the length of the KinCom’s lever to the buckle where the foot was strapped and used in analyses. Theses strength tests was performed after the completion of the unanticipated hop test to avoid fatigue during the hop.

**Hop design**
The participants performed 10 unanticipated hops with their hands behind their back holding a short rope (two decimeter long with a large knot on each side). Requirements for distances to hop were normalized to 25% of the individual body length. Each hop began with the person standing on the dominant leg on a force plate and making a hop forward over the predetermined distance. A projector then lit up the subsequent direction at take-off, which was either medial or lateral relative to the dominant leg at a distance of 25% of body length and at an angle of 45 degrees (see Figure 1). For the hop to be approved, the participant had to hop in the correct direction and reach the point of light that was illuminated by the projector, as well as to maintain balance and control of the landing. One experienced assessor (J.M.) decided between successful and unsuccessful trials. The order of the unanticipated hop direction was
fixed randomly, which means that the direction was not predictable, but with the requirement that it, in the end, were five hops in the medial direction and five in the lateral direction. Verbal instructions were given before the test session began and the participants performed two test trials for each leg which was pre-determined to both medial and lateral directions without their knowledge. This design was used in order to let participants try both possible hop directions for both legs in the test trials before the test began for familiarization.

**Kinematic analysis**

For each trial a complete 3-D analysis with motion and force data of the leg executing the hop was performed. Two events were used to extract the part of the kinematic data that was analysed, and these events were based on the vertical ground reaction force
(VGRF) in each hop. The loading phase of interest in which the kinematics was extracted from were from initial contact (IC), which was defined as when VGRF exceeded 10 Newton (N), to peak push off (PPO) which was the point when the last distinct peak in VGRF appeared before its decline (see Figure 2 for description). In response to the large increase in VGRF that appear after the IC, the knee may be required to adopt a joint posture that serves to decrease the rate of loading. For instance, the knee, hip and ankle all flex to allow for shock absorption, and VGRF decreases (58). This was followed by another increase in VGRF, the PPO, where force is developed to hop towards the new direction. If the graph showed several peaks in VGRF after the shock absorption phase the last peak in VGRF was defined as PPO. This phase was used for the analysis to exclude maximal or minimal angles that might occur in a later stage during the cutting movement since the foot is fixed to the ground while the rest of the body is turned towards the new hop direction. Also, there is a kinematic phenomenon called “screw-home mechanism” which means that during the last 20° of extension the tibia will rotate externally to femur to stabilize the knee (59, 60). Angles in the later stage of the loading phase could therefore be considered as less important to investigate in relation to the injury mechanism of the ACL (61).

So, peak angles in the frontal, transverse and sagittal plane were calculated from the IC to the last PPO of loading phase for each hop. Flexion, adduction and internal rotation were defined as positive values in the coordinate system, with the consequence of extension, abduction and external rotation as negative values and flexion, adduction and internal rotation as positive values. There were two possible outcomes for each hop and leg: an unanticipated hop in medial direction or in lateral direction. Also the ground contact time was registered from IC to the moment when the VGRF fell below 10 N.
Figure 2. Description of the phase used in the kinematic analysis based on vertical ground reaction force. The loading phase starts when the subject land on the force plate, then a steep increase in VGRF occurs followed by a decline in the shock absorption. Next a further increase of VGRF occurs when the subject pushes off to hop in the new direction. IC – Initial contact; PPO – Peak push off.

**Experimental setup**

The test was performed on two test occasions approximately one to three weeks apart in a motion laboratory at the Physiotherapy, Umeå University, with a 3-dimensional motion analysis system (Oqus, Qualisys, Gothenburg) with eight high-speed cameras (<1000 Hz), and three force plates (Kistler Winterthur, Switzerland, 240 Hz). The kinematic data for this study was collected as a part of a larger ongoing study where the participants performed several tests in addition to the unanticipated hop test with a change of direction (See appendix A for description of all tests).

A calibration of the movement analysis system was performed before every test occasion by using an L-shaped reference structure near one of the force plates to acquire the correct coordinate system (X as flexion-extension axis, Y as adduction-abduction axis, Z as internal-, external rotation axis). The calibration staff was then moved inside the measurement area in all three directions by spinning and moving the staff. A successful calibration of all systems had the requirements of 1) a standard deviation of
wand length ≤ 0.7 mm, 2) a measurement volume covering the area of movement, and 3) force plates showed force vectors in all directions when stepping and leaning forward, backward, and to the left and right. Zero force baseline correction was used when exported to Visual 3D after data processing in Qualisys track manager to counter any possible drift in force with regard to time due to the technique with piezoelectric crystals in the force plates.

Before the performance of the tests, 56 reflective markers were placed on the following specific anatomical locations: front head, right/left head, right/left shoulder, right/left elbow, right/left wrist, sacrum, right/left crista, right/left ASIS, right/left trochanter, right/left leg lateral/medial epicondyle, right/left tuberositas tibiae, right/left head of fibula, right/left medial/lateral malleolus, right/left sustentaculum tali, right/left lateral calcaneus, right/left foot dorsal proximal end of calcaneus, right/left foot dorsal distal end of calcaneus, right/left foot head of 5th metatarsal, right/left foot medial aspect of first metatarsal, and on the right/left foot proximal base of first metatarsal (See appendix B). A cluster of four markers were also attached to the right and left thighs, and a cluster of three markers were attached to the right and left shanks. These clusters can be more stiff than individually attached markers and may reduce errors caused by soft tissue movement (62). A stationary trial and a movement of circumduction of the hip and ankle were first completed with each participant to define the segmental coordinate system. After this stationary trial nine marker was removed from the sacrum, bilateral trochanter, bilateral medial and lateral epicondyles, and from the bilateral medial malleolus.

The following data reduction process was performed. The reflective markers recorded for each trial was captured, identified and computerized in Qualisys track manager (Oqus®, Qualisys AB, Gothenburg, Sweden) and 3D marker coordinates was constructed. The data was then exported to Visual 3D (C-Motion Inc. Germantown, Maryland, USA) where a full-body model was constructed, events were set and pipeline scripts were used to export the kinematic data of interest.
Statistical analysis

A power calculation was performed prior to this study based on previous experience, it was made for the larger ongoing project aiming for in total 30 participants in each group. This is an exploratory pilot study on a subgroup of data. Calculations of the measured outcomes were only made on the participant’s dominant leg, which was defined as the preferred leg to kick a ball.

The reliability of the kinematic variables extracted from the unanticipated hop test was calculated by Intraclass correlation coefficient (ICC) within and between sessions. The version of ICC was 2.1 for within session reliability and 2.k for test-retest, the setup was two-way random, type absolute agreement and averaged measures model. The test-retest values was calculated based on the mean of successful trials from test 1 compared to the mean of successful trails in test 2. The within-session reliability was calculated based on the individual kinematic value from each hop trial in hop one to three in test 1. The classification of Fleiss (63) was used to categorize the ICC: <0.4 are considered poor reliability, between 0.4 – 0.75 good reliability and >0.75 excellent reliability. To establish if there were any differences between test occasions a supplied F-test was calculated to display the repeated measures analysis-of-variance. This was done to clarify whether the repeated measure provided a learning effect, which means that the participant performs better on the second occasion without any training being the reason for such an improvement. SEM was calculated to provide an estimate of the error in the units of measurement, thus giving clinically relevant values for expected error in an individual. It was based on the standard deviation of the mean values of the measurements taken, and the ICC value for the measurement (SEM = SD * √(1 - r), where SD is the standard deviation and r the reliability coefficient). The data were also presented using a Bland-Altman analysis. This method was based on the combined mean from the two test occasions and the difference between test occasions, provided by the same participant. Independent samples t-test were used to assess for significant differences of the mean measurements between the groups when normal distribution was assumed by Shapiro-Wilk test. If normality distribution was rejected, the Mann-Whitney U test was used for group comparison. Statistical significance was set at P <0.05 for all tests. The statistical analysis was performed using SPSS software (IBM SPSS statistics, Armonk, New York, USA) version 23.
Ethical considerations

The study was approved by the Regional Ethical Review board, and all subjects received both verbal and written information (see appendix C for controls and appendix D for athletes) about the study and possible risks. Signed consent was obtained before the procedure started. All personal data was coded to be anonymized so that non-authorized persons could not identify the participants, then it was stored at a locked cabinet that only authorized persons had access to.

Results

No significant differences were detected for age, height, weight, body mass, BMI, one leg hop distance, isometric hamstring strength or isometric quadriceps strength (Table 1). One athlete and one control were excluded from the test-retest analysis due to only having performed one test session. Two athletes and one control were excluded from the analysis of within-session reliability due to not enough completed hops.

Within-session reliability

The within-session reliability for the first test session is presented in Table 2 as both ICC and SEM. For athletes the ICC ranged from 0.83 – 0.96 which indicates excellent within session reliability for all kinematic variables, and absolute values in SEM ranged from 0.9° - 2.1°. For the control group ICC ranged between 0.40 – 0.94 indicating poor to excellent reliability, the SEM varied from 0.8° – 6.4°. The least reliable variable for the control group, maximal flexion in medial direction, was the only within-session result categorized as poorly reliable. Of the measured kinematic variables, 22 out of 24 were reported to have excellent reliability.
TABLE 2. Within-session reliability of knee kinematics based on trial 1-3 from the hop test on the first test occasion for athletes and controls.

<table>
<thead>
<tr>
<th></th>
<th>Athletes (N=9)</th>
<th>Controls (N=7)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC T1</td>
<td>SEM T1</td>
</tr>
<tr>
<td><strong>Medial hop</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>Max</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>0.91</td>
</tr>
<tr>
<td>Adduction</td>
<td>Min</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>0.93</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>Min</td>
<td>0.90</td>
</tr>
<tr>
<td><strong>Lateral hop</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>Max</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>0.95</td>
</tr>
<tr>
<td>Adduction</td>
<td>Min</td>
<td>0.96</td>
</tr>
<tr>
<td></td>
<td>Max</td>
<td>0.96</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>Min</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Flexion, max (maximal flexion), min (minimal flexion); Adduction, max (adduction), min (abduction); Internal rotation, max (internal rotation), min (external rotation); ICC (intra class correlation); SEM (standard error of measurement); T1 (test occasion 1).

**Test-retest reliability**

The mean, SEM and ICC from the test-retest for each hop outcome is displayed in Table 3 for athletes and in Table 4 for the control group. Most of the variables achieved good to excellent test-retest reliability. ICC ranged between 0.56 – 0.96 for athletes and 0.26 – 0.93 for the control group. The highest ICC for athletes was obtained for minimal flexion in lateral direction (ICC: 0.95), whereas the control group attained lower reliability (ICC: 0.71), see figure 3. The variable with the lowest ICC for athletes was maximal adduction in lateral direction (ICC: 0.56), while the control group had slightly higher reliability (ICC: 0.84), see figure 4. The highest SEM was however minimal internal rotation with medial hop direction (2.9°) for athletes and maximal flexion lateral hop direction (3.1°) for the control group.
The ANOVA, which was performed in the test-retest reliability analysis, showed no significant differences between test and retest mean scores for any kinematic variables, which indicates absence of systematic bias (see Table 3 and 4).

TABLE 3. Data for the athletic group (N=10) of test-retest kinematic test measures made on two different occasions.

<table>
<thead>
<tr>
<th>Hop outcome</th>
<th>Angle</th>
<th>Mean (SD) T1</th>
<th>Mean (SD) T2</th>
<th>SEM</th>
<th>ANOVA (p-value)</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial hop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion (*)</td>
<td>Max</td>
<td>57.0 (6.9)</td>
<td>56.4 (7.7)</td>
<td>2.1</td>
<td>0.68</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>14.6 (5.3)</td>
<td>13.9 (5.7)</td>
<td>1.7</td>
<td>0.57</td>
<td>0.90</td>
</tr>
<tr>
<td>Adduction (*)</td>
<td>Max</td>
<td>10.2 (4.6)</td>
<td>12.6 (4.0)</td>
<td>2.5</td>
<td>0.08</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>0.76 (4.3)</td>
<td>1.4 (3.3)</td>
<td>1.4</td>
<td>0.41</td>
<td>0.87</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>Max</td>
<td>-2.8 (4.8)</td>
<td>-3.2 (3.9)</td>
<td>1.9</td>
<td>0.71</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>-14.8 (7.9)</td>
<td>-16.0 (5.4)</td>
<td>2.9</td>
<td>0.50</td>
<td>0.81</td>
</tr>
<tr>
<td>Lateral hop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion (*)</td>
<td>Max</td>
<td>57.2 (5.9)</td>
<td>57.9 (6.7)</td>
<td>1.5</td>
<td>0.47</td>
<td>0.94</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>14.0 (6.1)</td>
<td>14.5 (6.2)</td>
<td>1.3</td>
<td>0.57</td>
<td>0.95</td>
</tr>
<tr>
<td>Adduction (*)</td>
<td>Max</td>
<td>11.5 (3.0)</td>
<td>16.1 (3.5)</td>
<td>2.2</td>
<td>0.07</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>0.3 (5.2)</td>
<td>4.7 (4.6)</td>
<td>1.7</td>
<td>0.10</td>
<td>0.88</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>Max</td>
<td>-1.0 (3.6)</td>
<td>-5.4 (3.1)</td>
<td>2.0</td>
<td>0.26</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>-13.9 (3.2)</td>
<td>-19.3 (5.6)</td>
<td>2.4</td>
<td>0.27</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Flexion, max (maximal flexion), min (minimal flexion); Adduction, max (adduction), min (abduction); Internal rotation, max (internal rotation), min (external rotation); ICC (intra class correlation); SEM (standard error of measurement); SD (standard deviation); T1 (test occasion 1); T2 (test occasion 2); * (statistically significant difference (P<0.05)).
TABLE 4. Data for the control group (N=7) of test-retest kinematic test measures made on two different occasions.

<table>
<thead>
<tr>
<th>Hop outcome</th>
<th>Angle</th>
<th>Mean (SD) T1</th>
<th>Mean (SD) T2</th>
<th>SEM</th>
<th>ANOVA (p-value)</th>
<th>ICC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial hop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion (*)</td>
<td>Max</td>
<td>60.0 (5.9)</td>
<td>58.7 (10.9)</td>
<td>2.8</td>
<td>0.72</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>15.6 (4.5)</td>
<td>18.3 (5.9)</td>
<td>3.3</td>
<td>0.24</td>
<td>0.60</td>
</tr>
<tr>
<td>Adduction (*)</td>
<td>Max</td>
<td>8.8 (4.8)</td>
<td>8.9 (4.9)</td>
<td>1.1</td>
<td>0.96</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>-2.2 (3.4)</td>
<td>-2.7 (5.5)</td>
<td>0.8</td>
<td>0.56</td>
<td>0.97</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>Max</td>
<td>-0.2 (1.4)</td>
<td>0.3 (2.0)</td>
<td>1.5</td>
<td>0.57</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>-13.4 (3.4)</td>
<td>14.6 (3.3)</td>
<td>0.9</td>
<td>0.08</td>
<td>0.92</td>
</tr>
<tr>
<td>Lateral hop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion (*)</td>
<td>Max</td>
<td>56.9 (7.7)</td>
<td>59.7 (9.1)</td>
<td>3.1</td>
<td>0.22</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>17.6 (5.2)</td>
<td>17.3 (6.0)</td>
<td>3.0</td>
<td>0.87</td>
<td>0.71</td>
</tr>
<tr>
<td>Adduction (*)</td>
<td>Max</td>
<td>11.6 (3.0)</td>
<td>12.2 (5.8)</td>
<td>1.8</td>
<td>0.60</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>0.3 (5.2)</td>
<td>0.2 (6.1)</td>
<td>1.5</td>
<td>0.95</td>
<td>0.93</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>Max</td>
<td>-1.0 (3.6)</td>
<td>-0.2 (2.5)</td>
<td>2.2</td>
<td>0.62</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Min</td>
<td>-13.9 (3.2)</td>
<td>-15.9 (3.4)</td>
<td>2.8</td>
<td>0.26</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Flexion, max (maximal flexion), min (minimal flexion); Adduction, max (adduction), min (abduction); Internal rotation, max (internal rotation), min (external rotation); ICC (intra class correlation); SEM (standard error of measurement); SD (standard deviation); T1 (test occasion 1); T2 (test occasion 2); * (statistically significant difference (P<0.05)).
Figure 3. Bland-Altman plot for kinematic test-retest reliability for minimal flexion in lateral direction between athletes and controls. The middle line represents the mean difference between the 2 trials.
Group comparisons

Knee joint angles were compared between female elite floorball players and a control group performing an unanticipated cutting manoeuvre between IC and PPO of the loading phase. Contrary to the hypothesis the groups exhibited comparable knee joint kinematics in most variables (P>0.05). The athletes, however, performed the task with significantly different internal rotation in both medial and lateral hop direction during the second test session, with athletes having greater internal rotation than the control group. In the medial direction athletes had a mean maximal internal rotation of -3.2 ± 3.8°, whereas the control group had a mean maximal internal rotation of -0.3 ± 2.0°. In the lateral direction the athletes presented a mean of -5.4 ± 3.0° and the control group -0.2 ± 2.5°. The athletes also displayed a longer contact time of 0.74 ± 0.29 s on the second test session when hopping to the lateral direction, compared to 0.55 ± 0.15 s for the control group. No other significant differences could be seen.
Discussion
The overall objective was to determine if a new knee-demanding test with an unanticipated change of direction might contribute to the assessment of knee function and if it differs between elite floorball athletes and a control group. The first step and purpose of this study was to establish the within-session and test-retest reliability for the measured kinematic variables. The results showed that almost all variables had excellent reliability within a test session and the majority of variables was classified as good to excellent for test-retest reliability. In the comparison of knee kinematics two variables differed between the groups, on the second test occasion, so did the contact time when hopping in a lateral direction.

Results discussion
Reliability
When performing three-dimensional motion analyses, the ability to be able to reliably measure and identify changes in kinematic variables in a population on different occasions is important. High reliability infers that there is a good precision in the single measurement and that the test can detect differences between measurements. If low reliability is obtained it shows that there will be differences upon retesting, and therefore the outcomes cannot be meaningfully interpreted (64). Previously kinematic data from anticipated cutting hop test has been suggested to be reliable, both within-session and between-session (55, 57, 65). However, the current study is the first to investigate and present within-session and test-retest reliability for several knee kinematic variables in an unanticipated hop test with a change of direction.

The majority of measured kinematic variables displayed excellent relative within-session reliability. Only maximal flexion with lateral direction and maximal internal rotation with lateral direction for the control group showed lower ICCs, 0.40 and 0.64 respectively. The maximal flexion with lateral direction for the control group presented the largest SEM value (6.4°), in the within-session reliability analysis. The good repeatability observed within-session suggests that errors due to soft tissue movement and movement variability were somewhat repeatable and systematic. The test-retest ICCs were generally lower than the within-session reliability. Similar results has been
found in three-dimensional reliability analysis of the knee for vertical drop jump (66) and running (67).

Most of the test-retest ICC values for the kinematic variables achieved good to excellent reliability (see Table 3 for athletes and Table 4 for controls). Generally the reliability seems to be greater for the athletic group since eight variables could be classified as excellent and four as good. Whereas for the control group seven variables was considered excellent, three as good and two as poor. However, no analysis was performed to investigate if ICCs was statistically different between groups, thus restricting these results to observations. The kinematic variables which displayed poor reliability was maximal internal rotation with medial direction (ICC: 0.27) and minimal internal rotation with lateral direction (ICC: 0.26) for the control group. However the SEM for these variables was 1.5° and 2.8° which is comparable to the reliability of the other kinematic variables within the range of good to excellent reliability. Similarly the two variables with the highest SEM; minimal flexion in medial direction (SEM: 3.3°) and maximal flexion in lateral direction (SEM: 3.1°), both from the control group, showed relatively high ICC values (0.60 and 0.86 respectively). Both of these outcomes are movements in the sagittal plane, which means that they have the largest range of motion compared to other planes, therefore the high SEM values for flexion which is seen both within-session and test-retest only represent a small relative part of the possible range of motion and could possibly be considered as acceptable error.

An important question in the reliability of a test is whether the measures are reliable enough for clinical decision-making. Although absolute and relative reliability measures have commonly been reported in different hop tests (66, 68) it is in isolation difficult to determine whether they are reliable enough. There is no universally applicable standard of what level of ICC will be found as acceptable, it has to be determined by the specific context of the test, with the level of acceptable measurement error relating to its purpose (69). Although, distributions to be able to classify reliability have been proposed where ICCs below 0.40 are considered as poor, 0.40–0.75 as moderate, and values above 0.75 as excellent reliability (63). When interpreting the score of ICC, one should also have in mind that the ICC is affected by the homogeneity of the population. So, the attained value will depend greatly on the variance of the scores in the group,
where low between-subject variability will decrease the value of the ICC even if the test-retest variation is low (70). The SEM is important to display, together with the ICC, since it provides an absolute index of the expected error for the individual performing the test. However, there is no clarity regarding an acceptable SEM so the context of the measurement needs to be used to decide what is clinically acceptable.

**Comparison between athletes and non-athletes**

The level of experience in sports have been suggested as a potential factor in the increased risk of ACL injury as the experience affects a persons ability to anticipate and respond to sport specific stimuli (71, 72). A feed-forward mechanism based on the anticipation of the load or movement has a preparatory effect of activation. This preparatory activation can evolve and be altered trough the assimilation of earlier experiences of the skill or movement (73). Therefore it was hypothesised that during an athletic task an elite floorball athlete would perform a more effective decision-making and have greater knee flexion and less knee abduction compared to a person with less experience. However, when comparing the kinematics between floorball athletes and a matched control group the majority of measured variables did not show any significant differences. This is conflicting with the results of McLean et al. (16) who reported that less experience were a vital factor for increased variability in knee kinematics during a cutting task. Also, Kipp et al. (74) showed results in which a group of recreational athletes had an greater peak knee abduction angle and knee abduction moment compared to elite atheletes, when going from an anticipated cutting maneouver to unanticipated conditions. Contrary Howard and Powers (55) showed that female athletes with more experience, compared to novice, had higher peak knee flexion-, adduction- and internal rotation moments during the initial stance phase at an unanticipated side-stepping maneouver, which is a movement pattern known to increase the risk of an ACL injury (48). The cause for these results where assumed to be due to the presence of greater co-contraction in the novice group. They presented a significantly higher co-contraction of quadriceps and hamstring on the measured electromyography (EMG). So, it seems that the level of experience has an effect on biomechanical differences, but it is not evident that more experience of knee demanding situations leads to more optimal kinematics with greater knee flexion and less knee abduction during an unanticipated hop test.
The athletes included in this study had, in addition to being elite athletes, the requirement to regularly perform knee specific demanding exercises, which was not allowed for the control group. The existing evidence supports that the use of such exercise-based injury prevention programs can reduce the risk of ACL injuries (75). The proposed effect of these exercises is to improve biomechanical and neuromuscular function and thereby reduce the risk of sustaining an injury. It could therefore be assumed that the effect of these exercises could be examined by observing biomechanical and neuromuscular characteristics, such as kinematics and kinetics, during a task which involves hop, landing and cutting movements. Research have demonstrated increased improvements in movement patterns such as knee flexion, knee valgus and hip motion after the completion of exercise-based injury prevention programs (76). It was hypothesized that the athletes would obtain kinematic values with greater knee flexion and less knee abduction, which could be categorized to be less deleterious, compared to the control group, and therefore function as a criteria before returning to sports from an ACL injury.

The lower limb kinematics displayed by the participants of the present study during the execution of the unanticipated manoeuvres revealed that the athletes displayed greater maximal internal rotation in both medial and lateral direction during the second test occasion compared to the control group. This rotation have been known to increase the load of the ACL, though it is the combination of excessive motion in the frontal, sagittal and transverse plane which have been proposed to be the risk factor for rupture of the ACL ligament (61). Injury risk may also be influenced by the speed at which an person performs a skill, given that most noncontact ACL injuries occur rapidly (77). The athletic groups presented a significantly longer contact time when performing the hop in a lateral direction. It has been demonstrated that a landing from a cutting task with longer contact time are softer and provide greater knee flexion angle at initial ground contact, which is thought to reduce ACL loading (78). A possible reason for why athletes produced some different kinematics compared with the control group is that athletes might not adopt a movement if it does not result in a more effective performance and therefore decrease the efficiency of the executed movement. Vescovi et al (79) showed that after 12 weeks of participation in ACL injury prevention program the agility
performance, with sprint and change of direction, had decreased. Cochrane et al (80) also showed that after 12 weeks of resistance training the participants had attained movement pattern that could both increase and decrease risk of ACL injury, although most changes would act to decrease injury risk. Since strength training usually is implemented by athletes to improve their performance it could had an effect on the achieved kinematics for the participants in this study. Interestingly however, is that this study found no significant difference between the athletes and control group in the quadriceps and hamstring MVIC test performed after the hop test (see Table 1). Perhaps the included control group in this study could be homogen with the elite athletes in a strength aspect.

**Methodological considerations**

*Reliability*

There may be several reasons for why the difference in kinematics occur, for the participant's part it may be about the physical or emotional state, learning effects, concentration etc. (52, 81). Previous studies have mentioned the repeated replacement of the reflective markers as a crucial factor for the reliability since they establish the coordinate system from which the angles are calculated, and a change in replacement would result in a difference, which is greater than the individual's true variation (67, 82). To minimize this error one experienced assessor attached all the markers on all participants and used a standardized protocol to check that all the markers were fitted. The natural variation of the knee during demanding tasks should also be taken in to account. Deviations in the technique have been shown to alter due to the individual’s horizontal force (83), foot position (84) and postural control (85).

Further potential source affecting both the within-session and test-retest reliability could be the challenging nature of the task, which may have been altered motor performance between trials. To help control for the cause of variability, the hop length in the current study was individualized to 25% of the individual’s length. This was done because if a shorter person were to hop a predetermined distance, then that would be a relatively longer distance compared to for a tall person. This standardization should have limited some potential differences in motor performance. To complete a successful movement during landing and cutting tasks it has been suggested that the individual
rely on pre-planned control strategies (86, 87). When performing an unanticipated cutting task the unawareness of what will happen changes the individual’s movement pattern to abnormal joint kinematics, which is more strenuous for the ACL (44). However, in the hop that the participants performed there were only two possible hop outcomes (lateral and medial), and one of them could have been cognitively preselected even though the order was randomized. This would make only the other hop outcome unanticipated and the variability between each hop could increase if the conditions are different. As a consequence, the reliability could have been affected since there is a clear discrepancy in kinematics between anticipated and unanticipated hops (88).

The number of trials selected for the evaluation of within-session reliability may potentially also have had an effect on the attained values. The participants performed one test hop in each direction before the three-dimensional analysis began. Then the first three trials in both directions were used for the analysis. This was partially done to have sufficient data for the analysis. There is no consensus on which or how many number of trials should be used for within-session reliability in hop tests. Munro et al. (89) evaluated a crossover hop test and came to the conclusion that the learning effects was stabilized after four trials. For the test-retest reliability analysis, the score of one to five trials was used for the calculation to a single mean. Due to the spontaneous variability of an unanticipated cutting task this could have led to a large variation, especially if only a few trails were acceptable, and therefore affecting the reliability negatively. On the other hand, the variation in the performance is likely to reflect the variation in cutting techniques used during an actual floorball training or game. Therefore, it could be detected which individuals has greater variability in dynamic knee function and which has less variation.

The function of a hop test
Three-dimensional motion analysis of different hop tests to evaluate the knee function has become increasingly common within the research of ACL injuries (49-51). Information, such as kinematics and kinetics, regarding the mechanics of the musculoskeletal system can be collected and broaden the understanding of a person’s injury risk in relation to performance. When using this kind of method it is important to have the multiplanar nature of ACL injuries (8) in mind. Based on video analyses the
mechanism for ACL injury has frequently been described to occur when the knee is in a combination of rotation, abduction and close to full extension (77, 90, 91). This combination suggests that an individual who displays exceeded kinematics in multiple planes is more susceptible to an injury. A noteworthy reflection is at what point in time that the risk increases. Hewett et al. (92) showed the value of a predictive assessment of knee abduction angle and moment during a drop vertical jump in athletes who sustained an ACL injury. Female high school athletes (N=205) were screened in a biomechanical three-dimensional movement analysis before the start of their competitive season of basketball, soccer or volleyball. Nine of the participants sustained an ACL injury, and when compared with the uninjured participants they found that the ACL injured had an eight time higher knee abduction angle and 6.4 times higher knee abduction moment. However, more recently a study by Krosshaug et al. (93) tried to replicate the study design with a cohort of 782 athletes, and 42 occurred ACL injuries. They found no predictive value of either knee abduction angle or knee abduction moment that had been collected from a vertical drop jump. A suggested reason for the lack of findings was that the hop test was not challenging enough to unveiling poor knee function in athletes. The use a hop test that generates higher load and are more similar to the actual injury scenario, such as a one-leg hop with a cutting manoeuvre, was proposed to be more suitable.

The performed hop test in this study may not accurately recreate the load required to recognize risk factors for an ACL injury, nor reflect the dynamic movement a floorball athlete execute in their athletic environment. In such surrounding there are more than two possible hop outcomes and the athlete may not have time pre-plan the moment before the hop. The internal focus that a participant can put on their own body in a laboratory environment have an effect on the executed movement, as compared to when focus has to be directed to external objects (94), which is the case in a changing environment of sports. Therefore, it could be difficult to say that this test is equivalent to a specific athletic situation. To cope with the unanticipated conditions of the test the participant could have completed the hop test with an increased caution and subsequently greater co-contraction to counter for the uncertainty associated with the condition. A preparatory increase in neuromuscular activity have been shown by Meinerz et al. (88) which demonstrated a greater activation of the gluteus maximus pre-
contact during a unanticipated cutting task compared to an anticipated. Besier et al. (86) also concluded that during an unanticipated manoeuvre subjects recruit a more general co-contraction pattern for the muscles around the knee compared to more selective muscle activation in an anticipated cutting manoeuvre. With this in mind the validity of an unanticipated hop test in a laboratory environment when researching noncontact ACL injury mechanisms could be questioned since it might not reflect the true knee demanding exposure.

It is however necessary that a test challenge the wide spectrum of sensorimotor control when assessing the knee function in relation to ACL injuries. This is demonstrated by the multifactorial scenario in which the injury occur: the inability to persevere the knee’s neuromuscular control and simultaneously be aware of external stimuli, such as complex visual input, variable surface, movement planning, rapid decision making, different player position, environment interactions and unanticipated perturbations (91, 95-97). It has been suggested by Farrow et al. (98) that an athletes has the ability to better process external information to improve a motor task, however only if the environment is realistic and context specific. This is supported by a study of Lee et al. (13) where sidestepping knee mechanics did not only differ depending on the athletes skill level but also when performing the sidestep in a quasi-game-realistic situation with three-dimensional projection of realistic opponents compared to an unanticipated trajectory of arrows. The addition of more complex and realistic tasks during the unanticipated hop could perhaps better mimic the biomechanics which occur in sports. If the task would be sensitive enough to isolate limb deficits, then the athlete could be targeted with additional specific neuromuscular training which has been proven to be especially effective for athletes with a history of an ACL injury (99).

However, one hop test cannot be considered enough to use when deciding if it is safe to return to sports after an ACL injury. A battery of tests which evaluates different aspects of the knee function should be used to facilitate information regarding the status of the knee. In addition to the test battery, psychological outcome measures must be added to ensure that participants in sports are physically and psychologically capable of returning to sport (100).
Also, it is difficult to assess the knee function based on the kinematics of the knee alone since it may not reveal all important factors. The kinematics will characterize the outcome of a movement and can therefore recognize movement patterns and lower limb postures associated with an increase of the ACL, and thus, increased injury risk. With the addition of joint kinetics, the analysis would be more rewarding for the understanding of the injury risk of an individual who perform a cutting hop test. Specifically, high knee abduction moment and internal tibial rotation moments have been shown to be able to produce a great amount of strain to the ACL (48). This study focused only on the kinematic variables of the knee. Trunk, hip and upper body are also important to take into consideration since they can affect lower limb biomechanical and neuromuscular ACL injury risk factors (17, 101). So the integration of these features is important for the assessment of knee function during a hop test.

It must be recognized that an ACL injured population could demonstrate different knee kinematics during the unanticipated hop with a change of direction, and therefore the results from this study might not be generalizable to them. Future studies should use this hop test on such a population to validate its utility as a criteria-based test before returning to sports. Secondly, no power calculation was conducted prior to this pilot study, therefore it is unknown if the sample size was too small to find any significant relationships from the collected measures. Thus, the non-significant results related to the differences between groups could be due to a Type II error.

Conclusion
This study has expanded the understanding for measures of reliability for knee kinematics by providing within-session and test-retest reliability during a hop test with an unanticipated component for female elite athletes and female controls. Good to excellent reliability could be achieved for the large majority of measures, both within-session and test-retest, and therefore adequately reliability could be obtained from the hop test. The assessment of knee kinematics indicates that elite floorball athletes demonstrated different coronal-plane mechanics compared with the control group on the second test occasion, this could be due to the fact that the athletes adopt a movement pattern to increase the efficiency of the cutting maneuver. However, the
results should be interpreted with caution since the study population were relatively small.
References


Appendices

Appendix A. Description of the test protocol.

1) TEST Joint position test lying

Utrustning: Yogamatta, huvudbonad med inbyggd spegel, datorskärm, bräda

Utförande: Starta med det icke-skadade/dominanta benet. Totalt 24 benextensions/flexionsförsök kommer att utföras av varje FP. Varje ben kommer således att utföra 10 försök mot en sökt ledvinkel av 40° och 10 försök med en sökt ledvinkel av 65°. Först genomförs tre uppvärmningsförsök till full extension med realtidsvisuell feedback som ger ledvinkelhastighet av knäet i ett försök att replikera den sökta ledvinkelhastigheten av 10°/s. Sedan utförs ett feedbackförsök med information om slutvinkel, följt av ett replikeringsförsök. FP kommer att hålla i en triggerknapp som de kommer att ha på magen under testets gång. Totalt genomförs 5 replikationsförsök för varje ledvinkel för varje ben. Alla FP kommer att utföra alla test på det icke-skadade/icle-dominanta benet först innan de upprepar testet på det kontralaterala benet. Startpositionen kommer att vara ryggliggande på en yogamatta (för komfort för höft och överkropp) med benen i 100° flexion (ett block kommer att förhindra deras fötter från att röra sig förbi den sökta positionen) och anklarna fixerade i en neutral position. Huvudet kommer att placeras i en anpassad huvudbonad som har en vinklad spegel för att reflektera bilder från en datorskärm till FP. Datorskärmen kommer att visa realtids ledvinkelhastighet under uppvärmningsförsöken samt för att visa skriven information under testets gång.

Feedbackförsöket: Vid en visuell signal så kommer FP att föra foten längs brädan genom att extendera benet med den sökta hastigheten till dess att en STOP-bild på datorskärm menar att den sökta ledvinkeln har nåtts. FP kommer att trycka på triggerknappen en gång efter STOP-bilden har visats och när de känner sig stabila i knävinkeln. Vid instruktioner återgår sedan FP till startposition efter två sekunder genom att böja benet i en kontrollerad hastighet.

Replikationsförsök: En visuell signal visar att FP ska försöka replikera exakt samma knävinkel som tidigare genom att extendera samma ben i samma ledvinkelhastighet. När FP anser att den sökta ledvinkeln är nådd så trycker FP på knappen de håller i och återgår sedan till startpositionen.

Testet godkänns inte om: FP rör armar och det kontralaterala benet eller huvudet, försöker återgå till fel ledvinkel, om knappen inte fungerar, om ledvinkelhastigheten anses vara för snabb eller långsam.

2) TEST Join position testing standing

Utrustning: Låda, balansstöd, triggerknapp, hälkil, ögonbindel.

Utförande: FP kommer att stå på en hälkil på en låda och hålla i balansstödet. Fem repetitioner med två olika stopvinklar på 40 och 65° kommer att utföras på båda benen. FP kommer att utföra först två uppvärmningsförsök för varje ben med information om vinkelhastigheten för att kunna replikera den sökta hastigheten av omkring 10°/s. Försöken kommer börja med det icke-skadade/dominanta benet till 40°. FP kommer att ta sig ögonbindel, ta tag i triggerknappen och balansstödet (armen i 90° flexion) och föra det icke-skadade/dominanta benet utanför boxen och låta det hänga fritt, detta är startpositionen. På signal från testledaren kommer FP att böja det testade benet sakta i den sökta hastigheten av 10°/s tills de hör signalen som indikerar rätt grad av vinkel. FP kommer att trycka på triggerknappen när de har stannat och känner sig stabila. Efter två sekunder hörs de signalen och testledaren ger instruktioner att FP ska gå tillbaka till startpositionen i valfri hastighet och därefter
återigen böja på benet tills de tror sig funnit den sökta vinkeln. De trycker då på triggern och går därefter tillbaka till startpositionen. Därefter utfors testet enligt samma procedur på 65° innan personen byter sida och testar andra benet.

**Testet är inte godkänt om:** FP lyfter hälen, tappar balansen, rör armarna, om ögonbindeln åker av, om hastigheten är för snabb eller för långsam, om inte trigger-knappen fungerar eller FP glömmer att trycka. Gör samma repetition igen och skriv kommentarer.

3) **TEST Step down**

**Utrustning:** Två lådor ca 17 och 34 cm höga, ställs in efter 0.11 och 0.22 * kroppslängd och två kraftplattor, en på den lägre boxen och en på golvet, trappstegsdjup är ca 27 cm, ramp.

**Utförande:** 6 repetitioner på varje ben med start med det icke-skadade/dominanta benet. Ett testförsök genomförs före inspelnning på varje ben. Händerna bakom rygg och håll i handtaget med båda händerna. FP startar genom att stå på den översta boxen med tårna på kanten av lådan. Sedan flyttar FP all vikt på ett ben och kliver ner med det andra benet på den andra lådan, och tar ett till steg ner till golvet med samma utförande, och sedan rakt fram till tejpen, sedan rakt tillbaka bredvid pallarna. FP byter ben vid varje försök så ingen vila.

**Testet är inte godkänt om:** FP tappar balansen, rör armarna, kliver fel.

4) **TEST Step down pivot shift**

**Utrustning:** Två lådor med höjd av 0.11 * kroppslängd och 0.22 * kroppslängd och två kraftplattor, en på den lägre boxen och en på golvet, trappstegsdjup är ca 27 cm, ramp.

**Utförande:** 6 repetitioner på varje ben med start med det icke-skadade/dominanta benet. Ett testförsök genomförs före inspelnning på varje ben. Händerna bakom rygg och håll i handtaget med båda händerna. FP startar genom att stå på den översta boxen med tårna på kanten av lådan. Sedan flyttar FP all vikt på ett ben och kliver ner med det andra benet på den andra lådan, och tar ett till steg ner till golvet med samma utförande, och sedan ett steg åt sidan sådant att FP kliver över den främre foten med ca 45° vinkel, och tar sedan ännu ett steg till framåt i den nya riktningen. FP byter ben vid varje försök så ingen vila.

**Testet är inte godkänt om:** FP tappar balansen, rör armarna, kliver fel.

5) **TEST Static balance 20 s**

**Utrustning:** Kraftplatta, tidtagarur.

**Utförande:** Starta med det icke-skadade/dominanta benet. Stå på kraftplattan. Händerna bakom rygg och håll i handtaget med båda händerna, flytta över viken på det ben som testas och stå så stilla som möjligt i 20 s. Byt ben och kör igen, upprepa till alla repetitioner gjorda.

**Testet är inte godkänt om:** FP lyfter hälarna, tappar balansen, rör armarna.

6) **TEST Two_leg_squat**

**Utrustning:** Kraftplatta.

**Utförande:** 6 repetitioner i ett långsamt och kontrollerat tempo kommer att genomföras. Full ROM är sökt utan att hälarna lyfter från marken eller att axlar rör sig framför knälederna vid observation
från sidan. Händerna bakom rygg och håll i handtaget med båda händerna. Tre testrepetitioner genomförs före inspelning för möjliga förändringar och korrektioner. FP kommer att stå med ett ben på varje kraftplatta med foterna skuldebrett isär och något utåtriktade. När testledare säger till så kommer FP att utföra 6 knäböj i ett långsam och kontrollerat tempo.

**Testet är inte godkänt om:** FP lyfter hälarna, tappar balansen, rör armarna, axlarna åker framför knäna, om hastigheten är för snabb eller för långsam.

7) **TEST One-Leg hop for distance**

**Utrustning:** Kraftplatta

**Utövande:** 3 hopp på varje ben genomförs. FP startar med det icke-skadade/dominanta benet och alternarar ben mellan varje hopp. Ett testhopp genomförs före inspelning på varje ben där FP hoppar från kraftplatta bortåt för att skatta avstånd. De ska landa på kraftplattan vid utförandet. Händer bakom rygg och håll i handtaget med båda händerna. FP landar på samma ben och håller balansen i 5 s.

**Vila mellan försöken:** Ingen vila, benen alterneras mellan varje försök.

**Testet är inte godkänt om:** FP tappar balans före eller under hoppet, armarna rörs, hälarna lyfter från marken innan och efter hoppet, axlarna positioneras framför knäna. Skriv kommentarer nedanför.

8) **TEST One-Leg Vertical hop**

**Utrustning:** Kraftplatta

**Utövande:** 3 hopp på varje ben genomförs. FP startar med det icke-skadade/dominanta benet och alternarar ben mellan varje hopp. Ett testhopp genomförs före inspelning på varje ben. Händer bakom rygg och håll i handtaget med båda händerna. FP sätter ned foten av testbenet i mitten av kraftplattan och står på båda benen med armarna i midjan. När testledare säger till så flyttas all vikt över till testbenet genom att lyfta det andra benet och balans hålls i ca 2 s. Sedan böjer de snabbt på benet och hoppar så högt som möjligt så snabbt som möjligt rakt upp. FP hoppar och landar med testbenet rakt så landning blir kontrollerad, de får inte böja benet eller dra upp det mot bröstet. FP landar på samma ben och håller balansen i 5 s.

**Vila mellan försöken:** Ingen vila, benen alterneras mellan varje försök.

**Testet är inte godkänt om:** FP tappar balans före eller under hoppet, armarna rörs, hälarna lyfter från marken innan och efter hoppet, axlarna positioneras framför knäna. Skriv kommentarer nedanför.

9) **TEST standardised one-leg side hop**

**Utrustning:** Två kraftplattor, markeringstejp

**Utövande:** Hoppen kommer att utföras mellan två markeringstejp med ett avstånd av 0.25 * kroppslängd. Händer bakom rygg med fattning av redskap med båda händerna. Ett testförsök genomförs på varje ben innan inspelning. FP startar med det icke-skadade/dominanta benet och alternarar benen varje försök. Testet startas genom att stå på benet precis utanför markeringstejpen och hålla balansen i två sekunder, sedan hoppar FP lateralt åt sidan över den andra markeringstejpen och hoppar omedelbart tillbaka så nära men över andra sidan markeringstejpen som möjligt. Vid
landning ska FP hålla balansen i fem sekunder och försöka stabilisera sig så mycket som möjligt utan att sätta ner den andra foten. Sedan byter de ben och utför samma hopp, så de alternerar benen varje hopp för att undvika trötthet. Så om FP har skadat höger ben börjar testet med att FP står på vänster ben till höger om den högra markeringstejpen och hoppar sedan vänster i sidled över den vänstra markeringstejpen och omedelbart tillbaka över den högra tejpen och håller balansen i 5 s efter att de stabiliserat sig, sedan upprepar FP samma sak med det andra benet. FP utför 10 hoppar för varje ben.

Vila mellan försök: Ingen vila mellan försök med samma hopplängd då de alternerar benen.

Testet godkänns inte om: Hopparen inte är på tejpen för den beräknade hopplängden, om TP inte kan stabilisera och hålla balansen innan eller efter hopp, om FP sätter ner den andra foten för balans.

14) TEST Improvisation hop

Utrustning: Två kraftplattor, markeringstejp, dataprogram, projektor

Utförande: FP utför 10 hoppar per ben. Även här normaliseras hoppavståndet med 0.25 * kroppslängd. Testet utförs på en kraftplatta med ett hopp framåt samt med ett hopp åt sidan med en vinkel av ca 45° till vänster eller till höger. Händerna håller i redskapet bakom ryggen. FP startar med det icke-skadade/dominanta benet och alternerar benen varje försök. Kontrollerad randomisering sker åt sidorna, med 5 hoppar åt höger och åt vänster för varje ben. Två försök för varje ben som är programmerat att gå till båda riktningarna kommer att utföras innan inspelning så FP får prova på alla möjliga utfall av rörelsen innan tester startar. FP kommer att stå bakom en markeringstejp på den första kraftplattan tittandes på riktlinjerna som en projektor visar på golvet. FP kommer att stå på ett ben och hålla balansen i två sekunder innan FP hoppar in i rutan som visas av projektorn på golvet, och sedan omedelbart hoppar till antingen vänster eller höger beroende på instruktioner från projektorn som ges precis innan det första hoppet. FP ska landa på samma ben och hålla balansen i två sekunder.

Vila mellan försök: Ingen vila mellan försök med samma hopplängd då de alternerar benen.

Testet godkänns inte om: Hopparen inte är över den beräknade hopplängden, om TP inte kan stabilisera och hålla balansen innan eller efter hopp, om FP sätter ner den andra foten för balans, om FP ej hoppar i den riktning som instruktionerna visar.

15) TEST KinCom isometric

Utrustning: KinCom dynamometer

Settings: Seat back angle = 78°, seat bottom angle = 10°, mechanical lever angle = 65°. Same settings were used for quadriceps and hamstrings.

Perform three maximal repetitions with 5 seconds contraction and 5 seconds rest in between. Start with quadriceps for the dominant leg, change settings and follow with hamstrings on the same leg. Change settings for the other leg, do again with quadriceps first and hamstring after.

ENCOURAGE VERBALLY THROUGHOUT THE TESTING!
Appendix B. Description of marker placement.
<table>
<thead>
<tr>
<th>Marker name</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>f_head</td>
<td>Front head</td>
</tr>
<tr>
<td>r/l_head</td>
<td>Right/left head</td>
</tr>
<tr>
<td>r/l_shoulder</td>
<td>Superior surface of the mid-point of the acromion process</td>
</tr>
<tr>
<td>r/l_elbow</td>
<td>Lateral epicondyle of the humerus</td>
</tr>
<tr>
<td>r/l_wrist</td>
<td>Between the styloid processes of radius and ulna. On the inside.</td>
</tr>
<tr>
<td>sacrum</td>
<td>Midpoint of the right and left PSIS.</td>
</tr>
<tr>
<td>r/l_crista</td>
<td>At the most superior and lateral point of the crest.</td>
</tr>
<tr>
<td>r/l_asis</td>
<td>Anterior superior iliac spine</td>
</tr>
<tr>
<td>r/l_trochanter</td>
<td>The most prominent part of the trochanter major</td>
</tr>
<tr>
<td>r/l_thigh - 1</td>
<td>Cluster on middle thigh (lateral marker)</td>
</tr>
<tr>
<td>r/l_thigh - 2</td>
<td>Cluster on middle thigh (lower inferior marker)</td>
</tr>
<tr>
<td>r/l_thigh - 3</td>
<td>Cluster on middle thigh (medial marker)</td>
</tr>
<tr>
<td>r/l_thigh - 4</td>
<td>Cluster on middle thigh (upper inferior marker)</td>
</tr>
<tr>
<td>r/l_kneejoint</td>
<td>Lateral epicondyle</td>
</tr>
<tr>
<td>r/l_m_kneejoint</td>
<td>Medial epicondyle</td>
</tr>
<tr>
<td>r/l_tub</td>
<td>Tuberositas tibiae</td>
</tr>
<tr>
<td>r/l_hfib</td>
<td>Head of the fibula</td>
</tr>
<tr>
<td>r/l_shank - 1</td>
<td>Cluster on middle shank (lateral marker)</td>
</tr>
<tr>
<td>r/l_shank - 2</td>
<td>Cluster on middle shank (inferior marker)</td>
</tr>
<tr>
<td>r/l_shank - 3</td>
<td>Cluster on middle shank (medial marker)</td>
</tr>
<tr>
<td>r/l_m_pal</td>
<td>Medial malleolus</td>
</tr>
<tr>
<td>r/l_pal</td>
<td>The most lateral aspect of the lateral malleolus</td>
</tr>
<tr>
<td>r/l_stal</td>
<td>Sustentaculum tal |</td>
</tr>
<tr>
<td>r/l_lcal</td>
<td>Lateral calcaneus</td>
</tr>
<tr>
<td>r/l_cal2</td>
<td>Proximal end of the midline (posterior aspect of the calcaneus)</td>
</tr>
<tr>
<td>r/l_cal1</td>
<td>Distal end of the midline (posterior aspect of the calcaneus)</td>
</tr>
<tr>
<td>r/l_l_foot</td>
<td>Head of the 5th metatarsal (also called d5mt)</td>
</tr>
<tr>
<td>r/l_d1mt</td>
<td>Medial aspect of the first metatarsal</td>
</tr>
<tr>
<td>r/l_p1mt</td>
<td>Proximal base of the first metatarsal</td>
</tr>
</tbody>
</table>
Appendix C. Participant information and form of consent for elite floorball athletes.

Utvärdering av knäfunktion hos personer utan knäbesvär

Denna information vänder sig till dig som är kvinna och som inte har några besvär från dina knäleder och vill delta i en studie där knäfunktion undersöks. Vår forskargrupp vid Enheten för fysioterapi (tidigare sjukgymnastik), Umeå Universitet genomför en studie som följer personer efter främre korsbandsskada.

Vi vill genomföra en del knätester som rör stabilitet och därför tillfrågas just Du om att delta i studien. Idag finns det nämligen ingen samstämmighet om vilka tester som tillräckligt väl utvärderar knäfunktion under aktivitet i rehabilitering. Detta medför en förhöjd risk för ny skada, eller skada på det friska benet då man i större grad förlitar sig på det benet under aktivitet. Denna forskning kommer att ge kunskap i framtiden för utvärdering av knäfunktion för att bättre uttala sig om när ex. återgång till idrott eller annan aktivitet är lämplig.

Vi söker Dig som är kvinna och utan besvär från knälederna och utan neurologisk eller reumatisk sjukdom som är mellan 17 – 35 år. Du får inte vara fysiskt aktiv med fem eller fler träningstider i veckan eller träna specifikt inriktad styrka eller teknik för att stärka knäleden vid två eller fler pass i veckan. Träning som ingår i diverse gruppsträningspass eller enklare styrketräningsspass går bra.

Du tillfrågas nu om att delta i denna undersökning där styrka, funktion och rörelsemönster undersöks. Test av dina knän sker vid två tillfällen i vårt rörelselaboratorium, vån 2, på Vårdvetarhuset.

För att studera rörelse använder vi ett 3-dimensionellt kamerasystem som filmar under testerna och för registrering av muskelaktivitet används elektromyografi (EMG). För detta kommer reflexmarkörer och elektroder att tejpas fast på huden. Inget av detta medför obehag eller smärta.

**Tester**

- Testerna består av två tester som skattar uppfattad position av böjning i knäleden (så kallat proprioceptionstest), balanstest, knäböjningar, trappgång, hopptester och styrketest.
- För att elektroderna skall fästa på benen kommer vi att behöva raka bort hårar på dessa ställen. Detta medför inget obehag.

**Förberedelser inför test**

- **Klädsel**: åtsittande korta tights och sportbh. Detta är **viktigt** för placering av markörer och elektroder och för att inte fladdrande tyg ska dölja markörerna.
- **Använd inte hudkräm** då denna gör att markörerna fäster sämre.
- **Ingen hård träning** dagen innan test.

Hela proceduren inkl. förberedelser, enkäter, information och tester är beräknad till ca 1 timme. Dagarna efter testtillfället kan du möjligvis få lite träningsvärk. Detta är dock helt normalt och ofarligt.
och värken försvinner inom ett par dagar. Skulle du olyckligtvis drabbas av skada erbjuds du uppföljande tester vilket kan vara till nytta i din rehabilitering. Möjlighet till rådgivning utifrån skadeförebyggande perspektiv finns vid önskemål.


Ditt deltagande i denna studie är helt frivilligt och du kan när som helst avbryta din medverkan utan förklaring. Umeå Universitets försäkring vid kammarkollegiet gäller för dig under ditt besök.

Om du har specifika frågor kring forskningsprojektet och dina eventuella resultat är du välkommen att kontakta Jonas Markström enligt nedanstående kontaktuppgifter. Jonas kommer att kontakta dig för att ge mer information inför ditt ställningstagande till deltagande i studien och bokande av tid.

**Kontaktperson:**
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090 – 786 66 65

**Huvudansvarig för projektet:**
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Professor  
Leg. Sjukgymnast  
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Enheten för Fysioterapi, Samhällsmedicin och rehabilitering, Umeå Universitet 90187 Umeå.

Jag har muntligt informerats om studien samt tagit del av ovanstående skriftliga information. Jag samtycker till att delta i studien och är införstådd med att mitt deltagande är frivilligt. Vidare är jag medveten om att jag när som helst, utan närmare förklaring, kan avbryta mitt deltagande.

Namnteckning  
Datum

Namnförtydligande  
Telefon

e-post adress
Appendix D. Participant information and form of consent for the control group.

Utvärdering av knäfunktion hos elitatleter utan knäbesvär

Denna information vänder sig till dig som är kvinna och som inte har några besvär från dina knäleder och vill delta i en studie där knäfunktion undersöks. Vår forskargrupp vid Enheten för fysioterapi (tidigare sjukgymnastik), Umeå Universitet genomför en studie som följer personer efter främre korsbandsskada.

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Du tillfrågas nu om att delta i denna undersökning där styrka, funktion och rörelsemönster undersöks. Test av dina knän sker vid två tillfällen i vårt rörelselaboratorium, vån 2, på Vårdvetarhuset.

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**Tester**

- Testerna består av två tester som skattar uppfattad position av böjning i knäleden (så kallat proprioceptionstest), balanstest, knäböjningar, trappgång, hopptester och styrketest.
- För att elektroderna skall fästa på benen kommer vi att behöva raka bort hår på dessa ställen. Detta medför inget obehag.

**Förberedelser inför test**

- Klädsel: åtsittande korta tights och sportbh. Detta är viktigt för placering av markörer och elektroder och för att inte fladdrande tyg ska dölja markörerna.
- Använd inte hudkräm då denna gör att markörerna fäster sämre.
- Ingen hård träning dagen innan test.


Ditt deltagande i denna studie är helt frivilligt och du kan när som helst avbryta din medverkan utan förklaring. Umeå Universitets försäkring vid kammarkollegiet gäller för dig under ditt besök.

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