Effects of hip and trunk kinematics on peak frontal plane knee moments during sidestep cutting

A cross-sectional study

Adam Snær Jóhannesson

Thesis for the degree of Master of Science in Physical Therapy
June 2019
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Number of credits: 30
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Department of Physical Therapy
Faculty of Medicine
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June 2019
Áhrif stöðu mjaðmar og búks á krafta í hné í krúnusniðsfleti við stefnubreytingu

Þverskurðssniðin rannisókn

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Ritgerð til meistaragráðu í sjúkraþjálfun
Fjöldi eininga: 30
Leiðbeinendur: Haraldur Björn Sigurðsson og Kristín Briem

Námsbraut í sjúkraþjálfun
Læknadeild
Heilbrigðisvísindasvið Háskóla Íslands
Júní 2019
Abstract

Most ACL injuries occur during non-contact sporting situations during single leg landing or cutting maneuvers. The ACL can be loaded by external frontal plane knee moments. Studies have observed the associations in kinematics of the hips and trunk with knee valgus moments during a long timeframe of the stance phase of a landing or cutting maneuver. ACL injuries, however, occur during the first 100 ms of the stance phase and therefore it is important to analyze the associations of kinematics of the hips and trunk and knee moments during this time, which could be different.

A cross-sectional study was conducted on 105 participants at the age of 14-17 years old. With anatomical and tracking markers secured on the participants, they performed sidestep cutting maneuvers on a force plate while a camera system from Qualysis recorded data from the markers and force plates. Peak frontal plane knee moments, hip and trunk kinematics of 2236 sidestep cuts during the first 100 ms of the stance phase were analyzed in visual 3D. Linear and multiple regressions were conducted to examine the associations of hip and trunk kinematics on peak frontal plane knee moments.

Regression results showed significant associations of hip abduction, hip internal rotation, hip internal rotation excursions and trunk lean to the stance leg with peak knee valgus moments during the 100 ms of the stance phase. Hip internal rotation, hip external rotation excursions and trunk lean to the stance leg were associated with peak knee varus moments. The influence of hip and trunk kinematics on peak frontal plane knee moments was small and may therefore not be important regarding ACL injuries.
Ágrip

Flest fremri krossbandaslit gerast í hreyfingum án snertinga í íþróttum, oftast þegar íþróttamaðurinn lendir á einum fæti eða framkvæmir stefnubreþytingu. Fremra krossbandið getur verið undir álægri af kröftum í krúnusniðsfleti sem koma á hnéð. Rannsóknir hafa skoðað sambandið á milli stöðu á mjaðmar og búks á valgus hné krafla á meðan stöðufasa stendur í lendingu eða í stefnubreþytingu. Fremra krossbandaslit gerast hins vegar af fyrstu 100 ms af stöðufasa. Því er mikilvægt að skoða sambandið á milli stöðu búks og mjaðmar á krafla á hné á þessum tíma, þar sem að sambandið gæti verið óðruvisi.

Gerð var þverskurðsniðin rannsókn sem samanstóð af 105 þáttakendum frá aldrinum 14-17 ára. Þáttakendurnir framkvæmdu stefnubreþytingar á kraftplötu með endurskinsmerki á líkamanum á meðan að mydavéla kerfi frá Qualysis tók upp hreyfingarnar í þrivídd. Skoðaðir í Visual 3D voru hné kraflar í krúnusniðsfleti og hreyfingar á búk og mjöðm frá 2236 stefnubreþytingum á fyrstu 100 ms af stöðufasa. Einfaldar aðhvarfsgreiningar og marghliða aðfallsgreiningar voru gerðar til að skoða sambandið á milli stöðu búks og mjaðmar á hámárkra krafla í hné í krúnusniðsfleti.

Niðurstöður syndu að mjaðmafráfærsla, innsnúningur á mjöðm, innsnúnings færsla á mjöðm og hliðarhalli á búk að stöðufæti höfðu áhrif á valgus krafla í hné fyrstu 100 ms af stöðufasa og að innsnúningur á mjöðm, útsnúnings færsla á mjöðm og hliðarhalli á búk að stöðufæti hafði áhrif á varus krafl í hné fyrstu 100 ms af stöðufasa. Stöður og hreyfingar á mjöðm og búk höfðu lítil áhrif á hámárks hné krafla í krúnusniðsfleti og gætu því haft lítil áhrif á fremra krossbandaslit.
Acknowledgement (and funding)

This study was conducted in the Research Center of Movement Science in the University of Iceland. This study was funded by Rannis.

Special thanks to my supervisors Haraldur Björn Sigurðsson and Kristín Briem for their supervision.

Thanks to all the athletes who participated in the study.
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Abbreviations

ACL – Anterior cruciate ligament
GRF – Ground reaction force
OA – Osteoarthritis
ms - Milliseconds
1 Introduction

1.1 Epidemiology of ACL injuries
Injuries are common in sports and are 3.5-fold more common in sporting games compared to sports practice, where 13.8 injuries have been reported per 1000 athletic exposures in common American collegiate sports, with most injuries occurring to the lower body (1). In recorded injuries over 16 years across 15 different collegiate sports, anterior cruciate ligament (ACL) injuries accounted for 3% of all injuries (1). Around 200,000 ACL injuries occur in the United States of America (USA) per year (2). Athletes sustaining ACL injuries are typically in their late teens or twenties (3-5) with females generally showing a 2-3 times higher rate of ACL injuries, and get injured at a younger age (6, 7) compared to males (8). With an increased participation in organized sports, the incidence of ACL injuries is rising (4, 8).

1.2 The consequences of an ACL injury
After an ACL injury, ACL reconstruction surgeries are common (9), followed by a long recovery period before the athlete returns back to his sport (10), but one will likely have a shorter sporting career, decreased sports performance (11) and an increased risk for re-injury by contralateral or ipsilateral ACL injuries (12). Whether or not the athlete successfully returns to its sport, people who sustain an ACL injury are at an increased risk for developing osteoarthritis (OA) in the tibiofemoral and/or the patellofemoral knee joint later in life, with this risk increasing substantially if an injury to the meniscus was accompanied with the ACL injury (13). Usually people start to develop knee joint degeneration 5 to 15 years after ACL injury (14). The onset of knee OA can result in increased pain, functional limitations (15, 16) and a decreased quality of life (17). ACL injuries therefore lead to large financial costs (18, 19). These consequences of ACL injuries make it important to analyze the mechanism of the injury in order to lower their incidence.

1.3 Mechanism of an ACL injury
About 70 - 75% of ACL injuries occur during non-contact situations in soccer and basketball (20). Typically, the athlete injures his ACL when he is landing on one foot or performing cutting maneuvers (21-24). ACL injuries occur very early on in the stance phase, less than 100 ms after initial contact (25) and with an impact force (26). The ACL is a key stabilizer of the knee, primarily resisting anterior translation of the tibia relative to the femur and tibial internal rotation (27). Cadaver studies have examined the individual forces that load the ACL by applying external forces to the knee. The forces that load the ACL include anterior tibial translation forces, internal rotation forces, valgus and varus forces (28). ACL injury, however, is likely a result of combined forces loading the ACL giving that these forces load the ACL even more in combination than individually (29, 30). Compressive forces to a posteriorly tilted tibial plateau can load the ACL by displacing the tibia forward and internally rotating the tibia (31, 32). During landing, the ACL can be loaded by a knee valgus moment mechanism as the lateral tibial compartment is under compressive forces, with a posteriorly tilted lateral tibial plateau, these compressive forces create a coupling of anterior tibial translation and tibial internal rotation, loading the ACL (33). It is not clear from the literature if pre-screening methods
of knee valgus moments can predict a future ACL injury. One prospective study showed that greater knee valgus moments at landing was a risk factor for future ACL injuries (34). However, a recent prospective study did not find greater knee valgus moments in landing able to predict future ACL injuries (35). A knee valgus moment injury mechanism has been observed in video analysis of ACL injuries. At the time of an ACL injury, the athlete’s knee has been seen in extension or low flexion angles (21, 24, 36, 37) with the tibia internally rotated (21, 23) and with a greater valgus knee motion (21, 23, 24, 37) compared to non-injured subjects (38, 39). The ACL can also be loaded by knee varus loads, by compressing the medial tibial plateau and generating anterior tibial translation forces (33). Therefore, a knee varus moment ACL injury mechanism could occur from high compressive forces and a knee varus moment. An increased varus knee motion has been observed in non-contact ACL injury situations, although much less commonly than an increased valgus motion (21).

Studies examining frontal plane knee moments during sidestep cutting have examined the associations of knee, hip and trunk kinematics and knee valgus moments during a long timeframe of the stance phase (40-47) and could therefore be missing a critical frontal plane knee moment during the first 100 ms of the stance phase. The magnitude of the frontal plane knee moment can be influenced to some extent by the initial ground reaction force (GRF) or impact force during the first 100 ms of the stance phase (48). During high speed and unanticipated field of play as the athlete abducts his hip to perform a sidestep cut, the orientation of the foot, which can occur through rotation of the hip, can likely contribute to knee valgus or varus loads by its landing on the ground, depending on the position the athlete is in during cutting. This combination of an impact force and knee valgus/varus forces can cause high loads on the ACL by anteriorly translating the tibia (30, 33).

An association of a greater knee valgus angle at initial contact during a sidestep cut and greater peak knee valgus moments has been established in controlled laboratory studies (44, 45, 49). This association could be explained by the GRF vector being oriented more lateral to the knee joint center of rotation (46, 49) as the knee is displaced medially.

At the time of an ACL injury, the athletes hip is generally internally rotated (37, 50) and abducted (22, 37, 50) with decreasing degrees of abduction during the stance phase (50). These hip positions have been examined in sidestep cutting maneuvers in laboratory studies (41, 45, 46, 49, 51). An athlete performing a sidestep cutting maneuver with a wider step width, characterized by greater hip abduction angles at initial contact has been associated with greater knee valgus moments during the stance phase (41, 46, 49), but as the athlete performs a sidestep cut with the foot closer to the midline after technique training, peak knee valgus moments during stance phase decrease (40). Furthermore a position of hip internal rotation at initial contact during a sidestep cut has also been associated with greater peak knee valgus moments during the stance phase of the cut (45, 46, 49). These movement strategies of hip internal rotation and abduction can effectively orient the GRF vector lateral to the knee joint.

Video analysis have observed a movement strategy of greater trunk lean to the stance leg in ACL injury situations in female athletes (38). Laboratory studies have examined the movement of the trunk at various positions and its relation to knee valgus moments (43, 44, 47). Trunk lean to the stance leg at initial contact (44), during the stance phase of a sidestep cut (43) and at peak knee
valgus moments at landing (47) have been associated with greater peak knee valgus moments during the stance phase. As the athlete leans his trunk to the stance leg, the GRF vector is oriented more lateral to the knee joint. Trunk rotation also has an effect on the magnitude of knee valgus moments when the athlete is performing a sidestep cutting maneuver, with decreased rotation of the trunk towards the cutting direction being associated with greater knee valgus moments (42). Athletes have effectively reduced knee valgus moments during a sidestep cut by performing the cut with less lateral trunk lean to the stance leg with technique training (40), which emphasizes that technique and kinematic positioning of the trunk influences knee valgus moments in the stance phase of a sidestep cut.

The orientation of the GRF vector plays a role in loading of the knee joint, with a GRF that is more medial to the knee joint being associated with greater knee varus moments in the earlier stance phase of gait (52) explained for example by a greater varus knee angle being associated with greater knee varus moments in healthy individuals during gait (53). Furthermore, a greater trunk lean to the stance leg has been shown to reduce knee varus moments in the gait of healthy subjects (54). Therefore, a trunk lean away from the stance leg could possibly increase knee varus moments. Since focused gait training composing of increased hip internal rotation and hip adduction can effectively reduce knee varus moments in healthy individuals with a varus aligned knee (55), an opposite movement pattern of external hip rotation and hip abduction could increase the knee varus moments. The association of kinematic patterns and knee varus moments have been less studies in athletic dynamic movements such as sidestep cutting. Greater knee varus moments however have been observed in cutting maneuvers compared to straight running (56), furthermore a greater knee varus moment has been observed with a greater lateral false step during running (51). Therefore, knee varus moments can also be influenced by the athlete’s kinematics during dynamic movements. The kinematic patterns of knee varus moments and knee valgus moments likely differ, by kinematic angles that are opposite of each other. But these kinematic differences have not been researched in dynamic movements. High knee varus loads in combination with high impact loads could possibly increase the risk for ACL injuries. It is important to understand the kinematic patterns associated with both knee valgus and knee varus moments to effectively develop a sidestep cutting technique training plan that reduces both knee valgus and knee varus knee moments to reduce the risk of ACL injuries.

Therefore, the purpose of this study is to examine the kinematic positions of the hips and trunk and their associations with the magnitude of peak frontal plane knee moments during the first 100 ms of the stance phase of a sidestep cut and to compare the kinematics of athletes that develop peak knee valgus moments and peak knee varus moments.
Hypothesis

1. Frontal plane hip angles at initial contact are associated with peak knee valgus moments during the first 100 ms of the stance phase.

2. Frontal plane hip angles at initial contact are associated with peak knee varus moments during the first 100 ms of the stance phase.

3. Transverse plane hip angles at initial contact are associated with peak knee valgus moments during the first 100 ms of the stance phase.

4. Transverse plane hip angles at initial contact are associated with peak knee varus moments during the first 100 ms of the stance phase.

5. Frontal plane hip excursions from initial contact to peak knee valgus moments are associated with peak knee valgus moments during the first 100 ms of the stance phase.

6. Frontal plane hip excursions from initial contact to peak knee varus moments are associated with peak knee varus moments during the first 100 ms of the stance phase.

7. Transverse plane hip excursions from initial contact to peak knee valgus moments are associated with peak knee valgus moments during the first 100 ms of the stance phase.

8. Transverse plane hip excursions from initial contact to peak knee varus moments are associated with peak knee varus moments during the first 100 ms of the stance phase.

9. Frontal plane trunk angles at the peak knee valgus moments are associated with peak knee valgus moments during the first 100 ms of the stance.

10. Frontal plane trunk angles at the peak knee varus moment are associated with peak knee varus moments during the first 100 ms of the stance phase.

11. Kinematics of the hips and trunk are different in trials with peak knee valgus moments and peak knee varus moments.
2 Aim

The primary aim of this study is to examine the relationship of hip and trunk kinematics individually on peak frontal plane knee moments.

The secondary aims of the study are to examine the combined effects of hip and trunk kinematics on peak frontal plane knee moments.
3 Methods

3.1 Research design
This is a cross-sectional laboratory study. An ethical approval was provided by the national bioethics committee of Iceland. The parents or guardian of the participant and the participant signed an informed consent (Appendix I).

3.2 Participants
Data from 105 athletes (81 girls and 24 boys) in soccer and team handball sports between the ages of 14-17 was collected. The average height of the participants was 186 cm and the average weight was 65.4 kg. These athletes had previously participated in research from the same research lab about 5 years earlier. Some of these athletes had dropped out of sports. Exclusion criteria were inability to perform drop jumps, cuts, or strength testing.

3.3 Data collection
Measurements were done in the research lab of movement science at the University of Iceland. The participant started by changing his or her clothes to an appropriate clothing, with males being bare-chested and wearing shorts, females wore a sports top and shorts. All participants wore athletic shoes. Bodyweight and height were measured in each participant. Then the participant would warm up for 5 minutes on a stationary bicycle. After the warmup, isometric muscle strength test measurements were performed, however data from these strength measurements were not used in the current study but are explained further in Appendix II. After the strength measurements, reflective markers were placed on the skin of the participant, to define the position and tracking of the joints. The markers were placed on the participant by the same physiotherapist to increase reliability. The reliability of the data from the markers has been studied. Showing fairly good reliability of internal/external rotation angles in low knee flexion angles, but lacking in abduction/adduction at all flexion angles (57).

The pelvis was composed of anatomical markers positioned on the iliac crests and greater trochanters. With tracking markers positioned at the anterior superior iliac spine, posterior superior iliac spine and sacrum. The thighs were composed of anatomical markers positioned on the greater trochanters and lateral and medial epicondyles at the knee. Four tracking markers were positioned on each thigh. The shank was composed of anatomical markers positioned on the lateral epicondyles of the knee, medial epicondyles of the knee, lateral malleolus and medial malleolus. Four tracking markers were positioned on each shank. The foot was composed of anatomical markers positioned on the medial malleolus, lateral malleolus, the first metatarsal and the fifth metatarsal. Tracking markers for the foot were positioned at the upper aspect of the calcaneus, lower aspect of the calcaneus, the first metatarsal and the fifth metatarsal. The thorax was composed of anatomical markers positioned on the iliac crests and acromion processes. Tracking markers of the thorax were positioned at C7, acromion processes, sternum and T10.
In line with research supporting that higher knee valgus moments occur in sidestep cutting in comparison to a drop jump (58), a sidestep cutting maneuver was analyzed. From standing the participants performed sidestep cutting trials pre- and post-fatigue, each participant performed at least 20 trials, some participants performed additional trials because of technical difficulties. The sidestep cutting trials were performed without any approach steps on the AMTI force plates with a 2000 Hz sampling rate to measure the GRF while an 8 camera Qualisys camera system recorded the movements of the markers in three dimensions with a 400 Hz sampling rate. A fatigue protocol was used on the participants and is explained in detail by Appendix II. In this study the effects of the fatigue protocol were not analyzed.

Figure 1. The sidestep cutting condition

A small box was placed in front of the force plate to mimic an opponent (Figure 1.)

Figure 2. The biomechanical model

Qualysis track manager software was used to measure motion and information from the markers and force plate data. These measurements were then exported to c3d files and analyzed using the Visual 3D software. In Visual 3D, a biomechanical model is built and defined to represent joint segments. The biomechanical model used to analyze kinematics and kinetics can be seen in Figure 2.
3.4 Data synthesis

The kinematics were calculated by determining the orientation of a distal segment relative to its parent segment using a 6 degree of freedom method, with the pelvis as the center of the model. Inverse dynamics was used to calculate joint moments.

Figure 3. Peak knee valgus moment

For the dependent variable, the peak frontal plane knee moment, we rectified the frontal plane knee moment curve and identified the absolute peak value during the first 100 ms of the sidestep cutting stance phase. The peak frontal plane knee moment will therefore have either a valgus value (valgus group) or a varus value (varus group) (Figures 3 and 4). The peak frontal plane knee moments are reported as external moments, normalized by body weight (Nm/kg).

Initial contact was defined as when the force reached > 5N on the force plates. Kinematic variables used in this study included hip excursions that were calculated by the subtracting joint angles at initial contact from angles extracted at the time of the peak frontal plane moment. Frontal and transverse plane hip angles collected at initial contact and frontal plane trunk angles, collected at peak frontal plane knee moments.
3.5 Statistical analysis

Statistical analysis was performed using SAS [SAS Enterprise Guide version 7.15, SAS institute Inc.]

Two sample t-tests were used to analyze the differences in kinematic variables between varus and valgus groups with the difference in variance between groups considered. A linear regression was used to determine the relationship between the kinematic variables and peak frontal plane knee moments separately for the valgus and varus groups. Two separate multiple linear regression analysis were performed with all the independent variables together to determine the relationship of combined hip and trunk kinematics of the valgus and varus groups on peak knee valgus moments and peak knee varus moments. The level of significance was set at 0.05.
4 Results

4.1 Group comparison

The sidestep cutting trials composed of 2248 trials. Of those trials, 12 trials were excluded due to technical errors. In total, 2236 sidestep cut trials were therefore analysed. There were 714 trials with a peak knee valgus moment (valgus group) and 1522 trials had a peak knee varus moment (varus group).

Table 1. Analysis of knee moments and kinematics.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Valgus group mean (SD)</th>
<th>Valgus group range</th>
<th>Varus group mean (SD)</th>
<th>Varus group range</th>
<th>P - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valgus + Varus -</td>
<td>0.22 (0.17) Nm/kg</td>
<td>0.01 – 1.78 Nm/kg</td>
<td>-0.41 (0.24) Nm/kg</td>
<td>-1.70 – -0.003 Nm/kg</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Hip abduction + Hip adduction -</td>
<td>-15.72° (8.05°)</td>
<td>-40.05° – 8.11°</td>
<td>-12.09° (7.61°)</td>
<td>-34.53°– 12.83°</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Hip internal rotation + Hip external rotation -</td>
<td>8.33° (9.01°)</td>
<td>-17.16°– 40.25°</td>
<td>9.29° (8.32°)</td>
<td>-19.99°– 38.20°</td>
<td>0.0167</td>
</tr>
<tr>
<td>Hip abduction excursion + Hip adduction excursion -</td>
<td>-0.30° (2.98°)</td>
<td>-16.38° – 19.08°</td>
<td>0.82° (4.98°)</td>
<td>-15.48° – 19.27°</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Hip internal rotation excursion + Hip external rotation excursion -</td>
<td>2.20° (3.36°)</td>
<td>-14.65°– 14.30°</td>
<td>2.85° (4.67°)</td>
<td>-13.13° – 19.44°</td>
<td>0.0002</td>
</tr>
<tr>
<td>Trunk lean to the stance leg + Trunk lean away from the stance leg -</td>
<td>8.03° (7.65°)</td>
<td>-27.44°– 38.78°</td>
<td>12.03° (7.61°)</td>
<td>-39.67°– 39.32°</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
A significant difference was established in the means of frontal plane hip angles (effect size 0.47), transverse plane hip angles (effect size 0.11), frontal plane hip excursions (effect size 0.25), transverse plane hip excursions (effect size 0.15) and frontal plane trunk angles (effect size 0.53) between the groups as seen in Table 1. Also, the varus group had on average higher forces (-0.41 Nm/kg) compared to the valgus group (0.22 Nm/kg), p=<.0001.

4.2 Linear regression analysis

Table 2. Associations of frontal plane hip angles (°) and peak frontal plane knee moments (Nm/kg).

<table>
<thead>
<tr>
<th>Group</th>
<th>R^2</th>
<th>Intercept</th>
<th>Slope</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valgus</td>
<td>0.034</td>
<td>0.162</td>
<td>-0.004</td>
<td>-0.005</td>
<td>-0.002</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Varus</td>
<td>0.006</td>
<td>-0.436</td>
<td>-0.003</td>
<td>-0.004</td>
<td>-0.001</td>
<td>0.0027</td>
</tr>
</tbody>
</table>

Figure 5. Linear regression of frontal plane hip angles (°) and peak knee valgus moments (Nm/kg).

Frontal plane hip angles at initial contact have a significant effect on the variance of peak knee valgus moments as seen in Table 2 and Figure 5.
**Figure 6.** Linear regression of frontal plane hip angles (°) and peak knee varus moments (Nm/kg).

Frontal plane hip angles at initial contact have a significant effect on the variance of peak knee varus moments as seen in Table 2 and Figure 6.

**Table 3.** Associations of transverse plane hip angles (°) and peak frontal plane knee moments (Nm/kg).

<table>
<thead>
<tr>
<th>Group</th>
<th>$R^2$</th>
<th>Intercept</th>
<th>Slope</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Valgus</td>
<td>0.0002</td>
<td>0.226</td>
<td>-0.003</td>
<td>-0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>Varus</td>
<td>0.019</td>
<td>-0.368</td>
<td>-0.004</td>
<td>-0.005</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Figure 7. Linear regression of transverse plane hip angles (°) and peak knee varus moments (Nm/kg).

Transverse plane hip angles at initial contact have a significant effect on the variance of peak knee varus moments as seen in Table 3 and Figure 7.

Table 4. Associations of frontal plane hip excursions (°) and peak frontal plane knee moments (Nm/kg).

<table>
<thead>
<tr>
<th>Group</th>
<th>R^2</th>
<th>Intercept</th>
<th>Slope</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valgus</td>
<td>0.0003</td>
<td>0.223</td>
<td>-0.001</td>
<td>-0.005</td>
<td>0.003</td>
<td>0.666</td>
</tr>
<tr>
<td>Varus</td>
<td>0.001</td>
<td>-0.404</td>
<td>-0.002</td>
<td>-0.004</td>
<td>0.001</td>
<td>0.180</td>
</tr>
</tbody>
</table>

Frontal plane hip excursions did not significantly explain the variance of peak knee valgus moments or peak knee varus moments as seen in Table 4.

Table 5. Associations of transverse plane hip excursions (°) and peak frontal plane knee moments (Nm/kg).

<table>
<thead>
<tr>
<th>Group</th>
<th>R^2</th>
<th>Intercept</th>
<th>Slope</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valgus</td>
<td>0.008</td>
<td>0.213</td>
<td>-0.004</td>
<td>0.001</td>
<td>0.008</td>
<td>0.019</td>
</tr>
<tr>
<td>Varus</td>
<td>0.010</td>
<td>-0.420</td>
<td>-0.005</td>
<td>0.003</td>
<td>0.008</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
Figure 8. Linear regression of transverse plane hip excursions (°) and peak knee valgus moments (Nm/kg).

Transverse plane hip excursions have a significant effect on the variance on peak knee valgus moments as seen in Table 5 and Figure 8.

Figure 9. Linear regression of transverse plane hip excursions (°) and peak knee varus moments (Nm/kg).

Transverse plane hip excursions have a significant effect on the variance on peak knee varus moments as seen in Table 5 and Figure 9.
**Table 6.** Associations of frontal plane trunk angles (°) and peak frontal plane knee moments (Nm/kg).

<table>
<thead>
<tr>
<th>Group</th>
<th>$R^2$</th>
<th>Intercept</th>
<th>Slope</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valgus</td>
<td>0.016</td>
<td>0.201</td>
<td>0.003</td>
<td>0.001 - 0.004</td>
<td>0.004</td>
<td>0.0007</td>
</tr>
<tr>
<td>Varus</td>
<td>0.019</td>
<td>-0.352</td>
<td>-0.004</td>
<td>-0.006 - 0.003</td>
<td>0.003</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

**Figure 10.** Linear regression of frontal plane trunk angles (°) and peak knee valgus moments (Nm/kg).

Frontal plane trunk angles significantly explained the variance in peak knee valgus moments as seen in Table 6 and Figure 10.
Figure 11  Linear regression of frontal plane trunk angles (°) and peak knee varus moments (Nm/kg).

Frontal plane trunk angles significantly explained the variance in peak knee varus moments as seen in Table 6 and Figure 11.
4.3 Multiple regression analysis

Table 7. Multiple regression analysis of hip and trunk kinematics (*) on peak frontal plane knee moments (Nm/kg).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hip abd/add Valgus group</th>
<th>Hip abd/add Varus group</th>
<th>Hip ir/er Valgus group</th>
<th>Hip ir/er Varus group</th>
<th>Hip abd exc/ hip add exc Valgus group</th>
<th>Hip abd exc/ hip add exc Varus group</th>
<th>Hip ir exc/ hip er exc Valgus group</th>
<th>Hip ir exc/ hip er exc Varus group</th>
<th>Trunk lean to/away from stance leg Valgus group</th>
<th>Trunk lean to/away from stance leg Varus group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>-0.006</td>
<td>-0.001</td>
<td>0.002</td>
<td>-0.003</td>
<td>-0.004</td>
<td>0.001</td>
<td>0.004</td>
<td>0.003</td>
<td>0.005</td>
<td>-0.004</td>
</tr>
<tr>
<td>95% CI lower</td>
<td>-0.004</td>
<td>-0.002</td>
<td>0.0001</td>
<td>-0.005</td>
<td>-0.008</td>
<td>-0.001</td>
<td>0.0002</td>
<td>0.0004</td>
<td>0.003</td>
<td>-0.006</td>
</tr>
<tr>
<td>95% CI upper</td>
<td>-0.008</td>
<td>0.001</td>
<td>0.003</td>
<td>-0.002</td>
<td>0.0003</td>
<td>0.004</td>
<td>0.007</td>
<td>0.006</td>
<td>0.007</td>
<td>-0.002</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;.0001</td>
<td>0.436</td>
<td>0.036</td>
<td>&lt;.0001</td>
<td>0.066</td>
<td>0.387</td>
<td>0.037</td>
<td>0.022</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

A significant effect of combined hip and trunk kinematics on peak frontal plane knee moments, with the valgus group demonstrating an adjusted R square of 0.082 (p.<.0001) and the varus group demonstrating an adjusted R square of 0.041 (p.<.0001), as seen in Table 7.
5 Discussion

The aims of the current study were to examine the associations of peak knee valgus and peak knee varus moments with the kinematics of the hips and trunk during the first 100 ms of the stance phase. The main findings of this study were that significant, but likely unimportant associations were found between hip and trunk kinematics and peak frontal plane knee moments regarding ACL injuries. This study also supported the hypothesis that the kinematics of the hips and trunk differ in the valgus and varus groups by finding that the means of the hips and trunk kinematics differed significantly.

5.1 Combined effects of hip and trunk kinematics on peak frontal plane knee moments

When all variables were considered in a multiple regression analysis, peak knee valgus moments were significantly associated with greater hip abduction and hip internal rotation angles at initial contact, the trunk leaning to the stance leg and greater hip internal rotation excursions. All these variables together explained the variance in peak knee valgus moments by 8.2%. For every 10° increase in trunk lean to the stance leg, the peak knee valgus moment is expected to go up by 0.05 Nm/kg. For every 10° increase in hip abduction the peak knee valgus moment is expected to go up by 0.06 Nm/kg. For every 10° increase in hip internal rotation the peak knee valgus moment is expected to go up by 0.02 Nm/kg and for every 10° increase in hip internal rotation excursion the peak knee valgus moment is expected to go up by 0.04 Nm/kg. The slopes of each variable increased when all the variables were put together, indicating that the combined effects of the variables yield a greater influence on peak knee valgus moments. Greater hip internal rotation angles at initial contact, greater hip external rotation excursions and frontal plane trunk lean to the stance leg were significantly associated the variance in peak knee varus moments, explaining the variance in peak knee varus moment by 4.1%. Although significant, these associations were small. Changes in the combined kinematics of the hips and trunk yielded a small change in peak knee valgus and varus moments and therefore may not be important in relation to ACL injuries.

5.2 Individual kinematic effects on peak frontal plane knee moments

The studies hypothesis of an association between frontal plane hip angles and peak knee valgus moments individually was supported. In the valgus group greater hip abduction at initial contact significantly explained the variance in peak frontal plane knee moments by 3.4%. Although significant, the relationship was rather small, with a slope of 0.004 Nm/kg. Sigward et al. (46) reported a relationship of knee valgus moments and hip abduction angles at initial contact in subjects with excessive valgus moments. These researchers collected valgus moments during the first 20% of the stance phase, similar to the first 100 ms and also found differences in the kinematics in groups. With greater hip abduction angles at initial contact in subjects that developed high valgus moments compared to subjects with normal knee valgus moments (effect size 0.79). In the current study, the hip abduction angle at initial contact was greater for the valgus group with an effect size of 0.47.

The hypothesis of an association between frontal plane hip angles and peak knee varus moments was also supported. The varus group showed significant negative associations between hip abduction
angles at initial contact and greater peak knee varus moments with an explained variance of 0.6% in peak frontal plane moments. This association is very small and probably not strong enough to be under consideration regarding ACL injuries.

The results of this study did not support the studies hypothesis of transverse plane hip angles being associated with peak knee valgus moment \((p=0.68)\). This is in contrast with other studies showing a significant relationship with hip internal rotation angles being associated with greater knee valgus moments in a greater timeframe of the stance phase \((R^2=0.60)\) (45). The individual effects of hip internal rotation might therefore not have an effect on valgus moments during the first 100ms of the stance phase, where the knee valgus moment might be more influenced by the impact force.

The results supported the hypothesis that transverse plane hip angles at initial contact are associated with peak knee varus moments. Greater hip internal rotation angles at initial contact were associated, but weakly with greater peak knee varus moments. Explaining 1.9% of the variance. As the athlete rotates his hip prior to initial contact, the foot at initial contact could be oriented in such a way to generate varus moments. However, initial contact hip internal rotation had a small slope of 0.004 Nm/kg, making the individual effects of hip internal rotation in regards to varus moments and ACL injury unimportant.

This study did not find a significant association of frontal plane hip excursions and peak knee valgus moments or peak knee varus moments. This is in contrast to the studies initial hypothesis. Perhaps the frontal plane hip excursions may not effectively alter the orientation of the GRF vector enough in this short phase from initial contact to peak frontal plane knee moments during the first 100ms of the stance phase to cause significant variations in peak frontal plane knee moments, as the excursion less than a degree on average during the time from initial contact to the peak frontal plane knee moment. Frontal plane hip angles at initial contact may therefore be more important than the frontal plane hip excursion in developing frontal plane knee moments by generating lateral GRF as he plants the foot to the ground with greater hip abduction.

The results of this study supported the hypothesis of an association of transverse plane hip excursions and peak knee valgus moments by a small but significant association. Indicating that as the hip internally rotated more from initial contact to the point of peak frontal plane knee moments, the knee valgus value would increase. However this increase was small with a slope of 0.004 Nm/kg, making the contribution of internal hip rotation excursions unimportant in regards to ACL injuries.

The hypothesis of transverse plane hip excursions being associated with peak knee varus moments was also supported. With less internal rotation and greater hip external rotation excursion, the varus group increased the peak knee varus moment. Possibly by orientating the GRF vector medially to the knee joint. This effect on the magnitude of knee varus moments were small with a slope of 0.005 Nm/kg and thus unimportant.

The results of the study supported the hypothesis of frontal plane trunk angles being associated with peak knee valgus moments. Greater trunk lean to the stance leg resulted in higher peak knee valgus moments, with a slope of 0.003 Nm/kg. Giving that this slope is low, the individual effects might not have a considerable effects on ACL injury risk. Jones et al (44). reported a stronger relationship of
trunk lean to the stance leg at initial contact and valgus moments in the weight acceptance phase of a sidestep cut, explaining 18% of the variance in valgus moments. In the current study, giving that this slope is low, the individual effects of trunk lean to the stance leg might not have an important relationship on ACL injuries during the first 100 ms.

In line with the studies hypothesis, the current study also found a significant association of peak knee varus moments and frontal plane trunk angles, with greater trunk lean to stance leg being associated with greater peak knee varus moments. This is contrary to what one would expect, in that as the athlete leans their trunk away from stance leg to generate more medially orientated GRF vector. However the vast majority of the trials in both groups performed a sidestep cut with the trunk leaning towards the stance leg. Also the slope was low (0.004 Nm/kg) therefore the individual effects of frontal plane trunk angles on peak knee varus moments are not large, making them unimportant in regards to ACL injuries.

This current study goes in contrast to other studies (41-45) examining hip and trunk kinematics later in the stance phase, by reporting low associations of hip and trunk kinematics on peak knee valgus and peak knee varus moments. This could be because the peak frontal plane knee moment is more influenced by the initial impact force during the first 100 ms of the stance phase, therefore we see low associations of the kinematics of the hips and trunk at this time in the stance phase. It is clear that variables other than the kinematics of the hips and trunk might influence the variance in frontal plane knee moments that we did not cover in the current study, such as the impact force, direction of the GRF knee angle and foot angle at initial contact. The results of the previous studies could be explained by the absence of a high impact force later on in the stance phase, resulting in a higher relationship between the kinematics of the athlete and the frontal plane moment, possibly occurring later than the expected time to injure an ACL.

Going forward, further research is needed to examine the effects of kinematic positions on the effects on knee moments that cause an greater load on ACL injuries in a shorter timeframe of the stance phase of a sidestep cut. Expanding the effects of other kinematic variables than the hips and trunk on the knee moments in order to create sidestep cutting technique guidelines, relevant to ACL injuries. Furthermore more studies are needed to examine the effects of initial impulse forces on frontal plane knee moments and compare the effects of that force and the athletes kinematic positions during the first 100 ms to get a better picture of what truly matters in ACL injuries.

5.3 Strengths
This study included a large sample size, making the data more precise and will reduce the risk of a false – negative (type 2 error). The study examined the first 100 ms of the stance phase of a sidestep cut, which is where ACL injuries occur (50). Therefore, the current study is more relevant to ACL injuries than other studies that did not limit this timeframe. The regression analysis allows us to examine the relationships between variables and allows us to estimate the magnitude of change in one variable in relation to another variable.
5.4 Limitations

There are some limitations in this study. First, the linear regression analysis can also have some limitations in that it does not equal causation, it only examines the relationships between variables. Regressions are also sensitive to outliers, however, this study did include a large sample size. In this study, the participants performed the sidestep cut when they were ready and with no prior run which might have resulted in lower frontal plane knee moments. This does not resemble the unanticipated nature of sports environments. Studies have found greater valgus moments in unanticipated sidestep cutting trials compared to anticipated sidestep cutting trials (59). This study only included the frontal plane knee moments, whereas other forces influence the load on the ACL such as anterior tibial translation force and internal rotation moment (29). Some of the subjects had dropped out of sports and might therefore be more deconditioned. This study only analyzed the kinematic variables in relation to knee moments and we did not account for the fatigue protocol which can influence the kinematics and knee moments during sidestep cutting (60). This study did not analyze the difference of kinematics or knee moments between genders. Where other studies have shown a difference in kinematics and moments between the genders during sidestep cutting (61, 62). A large sample size was used in this study, making the analysis of the variables more sensitive to small changes, resulting in associations that are significant. Some of the athletes performed additional sidestep cutting trials due to technical difficulties, this could lead to some data possibly being flawed.
6 Conclusion

A sidestep cutting technique composed of a trunk lean to the stance leg, initial contact hip abduction and internal rotation and hip internal rotation excursions is associated with peak knee valgus moments during the first 100 ms of the stance phase. Furthermore a sidestep cutting technique composed of greater hip internal rotation, hip external rotation excursions and trunk lean to the stance leg are associated with peak knee varus moments. However the change in knee moments for changes in the kinematics were small in both groups and therefore may not be important in relation to ACL injuries. Other factors such as the magnitude of the impact force can play a larger role in influencing peak frontal plane knee moments. The effects of the kinematics of the hips and trunk on peak frontal plane knee moments were lower than previously established and may therefore play a smaller role in ACL injuries than previously considered. Researchers need to examine the effects of kinematics during the first 100 ms to make technique recommendations that are more specific to ACL injuries.
Reference


Appendix I

Háskóli Íslands
Læknaeild
Rannsóknastofa í hreyfivísindum
Námsbraut í sjúkraþjálfun

Rannsókn á vegum Námsbraut í sjúkraþjálfun við Heilbrigðisvisindasvið Háskóla Íslands;

Kynbundin áhætta krossbandaslits: aldurstengdar breytingar hjá ungmennum sem stunda handbolta og fótbolta.

SAMÞYKKISYFIRLYSING FYRIR ÞÁTTTAKENDUR/FORRÁÐAMENN


Þátttaka í rannsókninni felur í sér að mæta í eitt skipti til mælinga þar sem mælitæki og nemar verða sett á líkaman til að mæla styrk og raðvirkni vöðva og hreyfimynstur í neðri útilimum við framkvæmd staðlaðra æfinga. Einnig verður hæð og þyngd mæld. Allur undirbúningur ásamt mælingum vara alls í um 2 klst. Hugsanlega verða þátttakendur beðnir um að taka þátt í áframhaldandi rannsóknum tengdum rannsóknarverkefninu.

Ég staðfesti hér með undirskrift minni að ég hef lesið upplýsingarnar um rannsóknina sem mér voru afhentar, hef fengið tækilæki til að spyrja spurningum um rannsóknina og fengið fullnægjandi svör og útskyrningar á atriðum sem mér voru óljós. Ég hef af fúsum og frjálsum vilja ákveði að taka þátt í rannsókninni. Mér er ljóst, að þó ég hafi skrifað undir þessa samstarfsfyrlyýsingu, get ég stöðvað þátttöku mína hvenær sem er án útskyringa og án áhrifa á mína íþróttatæki eða læknisþjónustu í framtíðinni.

Mér er ljóst að rannsóknargögnum verður eytt að rannsókn lokinni og mér hefur verið skýrt frá því að þátttakendur eru tryggðir fyrir óhöppum sem hugsanlegt er að verði á meðan æfingar eru gerðar í rannsókninni.

Dagsetning

Undirskrift forráðamanns og nafn þátttakanda

Undirritaður, starfsmaður rannsóknarinnar, staðfestir hér með að hafa veitit upplýsingar um eðli og tilgang rannsóknarinnar, í samræmi við lög og reglur um visindarannsóknir

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## Appendix II

<table>
<thead>
<tr>
<th>Nafn rannsakanda</th>
<th>ACL rannsókn</th>
<th>Verklýsing</th>
<th>Ann-Helen Odberg</th>
<th>Arna Friðriksdóttir</th>
<th>Hjálmar Jens Sigurðsson</th>
<th>Haraldur Björn Sigurðsson</th>
</tr>
</thead>
</table>

**Það sem þarf að vera til: - Halli**

- Kraftmælir (muna að „calibrera“ mælinn og nota t.d. 2kg. Löð).
- 3 Koddar (2 milli fóta, 1undir höfuð)
- 2 electróður
- Gel undir electróður/trióður
- Belti
- pallur til að hoppa af (30cm)
- pallur til að standa, meðan verið er að festa markera
- Handklæði
- Batterí
- spritt
- bómull
- pennar
- Tölva með opinni skráningu
- útprentuð blöð með
  - samþykki fullorðnir
  - samþykki börn
- Bón og tvist til að bóna slideboard (þarf að gerast 1 x í viku)
- Djús, kex eða annað til að gefa krökkum eftir mælingar eða ef eithvað kemur upp á.
### UNDIRBÚNINGUR FYRIR MÆLINGU/Prófdagur - Halli

<table>
<thead>
<tr>
<th>TESTGÖGN:</th>
<th>HVÅÐ:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duckt tape</td>
<td>Rífa niður í 14 ræmur</td>
</tr>
<tr>
<td>Markerar</td>
<td>Lím á alla markerana</td>
</tr>
<tr>
<td>Testföt</td>
<td>Að fötin séu hrein</td>
</tr>
<tr>
<td>Upplýsingablöð x2 (foreldrar og þátttakendur)</td>
<td>Sambýkki fullorðin</td>
</tr>
<tr>
<td>Myndavélar</td>
<td>Calibrera: Horn á kraftplötu 3, calibration í 50sek, fá tölur undir 2.0. - tölurnar þurfa að vera undir 2.0. Hornið er á kraftplötu 3</td>
</tr>
<tr>
<td>EMG</td>
<td>Prófa allar electróðurnar og sjá hvort þær eru ekki í lagi</td>
</tr>
<tr>
<td>Kraftmælir</td>
<td>Stilltur á high og 5Kg þróskuld</td>
</tr>
<tr>
<td>Tölva</td>
<td>Opna Trigno Control Utility =&gt; kveikja á elektróðum og sjá grænar í control utility</td>
</tr>
<tr>
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</tr>
<tr>
<td>Slideboard</td>
<td>bónað ef mæling gengur upp í 5</td>
</tr>
</tbody>
</table>

---

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Móttaka þátttakenda/við komu á rannsóknarstofu (Halli)

- Þátttakendur ásamt foreldrum/forráðamönnum koma inn og fá afhent upplýsingablað til að lesa yfir og skrifa undir
- Farið í gegnum framkvæmd rannsóknar með foreldrum/forráðamönnum og barni og útskýrt hvað muni fara fram við rannsóknina. Spurningum svarað ef einhverjar eru um framkvæmd rannsóknar
- Ef þátttakendur hafa ekki með sér auka skó, eru mátaðir skór frá okkur.
- Þátttakendur fá stuttbuxur og topp (stúlkur) og sýnt hvar þau geta skipt um föt
- Fyrirmæli: „Vertu í nærbuxum og sokkum og farðu í stuttbuxurnar yfir. Stelpur fara í toppinn. Komdu svo fram þegar þu eftir þilúin/nn.“

ÞYNGD, HÆÐ OG FÓTLEGGJALENGD - Aðstoðarmaður

- Viðfang er ekki í skóm á meðan mælingar á hæð, þyngd og fótleggjalengd eru framkvæmdar.
- Lengd fótleggjar notuð til að að ákvarða bil milli fjala á skautabretti/slideboard
- Viðfang fer í skó að loknum mælingum á fótleggjalengd

<table>
<thead>
<tr>
<th>MÆLING:</th>
<th>FYRIRMÆLI:</th>
<th>FRAMKVÆMD MÆLING:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Þyngd</td>
<td>„Stígðu upp á vigtina með allan fótinn inni á vigtinn.“</td>
<td></td>
</tr>
<tr>
<td>Hæð</td>
<td>„Stattu með hæla upp við vegginn og horfðu beint fram, réttu vel úr þér.“</td>
<td>Mælt að hvirfli með málbandi á vegg</td>
</tr>
<tr>
<td>Fótleggjalengd</td>
<td>”Stattu jafnt í báðar fætur og horfðu beint fram.”</td>
<td>þátttakendur standa með mjaðmabreidd á milli fótta. Mælt frá hæðsta punkti lateral cristia iliaca hægra megin, og niður í gólf.</td>
</tr>
</tbody>
</table>

UPPHITUN - Aðstoðarmaður

Hjólað á þrekjóli í 5 mínútur á þægilegum hraða. Hæð á hnakki stillt (ágætt að miða við crista iliaca) þ.a. þægilegt sé að hjóla. Fundin hentug mótsstaða (hvorki of þungt né of létt). Fyrirmæli : „hjólaðu á þægilegum hraða."
STYRKTARMÆLINGAR og MVIC (EMG) - Aðstoðarmaður

- Í öllum mælingum þarf að gæta þess að staða liða sé:
  - Lat rot mjöðma: Viðfang sitjandi, sköflungur lóðréttur, hné og mjöðm í 90° flex, mjöðm hvorki í lat- né med rot
- Í öllum mælingum er fyrst gerð ein prufumæling til að viðfang kynnist hreyfingunni og til að ganga úr skugga um að allt sé sett upp á réttan hátt
  - Styrkur í prufumælingum er skráður þegar kraftmælir er notaður
  - Í GMED mælingum er MVIC mælt í fyrstu mælingu (af þremur) á eftir prufumælingu
- Kraftmælir
  - Þátttakandi fær eina prufumælingu. Síðan eru teknar þrjár mælingar með hámarkskrafti með um 15 sek hvíld á milli.
- EMG
  - EMG electróður eru staðsettar í hliðarlegu á 50% lengdar ímyndaðrar línu milli Crista iliaca og trochanter, úpp 1cm posterior við miðlínu. Gott að láta viðkomandi spenna vöðvan á meðan þreifað er fyrir réttr staðsetningu)
  - Alltaf að spritta húð undir tríóðu
  - Taka allt plast/pappír af tríóðu til að minnka líkur á að hún detti af
  - Setja smá gel undir tríóður
  - mælandi við EMG tölvu segir til um hvenær á að byrja og hætta að spenna vöðva (fyrsta mæling)

Vöðvarafrit - Halli

- MVIC
  - EMG upptaka stillt á 8 sek, hver mæling tekur ca 5 sek (ekki verið að spenna vöðva fyrstu og síðustu sekúndur upptöku)
  - mælandi við EMG tölvu segir til um hvenær á að byrja og hætta að spenna vöðva. EMG er stillt á eina electróðu í 8 sek.
<table>
<thead>
<tr>
<th>MÆLING:</th>
<th>FYRIRMÆLI:</th>
<th>FRAMKVÆMD:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abd í mjöðm (h + v)</td>
<td>&quot;Leggstu á hliðina.&quot; (randomiserað hvor hliðin er fyrst í mælingu)</td>
<td>Neðri mjöðm er í 30°-45° flexion og neðra hné í 90° flexion. Efri mjöðm er bein (0°) eða í smá extension og hné er beint (0°), axlí í beinni lín við mjöðm</td>
</tr>
<tr>
<td>Styrkur MVIC Ath töflu fyrir hvaða hlið byrjan</td>
<td>&quot;Lyftu fætinum beinum upp.&quot;</td>
<td>Tveir koddar settir á milli lærar til að halda mjöðm í neutral stöðu</td>
</tr>
<tr>
<td></td>
<td>Mælandi heldur mælinum stöðugum og hivet þátttakanda: &quot;koma svo, eins fast og þú getur!!&quot; Fylgjast með að þátttakandi velti sér ekki þannig að mjöðmarflexion verði ríkjandi</td>
<td>Mælandi þrýstir vel fast á móti hné til að koma í veg fyrir flexion í mjöðm</td>
</tr>
</tbody>
</table>

| Ext. Rót mjöðm (h + v) Ath töflu fyrir hvaða hlið byrjan | "Sestu á endann á bekknum með hnésbætur alveg upp að brúninni." | Þátttakandi sest á endan á bekknum með fætur fram af langhlið bekkjarins og hné alveg uppi við brún. |
| | „Krossleggðu hendur“ | Þrýstimæli er komið fyrir tveim fingurbreiddum ofan við malleolus medialis og haldið fóstum með belti sem fest er í súlu. Beltið er staðsett hornrétt á ökkla og sett utan um mælinn. Lengd beltisins er stillt þannig að það sé þétt að mælinum, skóflungur lóðréttur og snúningra í mjöðm sem næst 0°. |
| | "Ýttu á mælinn eins fast og þú getur. Ekki halla þér til hliðar eða nota hinn fótinn til að ýta í bekkinn”. | Mælandi þrýstir vel fast á móti hné til að koma í veg fyrir flexion í mjöðm |
### Qualisys Marker staðsetningar (alltaf miðað við miðju á marker/endurskini)

<table>
<thead>
<tr>
<th>Staðsetning</th>
<th>Skýring</th>
<th>Static</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hæll x4</td>
<td>2 markerar aftan á hvorn hæl</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Caput á MTP1 x 2</td>
<td>Stígur í tánna og þreifum í gegnum skóinn</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Caput á MTP5 x 2</td>
<td>Stígur í tánna og þreifum í gegnum skóinn</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Malleolus lat x 2</td>
<td>Utan á sokk á mest prominent/ysta punkt</td>
<td>X</td>
<td>---</td>
</tr>
<tr>
<td>Malleolus med x 2</td>
<td>Utan á sokk á mest prominent/ysta punkt</td>
<td>X</td>
<td>---</td>
</tr>
<tr>
<td>Femoral condyl lat x 2</td>
<td>Rétt ofan við liðbil hnés (beygja og rétta til að finna liðbilið). Finna mest prominent/ysta punkt lateralt á condyl</td>
<td>X</td>
<td>---</td>
</tr>
<tr>
<td>Femoral condyl med x 2</td>
<td>Rétt ofan við liðbil hnés (beygja og rétta til að finna liðbilið). Finna mest prominent/ysta punkt medialt á condyl.</td>
<td>X</td>
<td>---</td>
</tr>
<tr>
<td>Trochanter major x 2</td>
<td>Á mest prominent/ysta punkt (hreyfa pelvis til hlíðanna eða inn- og útrótera mjöðum til að finna trochanter). ATH að mjaðmir séu í neutral stöðu þegar marker er festur</td>
<td>X</td>
<td>---</td>
</tr>
<tr>
<td>SIAS x 2</td>
<td>Mest lateralt á SIAS</td>
<td>X</td>
<td>---</td>
</tr>
<tr>
<td>Crista x 2</td>
<td>Efsta á lateral brún crist iliaca</td>
<td>X</td>
<td>---</td>
</tr>
<tr>
<td>Sacrum (Cluster)</td>
<td>Marker á sacrum er miðja vegu milli SIPS og markeralengð fyrir neðan SIPS markerar</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Acromion x 2</td>
<td>Efsta punkt</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>T8 x 1</td>
<td>Á hryggind, telja niður frá C7</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>C7 x 1</td>
<td>Á hryggind, (við ext í hálsi hverfur C6 fram) beygja</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Manibrium sternum x 1</td>
<td>Milli sternoclaviclar liðanna (efri brún markers á eftri brún sternum)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cluster á læri x 2</td>
<td>Latero-posterior</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cluster á kálfa x 2</td>
<td>Latero-posterior</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Þátttakandi stígur niður af kassanum og passar að ekkert detti af. Athugað hvort allar electróður og allir markerar séu á sínum stað.

Þátttakandi kemur sér fyrir á kraftplötu 3 og static mynd er tekin á qualisis (5 sek). Athuga að allir markerar sjáist vel.
Static:
Eftir static mælingu eru markerar á medial / lateral hné, greater trochanter, sias, og medial og lateral malleolus teknir af

PRE-MÆLINGAR
Dynamískar mælingar
Sjá töflu fyrir röð mælinga

Halli:
QTM stillt á rað-upptökur af 7 sek mælingum
Gerðar eru 5 gildar mælingar í röð af hverri hreyfingu. Mæling er gild sé lending rétt á kraftplötu og allur stand-fasinn +1sek fyrir og eftir innan timarammans
Í fintum lenda fætur á kraftplötu 3 og í DJ lendir vinstri fótur á kraftplötu 4 og hægri á 3.

Aðstoðarmaður leiðbeinir með hreyfingar:

<table>
<thead>
<tr>
<th>MÆLING:</th>
<th>FYRIRMÆLI:</th>
<th>FRAMKVÆMD:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop-jump</td>
<td>„Stattu framarlega á kassanum og láttu þig detta/falla niður og um leið og þú lendir hoppar þú eins hátt upp og þú getur.“</td>
<td>Í upptöku, leiðbeinir sá sem situr við Qualisys með því að segja „tilbúin og byrja“ þegar þátttakandi má fara af stað.</td>
</tr>
<tr>
<td></td>
<td>”Horfðu á kallinn.“ (myndin á ljósa-standinum). Við reynum að kenna hreyfinguna ekki of mikið heldur nota óbeinar leiðbeiningar eins og “gerður hreyfinguna hraðar”, “gerðu eins og þu myndir gera í leik”, ”Aðeins kraftmeira”....</td>
<td></td>
</tr>
</tbody>
</table>
Þreytuprótokol

Aðstoðarmaður

Hjálpa viðfangi að skipt um skó þannig að viðfang þurfi ekki að beygja sig. Passa vel upp á markera á skóm. Efni sett utan um skóna og lausir endar allar girtir ofan í sokka. Viðkomandi er sýnt hvernig það er framkvæmt, fær að prófa nokkur rennsli og byrjar svo rólega að skauta.

Fyrirmæli:

„Nú gerum við þetta í 5 mínútum, fyrst byrjar þú rólega og nærð góðum takti. Eftir hverja mínútu segi ég aðeins hraðar og aðeins hraðar þangað til á síðustu mínútu, þá gefur þú allt í botn og reynir að gera eins mikið/hratt og þú getur.“

„Hallaðu þér aðeins fram og haltu taktinum. Þegar ég segi skaltu auka hraðann.“

(Halli: Á meðan þátttakandi er á skautabretti er gott að undirbúa tölvuna undir næstu mælingu og losa um skóna sem fara á í eftir skautið, til að allt gangi smurt fyrir sig fyrir post-mælingarnar.)

"Núna er 1 mínúta eftir, gefðu allt í þetta - koma svo, áfram!!"

Eftir að þátttakandi hefur verið á skautabrettinu í 5 mínútum er þreyta metin á NR-skala þar sem 0 er engin þreyta og 10 er mesta þreyta sem hún/hann hefur upplifað: „hvemrug metur þú þreytuna þína á skalanum 1-10 þar sem 0 er engin þreyta og 10 er mesta þreyta sem að þú hefur upplifað“

ATH:

Um leið og þreytuprotocol er lokið þarf að aðstoða viðfang við að skipta hratt um skó, þannig að viðfang þurfi ekki að beygja sig, og mælingar gerðar í öfugri röð

Post-processing – Halli / aðstoðarmaður

Mælingum lokið, markerar og electróður teknar af. Lim tekið af markerum og nýtt doubletape sett á áður en gengið er frá þeim. Gögn uninn í QTM og exportuð á heimasvæði fyrir V3d.