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INFLUENCE OF HIP STRENGTH ON ACL INJURY RELATED BIOMECHANICS DURING THE CUTTING MANEUVER IN PREADOLESCENT STUDENTS (Practical Implication for Physical Education Teachers and Sports Pedagogues)

Abstract

Anterior cruciate ligament (ACL) injuries are one of the most serious injuries of the lower limb and can result in a relatively low rate of return to sport and decreased quality of life in later years, as well as to the psychological attitude towards sports among young people. Previous research has investigated the interaction between the hip muscles and knee valgus moments where some studies have concluded that decreased hip abductor and external rotator strength is a risk factor for ACL injury, but no research has been conducted on preadolescent population. Data from 271 students (174 girls), age 9-12 were collected while performing cutting manoeuvre and the isometric maximal voluntary contraction of hip external rotators and abductors. Our results show that no significant correlation was found between the hip strength does not influence the knee VM during the cutting manoeuvre in this age group which is in line with many previous studies conducted on older population.

Keywords: ACL; injury prevention; cutting manoeuvre; hip strength; biomechanics; pedagogical observation.

Introduction. Anterior cruciate ligament (ACL) injuries are one of the most serious injuries of the lower limb and can result in a relatively low rate of return to sport (Arder et al., 2011) [1], decreased quality of life in later years (Filbay et al., 2015) [2], and a high rate of knee osteoarthritis (Ajuied et al., 2014) [3]. It is an expensive injury indicating cost-effectiveness for prevention programs (Swart et al., 2014) [4]. Excessive lower extremity valgus during dynamic activities (e.g. landing, cutting manoeuvre) has been linked with the development of ACL injuries.

Frequent and often injuries can develop negative attitude towards sport and physical activity. Compared to males, adult females show a 2-3 fold increased incidence in ACL injury per hour of exposure (Walden et al., 2011)

[5]. Myer et al. (2011) [6] state in their review article that the most ACL injuries in female athletes occur during a non-contact episode, typically during deceleration, lateral pivoting, or landing tasks that are often associated with high external knee joint loads. In the past, ACL injuries were believed to be a problem affecting the adults participating in competitive sports, but Shaw and Finch (2017) [7] found that ACL injuries are an emerging issue in children and adolescents too, with girls both sustaining the injury at a younger age than boys (Sanders et al., 2016) [8], and receiving reconstructive surgery at a younger age (Nicholls et al., 2017) [9]. Growth and development of the hamstring muscles shows different pattern in boys and girls and as a consequence also there is discrepancy in rate of force development, which affects the

Q-R ratio. The literature shows different results when the differences between boys and girls starts to appear. Apart from gender-specific differences, hip strength or weakness can cause alterations in the knee valgus moment (VM). The hip joint provides stability for the lower extremity. Hip function is very complex and it is dependent on a synergic interaction of muscles to provide dynamic stability during motion. During the loading phase of cutting and landing, external moments acting on the hip create flexion, adduction and internal rotation moments that is recognized as lower extremity valgus (Powers, 2010) [10]. Recently, the influence of hip strength on knee function has been explored in light of the ACL injury prevention. Previous research has investigated the interaction between the hip muscles and knee VM where some studies have concluded that decreased hip abductor and external rotator strength is a risk factor for ACL injury (Ramskov et al., 2015) [11]. On the other hand, Jacobs et al (2007) [12] found a moderate but non-statistically significant negative correlation between hip abduction strength and knee valgus peak joint displacement during a single leg landing task. Sigward et al (2008) [13] found no significant correlations among hip extension, abduction and external rotation strength, and knee kinematics during a drop landing task. To the best of our knowledge, this is the first study to investigate the correlation between hip strength and ACL injury-related biomechanics during the cutting maneuver in preadolescent students.

The aim of this study was to investigate the correlation between hip strength and ACL injury-related biomechanics during the cutting maneuver in preadolescent, within the first 100 ms of the cutting manoeuvre, which is the time-frame where ACL injuries occur. We hypothesized that at this age, hip strength will not influence the knee VM.

Methods: Participants. The study was approved by a National Bioethics Committee of Iceland. In total, 293 students were recruited from local handball and soccer clubs, but out of those we used data of 271 students (174 girls) was used for the further analysis. Data

for twenty-two participants were excluded due to technical errors or erroneous performance. Prior to participation, all procedures were explained to each student and informed consent was signed by the participant and a parent or guardian. Students were aged between 9 and 12 years and were recruited from the teams' age-based training groups. Exclusion criteria were a history of torn knee ligaments or muscles of the lower extremities, intra-articular corticosteroid injections within the previous 3 months, neurological impairments, impaired balance, and any orthopaedic problems of the lower limb.

Data collection. After a 5-minute warm-up on a stationary bicycle, an isometric MVC of the hip abductors was performed, using a belt secured dynamometer with the subject in a side-lying position and hips in 0-5° flexion and 0-5° abduction. Strength testing of the hip external rotators followed. For the hip external rotator strength test, the subject was seated with arms crossed and no backrest. Hip rotation was neutral and knees flexed to 90° and feet off the ground. Strength was measured with a belt-secured dynamometer. For each strength test, a familiarization attempt was performed, followed by recorded maximal trials.

Kinematics were collected at 200 Hz using a marker set with 46 markers and an 8-camera Qualisys motion capture cameras (Qualisys Corp, Sweden) positioned around a calibrated test area. Kinetics were simultaneously collected at 2000 Hz from a force platform (AMTI, Watertown, MA) embedded into the floor. Where possible markers were placed directly onto the skin, to minimize movement artefacts resulting from loose clothing. A static measurement was used to define segments and joint centres based on anatomic markers, while clusters of 4 markers tracked each segment during dynamic trials.

Participants performed 5 cutting manoeuvres against a dummy opponent. The movement was performed from a ready position without a run-up using a self-selected change of direction angle. Participants took a quick sideways step on to the tested leg before accelerating to a maximal take-off away from the tested leg. Students were encouraged to use as much speed and explosiveness as they could.



Figure 1. Hip abduction isometric strength testing with a handheld digital dynamometer. Picture was presented by Saper et al, 2019 (DOI: 10.1177/2325967119828953) [14]

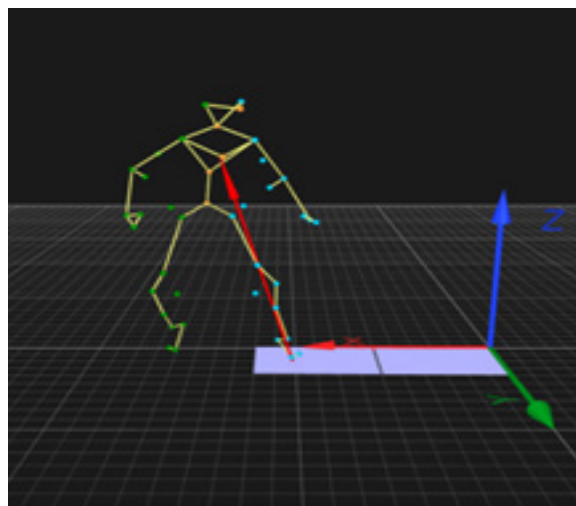


Figure 2. Cutting maneuver presented in Qualisys motion capture system

Data synthesis and statistical analysis. Kinematic outcome variables within the first 100 ms of stance were chosen as a marker for ACL loading according to two proposed injury mechanisms supported by prospective risk factor studies. Knee moments were normalized by body weight and presented as Nm/kg. The frontal plane knee moments are reported as peak external moments identified within the first 100ms as local maxima, the largest of which from each trial recorded was used for analysis. Positive values of frontal plane knee moments are referred to as knee valgus moments, while negative values represent knee varus moment.

Inverse kinematics were performed in Visual

3D (C-Motion). Data were imported to R (R Foundation for Statistical Computing, Vienna, Austria) for analysis and processing. R based program, Jamovi, was used for calculation the differences between the genders by using an independent t-test and Pearson product-moment correlation to determine whether there was a significant correlation between the hip strength measurements and knee VM. Power analysis was performed using G*Power. The average value of knee valgus moments for 5 cutting manoeuvres was used for the further analysis.

Results. Participant characteristics. There were no differences in age ($p=0.778$), height ($p=0.716$), strength of right abductors (Rabd)

($p=0.748$), left abductors (Labd) ($p=0.931$), right external rotators (Rext) ($p=0.351$) and left external rotators (Lext) ($p=0.305$), but significant differences were found in weight ($p=0.001$) between the genders (Table 1).

Table 1.

Participants characteristics

Gender	Age (yr)	Height (cm)	Weight (kg)	Rabd (N/kg)	Labd (N/kg)	Rext (N/kg)	Lext (N/kg)	Knee VM (Nm/kg)	
Mean	Boys	10.6	150	41	13.3	12.6	7.43	7.08	0.32
	Girls	10.8	150	42.1	13.8	13.5	6.72	6.52	0.25
SD	Boys	0.7	7.9	8.3	3.8	4.0	2.5	2.5	0.19
	Girls	0.8	8.0	9.3	3.7	3.6	1.9	1.9	0.16
t-test		-1.9	0.36	-3.22	-0.32	0.08	0.93	1.02	0.46
p value		0.778	0.716	0.001	0.748	0.931	0.351	0.305	0.64

Knee valgus moments. Statistical results of the differences (Independent t-test) were reported in Table 1. No differences were found in knee VM ($p=0.64$) between boys and girls (Table 1).

Correlation between the hip strength and knee VM. No statistically significant correlations were found among any hip strength measurements and knee VM (Table 2).

Table 2

Correlation Matrix

		Rabd	Labd	Rext	Lext
Pearson's r	Knee VM	-0.106	-0.085	0.029	0.048
p-value		0.081	0.165	0.637	0.429

Discussion. The aim of this study was to investigate the correlation between hip strength and ACL injury-related biomechanics during the cutting maneuver in preadolescent students within the first 100 ms of the cutting manoeuvre. Presented results showed that the hip strength does not influence the knee VM during the cutting maneuver in this age group, but certainly we can say that hip strength provides an important support in the stability of the lower limbs. Our findings are similar to previous work of Cashman et al (2012) [15] that has investigated the relationship between hip muscle strength and dynamic lower extremity valgus. The authors reported weak correlation between weaker hip strength and dynamic lower extremity valgus. However, this research focused just on adult males. No significant correlation between the hip abduction strength and knee VM was found in other studies (Lawrence et al., 2008 [16]; Munkh-Erdene et al., 2011 [17];

Bandholm et al., 2011 [18]; Smith et al., 2014 [19]; Hollman et al., 2014 [20]; Nilstad et al., 2015 [21]; Baggaley et al. 2015 [22]; Malloy et al., 2016) [23]. Furthermore, our findings are in a line with findings of Malloy et al., 2016 [23]; Suzuki et al., 2015 [24] and Baldon et al., 2011, who did not find a significant correlation between the strength of external rotators of hip and different dynamic tasks such as high level hop, single leg drop jumps and single leg squats.

Injury prevention plays very important part in professional and amateur sports as well as in recreational sports activities and in last years more and more in preadolescent students involved in school sport activities (Grossman, 2000; Rivara, 2002; Abernethy & Bleakley). Strength and conditioning coaches, performance staff and physical therapists dedicate their time and resources to programs that enhance hip and knee control to prevent injury. The relationship between hip strength and dynamic valgus is very

complex and not possible to separate from the general injury prevention. Human movement patterns are very different, movement variability is large and multifactorial and correlation is not the same as causation (Dix et al., 2019) [25]. A relationship between hip muscle strength and lower extremity valgus kinematics shall be overviewed in a much broader context because strength testing and kinematic assessment tasks not always challenge the participants capacity to a level demanded in sport. Injury prevention programs have an important role since the ACL injuries can result in a relatively low rate of return to sport (Arderm et al., 2011) [1], decreased quality of life in later years (Filbay et al., 2015) [2], and a high rate of knee osteoarthritis (Ajuied

et al., 2014) [3] and gonarthrosis at earlier age (Roos et al., 1994).

Conclusion. Future studies should increasingly attempt to bridge the gap between the laboratory and the sports field and interpret potential relationship within the complexity of human movement behavior. By using more appropriate kinematic and kinetic evaluation tasks and strength testing, the future studies should be able to provide better and more reliable evidence of whether a correlation exists between hip strength and dynamic knee valgus. Also, the future studies should more look into the psychological impact of the ACL injuries and the consequences that can have on the preadolescents.

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Орта мектеп жасындағы оқушылардың жылдам-қатқыл серпу жаттығуларын жасау кезіндегі алдыңғы айкастүрлес сіңірдің (ААС) жарақаттануымен байланысты биомеханика бойынша жамбас күшінің ықпалын педагогикалық бақылау (дене тәрбиесі мұғалімдері мен спорттық педагогтар үшін практикалық ұсыныстар)

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Аңдатпа

Алдыңғы айкастүрлес сіңірдің (ААС) жарақаттануы адамның аяқ бөлігінің ауыр жарақаттарының бірі болып табылады да, оның зардаптары спортшының спортқа кеш оралуына, психологиялық тұрғыда жастардың спортқа деген теріс көзқарасын және кейінгі жылдары өмір сүру қабілеттілігіне кері әсерін тигізеді. Алдыңғы зерттеулерде көрсетілгендей, жамбас бұлшық еттері мен тізе буынының вальгустік сәттерінің (VM) өзара қимыл-әрекеттері анықталған-ды. Мына зерттеулерден кері созылатын жамбас-сан буыны мен сыртқы айналдырғыш күшінің төмендеуі арқылы ААС жарақат алу қауіптілігі факторы жайлы нәтиже шығаруға болады, алайда, орта мектеп жасындағы оқушылар арасында мұндай зерттеулер жүргізілген жоқ. Кері созылатын

жамбас бұлшық еттердің жылдам-қатқыл қимыл-әрекеттері мен сыртқы айналдырғыштардың ерікті түрдегі изометриялық барынша қысқаруын орындау барысында 271 оқушы қыздардың (оның ішінде, 9-12 жастағы 174 қыз) ақпараттары жиналды. Жаттықтыру және жауапты жарыстар кезінде жарақат алған айналысушылардың психологиялық хал-ахуалдарын да ескерген абзал. Біздің нәтижелерімізде көрсетілгендей, бұл жастық топта жамбас бұлшық еттерінің арасында анықталған қандай да бір мәні бар корреляция жылдам-қатқыл қимыл-әрекеттер кезінде тізе буындарының VM-на ешбір әсер ете алмайды. Оны жасы келген адамдар арасында өткізілген көптеген алдыңғы зерттеулердің нәтижелерінен ақ білуге болады.

Түйін сөздер: ААС; жарақаттарды алдын-алу; жылдам-қатқыл қимыл-әрекеттер; жамбас-сан бұлшық еттер күші; биомеханика; педагогикалық бақылау.

Педагогическое наблюдение на влияние силы бедра по биомеханике, связанной с травмой передней крестообразной связки (ПКС), во время резких толчковых упражнений у школьников среднего возраста (практические рекомендации для учителей физического воспитания и спортивных педагогов)

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Аннотация

Травмы передней крестообразной связки (ПКС) являются одними из наиболее серьезных повреждений нижней конечности, могут привести к позднему возвращению в спорт и снижению жизнеспособности, а также к психологическому отношению к спорту среди молодежи в более поздние годы. В предыдущих исследованиях было показано взаимодействие мышц бедра и вальгусных моментов (VM) коленного сустава. Из данных исследований можно сделать вывод, что снижение силы отводящего тазобедренного сустава и внешнего вращателя является фактором риска травмы ПКС, но до этих пор никаких исследований среди школьников не проводились. При выполнении резких маневров и изометрического максимального произвольного сокращения внешних вращателей, отводящих мышц бедра были собраны данные 271 школьниц (174 девочек в возрасте 9-12 лет). Следует учитывать и психологическое состояние занимающихся, которые получили травмы во время тренировок или ответственных соревнований. Наши результаты показывают, что в этой возрастной группе никакая значимая корреляция, обнаруженная между силой бедра, не влияют на VM колена во время резкого маневра, что согласуется со многими предыдущими исследованиями, проведенными на пожилых людях.

Ключевые слова: ПКС; профилактика травм; режущий маневр; сила бедра; биомеханика; педагогическое наблюдение.

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