TRENDELENBURG TEST AND ACL RISK FACTORS DURING UNANTICIPATED CUTTING MANOEUVRE – A PILOT STUDY

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The aim of this study was to find differences between the Trendelenburg test and risk factors for an ACL injury during a cutting manoeuvre in two age groups. Six female athletes divided into two groups (n3x2) participated in this study. Ten infrared cameras and force platform were used to collect the kinematic and kinetic data. The results of this pilot study suggest no hip weakness was observed in either group. The younger group had a larger difference between starting and finishing position during TT. In other side we found the higher values of the ACL risk factors in the older group.

KEY WORDS: biomechanics, ACL injury, prevention

INTRODUCTION: Female adolescents who participate in jumping and pivoting sports suffer Anterior Cruciate Ligament (ACL) injuries to a greater extent than males (Hewett et al., 1999). An ACL injury may occur during a non-contact situation involving cutting or landing (McDaniel et al.; 2010; Ford et al., 2003). The highest peak of ACL risk factors occur in the first 20-30% of the stance phase (Donnelly et al., 2017; McLean, 2005). The incidence of ACL injury increases in individuals up to 18 years of age. The highest incidence of ACL injury is between 15 – 18 years of age in female athletes (Shea et al., 2004). In addition, hip muscle weakness is associated with lower extremity injury (Leetun et al., 2004).
The **Trendelenburg test (TT)** is a quick physical examination used in physical therapy. This clinical test has been used for the identification of hip abduction weakness during single-leg stance position. Pelvis drop during TT which can be described by decreasing the frontal hip angle between starting and finishing position is associated with hip weakness (Powers, 2010). TT has been used for the identification of hip weakness to identify participants with hip joint osteoarthrosis (Youdas et al., 2010). Females with patellofemoral joint pain demonstrated weakness in hip abduction compared to the females who were asymptomatic (Ireland et al., 2003). Runners with hip weakness show a higher valgus knee position (Heinert et al., 2008). We are not aware of any study to evaluate the relationship between differences of hip frontal angle during TT and the associated risk factors of ACL injury during unanticipated cutting manoeuver.
Therefore, the first aim of the study was to find differences in the hip frontal plane angle during TT between different age groups. We hypothesised that the younger particpants will have a larger difference during TT than older participants. The second aim of this study was to investigate if there is association between TT and risk factors of ACL injury during unanticipated cutting manoeuver. We also hypothesised that the higher differences during the TT will be associated with higher values of ACL risk factors.

METHODS: Six female athletes divided into two age groups were recruited for this study. The first group (n=3) contained younger participants (15-17 years of age) while the second group (n=3) contained older participants (21-23 years of age). Anthropometric data is presented in Table 1. The participants had no musculoskeletal injuries, no history of surgery for traumatic injury of lower extremities and were not taking hormonal contraceptives. Participants were right leg dominant. Participants performed TT (i.e., standing on one leg for 30 seconds) (Hardcastle & Nade, 1985) followed by an unanticipated cutting manoeuvre task. The change of direction was set at 45° during self-preferred approach speed. The approach speed was measured using a time-measuring device (P-2RB / 1, EGMedical, Ltd., Czech Republic) and two

photocells (OPZZ, EGMedical, Ltd., Czech Republic). The first photocell was placed at 90% of the stride distance from the centre of the force plate and the second 2 m from the first photo cell. The position of the first photocell was based on the length of the participant´s stride during running and triggered a signal for change of direction by arrow to the left. An arrow pointing up indicated run straight ahead. Each participant performed five successful trials of an unanticipated cutting manoeuvre. A force platform (Kistler, 9286 AA, Switzerland), sampling at 1200 Hz, was used to collect kinetic data. A motion-capture system (Qualisys Oqus, Gothenberg, Sweden), consisting of ten infrared cameras, was employed to collect the kinematic data at a sampling rate of 240 Hz. Retro-reflective markers were attached on lower extremities according to Hamill & Selbie (2004). Markers for a multi-segment foot model were applied on the foot (Leardini et al., 2007).
Raw data were processed using Visual3D software (C-motion, Rockville, MD, USA). The range of the analysed unanticipated cutting manoeuvre motion started with first foot-ground contact and finished at 30% of the stance phase. Force platform data were filtered using a fourth-order low-pass Butterworth filter with a cut-off of 50 Hz. The motion capture coordinate data were low-pass filtered using the same filter characteristics at a 14 Hz cut-off frequency. In order to determine the local coordinate system of the segment, all segments were modelled as frusta of right circular cones, while the pelvis was modelled as a cylinder. The local coordinate systems were defined using the standing calibration trial for each participant. Data for the right lower limb and pelvis were included in this study. The knee flexion joint angle was defined as the angle between the local coordinate systems of the thigh and shank in the sagittal plane (0° indicates full extension). The knee valgus (-) and varus (+) joint angles were defined as the angle between the local coordinate systems of the thigh and shank in the frontal plane. The knee valgus (+) and varus (-) joint moments of force in the frontal plane were calculated using a Newton-Euler inverse dynamics technique. The net knee moment of force was expressed in the local coordinate system of the thigh segment (Hamill & Selbie, 2004) and was normalised to body mass (kg). The frontal hip angle was defined as angle between thigh and the pelvis. The frontal plane hip angle differences during TT were calculated from the instant of first position of non-dominant knee in 90° and after 30 s during one-leg standing. To identify differences between the age groups, Cohen's d effect sizes were calculated. Effect size differences were defined as small (0.2), medium (0.5) and large (0.8) (Cohen, 1988). Spearman´s rank correlations were used to examine relationships between TT and risk factors.

Table 1: Antropometric data

	Age (y)	Height (cm)	Mass (kg)
15-17 (n=3)	15.7 ± 1.2	157.7 ± 4	54.3 ± 2.5
21-23 (n=3)	22 ± 1	173.1 ± 5.9	69.3 ± 9.6

RESULTS: The difference between age groups in TT and risk factors of ACL injury during unanticipated cutting manoeuvre is presented in Table 2. Figure 1 presents the correlations between TT and risk factors of risk factors of ACL injury. Very high negative correlation was found between TT and knee abduction moment during 30% stance phase in cutting manoeuvre (-0.943) while a very high correlation was found between TT and knee valgus angle in the same movement (0.714).

Table 2: Mean and standard deviation of knee flexion at the initial contact, local maximum of valgus moment and angle in frontal plane during first 30% stance phase during unanticipated cutting manoeuvre and frontal hip angle differences during Trendelenburg test (n=6).

	Age 15-17 (n=3)	Age 21-23 (n=3)	Effect Size
Knee angle flex/ext (°)	25.79 (3.99)	23.48 (4.01)	0.58
Knee valgus/varus (^{0})	-4.21 (4.41)	-12.48 (4.61)	0.68
Knee valgus/varus (Nm.kg-1)	0.92 (0.5)	2.47 (0.96)	0.71
Trendelenburg test (^{0})	3.72 (0.62)	1.14 (1.21)	0.80
Approach speed (m/s)	4.56 (0.24)	4.65 (0.29)	0.17
Exit speed (m/s)	4.42 (0.32)	4.51 (0.43)	0.12

Note: (+) Varus angle, valgus moment; flex; (-) valgus angle, varus moment

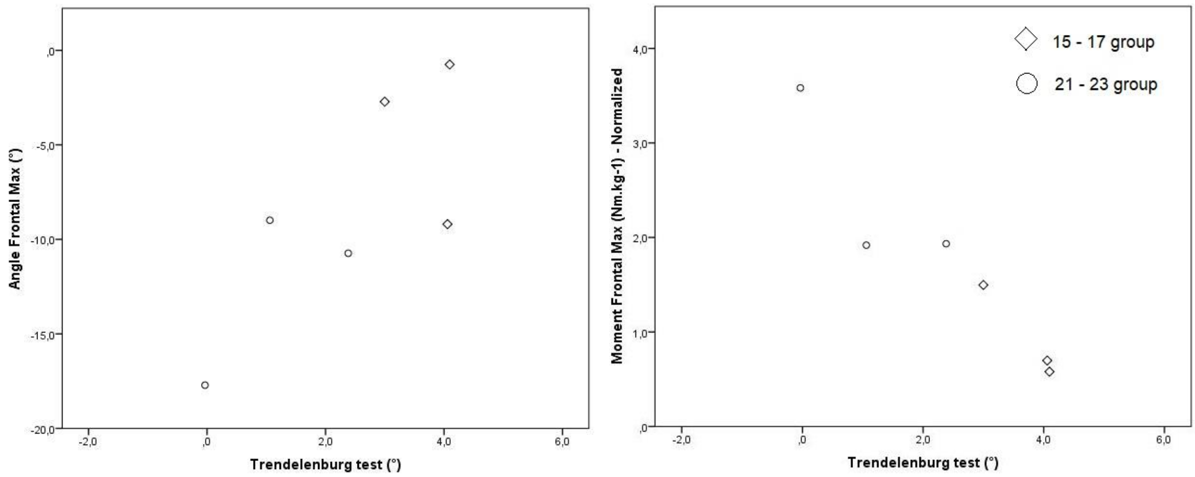

Figure 1: Correlation between TT and risk factors

DISCUSSION: The first aim of the study was to find differences in the hip frontal plane angle during TT between different age groups. We hypothesized that the younger group would have a greater difference during the TT than the older group. The younger group had a larger difference in hip angle in the frontal plane (3.72 ± 0.62°) in TT than in the older group (1.4 ± 1.21°). There was no decrease in frontal hip angle between starting and finishing position in either group which is associated with hip weakness (Powers, 2010). Both groups showed increasing of the frontal hip angle between starting and finishing position only. Although the larger difference between the starting position finishing positions was found in the younger group, the higher standard deviation in the older group points to a larger inter-individual variability. Therefore, high inter-individual variability and low number of participants may be a limitation which may mask real differences among age groups.
The second aim of this study was to investigate if there was an association between TT and risk factors of ACL injury during an unanticipated cutting manoeuver. We hypothesized that the greater differences during the TT between groups would associated with higher values of ACL risk factors. We are not able to suggest that greater differences in TT are associated with risk factors of ACL injury due to that both groups showed increasing of frontal hip angle between starting and finishing position which is not associated with hip weakness. We found a difference in risk factors during unanticipated cutting manoeuvre in these two groups. The knee flexion angle was higher in the younger group which could be a protective strategy for an ACL injury that is supported by Boden et al. (2000). We also found the difference between knee valgus angle and moment. These parameters are associated with increased stress and strain on the ACL (Xie et al., 2016; Cortes et al., 2012). Both parameters in the older group (e.g. valgus moment = 0.92 ± 0.5 Nm/Kg and angle = -4.21 ± 4.41 Nm/Kg) pointed to a possibly risky movement. In a previous study, we found more risky movement is associated with a higher knee abduction moment, valgus angle and rearfoot position (Beinhauerova et al., 2019) on different movement task strategies (Zahradnik et al., 2015). These studies suggested that players can solve the same motor task (i.e. landing) using different strategies shortly after initial contact.
There was no difference between the approach speed and exit speed between groups. Despite the reported higher incidence of ACL injury between 15 and 18 years of age by Shea et al. (2004) we found greater risky behaviour of ACL injury in the older group.

CONCLUSION: The results of this pilot study suggest no hip weakness was observed in either group. The younger group had a larger difference between starting and finishing positions during TT. Despite this, we found a higher relationship of ACL risk factors in the older group with a reported lower incidence of ACL injury. In the future study, we need participants with a hip weakness to find a relationship between results of TT and risk factors of ACL injury.

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