FATIGUE IMPAIRS KINEMATICS BUT NOT KINETICS OF LANDING AND CUTTING MOVEMENTS IN ELITE YOUTH FEMALE HANDBALL PLAYERS

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Lower extremities are the most affected areas of injuries in indoor team handball, especially for female youth player. The mechanics of such injuries are well-known, however little is known about the influence of fatigue injury on risk factors. This study addresses fatigue-induced changes of movements that are associated lower extremity injuries in female youth handball players. Kinematics and kinetic data of 15 elite youth female team handball players were recorded for double- and single-leg landings as well as sidecutting maneuvers before, in the middle of and after a simulated handball specific load protocol. The protocol consisted of exercises typical for handball match activity. RPE was used as measure of fatigability and showed values ranging from 13 to 18 at the end of the treatment. ANOVA revealed fatigue related changes in initial knee flexion angle of the non-dominant leg in all tasks. For the cutting task, significant changes of the initial knee angle of the dominant leg, the initial and maximum hip flexion angle as well as maximum knee flexion angle of the non-dominant leg were observed. Consequently, fatigue players exhibited more extended movement patterns. In summary, the fatiguing protocol caused changes in landing and cutting kinematics of the non-dominant leg predominantly, whereas movement kinetics where not affected.

KEYWORDS: handball, fatigue, injury, lower extremities.

INTRODUCTION: In team handball as well as in other team sports involving pivoting movements, high incidents of non-contact injuries were reported especially in elite adult team players. Little is known about injuries of young handball players, especially in female athletes. Lower extremities are the most common area of injuries, accounting for more than 50 % of the overall injury rate in youth athlete. Knee injuries, mainly anterior cruciate ligament (ACL) ruptures, are the most frequent severe injury in the age group of 15 to 19 years (Achenbach, 2018). It is widely known, that females bear a higher risk of ACL injuries, which increases during adolescence (Waldén et al., 2011). In female youth athletes, a dynamic valgus of the knee has been identified as a preliminary predictor of ACL injuries, even in comparison with male athletes. In addition, an increase of ACL injuries incidences with playing time has been reported. This suggests that fatigue may affect the risk of non-contact ACL injury (Hawkins et al., 1998). Impaired neuromuscular control, proprioception (Hiemstra et al., 2001), postural control (Caron, 2003; Marchetti et al., 2013), and movement coordination (Cowley et al., 2017; Samaan et al., 2015) have been identified as factors related to an injuries that occur during landing tasks. In addition, it has also been shown that playing time-related fatigue influences movement kinematics and kinetics (Benjaminse et al., 2008; Cortes et al., 2013; Lessi et al., 2017). Fatigued athletes execute more extended landing patterns because of smaller hip and/or knee flexion angles as well as increased peak knee abduction moments(Borotikar et al., 2008; McLean et al., 2007). However, findings on how fatigue affects kinematics and kinetics of landing and cutting movements are still inconsistent (Santamaria et al., 2010). Therefore, the aim of the present study was to investigate the effect of exercise-induced fatigue on landing and cutting biomechanics associated with ACL-injury mechanisms in elite youth female handball players. It was hypothesized that changes of intrinsic movement patterns (e.g. valgus angle and moment at the knee joint, internal-external rotation angles and moments) induced by a simulated match play load are correlated with an increased risk of ACL injury.

METHODS:

Fifteen elite youth female handball players (age 15.9 ± 0.9 years, height 171 ± 5 cm, weight 70 ± 9 kg) volunteered to participate the study. All players were recruited from a handball team in the first national league and a regional handball performance centre. No players suffered from any injury at the time of the testings.

A controlled cohort repeated-measures experimental design was applied to determine the effects of fatigue on biomechanics in landing and cutting movements associated with ACL-injury risk. Each test session started with a standardized warm-up consisting of 10 min light to moderate handball-specific movements. The laboratory-based test battery included double-leg drop vertical jumps (DVJ), single-leg drop landings (SLL) and a sidecutting task (SC), performed with both legs, respectively. Players completed the test battery three times: before the start, at half-time and at the end of the load treatment. For each trial, they executed three times each task. Unsuccessful performances were repeated. The fatigue protocol (Zebis et al., 2011) included a series of intermittent exercises (side-steps, cross-over steps, jumps, high- and low-intensity running). The protocol was completed two times during the laboratory testing session. Immediately after finishing the load protocol, the Borg 15-point category scale was used to rate the perceived exertion (RPE).

Lower-body motion of the athletes was captured using a three-dimensional motion capture system consisting of 12 infrared cameras (120 Hz, Qualisys©, Göteborg, Sweden) with a lower-body marker set of 40 markers. Ankle, knee and hip joint angles as well as resultant internal joint moments were determined using a rigid body model including a forefoot, rearfoot, shank, thigh and pelvis segment according to Willwacher et al. (2016). A customized MATLAB routine (MathWorks©, Natick, USA) was used to calculate kinematic and kinetic parameters by a three-dimensional inverse dynamics model. All landing and cuttings tasks were performed on two 0.9 x 0.6 m force plates (AMTI©, Watertown, USA) sampled at 1,000 Hz and time synchronized to the motion analysis system.

Hip and knee flexion-extension, abduction-adduction and internal-external rotation angles were calculated and served as kinematic variables. Kinetics implied knee flexion-extension moment, dynamic knee valgus moment, hip flexion-extension moment and hip abduction-adduction moment. All joint moments were normalized to body weight. Kinematic and kinetic parameters were determined at the two instances initial contact (IC) and maximum value within the first 100 ms after IC (MAX).

For each task, the average of the three trials was calculated for each parameter. Means of pre, half-time and post test were compared by a one-way repeated measures analysis of variance (ANOVA) for the dominant and non-dominant leg separately. In case of a significant effect ($p < 0.05$), post hoc test was performed using pairwise t-test following Fisher's least significant difference approach. Effect sizes (Cohen´s d) for each parameter and condition were calculated. RPE values were analysed using a dependent sample t-test.

RESULTS: Mean RPE value recorded after cessation of the first fatigue protocol was 14.6 ± 0.8 with a minimum of 13 and a maximum of 16 respectively. Corresponding values after finishing the second protocol were 17.2 ± 0.8, 15 and 18, indicating a significant ($p<.001$) increase of RPE at the end of the treatment. Table 1 shows an overview of the results of the ANOVA. For significant main effects, the p value, the effect size, the tasks and the instance (IC; MAX) are reported. ANOVA revealed no effects on fatigue for the joint moments neither of the dominant nor the non-dominant leg. Knee flexion of the dominant leg and hip flexion on the site of the non-dominant leg in the SC task as well as knee flexion of the non-dominant leg during all tasks showed significant differences after fatigue. Results indicate that, for all tasks, participants extended their knee of the non-dominant leg higher at initial contact when fatigued. In the dominant leg, this result can only be observed during the SC. Additionally, initial hip flexion of the non-dominant leg increased in the cutting task with fatigue. Knee flexion angles of the non-dominant leg achieved lower peak values during SC and DVJ.

Table 1: Overview of the results of ANOVA.

	dominant leg			non-dominant leg		
	task; instance	p-value	effect size	task; instance	p-value	effect size
Joint angles						
Hip flexion		ns		SC; IC +	.005	.313
				MAX	.024	.234
Hip adduction		ns		ns		
Knee flexion	SC; IC	.002	.359	SC; IC +	.010	.282
				MAX	.000	.430
				DVJ; IC +	.003	.339
				MAX	.000	.487
				SLL; IC	.038	.209
Knee abduction		ns		ns		
Knee internal rotation		ns		ns		
Joint moments		ns		ns		
Hip flexion		ns		ns		
Hip adduction		ns		ns		
Knee flexion		ns		ns		
Knee abduction		ns		ns		

DISCUSSION: Kinematics of cutting and landing movements changed primarily for the non-dominant leg if elite youth female handball players were exposed to a simulated match load. Individual responses to the fatiguing protocol varied depending on the stage of load protocols. Post test RPE values ranged from 13 to 18, implying that some participants ranked the protocol as “somewhat hard” in contrast to players who stated that it was “very hard”. This might affect the individual results of cutting and landing biomechanics as the variability in perception of fatigue depends on several factors such as fitness level or the ability to recover. On the other hand, the protocol could have induced high cardiovascular load, whereas neuromuscular fatigue was only moderate and injury risk might not have been not affect considerably. Overall, our results are in line with previous work, indicating that inconsistencies in fatigue effects on cutting and landing kinematics and kinetics are caused by the diversity in fatigue protocols being used (Santamaria & Webster, 2010). Therefore, it should be discussed how fatigue should be induced. A standardized protocol that causes the same amount of fatigue in each individual might be helpful to compare findings. We tried to take this into account by using a standardized protocol according to Zebis et al. (2011). However, an important limitation of this protocol could be that it was developed for adults and will not reliable represent the individual load in a real match play, as players on high level of fitness will experience less fatigue by the simulated load protocol than players who have a poor fitness level, but perform harder in a real match. To analyse this aspect in depth, Smeets et al. (2019) assessed whether fatigability of individuals was related with movement alterations by using statistical parametric mapping instead of discrete values such as mean or peak angels. Their results confirmed that high fatigability of athletes was associated with kinematics and kinetics associated with a higher risk of injury (e.g. larger knee valgus moments). We see those trends in the descriptive data of our study too. However, these aspects might be subject of further detailed analyses. Additionally, the development of a new handball-specific overground match simulation for future studies should be taken into account.

Nevertheless, we assume it important, that mainly the non-dominant leg is affected by fatigue, especially for hip and knee. For the non-dominant leg, our results are in line with Augustsson et al. (2006), who also observed that hip and knee joint angles decreased during single-leg hops following a fatigue protocol. In addition, McLean et al. (2009) stated that the tendency to land with the knee and hip more extended in conjunction with a decreased peak flexion moment likely represents an adaptive strategy to ensure a successful landing. A similar result was found at the hip joint angles, highlighting their stabilizing role during the absorption phase of landing tasks. Although not significant, a trend as reported by McLean et al. (2009) was apparent for joint moments in our study, showing different characteristics for the dominant and non-dominant leg. These findings seem to further support the hypothesis that fatigue may be an integral component of ACL injury mechanism, especially in the non-dominant limb.

CONCLUSION:

Performing under condition of fatigue revealed modifications in cutting and landing kinematics of the non-dominant leg within a group of elite youth female handball players. These findings highlight a potential role of the non-dominant leg within the fatigue-induced cutting and landing tasks. Targeted training of the non-dominant leg should thus necessarily be incorporated within ACL injury prevention strategies as well as return to play assessments to achieve a comprehensive reduction of the injury risk.

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