EFFECT OF FATIGUE ON KNEE KINEMATICS AND KINETICS DURING SIDESTEP CUTTING AND SINGLE LEG LANDING IN FEMALE HANDBALL ATHLETES

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The purpose of this study was to investigate the effect of fatigue in knee biomechanics in female handball athletes during the sidestep cutting and single-leg landing. Twenty female handball athletes participated in this study. The fatigue protocol was composed of specific handball movements/actions. The participants performed three trials of the sidestep cutting and single-leg drop landing before (baseline) and after the fatigue protocol. The effect of the fatigue was compared using a paired t-test compared using statistical parametric mapping. During sidestep cutting, the athletes performed the task with lower knee flexion and greater knee abduction during the fatigue state. During the single-leg landing, an increase in the knee valgus was found during the fatigue state. No difference was found on knee kinetics. The fatigue impacted the knee kinematics decreasing the knee flexion during the sidestep cutting and increasing the knee valgus during both, sidestep cutting and single-leg landing tasks.

KEYWORDS: knee, kinematics, fatigue, handball, sidestep cutting, side-leg drop landing

INTRODUCTION:

Non-contact anterior cruciate ligament ruptures generally occur during single-landing and sidestep cutting maneuvers when the knee joint is near to the full extension with additional valgus and internal rotation (Hewett, Torg, & Boden, 2009). These movements are frequently observed in handball games, in which athletes perform rapid changes of direction and jumping/landing tasks which increases the incidence of lower limb injuries (Bedo, Manechini, Nunomura, Menezes, & Silva, 2019; Olsen, Myklebust, Engebretsen, & Bahr, 2006).
Likewise, fatigue is a commonly accepted risk factor for anterior cruciate ligament (ACL) injury, since it is hypothesized that fatigue leads to kinematics and kinetics adaptations in the lower limbs joints, as well as reductions in muscle strength and changes in muscle contraction pattern (Beaulieu, Lamontagne, & Xu, 2009; Bourne, Webster, & Hewett, 2019). Still, few prospective studies were able to elaborate fatigue protocol s consistent to affect lower limb kinematic or kinetic, since current fatigue protocols try to simplify the complex system of fatigue (Benjaminse, Webster, Kimp, Meijer, & Gokeler, 2019).
Therefore, this study aimed to investigate the influence of a fatigue protocol in knee kinematics in female handball athletes during the sidestep cutting and single-leg landing tasks. We hypothesized that, compared to the no fatigue scenario (baseline), the knee kinematics would be affected by the fatigue shortly after the initial ground contact.

METHODS: Twenty female handball athletes (21.9±3.4 years; 63.5±9.1 kg; 1.76±0.07 m; 7.2±3.2 years of experience; 240±180.4 minutes of practice/week) with no report of ACL ruptures, and without lower limb injuries in the last six months participated in this study. The ethical approval was granted by the local university and all participants provided written informed consent.
The fatigue protocol was performed within the laboratory environment, in a circuit composed by specific handball movements/actions (i.e: sprint, plyometric jumps, lateral and back shifiting). The participants performed two laps in the circuit for warming-up and acclimation. The protocol was divided into rounds with a gradual increase in volume, where the number of laps in the circuit was the number of rounds (i.e., round I [1 lap]; round II [2 laps]; round III [3 laps]; and so on) (Bedo et al., 2020). The state of fatigue was characterized by the inability of

the participant to continue performing the protocol. The fatigue parameters, such as heart rate and the rate of perceived exertion (using the Foster scale [0-10]) were assessed a prior and after the fatigue protocol.
The participants performed three trials of the sidestep cutting maneuver and single-leg drop landing before (baseline) and after the fatigue protocol. All the single-leg tasks were performed with the non-dominant limb, which was determined as the leg used to kick a ball as far as possible. All participants wore the shoes they normally use during handball practices and the tasks were performed during the first five minutes after the fatigue detection, where the fatigue effects are still present (Bedo et al., 2020).
The motion capture system included eight infrared cameras at 250 Hz (MX-T40S, Vicon, Oxford, UK), which tracked 20 lower-limb reflective marker trajectories (Mantovani & Lamontagne, 2017) and one force plate (Bertec, Columbus, USA). The markers trajectories were reconstructed, labeled and filtered in the Nexus 2.8 software (Vicon, Oxford, UK). Next, through the same software, the knee angles and moments were calculated in the sagittal, frontal and transversal planes. The heart rate and RPE variables were compared using paired samples t-tests using the Statistical Package for the Social Sciences (SPSS Statistics v.23, IBM Corporation, Armonk, USA). Knee kinematics and kinetics outputs were time-normalized, and their waveforms were paired t-test compared using statistical parametric mapping (SPM) (Pataky, 2010) with a level of significance set at p-value < 0.05.

RESULTS:
The heart rate (baseline: 82.45 ± 8.14 bpm *vs.* fatigue: 194.35 ± 7.38 bpm) and the rate of perceived exertion (baseline: 0 ± 0 *vs.* fatigue: 10 ± 0) increased significantly after the fatigue protocol (both p < 0.0001).
The SPM analysis showed that the fatigue altered the knee kinematics during sidestep cutting maneuver and single-leg landing. During sidestep cutting, the athletes performed the task with a lower knee flexion during the fatigue state (from 6 to 38% of the cycle, p < 0.001; and from 52 to 75% of the cycle p < 0.001) in comparison with the non-fatigue state (Figure 1). Greater knee abduction was also found during the fatigue state in comparison with the baseline values (from 19 to 24% of the cycle, p = 0.394).

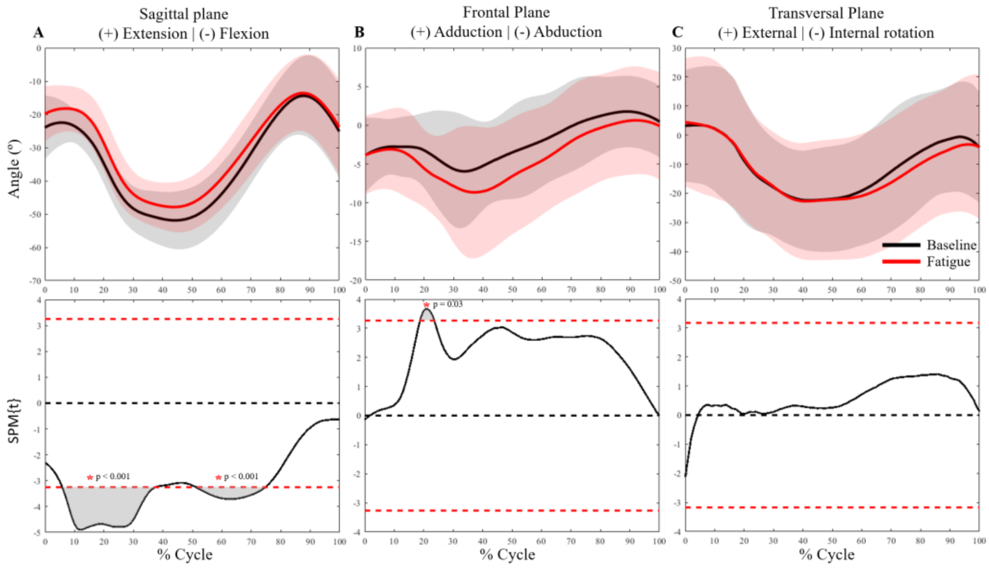

Figure 1. Knee joint kinematics and statistical parametric mapping (SPM) analysis of the sagittal, frontal and transversal plane angles waveforms during the sidestep cutting task of the non-dominant limb. The top plots represent averaged sagittal (left), frontal (middle) and transversal (right) knee angles; while the bottom plots represent the t-statistic as a function of time (SPMt). When the SPMt goes over the threshold (red dashed line), the significance is reached (*).

Similar results were found during the single-leg landing tasks, where an increase in the knee valgus was found during the fatigue state (from 3 to 9% of the cycle, p = 0.036; from 23 to 29% of the cycle, p = 0.0352; and from 38 to 40% to the cycle, p = 0.048). However, no difference was found to the sagittal and transversal planes (Figure 2). No differences in knee joint kinetics were found.

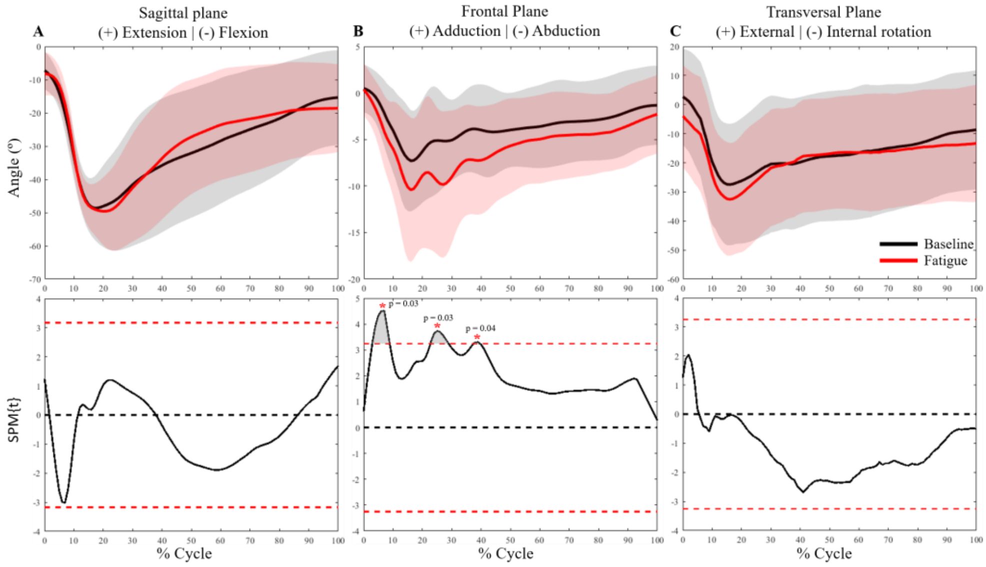

Figure 2. Knee joint kinematics and statistical parametric mapping (SPM) analysis of the sagittal, frontal and transversal plane angles waveform during the single-leg landing task of the non-dominant limb. The top plots represent averaged sagittal (left), frontal (middle) and transversal (right) knee angles; while the bottom plots represent the t-statistic as a function of time (SPMt). When the SPMt goes over the threshold (red dashed line), the significance is reached (*).

DISCUSSION:

The purpose of this study was to compare knee kinematics and kinetics during the sidestep cutting and single-leg landing tasks before and after a specific fatigue protocol for handball athletes. The main findings demonstrated that the frontal, in both tasks, and the sagittal, during the single leg-landing were affected by the fatigue protocol.

High knee valgus during the fatigue situation has been associated as an important factor for knee injuries , especially when these happen during the first half of tasks cycle (Koga et al., 2010), in particular during landing, changes of direction, and pivot movements with lower knee flexion (Koga et al., 2010; Makaruk, Czaplicki, Sacewicz, & Sadowski, 2014). Although no differences were found in joint moments, the decrease in the knee kinematics during the fatigue situation potentially promotes a high-risk modification in the joint loading (Bisseling, Hof, Bredeweg, Zwerver, & Mulder, 2007; Bressel & Cronin, 2005). Since a lower knee flexion likely affects the patellar tendon-tibial shaft and alters the angle of the hamstrings' insertion (Yu, Lin, & Garrett, 2006). In addition, it is necessary to consider how fatigue affects the lower limb joints during realistic sports situations (i.e., current protocol). General fatigue models appear to more practically simulate sports relevant movement tasks and may induce both local and central fatigue effects along the entire proprioception pathway (Allen & Proske, 2006).

The kinematic differences likely increase the knee load; however, no differences were found in the joint moments. Theoretically, the fatigue impacts the muscle capacity to absorb the landing energy, increasing the risk of injuries. However, the reduction of knee flexion is possibly an expected counteraction to reduce knee joint loads (Bourne et al., 2019). Therefore, future computational modeling studies that estimate joint contact loading are necessary in order to better evaluate how the knee joint loads during fatigue conditions. Recently studies have shown the muscles functions and medial/lateral tibiofemoral contact forces during sidestep cutting (Maniar, Bryant, Sritharan, Schache, & Opar, 2020; Maniar, Schache, Cole, & Opar, 2019), but further investigation should investigate the fatigue effects on muscle forces and joint contact forces.

CONCLUSION:

The fatigue impacted the knee kinematics decreasing the knee flexion during the sidestep cutting and increasing the knee valgus during both, sidestep cutting and single-leg landing tasks, likely increasing the risk of an ACL injury. Still, further studies should investigate other determinants of fatigue to better understand the level of deficits in the central or peripheric system.

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ACKNOWLEDGEMENTS:

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) – Brasil [Finance Code 001]; São Paulo Research Foundation (FAPESP) – Brazil [2019/04721-0] and partially developed and supported by the Human Movement Biomechanics Laboratory at the University of Ottawa, Canada.