CHANGES IN INJURY-RELATED LOWER EXTREMITY BIOMECHANICS DUE TO A BASKETBALL-SPECIFIC FATIGUE PROTOCOL

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The purpose of this study was to evaluate the effects of a basketball-specific fatigue protocol on lower extremity biomechanics and associated risk factors of ACL injury during a jump-stop task. The subjects consisted of twelve male collegiate basketball athletes. Participants performed six trials of jump-stop task. A basketball-specific fatigue protocol was performed and the biomechanical characteritics were conducted by paired t-tests with the significance level set at 0.05. The specific fatigue protocol caused a reduction of hip abduction and posterior ground reaction force. An increase of approach speed, knee flexion angle and vertical ground reaction force was also shown after fatigue. There was no difference on other variables. The basketball-specific fatigue protocol altered lower extremity biomechanics related to ACL injury risk during jump-stop tasks.

KEYWORDS: anterior cruciate ligament, injury, fatigue, biomechanics.

INTRODUCTION: Anterior cruciate ligament (ACL) injury is common in the athletic population especially in basketball and soccer (Agel, Arendt & Bershadsky, 2005). Cutting and stop-jump have also been proved to significantly increase the risk of non-contact ACL injury (Piasecki et al., 2003). The lifetime burden of ACL tears was pretty heavy estimated to be $7.6 billion annually (Mather et al., 2013) and anterior cruciate ligament injury has multiple negative health consequences including early onset of osteoarthritis and decreased activity level due to functional instability (Quammen et al., 2012).

There was a long-standing debate in the literature about whether or not fatigue causes lower-limb injury (Doyle & Tim, 2018). Few published fatigue protocols appear to have any consistent effect on any lower limb kinematic or kinetic variables known to increase ACL injury risk (Bourne, Webster & Hewett, 2019). The result that a fatigue-induced decreased knee flexion angle can increase ACL strain and the participant therefore may be at greater risk of injury had been proved by Benjaminse et al. (2007), which is consistent with the change reported by Quammen et al (2012). However, Xia et al. (2017) suggested that the post-fatigue increase of hip and knee flexion applied by participants was thought to be a compensatory response that might better suit to absorb the mechanical energy of the impact and play a positive role in reducing ACL injury. The difference among fatigue protocols could be one main reason for the divergence in the effect of fatigue. Athletes in most studies were exposed to general fatigue protocols (Bourne, Webster & Hewett, 2019) including cycling or prolonged running without involving a series of functional agility drills specific to the athletic event including jumping, squatting or agility tasks (Krosshaug et al., 2007). Therefore, the aim of this research was to create a basketball-specific fatigue protocol simulating the actual competitions and to determine the changes of injury-related biomechanical characteristics caused by fatigue.

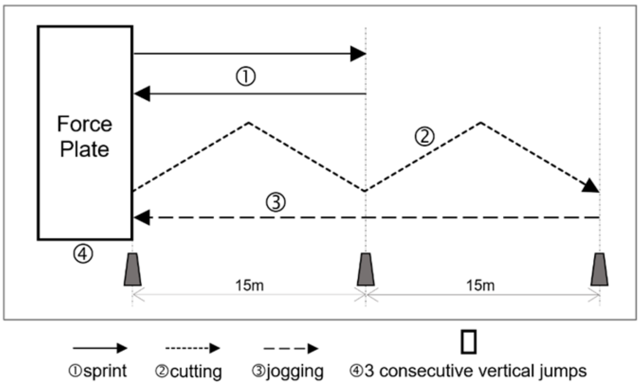
METHODS: Twelve male college basketball athletes (age: 20.1±0.6 years old; height: 179.1±9.5 cm; mass: 71.4±13.5 kg) were recruited in this study. All participants in the current investigation reported no known musculoskeletal injuries of the lower extremities within 6 months before data collection and did not engage in strenuous exercises within 24 h prior to the study. The participants provided written informed consents and the study was approved by the Institutional Review Board of Beijing Sport University.

Participants wore spandex shorts and running shoes. 10 min of warm-up involving jogging and static stretching exercise was allowed for each of them. Before data collection, 15 reflective markers were placed on specific body landmarks, with 4 being calibration markers attached to the medial knee and ankle (figure 1). After starting signal, the participant started sprinting 3 meters from the force plates at self-selected speed that was commonly used in competitions reflecting the individual difference and jumped before reaching the force plates. A successful trial was recognized when the participant cushioned and landed completely on both force plates with each foot separately and kept the body stable. Each participant was required to perform 6 trials for each jump-stop task in a pre-fatigue exercise test and the post-fatigue exercise test immediately after completing the fatigue protocol.

Comprehensively referring to the functional agility short-term fatigue protocols performed in the previous studies, a basketball-specific fatigue protocol simulating the fatigue during the actual basketball competitions was reassembled designed in this study, which included 3 consecutive vertical jumps (Cortes et al., 2013), a 30-m sprint (Chappell et al., 2005), 30-m cutting and jogging (Cortes et al., 2013) (figure 2). This sequence was repeated by participants until 80% of the maximal vertical jump was unable to reach (Cortes et al., 2012).

Markers attached to the L5–S1 junction, lateral malleoli and the heel were blocked.

Figure1: Reflective Markers



*the force plate is specially used to test the height of vertical jump during the fatigue

Figure2: Basketball-specific Fatigue Protocol

Eight high-speed cameras (Motion Analysis Raptor- 4, USA) sampling at 200 Hz and two force plates (Kistler 9281CA, Switzerland) sampling at 1000 Hz were used to collect the kinematics and dynamics data including joint angle and moment of lower limbs and ground reaction forces. Besides, the approach speed was measured by calculating the displacement of the center of the pelvis and the number of frames before and after landing. These variables were measured at initial contact, peak stance and peak vertical ground reaction force, which had been selected in previous studies (Xia et al., 2017; Cortes et al., 2012; Quammen et al., 2012). The markers data were smoothed by 13.3 Hz Butterworth low-pass filter and calculated by Cortex 2.6 software. The net moment of each joint was calculated by the inverse dynamics.

Paired t-tests was performed to examine the effect of fatigue on the biomechanical characteristics of lower extremities. The significance level was set at α =0.05 and statistical analyses were conducted in SPSS 24.0.

RESULTS: Descriptive statistics for kinematic and kinetic variables were represented in tables1 and 2. Fatigue influenced several kinematic variables. Specifically, an increased approach speed was significantly observed at initial contact (P=0.003, Cohen's d=1.333). The participants landed in a decreased hip abduction angle at initial contact post-fatigue compared with pre-fatigue (P=0.010, Cohen's d=0.577). An increased knee flexion at peak stance was also observed during post-fatigue condition (P=0.034, Cohen's d=1.243).

For the kinetics, the participants landed with increased vertical ground reaction force (P=0.031, Cohen's d=0.667). The effect of fatigue was also significant at peak vertical ground reaction force and the participants had a decreased posterior ground reaction force (P=0.014, Cohen's d=-0.6) during post-fatigue condition. No difference was found on moments of lower extremities between pre- and post-fatigue conditions.

Table 1: Descriptive statistics for kinematic variables between pre- and post-fatigue conditions

	Variables			
	Knee Flexion (+) (deg)	Knee valgus (-) (deg)	Knee Internal Rotation (-) (deg)	Hip Abduction (-) (deg)
@nitial Contact				
Pre-fatigue	33.6±11.5	-2.4±3.6	13.8±9.7	-12.0±6.3
Post-fatigue	38.2±17.6	0.0±7.8	14.2±15.2	-7.67±8.57*
Peak Stance				
Pre-fatigue	59.2±32.8	1.2±7.8	4.1±12.6	-11.3±10.7
Post-fatigue	73.5±12.2*	4.1±4.8	6.9±11.8	-8.5±8.5
Peak Vertical GRF				
Pre-fatigue	54.7±19.8	0.2±5.5	7.3±12.6	-13.1±12.5
Post-fatigue	60.7±12.2	2.0±4.4	9.0±11.6	-8.8±7.6

(*P<0.05)

Table 2: Descriptive statistics for kinetic variables between pre- and post-fatigue conditions

	Variables			
	Knee Valgus (-) Moment (BH·BW)	Knee Internal (+) Moment (BH·BW)	Posterior Ground Reaction Force (BW)	Vertical Ground Reaction Force (BW)
Initial Contact				
Pre-fatigue	0.044±0.097	-0.064±0.098	0.004±0.004	0.203±0.063
Post-fatigue	0.056±0.071	-0.162±0.169	0.008±0.005	0.245±0.063*
peak stance				
Pre-fatigue	0.086±0.171	-0.119±0.182	0.007±0.005	0.232±0.087

Post-fatigue	0.104±0.216	-0.058±0.156	0.005±0.004	0.257±0.058
peak vertical GRF				
Pre-fatigue	-0.103±0.681	-2.377±7.375	0.011±0.008	0.277±0.101
Post-fatigue	0.048±0.191	-0.160±0.154	0.005±0.012*	0.219±0.080

(*P<0.05)

DISCUSSION: It was obvious that the approach speed increased significantly contrary to the decrease of approach speed (Cortes et al., 2013) in previous studies. One of the plausible explanations could be that the participants in this study were required to perform the jump-stop task at self-selected speed instead of sprinting at maximum speed. Considering the effect of fatigue, faster speed and greater strength were chosen by most participants to guarantee high quality of the task during post-fatigue condition, which could also be associated with the increased vertical ground reaction force at initial contact.

For changes of joint angles, the reduction of hip abduction at initial contact was consistent with some results of previous studies suggested to be an adverse strategy to increase the risk of ACL injury (Cortes et al., 2013). However, the fatigue-induced hip abduction angle showed in 3 experimental results involved in a review increased or had no significant difference (Sue & Frank, 2018). Besides, the reduction of hip abduction during post-fatigue was accompanied by larger knee valgus during landing or stop-jump tasks especially for female athletes (Sue & Frank, 2018) but no significant change of knee valgus was found in this study, which probably because that the participants recruited were all males. The relationship between changes of hip angle and ACL injury therefore still needs further research.

It was worthy to mention that the observation of increased knee flexion at peak stance seemed to support the view that fatigue did not increase the lower-extremity injury risk (Xia et al. 2017). However, the increased approach speed might require a larger knee flexion to cushion. On the other hand, participants in this study were only required to sprint onto the force plates without following an immediate maximal vertical jump (Anne et al., 2007), which could decrease the dynamic stability and increase the knee flexion.

For the kinetics, the reduction in posterior ground reaction force was not completely consistent with the changes in previous study (Sue & Frank, 2018) and could not be considered a necessary factor for ACL injury. Besides, changes of moment shown in other studies did not show significantly in this study such as the increase in knee valgus moment (Krosshaug et al., 2007), which may be related to the difference of experimental design and fatigue protocols.

Since the small sample size of male participants without including two independent variables of gender and expectation in this study, the results could only be used for fatigue comparison instead of further considering the interaction of independent variables and the gender difference of dependent variables before and after fatigue.

CONCLUSION: The basketball-specific fatigue protocol in this study caused changes of injury-related lower extremity biomechanics. However, the changes caused by fatigue in different studies are not completely consistent due to the difference of fatigue protocol and task. The results in this study alone could not indicate that fatigue increases the risk of injury.

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