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The Effect of Fatigue on Lower Extremity Joint Kinematics and Performance

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OBJECTIVE

ACL injuries are multifactorial in nature meaning they can be the result of faulty biomechanics, individual genetic predisposition, or environmental factors (Alentorn- Geli et al., 2009). A focus of most healthcare professionals including physical therapists and athletic trainers includes the screening for preventable risk factors for non-contact ACL injuries. Preventable risk factors include asymmetry between a person's limbs, decreased hamstring strength, increased muscle fatigue, decreased landing angle of hip and knee flexion, increased valgus landing, and lack of flexibility in the hip internal rotators (Brophy, 2021). Given the short and long-term negative consequences of an ACL injury, it is important for healthcare providers to explore screening and prevention techniques to employ with at-risk athletic populations.

The most common clinical tool used to evaluate injury risk biomechanical patterns during a jump landing task is the Landing Error Scoring System (LESS) (Padua, 2009). Additionally, there is a need to determine if other jump tasks are more relevant for sports that do not involve as much jumping, like soccer. Fatigue can place the body into compromising positions that increase the risk of an ACL tear. Within the literature, there is a gap that examines the impact fatigue has on biomechanical risk factors for ACL injuries within certain populations. Of particular interest within an at-risk population are female soccer athletes. Therefore, the purpose of this study was to examine the effect fatigue has on lower extremity joint kinematics and performance during a variety of double and single leg jumping tasks.

SETTING AND DESIGN

This study was conducted in a 3-dimensional motion capture lab in a controlled laboratory environment. This study was a pre-test, post-test design in which each subject served as their own control. At the beginning of data collection, subjects were assigned a number, and this number was used as the identifier throughout the study to ensure subject anonymity.

PARTICIPANTS

Participants for this study were invited from a NCAA Division III women's soccer team. Interested participants reached out to the research team to secure a time for participation in the study. This study was approved by the Institutional Review Board (IRB) and as such, all subjects signed the approved consent form prior to participation in the study. Researchers reviewed the study protocol and associated risks prior to data collection and all subjects gave verbal assent to complete the study as well.

INTERVENTION

For this study, the focus will be on the effect of fatigue on lower extremity joint kinematics and performance.

METHODS

Reflective diodes were placed on anatomical landmarks previously determined through the Nexus "Plug-in-Gait Lower Body AI" pipeline and researchers also gathered anthropometric data for each subject. The pre-fatigue testing protocol consisted of three tests and were performed at the start of the researcher's command. The subjects completed three successful trials of the drop vertical jump test, the single leg hop for distance and triple hop for distance test. After

three successful trials of all jump tasks, subjects were asked to begin the fatigue protocol. For the fatigue protocol the subjects completed forty, fifteen-meter dashes with a 10 second rest between sprints. Subjects then returned to the lab and repeated the jump testing exactly as it was completed in the pre-test protocol.

MAIN OUTCOME MEASURES

The independent variable was the fatigue protocol. For data collection, the subjects completed a drop vertical jump (DVJ), and single-leg hop for distance (SLHD) and a triple-hop for distance (THD). The dependent variables were joint kinematics about the hip, knee and ankle during landing. Additionally, performance for the SHD and THD was recorded at both the pre- and post-test.

RESULTS

All data were analyzed using Statistical Package for the Social Sciences (SPSS), version 26. A total of nine subjects completed both pre- and post- fatigue testing successfully. A paired t-test was used to analyze each level of the dependent variable. An alpha level of $p \leq .05$ was established for all statistical analysis. The results indicate a significant difference between the single hop for distance values pre-fatigue (M= 149.51 cm; SD= 14.75) and hop distance post-fatigue (M= 159.66 cm; SD=13.74) ($p \leq 0.002$). However, the subjects jumped further in the post-fatigue protocol. The results indicate a significant difference during the DVJ dorsiflexion angle at maximum knee flexion during pre-fatigue (M= 25.68 degrees; SD= 4.08) DVJ dorsiflexion angle at maximum knee flexion during post-fatigue (M= 27.90 degrees; SD=3.66) ($p \leq 0.047$). There was a significant increase in dorsiflexion (DF) at the ankle when the subjects were fatigued at the point of maximum knee flexion (KF) during the DVJ test. There were no statistically significant results among the kinematic variables for the single leg hop for distance test or the triple hop for distance.

CONCLUSION

There was one statistically significant result during the single leg hop for distance performance test indicating that subjects jumped further during the post-fatigue single leg hop for distance test. Although it did not reach statistical significance, subjects also jumped farther in the post-fatigue triple hop for distance test as well. These findings are most likely due to the insufficient warm up prior to starting the pre-fatigue trial. Another possibility to consider is that the fatigue protocol that was selected was insufficient in producing fatigue. Studies have demonstrated that a series of drop jumps that would induce repeated stretch-shortening cycles of the muscles does result in acute muscle fatigue (Ribeiro et al., 2008; Magalhaes et al., 2011). However, given that the subjects were soccer athletes, a fatigue protocol was selected that was more sport-specific to the demands of soccer rather than task-specific to jumping. Given that the subjects jumped further in the post-fatigue testing, any interpretation of post-fatigue kinematic data must be evaluated with caution in attributing any result to the effect of fatigue in the study. There was an increase in dorsiflexion at max knee flexion during the drop vertical jump. Decreased dorsiflexion is a kinematic variable that has been associated with increased risk for ACL injury (Hamilton, 2011), so this result is not consistent with increased injury risk

The cost of injury to athletes is high from a financial, physical, emotional, and mental standpoint. Given the growing body of knowledge that has identified risk factors for injury it is important for clinicians to use whatever tools they have available, two-dimensional or three-dimensional, to evaluate injury risk. It is only through increased screening that the sports medicine community will amass enough data to

determine the most effective and efficient ways to screen all types and all levels of athletes for injury risk.

KEY WORDS: *Kinematics, Sports Injury, Jump Landing Task, Single Limb Hop Task*

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