CHANGES TO NEUROMECHANICAL COORDINATION OF ENERGY ABSORPTION IN THE LEGS AFTER NEUROMUSCULAR FATIGUE

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Introduction: Neuromuscular fatigue has been shown to alter physiological and neuromechanical characteristics of joints and soft tissues like muscle and has profound implications for understanding mechanisms of injury and recovery [1]. The sensorimotor system is able to leverage motor redundancies to compensate for such changes within these components, in order to continue task performance despite fatigue-induced deficiencies [2]. During single-legged jumps (SLJs), highly controlled coordination is necessary to generate sufficient force to propel the body upward while also stabilizing landing to minimize impact forces, requiring a delicate balance between positive and negative mechanical energy generation and absorption [3]. The efficient dissipation of mechanical energy is especially essential when landing from a jump, where failure to absorb power generated during the lift-off and aerial phases can result in instability and injury [4]. Our previous analyses highlight the use of an inter-joint strategy of compensation in the lift-off phase of SLJs following fatigue; the diminished mechanical work contribution of joints experiencing greater fatigue was offset by increased contributions of their less fatigued counterparts. The work presented here expands upon that dataset by identifying and quantifying the degree of redistribution in joint-level mechanical work during the power absorption phase of SLJs with the progression of fatigue. We **hypothesized** that, similar to positive mechanical work during lift-off, joints of the lower limb would experience varying degrees of fatigue when landing from a SLJ after strenuous exertion, resulting in shifts in the joint contributions to meet the negative mechanical work demands of power absorption. We **predicted** that the ankle would play a larger role in power absorption with the onset of fatigue, in order to compensate for diminished contributions at the knee and hip joints.

Methods: We collected data on nine healthy participants (25.2 ± 2.3 years; 71.85 ± 18.8 kg; 177.27 ± 14.47 cm; 4 male and 5 female) with the goal of inducing neuromuscular fatigue across major muscles of the lower limbs; participants provided informed consent prior to participating in this IRB-approved protocol. Following a brief warm-up, participants performed three maximal SLJs on their dominant leg. The maximum vertical displacement of these "pre-fatigue" jumps was recorded and used to calculate the target height for subsequent SLJs (75% of maximum displacement). Next, participants underwent the fatigue protocol in which they squatted repeatedly to a knee flexion angle of 90 degrees. Squatting occurred at a pace of 50 bpm and continued until one of two possible criteria was met: the participant squatted for four consecutive minutes or failed to complete three successive squat cycles to the target knee flexion angle to the given tempo. Once failure was reached, the participant repeated the three maximal SLJs. If the vertical displacement target was reached in any of these jumps, the fatigue protocol was repeated until all three SLJs failed to reach the target height, or until a maximum of five blocks of squatting occurred. Sagittal plane joint kinetics and kinematics were calculated and compared between the pre-protocol and the progression through the fatiguing protocol for the seven participants who completed all five squatting blocks and subsequent SLJs.

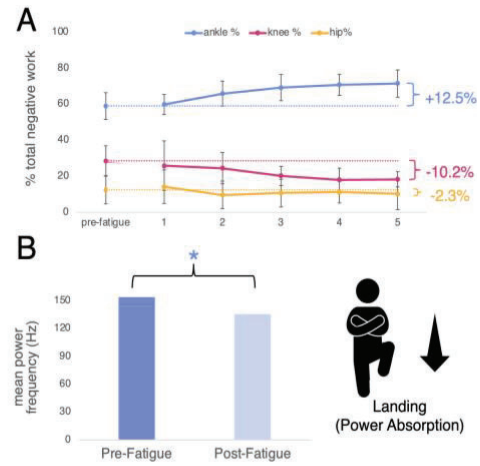

Figure 1: *A)* Mean ± SD of mechanical work contribution of ankle, knee, and hip during landing (n=7). Dashed lines indicate pre-fatigue baseline for each joint. *B)* Average mean power frequency of soleus muscle EMG during landing phase of SLJ across participants prior to and following the fatigue protocol. Asterisk indicates statistical significance (paired t-test, $p < 0.05$) and confirms presence of fatigue in key muscles.

Results & Discussion: We observed notable redistributions of joint contributions to total mechanical work across participants during landing (Fig. 1A). Our results show that the ankle joint compensated for diminished contributions by the hip and knee joints during power absorption (ankle: +12.5%; knee: -10.2%; hip: -2.3%). We used mean power frequency to confirm that fatigue was present in the soleus muscle following the protocol (Fig. 1B). From our data, we propose that reduced knee joint relative contributions to total mechanical negative power post-fatigue suggest that the knee joint experienced a greater degree of fatigue relative to the other joints, but this needs to be confirmed with a MPF analysis on knee muscles. In sum, shifting to greater ankle contributions during power absorption may suggest a strategy that spares injury about more proximal joints such as the knee and hip following fatigue.

Significance: The objective of this study is to pinpoint underlying changes in coordination strategies when the body experiences fatigue-induced deficiencies. We speculate that fatigued participants begin to prefer an ankle-based strategy in their landings, possibly as a protective mechanism over more fragile joints like the knee, which could have downstream implications for overall CoM dynamics. By quantifying and comparing shifts in joint-level power contributions during SLJ landings, we hope to further understand mechanisms of dynamic neuromuscular control in the context of jumping as well as other functionally relevant movements.

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References: [1] Padua et al. (2006), *J Athl Train* 41(3); [2] Bonnard et al. (1994), *Neurosci Lett* 166; [3] Augustsson et al. (2006), *Scand J Med Sci Sports* 16(2); [4] *Tamura et al. (2016), Orthop. J. Sports Med.* 4(1).