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The effect of fatigue and habituation on the stretch reflex of the ankle musculature

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Abstract

Many ankle injuries are said to occur when athletes are in a fatigued state; therefore, studies investigating the role that fatigue plays in ankle injuries are warranted. Furthermore, the contributions of the stretch reflex in countering the injury mechanism are still unclear. We hypothesized that (1) fatigue would impair the reflex response, (2) there would be no differences between genders, (3) habituation would be present, and (4) fatigue would exacerbate the effect of habituation. Forty healthy subjects participated and were divided into treatment and control groups. Stretch reflex measurements were taken for the tibialis anterior (TA), peroneus longus (PL), and peroneus brevis (PB) muscles in response to a rapid inversion perturbation. A fatigue intervention was administered to the treatment group, while the control group sat quietly. Post-test measurements were recorded within 5 min and reflex latency (RL) and amplitude (RA) were calculated. RA decreased significantly, however a significant improvement was noted in RL in the PL and PB muscles. The effect that peripheral fatigue has on RL should not be considered a cause of ankle injuries. However, the diminished RA may suggest reduced dynamic stability after fatigue. Habituation was present and was exacerbated by fatigue, indicating that reflex testing is affected by fatigue and habituation, which must be taken into consideration in future studies.
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1. Introduction

Ankle injuries are the most common orthopaedic injury incurred during sport participation (Garrick, 1977). Specifically, lateral ankle sprains, which involve the lateral ligament complex, are among the most common injuries seen in both sports and everyday life (Beckman and Buchanan, 1995; Ebig et al., 1997; Garrick, 1977; Willems et al., 2005). The disruption of the lateral ligament complex often leads to mechanical instability, peroneal muscle weakness, and a decrease in neuromuscular control mechanisms about the joint, leaving it particularly susceptible to further injury (Beckman and Buchanan, 1995; Benesch et al., 2000; Ebig et al., 1997; Fernandes et al., 2000; Hertel, 2000; Johnson and Johnson, 1993; Konradsen, 2002; Konradsen et al., 1998; Mora et al., 2003). In fact, recurrent sprains have been reported in over 70% of patients who had previously sustained an inversion ankle sprain (Braun, 1999; Yeung et al., 1994). Recurrent sprains, residual disability, a feeling of ‘‘giving way’’, and a sensation of joint weakness characterize functional ankle instability, a condition that often arises secondary to ankle trauma (Beckman and Buchanan, 1995; Fernandes et al., 2000; Konradsen et al., 1998; Konradsen and Ravn, 1991). Repeated ankle sprains associated with functional ankle instability have been linked to an increased risk of osteoarthritis (OA) and articular degeneration (Buckwalter et al., 2004; Gross and Marti, 1999; Harrington, 1979). Given that the majority of ankle OA cases occur secondary to ankle injury, it may be inferred that preventing ankle injuries will lead to a decreased incidence of ankle instability, and subsequently ankle OA, and the

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associated disability. Due to the significant amount of time lost from sport, work, and leisure-time activities, research on the factors that contribute to ankle injuries is warranted.

Neuromuscular control can be defined as the interaction between the nervous and musculoskeletal systems to produce a desired effect, specifically in response to a stimulus. During activity, dynamic and static restraints work together, via open-loop, reactive, and voluntary mechanisms, to maintain correct joint alignment in response to forces imposed on the joint (Moore et al., 2002). In the ankle specifically, the lateral ligaments are highly innervated by mechanoreceptors (Hertel, 2000; Myers et al., 2003), which when stretched sensitize the spindles in the peroneal muscles, through the γ-motor neuron system, subsequently causing a reflex contraction to oppose the stretch (Johansson et al., 1991). Many researchers have studied this reflex both as a function of reflex latency (RL) (Beckman and Buchanan, 1995; Ebig et al., 1997; Fernandes et al., 2000; Gruneberg et al., 2003; Johnson and Johnson, 1993; Konradsen et al., 1998; Konradsen and Ravn, 1991; Larsen and Lund, 1991; Mora et al., 2003; Myers et al., 2003; Santilli et al., 2005; Shima et al., 2005), reflex amplitude (RA) (Gruneberg et al., 2003; Myers et al., 2003; Santilli et al., 2005), and electromechanical delay (Moore et al., 2002; Mora et al., 2003; Yeung et al., 1999) yet there is a great deal of controversy in the literature as to the exact role that this reflex plays in preventing ankle sprains. Given the inconsistency of the results in studies involving subjects with unstable ankles and the lack of research on the body's normal response to inversion sprain mechanisms, studying the peroneal muscle reflex of normal subjects in response to stress may be beneficial in determining the cause of ankle sprains and long-term dysfunction, as well as lead to preventative initiatives and improved treatment measures.

With an increase in participation rates of females in sporting activities since the passing of Title IX, a dramatic discrepancy in injury rates between genders of ACL injuries has been documented (Moore et al., 2002). This gender bias in injury rates has generally been attributed to neuromuscular and biomechanical factors, however little work has been done at the ankle joint. Moore et al. (2002) found a difference between males and females in total motor time in response to a patellar tendon stretch, however this difference was attributed to electromechanical delay as opposed to premotor time. Furthermore, Benesch et al. (2000) found no differences between genders in peroneal reaction time. While it is generally accepted that no differences should exist between the genders in RL or RA, little research is available evaluating the effect of fatigue on reflex response between genders.

Habituation can be described as a decrease in response amplitude (RA) to a repeated, non-noxious stimulus and is a type of non-associative learning (Kandel et al., 2000). It has been found that large, automatic reactions (reflex responses) to unexpected movements of a supporting platform are progressively attenuated as the perturbation is repeated (Keshner et al., 1987; Stelmach et al., 1989). This habituation of the reflex response is a functional mechanism that allows a subject to minimize energy expenditure, once the individual is aware that the stimulus is, in fact, non-noxious (Keshner et al., 1987). While habituation is known to occur in both the upper (Floeter et al., 1998) and lower (Keshner et al., 1987; Stelmach et al., 1989) extremities, few studies have evaluated this phenomenon in the stretch reflex of the ankle musculature. Gruneberg et al. (2003) monitored habituation of the reflex responses during landing on inverting and non-inverting platforms and found that habituation was not present. However, no studies are available that monitor habituation while just standing on an inverting platform.

Some suggest that fatigue plays a significant role in the occurrence of ankle injuries (Gribble and Hertel, 2004; Huston et al., 2005; Ochsendorf et al., 2000; Pasquet et al., 2000; Yeung et al., 1999). Anecdotally, many injuries occur during the latter stages of activity when fatigue is present. Whether the onset of fatigue occurs centrally or peripherally, many researchers have documented decreases in the neuromuscular feedback system of the joint around which the fatigued muscles are located (Avela et al., 2001; Gribble and Hertel, 2004; Harkins et al., 2005; Moore et al., 2002; Ochsendorf et al., 2000; Pasquet et al., 2000; Van Lent et al., 1994; Yaggie and McGregor, 2002; Yeung et al., 1999). No studies have evaluated the reflex response times or amplitudes of the ankle musculature to ankle inversion stress before and immediately after isokinetic fatigue.

Generally, isokinetic fatigue has been defined as a force production decrease below 50% of the peak force, which is determined either from a pre-test maximal isometric contraction or peak force observed during the first three to five contractions in the fatigue protocol (Ochsendorf et al., 2000; Wikstrom et al., 2004; Yaggie and McGregor, 2002). Isokinetic force output is significantly greater for eccentric (ECC) than concentric (CON) muscle actions, while EMG activity is significantly greater for CON than ECC actions. In other words, ECC muscle activity can produce more force with less stimulation, effectively decreasing the amount of energy required to perform the task (Pasquet et al., 2000). Under fatigued conditions, CON muscle actions result in a greater loss of force than ECC actions (Pasquet et al., 2000). Therefore, in this study, fatigue was measured via a decrease in ECC force production because ECC muscle actions are more resistant to force reductions due to fatiguing exercises (Smith and Newham, 2007). Furthermore, ankle inversion injuries are caused by an inability of the peroneal muscles to eccentrically resist the inversion movement (Mora et al., 2003). Traditionally, isokinetic fatigue protocols have utilized CON movements solely, whereas unique to this study, fatigue was measured by decreases in ECC force production.

While many studies have evaluated peroneal reaction time, comparing healthy and injured ankles (Beckman and Buchanan, 1995; Ebig et al., 1997; Fernandes et al.,