BJMB
Brazilian Journal of Motor Behavior

Special Issue:
"Fatigue Role in Modulating Motor Skills and Muscular Responses"

Editorial: Fatigue Role in Modulating Motor Skills and Muscular Responses

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https://doi.org/10.20338/bjmb.v17i5.401

ABBREVIATIONS
CAI Chronic ankle instability
DOMS Delayed Onset Muscle Soreness

PUBLICATION DATA
Received 25 09 2023
Accepted 29 09 2023
Published 30 09 2023

This editorial beckons readers to the intricate relationship between fatigue and motor control skills. This theme is explored in the ensuing special issue through the lens of esteemed researchers in the field. The articles within this issue provide a comprehensive and insightful analysis of how fatigue acts as a silent saboteur, subtly undermining the efficiency and efficacy of motor responses and skills. Through a tapestry of carefully conducted studies and thought-provoking findings, contributors shed light on how fatigue insidiously affects neuromuscular responses, from altering muscle activation during specific tasks to influencing the onset of muscle soreness. This special issue, therefore, serves as a launching pad for a much-needed research agenda. It invites scholars and practitioners alike to engage with and further investigate the relationship between fatigue and motor control skills, thereby contributing to our growing understanding and knowledge of this area.

KEYWORDS: Fatigue | Motor Control | Neuromuscular Control | Postural Stability

IMPACT OF FATIGUE ON MOTOR SKILLS AND MUSCLE RESPONSES

The body perpetually experiences deformations, altering its resting state and obstructing its balance maintenance capabilities. This includes a spectrum of motor skills where maintaining balance is just one aspect. Yet, it is intertwined with various physiological functions that are essential for the execution of coordinated movements. As we explore motor skills, it is important to consider how the body harmonizes these functions to perform smooth and precise actions. Bouisset and Duchêne [1] noted that although respiratory movements introduce minor disturbances, they are not the exclusive contributors to postural sway. Slight angular adjustments in the lower trunk and limbs somewhat neutralize such activities [2]. De Luca et al. [3] pinpointed the neuromuscular system's incapacity to maintain steady tension as a fundamental cause of postural sway in an upright stance. Hence, the body's organization during motor activities is intricately crafted, incorporating visual, vestibular, musculotendinous, articular, and cutaneous sensory information [4]. Furthermore, motor control is influenced by various systems, with fatigue being a noteworthy factor due to its complexity and substantial impact on motor functions.

Fatigue is often defined as the inability to continue working at a specific exercise intensity [5–7]. It typically manifests suddenly at "the point" of exhaustion. However, fatigue begins almost immediately once exercise starts, with muscles' maximum force-generating capacity diminishing progressively from the onset of activity until they ultimately fail. In this context, a more accurate definition of fatigue might be any reduction in the ability to exert muscle force or power induced by exercise [8]. During exercise, muscle fatigue emerges from intricate interplays among various bodily systems, manifesting as a decline in the capacity to generate muscle force or power due to exercise [7].

Different models are proposed to explain exercise-induced fatigue. Historically, the scientific community efforts were concentrated on reducing the fatigue phenomenon to a simple and widely accepted concept. Who has never heard that lactate acidosis is the cause of exercise-induced fatigue? Factually, this theory has contributed to slowing down our progress regarding understanding the fatigue phenomenon. A more embracing model based on feedback – such as the Catastrophe model – or feedforward mechanisms (e.g., Central Governor Theory [9]) were also proposed to enhance the scientific knowledge about fatigue. Another attempt to define this phenomenon is to distinguish fatigue using the perceived and performance fatigability domains, which refer to the subject's feelings and incapability to perform the task. However, these models are limited to explaining the performance decline during self-paced events or the fatigue induced by disease states, demonstrating the difficulty of reducing the fatigue phenomenon to a simple concept.

Beyond these conceptual issues, fatigue, distinguished by its dual domains of perceived and performance fatigabilities, detrimentally impacts individuals' physical and cognitive functions. Given these implications, it is critical to expand our analysis to include a variety of motor skills. This should involve a thorough investigation into how fatigue influences the dynamic interplay between body segments, a fundamental aspect of activities ranging from basic gestures to coordinated movements. Thus, the present special issue aims to advance the knowledge about the fatigue effects in modulating motor skills and muscular responses.

The intricate connection between fatigue and motor control is a complex relationship deserving the exploration provided in this special issue. The contributions offer a panoramic view of fatigue's subtle yet profound influence on motor responses and skills. They provide invaluable insights for scholars and practitioners, from understanding how fatigue undermines motor efficiency to exploring its role in the onset of muscle soreness and the alteration of muscle activation. The findings presented herein are pivotal, serving as a beacon guiding future research in this domain. The work by Rinaldin et al. [10] and the study conducted by Teruya et al. [11] are particularly noteworthy, each addressing significant gaps in the literature and providing fresh perspectives on the role of fatigue in motor control and stability. The insights gleaned from these studies and others featured in this issue collectively contribute to a deeper understanding of the compensatory mechanisms activated during fatigue and the influence of muscle strength on stability in the lower extremities. Furthermore, exploring the relationship between hip abductor strength and lower limb stability, as presented by Cemin et al. [12], adds a valuable layer to our understanding of motor control under the influence of fatigue. This study, along with others in the issue, underscores the importance of considering physiological differences, such as sex, in the experience and manifestation of fatigue and pain, as highlighted by the research of Lemos et al. [13]. These considerations are crucial for developing more effective and personalized approaches to patient management, clinical evaluation, and rehabilitation in the face of fatigue and DOMS. Below the main findings of the studies of this special issue are presented.

Different studies have documented balance asymmetry under various conditions and tasks. In this context, the current issue features work by Rinaldin et al. [10] that addresses a gap in the literature regarding the role of leg dominance in compensatory muscular activation between legs during unilateral muscular fatigue, especially during unanticipated stance perturbations. The findings highlight that compensatory activation is notably present in the lateral gastrocnemius muscle, playing a vital role in maintaining an upright stance. Intriguingly, this compensatory behavior is evident from the first muscular response in a fatigued state, suggesting that the central nervous system can preemptively anticipate the effects of unilateral muscular fatigue on reactive responses without previous experience. Moreover, the study found no significant impact of leg dominance on reactive responses under unilateral fatigue, reinforcing the concept of bi-hemispheric cortical participation in generating reactive postural responses. These findings contribute to the literature by providing insights into the compensatory mechanisms activated during unilateral fatigue and the lack of influence of footedness on these mechanisms.

In light of fatigue's impact on the lower extremities, existing literature emphasizes that individuals with chronic ankle instability (CAI) experience reduced muscle strength, limited dorsiflexion motion range, and delayed responses from ankle muscles [14]. Additionally, fatigue brings about significant alterations in neuromuscular responses. Considering the complex relationship between fatigue and muscle co-activation in individuals with CAI is crucial for understanding fatigue's extensive effects on neuromuscular function nality. The article by Teruya et al. [11] critically evaluates how fatigue influences muscle co-activation in individuals with CAI. It reveals a decrease in antagonistic and synergistic coactivations, indicating a reduced ability to stiffen the joint, which is essential for protecting the ankle during inversion movements, the primary mechanism leading to ankle sprains. This crucial finding underscores the need to develop and implement targeted interventions to enhance ankle stability in CAI patients, providing invaluable insights for clinicians and healthcare professionals caring for individuals with CAI.

Weakness in the hip abductor muscles, essential for maintaining posture [15], can lead to changes in the ankle muscles, potentially resulting in reduced postural balance [16]. Therefore, investigating compensatory mechanisms in bilateral tasks and the varied responses in the lower limb's distal muscles is essential for understanding their role in maintaining stability. The work of Cemin et al. [12] explored the impact of a session of hip abductor resistance exercise until failure on foot kinematics and electromyography amplitude of muscles crucial for foot stabilization during various landing tasks. The authors highlight the connection between hip abductor strength and stability in the lower extremities. They also provide valuable insights into the role of hip abductor muscles and their influence on lower limb stability during different landing tasks. The article's findings contribute to the existing literature by elucidating the relationship between proximal muscle strength and distal limb stability, offering a basis for future studies to investigate further this dynamic and its implications for tasks like running.

Fatigue is intrinsically linked to physical exercise, often culminating in Delayed Onset Muscle Soreness (DOMS) when the exercise is performed at high intensities, involving unusual movement amplitudes and speeds, or experiencing a sudden increase in exercise load [17]. DOMS is characterized by various symptoms, including pain, stiffness in joints and muscles, muscle swelling, and a decline in strength, which become evident when the affected muscles are stretched or palpated [18]. However, it is essential to note that adaptations to exercise and pain perception vary between sexes, with physiological differences influencing the experience of pain. Considering this, Lemos et al. [13] investigated whether there are differences in pain outcomes, measured using a Numerical Rating Scale, between males and females subjected to physical exercise designed to induce DOMS in the lower limbs. The study found that numerical rate scale outcomes are consistent between both sexes. Nonetheless, females exhibited lower absolute values of pressure pain threshold than males when DOMS was present. This crucial finding suggests that the sex difference in DOMS, as measured by the

pressure pain threshold, is likely attributable to females' heightened sensitivity to the pain threshold rather than the specific exercise performed. These results significantly affect clinical evaluations and patient management in sports performance and rehabilitation.

Thus, considering all the above mentioned results, the present special issue serves as a mirror reflecting the current state of knowledge and a window opening toward future possibilities in studying fatigue and motor control. The studies and findings in these pages invite researchers and practitioners to continue exploring fatigue's role in motor skills and control. Through continued inquiry and investigation, the field can look forward to developing more effective theories, strategies, and interventions to mitigate the impact of fatigue, ultimately enhancing the efficacy and efficiency of motor responses and skills in various contexts and populations.

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Citation: Bedo BLS, Kalva-Filho CA. (2023). Editorial: Fatigue Role in Modulating Motor Skills and Muscular Responses. *Brazilian Journal of Motor Behavior*, 17(5):182-185.

Funding: Nothing to declare.
Competing interests: The authors have declared that no competing interests exist.
DOI: https://doi.org/10.20338/bjmb.v17i5.401