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Elevating Muscle Ultrasound Examination: Real-time Detection of Fasciculation and Automated Motion Recognition for Improved Sensitivity and Specificity

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Abstract

To enhance the efficiency of an automated algorithm designed for identifying fasciculation and various movements in muscle ultrasound videos, we are implementing real-time fasciculation detection in muscle ultrasound through continuous analysis of live videos. However, relying solely on human observation imposes limitations on the acquired objective data. The automation of motion detection is anticipated to improve both sensitivity and specificity, thereby enhancing overall reliability. Our investigation focuses on atypical eye movements resulting from disorders affecting the extra ocular muscles and their innervation. We employ a bottom-up anatomical approach, examining the impact of lesions at each site on gaze control. Extra ocular muscles are susceptible to mitochondrial disorders, which restrict the range of eye movements and lead to ptosis, though diplopia is rarely a consequence.

Keywords: Ultrasound; Extra ocular muscles; Ptosis; Diplopia

Introduction

The most common disorder affecting the neuromuscular junction is myasthenia gravis, leading to variable weakness in the extra ocular muscles, diplopia, and ptosis. Palsies of the coulometer, trochlear, and abducens nerves result in weakness of specific muscles and movements, but adaptive changes, driven by visual demands, can induce secondary effects on eye movements. Brainstem disorders may disrupt the coordinated movements of the eyes or selectively impair certain types of eye movements. Congenital misalignment of the eyes can be caused by orbital, global, or visual factors. One form of early-onset ocular oscillation, known as nystagmus, is associated with strabismus and a failure to develop binocular vision. Animal models have been developed to gain insights into the pathogenesis of "latent nystagmus." These models have also contributed to understanding nystagmus in individuals with visual impairment due to hereditary retinal disorders and have provided opportunities to study gene therapy [1,2].

Results and Discussion

The etiology of infantile forms of nystagmus occurring in individuals without visual system disorders is not fully understood. However, numerous idiopathic nystagmus syndrome models have provided significant insights into its pathogenesis, and some observations have led to the development of promising therapeutic approaches. The activation waveforms of vastus intermedius, adductor magnus, and semimembranosus have not been previously reported for high knee flexion activities such as kneeling or squatting, likely due to the invasive methods required for their measurement. Given their substantial physiological cross-sectional areas, it is suggested that their contributions to knee joint loading could be considerable. This study aimed to quantify the activities of these muscles using fine-wire electromyography and to assess easily measurable surface sites as potential proxy measures using criteria of <10% maximum voluntary contraction root mean square and >0.85 R2 for successful representation of deep muscle activity compared to that measured at a surface site. However, none of the surface and fine-wire site pairs met both criteria for these activities. While some muscle pairs met the criteria for certain individuals, there was significant inter-participant variability. Therefore, future muscle models may benefit from fine-wire measurement of these muscles, but researchers must be cautious regarding electrode site specificity [3,4].

We investigated how kinematic redundancy interacts with the neurophysiological control mechanisms required for smooth and accurate rapid limb movements. Biomechanically, tendon excursions are overdetermined because the rotation of a few joints determines the lengths and velocities of many muscles. However, we observed significant differences in eccentric and concentric muscle speed profiles among trajectories, even among similar trajectories. These variations have important implications for their neural control, as each trajectory will require distinct, time-sensitive reflex modulation strategies. Failure to properly suppress the stretch reflex of any eccentrically contracting muscle, as Sherrington noted a century ago, can disrupt movement. Trajectories producing faster or more variable eccentric contractions will require more precise timing of reflex modulation across motor neuron pools, resulting in greater sensitivity to time delays, muscle mechanics, excitation/contraction dynamics, noise, errors, and perturbations. Combining key biomechanical and neuroscientific principles, we propose that kinematic and muscle redundancy is severely limited by the need to adjust reflex mechanisms in a task-specific and time-critical manner. This, in turn, has important implications for learning and executing precise, smooth, and repeatable movements and for rehabilitating everyday limb actions in developmental and neurological conditions, and stroke [5,6].

In skeletal muscle fibres, excitation-contraction coupling corresponds to the sequence of events from action potential firing to the initiation of contraction through an increase in cytosolic Ca2+. Mutations in genes encoding various components of this process can lead to clinical disorders such as dystonia, muscle weakness, paralysis,

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or muscle wasting. One approach to treating unilateral spatial neglect involves left neck muscle vibration, which has been shown to reduce clinical symptoms in patients with right-sided brain damage. This study aimed to assess the effects of a left neck muscle vibration protocol during arm movements in the peri-personal space on the spatial and egocentric perceptions of patients with left-sided spatial neglect (USN left). However, the practical application of such interventions often conflicts with patient care limitations [7,8].

Biomedical signals play a crucial role in developing human control systems to improve the quality of life. The electromyography signal is a complex signal controlled by the central nervous system. The CNS is believed to use flexible combinations of muscle synergies to solve and control redundant movements. Muscle synergy activities are unique in each muscle. The CNS indirectly controls the activation of a large number of muscles through two main mechanisms: automatic body responses and voluntary actions. Some studies suggest that automatic body responses can be used as a reference to adapt voluntary efforts. This work aims to analyse human movements from muscle synergy to assist the CNS in shaping synergy movements through recommendation using the concatenated non-negative matrix factorization method and pattern recognition. The goal is to compare the two results and determine their accuracy in helping the CNS structure synergy actions [9,10].

Neural coupling between the upper and lower limbs during human walking is supported by the modulation of cross-limb reflexes and the presence of rhythmic activity in proximal arm muscles. However, the involvement of distal arm muscles in cyclic movements and sensorimotor neuromodulator is also suggested. Here, we investigated the impact of rhythmic wrist movements, both separately and in conjunction with arm swinging, on the characteristics of involuntary cyclic leg movements evoked by muscle vibration in a gravity-neutral position and on the soleus H-reflex of the stationary legs.

Conclusion

The modulation of the H-reflex was assessed based on five conditions: stationary arms, voluntary alternating upper limb swinging, combined upper limb and wrist movement, wrist movements only, and upper limb movement with the addition of load. Rhythmic wrist movements significantly enhanced the amplitude of involuntary leg oscillations, including ankle joint oscillations and the H-reflex. This effect was attributed to the rhythmicity of wrist movement rather than a simple increase in tension in the upper limb muscles. This conclusion is supported by the fact that adding resistance to arm oscillations had an opposite inhibitory effect on the H-reflex. Our findings further suggest the existence of neural connections between the distal components of the upper and lower extremities, emphasizing the potential importance of incorporating wrist joint movements in motor neurorehabilitation.

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Conflict of Interest

None

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