Muscle Tone Physiology

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The simple definition of tone as the resistance to passive stretch is physiologically a complex interlaced network encompassing neural circuits in the brain, spinal cord, and muscle spindle. Disorders of muscle tone can arise from dysfunction in these pathways and manifest as hypertonia or hypotonia. The loss of supraspinal control mechanisms gives rise to hypertonia, resulting in spasticity or rigidity. On the other hand, dystonia and paratonia also manifest as abnormalities of muscle tone, but arise more due to the network dysfunction between the basal ganglia and the thalamo-cerebello-cortical connections.

spasticity rigidity dystonia paratonia

1. Introduction

Muscle tone is a complex and dynamic state, resulting from hierarchical and reciprocal anatomical connectivity. It is regulated by its input and output systems and has critical interplay with power and task performance requirements. Tone is basically a construct of motor control, upon which power is intrinsically balanced. This hierarchy of motor control includes cortex (extensive processing capability with highest degree of freedom), basal ganglia (learning and teaching of context dependent tasks with less degrees of freedom), cerebellum (fine-tuning), brainstem reticular system (common pathway for ascending and descending tracts), spinal cord (the main pathway for ascending and descending tracts), and muscle spindle (final common pathway with least degree of freedom). In this review, we have discussed the controversies regarding the definition of muscle tone and its classification, followed by the mechanisms and pathways responsible for maintaining tone. Spasticity and rigidity, the two types of hypertonia, have been elaborated in the context of the dysfunction in the supraspinal pathways and the interaction between spinal cord and muscle spindle. The other two disorders of altered tone, namely dystonia and paratonia, are not exactly related to the physiological dysfunction of the tone pathways. In the motor control system, spasticity and rigidity are predominantly an output system problem, while dystonia is a system level processing problem. Dystonia and paratonia have altered tone secondary to network disruption in the basal ganglia, the thalamocortical circuits, and their connections. The mechanisms underlying these have been discussed thereafter because they are important both clinically and pathophysiologically from a movement disorder perspective.

2. Definition of Muscle Tone

Muscle tone is traditionally defined as ‘the tension in the relaxed muscle’ or ‘the resistance, felt by the examiner during passive stretching of a joint when the muscles are at rest’ [1]. This definition of tone has some ambiguities such as, what does the ‘resistance to passive stretch’ mean is not clear and ‘felt by the examiner’ opens the door to subjective variation during clinical examination and interrater variability of the assessment [2]. Studies with electromyographic (EMG) assessment often equate muscle tone with baseline EMG level in a relaxed state. However, apart from the active or contractile component resulting from the activation of motor unit and detectable by EMG, muscle tone also has a passive or viscoelastic component, independent of neural activity that can't be detected by EMG. The viscoelastic component in turn depends upon multiple factors like the sarcomeric actin-myosin cross-bridges, the viscosity, elasticity, and extensibility of the contractile filaments, filamentous connection of the sarcomeric non-contractile proteins (e.g., desmin, titin), osmotic pressure of the cells, and also on the surrounding connective tissues [3][4].

Mathematically, muscle tone can be interpreted as the change in resistance or force per unit change in length (Δ force/Δ displacement of the tissue) [5]. In a relaxed state, resistance to an external motion (R_{TOT}) depends on inertia (R_{IN}), apparent stiffness (resistance to stretch/R_{ST}) and damping (resistance to velocity/R_{DA}): $R_{TOT} = R_{IN} + R_{DA} + R_{ST}$ [6]. However, all these definitions have a common fallacy of assuming that the person is in completely relaxed state, which is often impossible to achieve unless using muscle relaxants.

In contrast to this general notion, Bernstein highlighted the fact that muscle tone may actually reflect a state of preparedness to a movement and thus it may not be possible to estimate muscle tone when the person is asked to relax and not to make any movement [7]. Bernstein, in his hierarchical model of movement construction (tonus, synergies, space, action), postulated that muscle tone is an adaptive function of the neuromotor apparatus that responds adequately to commands coming from upper levels of movement construction by fine-tuning the excitability of the sensory and motor cells for the tasks of active postural or movement control [6][7]. This definition makes muscle tone an active contributor to movement and postural tasks. Similarly, Carpenter et al. have given a clinical definition of tone as "the constant muscular activity that is necessary as a background to actual movement in order to maintain the basic attitude of the body, particularly against the force of gravity" [8]. Thus, tone can be a construct that is required for motor control such that both static and dynamic tasks can be safely performed in the most thermodynamically efficient way.

3. Classification of Muscle Tone

Muscle tone can be classified as 'postural' and 'phasic' types. Postural tone is seen in axial muscles where gravity is the most important inciting factor. It results from a steady stretch on the muscles and tendons and manifests as prolonged muscle contraction. In contrast, phasic tone is what is commonly assessed clinically in the extremities as a rapid and short duration response. It results from the rapid stretching of a tendon and attached muscle and more precisely, the muscle spindle [9]. Apart from this, muscle tone can be classified into its active and passive components, as has already been described above.

References

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