



What it means to be ‘neuromuscular’: toward more appropriate use of the term in applied exercise and sport science research involving healthy participants

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Introduction

Neuromuscular function describes the translation and integration of excitatory and inhibitory synaptic potentials generated and received by upper and/or lower motoneurons into forces produced by the musculotendinous unit, thus encapsulating the entire motor pathway (O’Bryan et al. 2025). Since Liddell and Sherrington (1925) wrote “Styling as motor unit the motoneuron-axon and its adjunct muscle fibres” (page 511), the term ‘neuromuscular’ clearly encapsulates the integration between neural and muscular systems and the subsequent effects on critical outcomes known to influence human performance, including strength, speed, power, and fatigue development. However, it is becoming increasingly more common in the exercise and sports science literature to use the term ‘neuromuscular’ at the forefront in titles of original research articles without incorporating experimental techniques capable of evaluating the integration of neural and muscular mechanisms underlying human performance. Indeed, many studies use the term ‘neuromuscular’ in the titles of their articles alongside functional outcomes or physical activities such as ‘power’, ‘exercise’, ‘warm-up’, ‘fitness’, ‘training’, ‘adaptations’, ‘fatigue’, ‘force’, ‘performance’ or ‘load’, without offering any new or deepened understanding of neuromuscular control. Our view is that using the term in this way is arbitrary due to limitations in research design and what can be said about the neuromuscular systems involvement. The purpose of this commentary is to advocate for a more standardised approach for future use of the term ‘neuromuscular’ in applied exercise and sports

science research involving healthy participants and highlight appropriate non-invasive experimental approaches that would better justify its use at the forefront of these studies.

Literature search

To support our point, we searched SPORTSDiscus database for recent original peer-reviewed research articles published from January 01 2023 to September 5 2025, conducted on apparently healthy participants, and published in English using the term ‘neuromuscular’ in the title AND including mention of the terms ‘strength’ OR ‘force’ OR ‘speed’ OR ‘velocity’ OR ‘power’ OR ‘fatigue’ OR ‘performance’ OR ‘endurance’ in the title or abstract. 278 articles met these criteria, 175 (63%) of which failed to implement experimental approaches that permit investigation into mechanistic neuromuscular processes that govern human performance. Just over half of these articles justified their use of the term ‘neuromuscular’ in the title by focusing on evaluations or training of ballistic-type movements, such as plyometric exercises or vertical countermovement jump height (57%). Although plyometric training and jump height performance centre on maximal power capabilities and optimisation of the force–velocity profile (Samozino et al. 2012), from a mechanistic standpoint these ballistic-type performances are influenced by a plethora of neuromuscular processes including (but not limited to) skeletal muscle mass and fibre type, motor unit recruitment thresholds and discharge rate, supraspinal excitation and inhibition, architectural features of skeletal muscle and rate of fascicle shortening, or potentiation and elastic energy of contractile and passive skeletal muscle elements during the stretch–shortening cycle (Cormie et al. 2011). Thus, adding the term ‘neuromuscular’ in the title of these articles is done so arbitrarily and provides no additional or refined information to the reader beyond what is already known about the neuromuscular contribution

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to these outcomes. For instance, describing jumping performance as ‘neuromuscular power’ does not clarify how this differs from simply ‘power’. The same applies to most of the remaining studies that used the term ‘neuromuscular’ to describe changes in isometric or dynamic force/torque or movement velocity assessed through standalone evaluations or performance test batteries.

More appropriate techniques to assess neuromuscular function

Of the remaining 103 (37%) of articles retrieved from our search, use of the term ‘neuromuscular’ in the title was considered more appropriate as these studies included some attempt to investigate the underlying neuromuscular mechanisms that contribute to performance outcomes (Fig. 1). This included assessment of voluntary and evoked force or surface electromyography (sEMG) outcomes in response to electrical stimulation of the peripheral axon (e.g. voluntary

activation, twitch forces, maximal muscle compound action potential, Hoffman reflex, V-wave) or transcranial magnetic stimulation (TMS) (e.g. amplitude or area of the motor evoked potential, short or long intracortical inhibition, cortical silent period). By applying a superimposed stimulus to the peripheral axon or motor cortex during a maximal voluntary contraction and comparing the size of the superimposed twitch to that evoked shortly after at rest (or estimated if using TMS), it may be possible to evaluate the capacity of supraspinal and spinal motoneurons to fully recruit existing skeletal muscle fibres and generate maximal force (Taylor 2009). Further, high and low frequency paired pulses applied to the peripheral axon at rest may provide insight into mechanisms that influence action potential transmission at or after the neuromuscular junction or intrinsic calcium-activated force and recovery within skeletal muscle fibres (Millet et al. 2011). These and various other electrical stimulation techniques can demonstrate good reliability in apparently healthy participants of all ages (O’Bryan et al. 2024), although some concerns with TMS have been raised (Héroux et al. 2015) and intra-rater reliability (and inter-rater reliability if more than one person measuring the outcomes) should be established for each experimental study. In addition to evoked responses, some studies utilised high-density surface electromyography (HDEMG) and decomposed signals into individual motor unit spike trains. This non-invasive method permits evaluation of motor unit outcomes such as recruitment threshold, conduction velocity and firing frequency and can reliably track motor units longitudinally, for example, before and after a training or rehabilitation intervention (Martinez-Valdes et al. 2017). Although currently restricted to submaximal contractions up to approximately 75% MVC and less motor units may be decomposed for some muscles in female compared to male participants, HDEMG can also be used to evaluate motor unit properties during rapid ballistic contractions and is associated with performance outcomes such as rate of force development (Del Vecchio et al. 2019). Perhaps most commonly within the retrieved articles was the sole use of bipolar sEMG to extract spatial and temporal outcomes including signal amplitude or mean frequency. However, the physiological and non-physiological factors which influence the surface signal must be respected for valid interpretations (Enoka and Duchateau 2015) and appropriate normalisation of raw signals is necessary to enable comparisons between individuals, muscles or time points. Further, the mean frequency of the sEMG signal does not correlate well with motor unit discharge patterns due to several factors known to influence the spectral characteristics of the signal and so its use in exercise and sports science research settings is questionable (Enoka and Duchateau 2015). Other potential non-invasive experimental approaches which may provide insight into the neuromuscular mechanisms that influence human performance but not

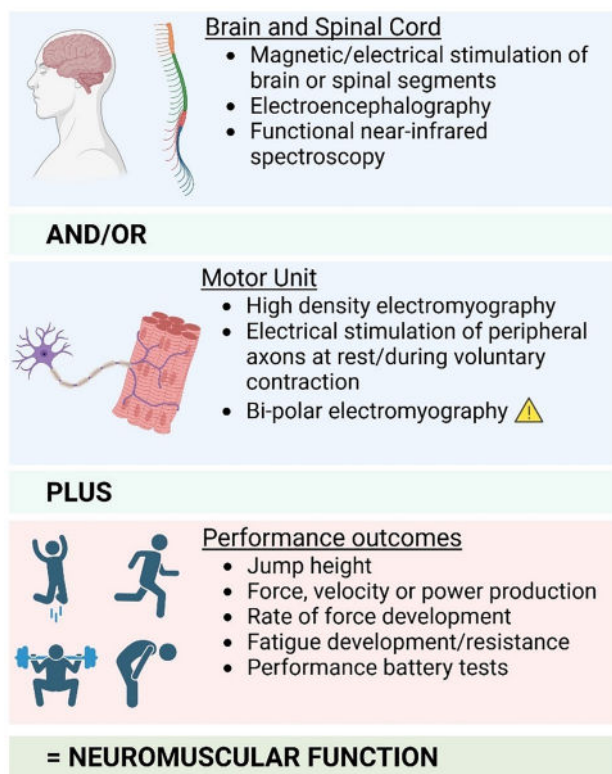


Fig. 1 Our view is that using the term neuromuscular in the title of applied exercise and sports science research articles should be reserved for when experimental approaches capable of evaluating the brain, spinal cord and/or the motor unit contribution to performance outcomes have been incorporated into the research design. Examples of appropriate non-invasive techniques are provided here, with caution advised if solely incorporating bi-polar surface electromyography. Figure Created in BioRender.com/19vm6zm

identified within our search, includes segmental stimulation of the spinal cord (e.g. cervical or thoracic) (McNeil et al. 2013), electroencephalography (Cheron et al. 2016) or functional near-infrared spectroscopy (Teo et al. 2024).

Conclusion

Our view is that using the term ‘neuromuscular’ in the title of applied exercise and sport science research articles including healthy participants implies to the reader that there is some experimental investigation into the neural and muscular mechanisms that underpin human performance. Omitting appropriate experimental techniques to evaluate neuromuscular function but using the term in the title is done so arbitrarily and provides no additional or deepened understanding to the reader. In such cases, we propose the term should be omitted from the title and abstract and considered for inclusion in the discussion section of the manuscript, with limitations about what the research findings can say about the neuromuscular mechanisms which underpin performance outcomes appropriately described. Here, we call for a more standardised approach whereby the use of the term ‘neuromuscular’ in the title of applied sport and exercise science articles is reserved for when appropriate experimental methods capable of evaluating the integration between the neural and muscular systems are coupled with performance outcomes. This will advance understanding and provide greater clarity for the exercise and sport science research community, ensuring that the complex mechanisms that underlie neuromuscular control of human performance are accurately represented and respected.

Author contributions SOB conceived the idea for the commentary, performed and interpreted the literature search, and drafted, edited and revised the manuscript. DH edited and revised the manuscript. Both authors approved the final version of the submitted manuscript.

Data availability The retrieved articles from the literature search are available from the corresponding author on reasonable request.

Declaration

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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