BIOMECHANICS PRIORITIES CONFERENCE
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Recommendation Title: Understanding the role and significance of noise and/or variability in movement

Recommendation Code: LF1E

Category: Cell/Tissue, Joint, Limb/Whole Body, Function, Outcomes

Recommendation

Background and Relevance

Existing principles used to explain how movement is controlled typically predict average, long-term behavior. However, neuromuscular noise continuously disrupts these movements, presenting a significant challenge for the nervous system. One possibility is that the nervous system must overcome all variability as a constraint limiting performance. Conversely, humans can exploit system redundancies to allow "beneficial variability" or to ignore variability that is irrelevant. Understanding the nature of this variability is thought be critical to understanding how humans perform skilled movements (e.g., Todorov, *Nat. Neurosci.*, 2004; Faisal et al., *Nat. Rev. Neurosci.*, 2008).

The stochastic (i.e., random) processes that give rise to movement variability originate at the cellular / sub-cellular scale. Therefore, understanding how movement variability arises must start with better understanding of these stochastic cellular processes and move to determine how cellular variability gives rise to movement variability.

This movement variability has direct and immediate clinical implications. As only one example, increased gait variability has been shown to prospectively predict falls in several independent studies (Maki, *JAGS*, 1997; Hausdorff et al., *Arch. PM&R*, 2001; DeMott et al., *Am. J. PM&R*, 2007). This suggests that variability is potentially a very powerful and underexploited tool for assessing movement competence and neuromuscular pathology.

However, we still do not know when or how much variability is "bad" or if or when variability is "good" (i.e., when variability leads to improved task performance and/or indicates greater resilience to perturbations, etc.).

Objective

The objective is to develop processes and procedures to identify when variability observed in a particular biomechanical parameter for a particular task is "bad" variability that indicates neuromuscular pathology.

Achieving this objective will require bridging the movement domain *down* to the tissue and potentially cellular domains and also *up* to the clinical domain. This will satisfy the translational goal of taking multi-scale approaches to assessing movement variability and making them specifically clinically relevant.

Recommended Actions

We recommend the following specific actions:

1. Develop multi-scale frameworks (experimental and/or computational) to determine how stochastic processes at the cellular level ultimately give rise to movement-related variability at the muscle, limb, and eventually the whole body levels.
    - Isolating "bad" variability first requires that we understand where variability comes from.

2. Develop experimental and/or computational frameworks for determining exactly which kinds and/or sources of variability (a) directly *compromise* task performance, (b) *enhance* performance, and (c) are *irrelevant* to task performance (i.e., do not affect task outcome either way) in various tasks.
    - The knowledge obtained in (1) must then be used to determine how variability at the neuromuscular level affects motor function at the level of task performance.

3. Develop clinically relevant metrics and test protocols to reveal treatment outcomes and to ultimately guide treatment decision making to identify optimal levels of variability in designated movement tasks.
    - The insights obtained in (2) should ultimately be used to directly inform clinical practice.