BIOMECHANICS PRIORITIES CONFERENCE
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Recommendation Title: Verifying model and simulation of human movement accuracy.

Recommendation Code: LF1C

Category: Limb/Whole Body, Function

Recommendation

Background and Relevance

Understanding pathological movement in a clinical setting is extremely difficult because of the highly complex and non-linear characteristics of the neuromusculoskeletal system, the dynamic coupling that allows muscles to accelerate joints and segments they do not span and the presence of biarticular muscles that at times accelerate joints in the opposite direction from their anatomical classification. As a result, the root causes of pathological movement are obscured, making patient assessment difficult and resulting in treatment outcomes that are often unpredictable and likely sub-optimal. However, muscle-actuated forward dynamics simulations offer an extremely useful tool for understanding pathological movement because they allow for the identification of causal relationships between muscle excitation, specific neuromuscular and musculoskeletal properties and movement performance. One of the primary challenges facing all modeling and simulation approaches, whether simple or complex, is confirming the accuracy of the simulation output. Verifying whether the model is truly predictive of human performance is a critical step in establishing modeling and simulation techniques as an effective research tool to improving clinical outcomes. However, establishing accuracy is a formidable challenge since many of the quantities of interest are not measureable.

Objectives

1) Improve models of the neuromusculoskeletal system and establish their validity for simulating lower extremity function, abnormal movement, and neural control. Establish testing methods and norms for accuracy acceptability and standards for model complexity (e.g., model complexity leads to computational intensity, how complex does a model need to be to answer specific research questions). Develop guidelines for which research questions can be answered with generic models versus detailed subject-specific models (e.g., planning a patient surgical intervention vs understanding healthy muscle function). Develop objective methods to identify what the minimum elements are to model and simulate a given locomotor task.

2) Similarly, establish norms of acceptability for experimental data (e.g., appropriate levels of dynamic consistency between ground reaction forces and body segment kinematics).

3) Develop a framework using advanced imaging techniques for efficient development of subject-specific models. Develop technology to measure important model parameters and quantities in vivo (e.g. tissue elasticity, dynamic muscle force).

4) Improve muscle and metabolic cost models to increase the accuracy of force and cost predictions.

Recommended Actions

1) Set standards for rigorous model testing and parameter sensitivity to identify how sensitive the model predictions are to specific modeling assumptions. This will allow one to systematically define without prejudice the next research needed to improve the model's success in meeting desired research objectives.

2) Develop carefully designed experimental studies (e.g., apply external perturbations, FES or use instrumented implants) to confirm simulation results and provide impetus for the next generation of further improved models.

3) Develop mechanisms to facilitate multidisciplinary collaborations (bring together expertise) and resources (computational speed, algorithms) to develop subject-specific musculoskeletal models.