Are Our **Musculoskeletal** models too strong?

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**Introduction:** Subject-specific musculoskeletal modeling has been a powerful tool in estimating determinants of gait or other behavioral tasks through a complex symphony of experimental measurements and robust assumptions. Often times, researchers will “over-build” models either by increasing the max isometric forces of muscles or adjusting parameters such as the muscle tendon slack length until the model is capable of performing a desired kinematic task that would otherwise be impossible solely using estimates from cadaveric anthropometry or isovelocity measurements from “less-than-ideal” subject populations. Here, we used OpenSim Moco [1] and the popular Rajagopal2016 model [2] with a novel computational framework to determine ranges of knee joint loading from analytical expressions and metabolic rate using the Bharghava muscle metabolics probe [3] over a range of self-selected walking speeds. By identifying these limitations on muscle controls and their downstream forces or costs, researchers can further tune model parameters to produce more realistic simulations of human locomotion, and hopefully aid clinicians in providing more accurate diagnoses of pathological locomotion.

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**Figure 1:** Figures must include a caption of at least 9-point font. Figures may be any reasonable size but must be referenced in the text (e.g. “Fig. 1” to refer to this figure) and be positioned on the far-left or far-right of the page with the abstract text wrapped square around the figure and the caption. Tables may also be included.

**Methods:** Data of 8 subjects each walking at 4 self-selected walking speeds [4] were used to develop subject-specific scaled models based on a modified 19 DOF 76 Muscle Rajagopal2016 model using OpenSim. Tendon slack lengths were optimized for performing the range of desired gait speeds and muscle-driven bilaterally-symmetric marker-tracking simulations were generated using Moco with marker-tracking, contact-tracking, and control effort goals. All cost terms in the objective function were squared and the control effort cost was divided by the whole-body euclidean distance travelled to serve as a proxy for metabolic cost. As the musculoskeletal system is dynamically redundant with many muscles applying forces to bodies across the same joints, there are a hypothetical infinite number of suboptimal ways that the muscles can operate together to perform the exact same kinematic task. Optimal solutions generated with 101 mesh points were then used to perform vertex enumeration [5] of the set of all possible muscle activations within the nullspace of the kinematic tasks. In post hoc analysis, knee joint loading expressions were determined analytically to construct a linear map from muscle activation to simulated articular forces at the knee, and muscle fiber type ratios [6] were used to inform the metabolic rate map from muscle activations for each percent of the gait cycle. Significant differences in muscle activation, joint reaction and metabolic rate were identified by one-way repeated measures ANOVA using one-dimensional statistical parametric mapping.

**Results & Discussion:**

**Significance:**

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**References:**

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