CAN PARTICIPANT-SPECIFIC SEGMENTAL INERTIAL PARAMETERS IMPROVE THE VALIDITY OF MUSCULOSKELETAL MODELS FOR FORWARD DYNAMICS SIMULATIONS DURING SIDESTEPPING?

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INTRODUCTION

Forward dynamic simulations run with musculoskeletal models in OpenSim can shed some light on the multiple, and often non-intuitive, muscle activation strategies employed to support ACL loading during non-contact sidestepping in sport. However, the validity of the musculoskeletal model for forward dynamic simulations may be compromised if the adopted segmental inertial parameters (IP) are not participant-specific. More specifically, inaccurate segmental IP may lead to inconsistencies between the measured ground reaction forces (GRF) and the model kinematics used to find a pattern of muscle excitations via the optimization solution. By default, OpenSim re-scales a generic musculoskeletal model to predict the IP of the participant. Although segmental IP of elite athletes are shown to be not accurately predicted using generic scaling equations [1], the effect of inaccurate segmental IP on the validity of the musculoskeletal model remains unknown.

The inconsistency between the experimental GRF data and the dynamics of the musculoskeletal model is assessed by computing the residual forces held at the pelvis segment using inverse dynamics. Therefore, the aim of this study was to determine whether musculoskeletal models that account for participant-specific segmental IP instead of re-scaled IP from a generic model yield reduced pelvic residual forces during non-contact sidestepping of elite athletes.

METHODS

Fourteen members (24.7 ± 3.4 years) of the Australian National Women's Hockey team, clear of any lower limb injury at the time of data collection participated in this study. Each participant underwent a full body DXA scan with the GE Lunar Prodigy DXA densitometer (GE Healthcare, Bucks, UK) as a means to estimate participant-specific segmental IP using a previously published method (DXA/Vol) [2]. Two musculoskeletal models were created per participant; one model adopted segmental IP re-scaled from a generic OpenSim model (OSIP) and the other model adopted the IPs estimated with DXA/Vol [2,3].

A full-body custom markerset comprising 56 markers was affixed to the participants who then completed a published planned sidestepping protocol [3]. Marker trajectory and GRF data for sidestepping were recorded using a 22-camera (250 Hz) motion capture system (Oxford Metrics, Oxon, UK) and a force platform (2,000 Hz, Advanced Mechanical Technology Inc., Watertown, MA) respectively. These data were then low-pass filtered (14 Hz) using a zero-lag 4^{th} order Butterworth filter and exported to OpenSim to compute the residual force components held at the pelvis segment for each of the two musculoskeletal models [3].

To compare the waveforms of the mean residual force components for each model, the test statistic SPM {t} was computed with the one-dimensional statistical parametric mapping package (SPM1D) in Matlab [4]. A critical threshold t* was computed using the random field theory [4] and the Šidák threshold p=0.0170 to maintain a constant family-wise error rate of α=0.05 for all residual force components.

RESULTS AND DISCUSSION

Significant differences were observed only in the transverse (13%–24% and 85%–100% stance, p<0.001) and sagittal (9%–25% stance, p<0.001) directions (fig 1). In these zones of significance however, DXA/Vol models did not always yield smaller residual force magnitude (i.e., values closer to 0). Indeed, the residual forces, mainly in the longitudinal direction, appear to be more meaningfully affected by other modeling (e.g., segment rigidity and joint constraints) and processing (e.g., kinematic signal) sources of errors (fig 1).

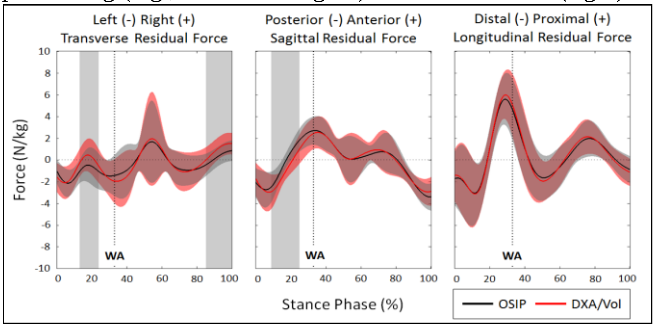

Figure 1: Mean residual force components and the zones of significance (shaded gray area). WA= weight acceptance.

CONCLUSIONS

Participant-specific segmental IP did not have a meaningful impact on the validity of the musculoskeletal model during planned sidestepping of elite female hockey players. Other modeling and processing sources of errors require attention before forward dynamic analysis of sidestepping be adopted.

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