Impact of Model Parameters on Ground Reaction Force Predictions in Musculoskeletal Modelling

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Summary

This study evaluated how model parameters affect ground reaction force (GRF) predictions in musculoskeletal simulations. A parameter study varying contact height and velocity thresholds and marker weights was conducted. While height and velocity thresholds had minimal impact, marker weights impact prediction errors. These findings highlight the importance of carefully selecting model parameters.

Introduction

Musculoskeletal models are a valuable tool to study human movement and musculoskeletal loading for a wide variety of different applications. Traditionally measured GRF are used as input. The measurement of GRF relies on force plates, which makes it expensive and mostly bound to laboratory settings. To address this issue new methods were introduced that derive GRF directly from full-body kinematics. One way to predict GRF is by including contact elements on the sole of the foot into musculoskeletal simulations and solving the forces of these elements as part of the muscle recruitment [1,2]. The sensitivity of this method towards model input parameters has not been thoroughly studied. This study aimed to assess how changes in model parameters affect the predicted GRF.

Methods

Musculoskeletal simulations (AMS, v8.0.0, AnyBody Technology, Denmark) were performed using the data set of the sixth grand challenge competition to predict in vivo knee loads [3]. To assess possible influences a parameter study was performed: The height threshold ($dist_{limit}$) and the velocity threshold (vel_{limit}) of the floor contact detection, as well as the marker weights for foot markers (MW_{foot}) and trunk markers (MW_{trunk}) were varied. Simulations were performed for a sample of 500 parameter combinations, generated via Latin-hypercube-sampling. Predicted and measured GRF were normalized to body weight (BW) and compared using the root mean square error (RMSE).

Results and Discussion

RMSE ranges from 0.06 to 0.14 BW (Figure 1). Previous studies fall within this range [1]. For $dist_{limit}$ and vel_{limit} no clear trend in the effect on the RMSE is visible. However, values at the lower end of the range for $dist_{limit}$ result in a high RMSE. Increasing MW_{foot} tends to increase the RMSE but the effect levels off for higher marker weights. Increasing MW_{trunk} tends to decrease the RMSE with the effect again levelling off for higher marker weights. However, due to the high scatter in the data the parameters that cause the highest and lowest RMSE do not follow the trends. To establish ground contact at the right moment, $dist_{limit}$ and vel_{limit} must be set accordingly. The results suggest that once these parameters are above a minimum threshold they no longer have a major influence.

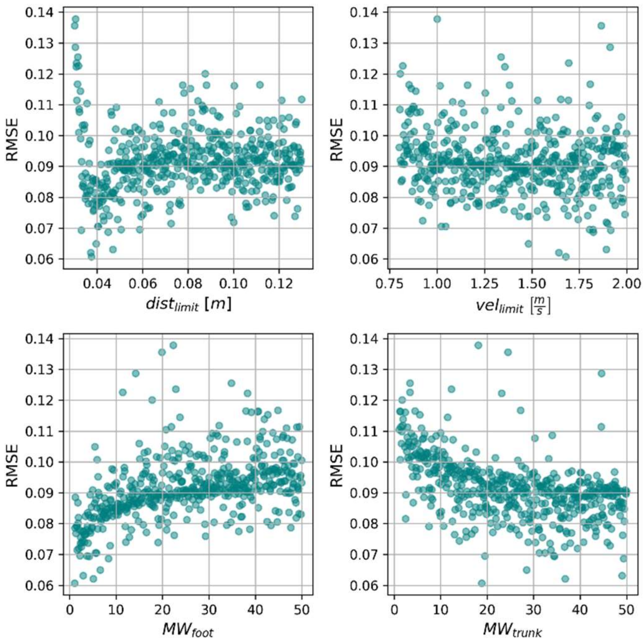

Figure 1: Influence of $dist_{limit}$, vel_{limit}, MW_{foot}, and MW_{trunk} on the RMSE between predicted and measured GRF

Marker weight affects full-body motion and therefore also predicted GRF. Interestingly, increasing the marker weight for the foot—which prioritizes closely tracking foot motion—does not lead to improved GRF prediction accuracy. Contrary a high marker weight for the trunk reduces the RMSE. If the recorded trunk motion is not followed accurately the resulting inertial forces are also not accurate leading to a deviation in predicted GRF. This is especially important as the mass of the trunk segment is high compared to other segments [4].

Conclusions

While height and velocity thresholds play a minor role, marker weights are important for predicting GRF. Researchers must be aware of how their choice of input parameters affects the error of predicted GRF.

References

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