SPRINTING DATA-TRACKING SIMULATION: A DIRECT COLLOCATION APPROACH

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INTRODUCTION

Predictive simulations are often used in sports biomechanics to explore optimal solutions that cannot be identified embracing experimental approaches. Understanding how to improve sprint running performance is a perfect case study in this regard. An important, and often neglected, first step towards ensuring realistic simulation results is to evaluate them against experimentally collected data (Yeadon & Challis, 1994). The aim of the current study was therefore to assess the capability of simultaneously reproducing kinematics and kinetics data during the acceleration phase of a sprint by solving a data-tracking problem.

METHODS

One male sprinter (age: 24 years; height: 1.79 m; mass: 72.2 kg; 100 m PB: 10.33 s) completed two maximal effort sprints on an indoor running track. Three-dimensional kinematics (250 Hz, Oqus, Qualisys AB, Sweden) and ground reaction forces (2000 Hz, Kistler, Switzerland) were collected between the 15-20 m mark. The data from one stance phase was used for the purposes of this study.

A full-body 37-DOF model (Hamner *et al*., 2010) driven by 37 ideal joint actuators was scaled in OpenSim 3.3 (Stanford University, USA) (Delp *et al*., 2007). Foot-ground contact was modelled using a smoothed Hunt-Crossley contact model (Serrancolí *et al*., 2018). Inverse kinematics and dynamics analyses were performed in OpenSim. The joint kinematics and torques together with the ground reaction forces served as the experimental data to track and were evaluated against using root mean squared errors (RMSE).

A data-tracking simulation of the contact phase was performed by converting an optimal control problem into a nonlinear programming (NLP) problem using a direct collocation method (Lin & Pandy, 2017). The NLP was solved by using the MATLAB optimisation toolbox function 'fmincon' (version 7.5, 2016b, MathWorks Inc., Natick, MA) in combination with OpenSim.

RESULTS AND DISCUSSION

Our data-tracking simulation was able to successfully reproduce the experimental ground reaction forces and kinematics with promising accuracy as shown by the RMSE (Table 1). The data-tracking simulation reduced the six pelvis residuals on average by ~92%, however the simulated joint moments (Figure 1), despite having a similar pattern to the experimental, showed quite a large RMSE (hip: 46.7, knee: 31.5, ankle: 30.7 Nm).

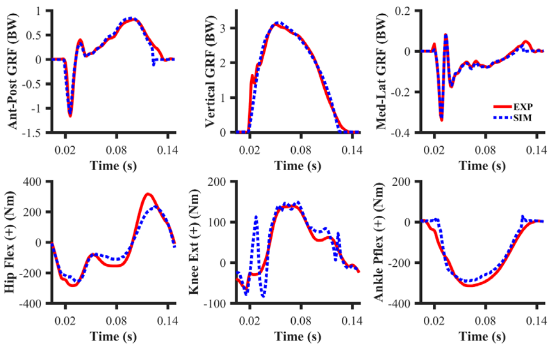

Figure 1: Simulated (dashed blue line) and experimental (solid red line) ground reaction forces (first row) and hip, knee and ankle joint moments (second row).

Table 1: RMSE between simulated and experimental data. Maximum RMSE are presented for kinematic data.

Variable	RMSE
Pelvis Orientation	4°
Pelvis Translation	0.37 cm
Joint Angle	3°
Pelvis Orientation Velocity	$45°\cdot s^{-1}$
Pelvis Translation Velocity	$0.15\ m\cdot s^{-1}$
Joint Angular Velocity	$55°\cdot s^{-1}$
Ant-Post GRF	0.09 BW
Vertical GRF	0.18 BW
Med-Lat GRF	0.01 BW

CONCLUSION

The simulation results are promising considering the dynamic nature of the movement tracked, the complexity of the model used, and the multiple data-tracking method. This is an excellent first step towards a fully predictive approach, where we aim to explore how changes in technique influence sprint running performance.

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