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PREDICTION OF GROUND REACTION FORCES DURING RUNNING

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Summary: Although research on running biomechanics has been increasing in popularity, some restrictions, especially regarding data acquisition, limit the development and application of computational models. While some alternatives exist to the use of stereography for collecting the human body kinematics, such as marker-less approaches, the same cannot be said of the methodologies used to measure ground reaction forces (GRF). Well established gold standard techniques in this field are force platforms, and both instrumented walkways and treadmills. However, these approaches are restricted to the laboratory setting, when available as they are expensive, and are not portable. Pressure insoles can overcome some of these methodologies' shortcomings, but there have been studies that describe clear differences in the shape and magnitude of the force curves when compared to force platforms. Moreover, frequent need of calibration and the lower sensitivity make the pressure insoles an unreliable alternative to measure GRF during running. Previous computational studies were able to estimate GRF using kinematic data and a biomechanical model of the human body, but the foot was modelled as a single rigid body. To the authors' best knowledge, the effect of the addition of degrees of freedom (dof) on the foot regarding the GRF estimation remains unknown. This work proposes an upgrade to the existing computational procedure used to estimate GRF quantification, while considering a complex foot structure. To this end, a full-body musculoskeletal model composed of 18 rigid bodies was created. The arms, forearms, head and trunk, pelvis, femora, patellae, tibiae, tali, calcanea and toes were constrained by spherical and revolute joints, totaling 25 dof. The movement of the patella was simplified, and it was considered rigid in relation to the femur. The muscle system included 80 muscle-tendon units with their contraction dynamics represented by a Hill-type muscle model. The GRFs are estimated by solving the Newton-Euler equations of motion, along with the indeterminate problem of muscular redundancy using Inverse Dynamics, an optimization routine, and a dynamic contact model. This dynamic contact model includes several contact elements on each foot of the musculoskeletal model and a strength profile attributed to each one. Kinematic data, required for the application of the developed methodology, were acquired at the Laboratory of Biomechanics of Lisbon. Subjects, with no story of musculoskeletal disorders, walked and ran at a self-selected speed over floor mounted force platforms for verification of the methodology. The markers were placed according to the ISB recommendations and were used to drive the musculoskeletal model. This method was applied to all subjects and compared to measured force plate data. Preliminary results showed that the proposed methodology was able to estimate GRFs that were consistent with the data from the force plates. The joint reaction forces, joint torques, and muscular activations estimated through inverse dynamics were also consistent with the literature. The proposed method is expected to be a valid alternative to the use of force plates in laboratorial settings, allowing for a higher flexibility of GRFs acquisition while still maintaining high accuracy.