MECHANICAL MODEL OF HUMAN STABILITY ON EXTERNAL FORCE-CAUSED FALL

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Introduction

Human movement analysis is an increasingly popular topic. However, there is still a need to develop knowledge about estimating the forces and moments of forces acting in the joints, since they cannot be measured unequivocally. The task gets even more difficult when the external force acting on the human body occurs. Thereto, the authors propose a model of human motion treated as a semi-closed chain, defined by the Euler-Newton equations [1]. This model was tested on the example of a force-caused fall, i.e. a fall that may occur during a sudden braking of a public transport vehicle. The input data were obtained with the use of an optoelectronic motion capture system BTS Smart, AMTI dynamometric plates and a dynamometer. The proposed model can be later on applied in devices for monitoring and assessing human movement.

Human body biomechanical model

The developed mechanical model can be described as a partially closed-chain two-dimensional model. Both legs are standing on separate dynamometric platforms so, the information on ground reaction forces (GRF) and centre of pressure (COP) of each of the lower limbs can be taken into calculation. Therefore, the values obtained from the platform on which the right leg is standing are treated as input data, while the analogous values obtained from the other platform are used to validate the model and the entire calculation procedure. This makes a closed chain from the right to the left lower limb. The part which makes the model partially closed chain is the upper part of the body – upper limbs and torso. To calculate the inertial and mass parameters, Demster's model was applied [2].

Mathematical model

In the described model the human body was divided into 13 segments: 2 feet, 2 shanks, 2 thighs, a torso with a head as one segment, 2 arms, 2 forearms, and 2 hands. For each segment, the set of three equations was written, in agreement with the Newton-Euler method. In the end, the set of 39 equations and 39 unknowns is obtained. To calculate the necessary acceleration input data, Taylor's series was used. This scheme was also applied for smoothing the data.

Results

The presented method allowed for the acquisition of a mechanical model of human motion in two-dimensional space. The vertical (Y) and horizontal (Z) forces obtained with the use of the model and measured by the force plates are shown in Figure 1. Additionally, the wavepath of the external force applied to the participant is shown. One can notice, that the waveform representations of the GRF in time are less accurate when the system is perturbated by an external disturbance – while accelerations and inertial parameters have a more significant impact on the performance of the model. However, the vertical force calculation gives an accurate outcome.

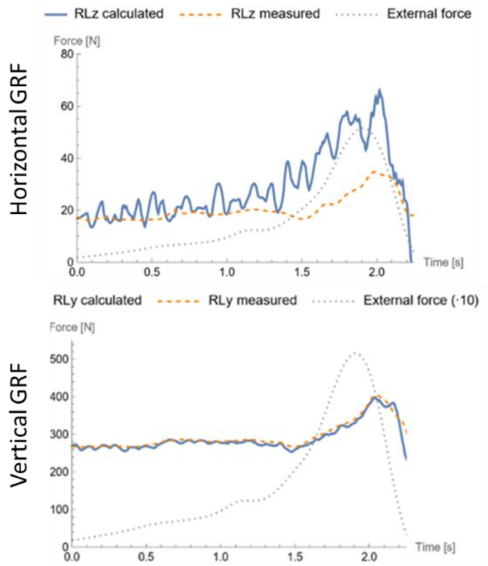

Figure 1. Obtained vertical and horizontal GRF and vertical GRF measured with the force plate for the external force-caused fall with a single pull.

Conclusions

The proposed model can be considered sufficient for biomechanical studies. The inertial parameters of segments of the body have a crucial impact on the performance of the model, especially when studying fast-changing movements.

References

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