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Correlation of Biomechanic Performace Measures with Acceleration and Deceleration in Human Overground Running

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Abstract: Biomechanics of human running has been researched by many scientists over the last decades. However, there are still open questions, especially about the role and operation of the central nervous system. Obviously, a certain optimization process, which employs a combination of possibly time variant cost functions, makes adaptation possible to the changing conditions. Our long-term goal is the understanding of these processes based on experimental evidences. Narrowing down this mighty problem, we focus on the exploration of the changes in kinematics, related to well-defined cost functions, such as energy dissipation, energy conservation or energy accumulation. These cost functions are in analogy with deceleration, constant speed locomotion and acceleration. Hence, we collected measurement data of eight athletes with five different tasks: 1) slow, 2) moderate, 3) high speed running, 4) acceleration and 5) deceleration. We identified the biomechanics performance measures from the literature that are in statistically proven correlation with the cost functions. Wilcoxon signed-rank test indicated the most significant difference in the relative and absolute angles, total force, angular velocity and distance between the centre of pressure and centre of mass in case of different cost functions.

Keywords: human running, biomechanics, acceleration, deceleration, gait optimization

1. Introduction

Scientific papers exuberate in measurement data related to acceleration in the stance phase [1, 2]. However, the literature lacks of analyses for deceleration, and particularly for the airborne phase. Thus, we collected new data related to varying speed locomotion. Eight non-professional athletes were observed while they were performing five different tasks. The kinematics was recorded by OptiTrack optical motion capture system, and we used Moticon Science Insoles to assess the foot pressure distribution. Metrics characterizing the locomotion were calculated from the raw data, including the joint/segmental angles, centre of pressure position and ground reaction force components.

2. Results and Discussion

The metrics $m_i(t)$, such as segmental angles and force data were stored as time functions. The scalar measures at phase-transitions and extremes were extracted: $m_i(t_{\mathrm{IC}})$ at initial contact, $m_i(t_{\mathrm{TO}})$ at toe off, $\max(m_i(t))$ and $\min(m_i(t))$. The average and the confidence interval (significance level p=0.95) were calculated to visualize the data. The most used visualization techniques are collected in Fig. 1. Wilcoxon signed-rank test was used to identify the metrics, based on which the cost-functions could be identified. According to the Wilcoxon signed-rank test, there is a significant difference in case of the relative and absolute segment angles, total force, angular velocity of the foot and distance between the centre of pressure and centre of mass.

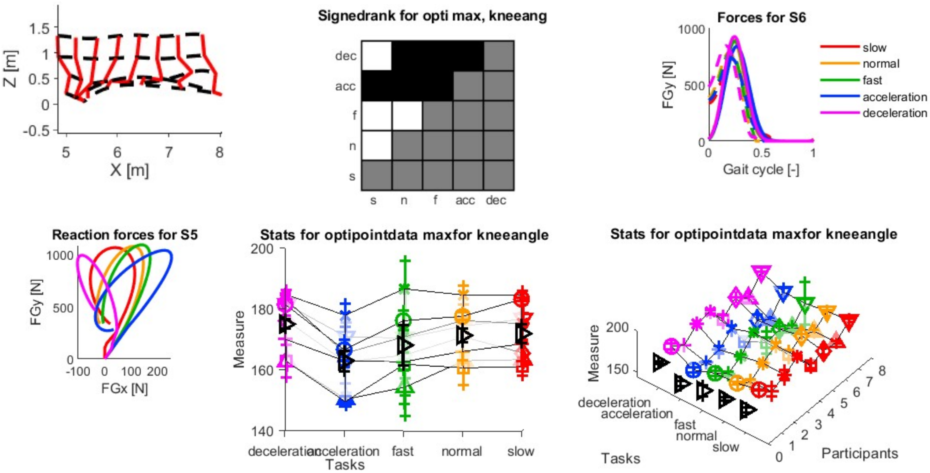

Fig. 1. Tools for data comparison and statistics: stroboscopic visualization of the motion (top left panel); matrix plot of the signed-rank test, where black / white tiles indicate significant difference / not proven difference for each scalar measure (top middle panel); measured and inverse dynamics calculated vertical ground reaction force (solid and dashed lines on the top right panel respectively); path of the ground-reaction force vector [1] (bottom left panel); confidence intervals for each task in case of each scalar measure (bottom middle panel); confidence intervals for each task and each subject in case of each scalar measure (bottom right panel).

3. Concluding Remarks

Metrics, which are already introduced in the literature, were used to observe quantitative changes between different cost functions in case of different velocities, acceleration or deceleration. These results allow us to create predictive models of human gait and kinematics reproduction. Functional role and movement strategy of each joint would be identified [2, 3] and included into the models in future work.

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