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Statistical Analysis of Performace Measures During Acceleration and Deceleration in Overground Running

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EXTENDED ABSTRACT

1 Introduction

Human running has been an increasingly popular research topic over the last decades. There are plenty of open questions, especially regarding the operation of the central nervous system (CNS) and the underlying optimization principles. Based on previous studies, the description of those optimization processes is possible based on a combination of time-variant cost functions. Our long-term goal is to understand this process based on experimental evidences, 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. Numerous scientific papers provide 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. We think that deceleration should be investigated, since better understanding of the CNS's optimization principles become possible. Furthermore, many injuries happen during deceleration. Thus, we collected new data related to varying speed locomotion and compared constant velocity running, acceleration and deceleration.

2 Methods

Eight non-professional athletes (3 males, 8 females, age: 17,9$\pm$3,9; height: age: 1,697$\pm$0,69 [m]; weight: 57,4$\pm$11,7 [kg]) participated in the measurement. They were performing five tasks corresponding to different cost functions: 1) slow, 2) moderate, 3) high speed running, 4) acceleration to full speed and 5) deceleration from full speed. The kinematics was recorded by OptiTrack motion capture system, and we used Moticon Science Insoles to assess the foot pressure distribution. The beginning and the transition of the gait cycles (initial contact - IC and toe off - TO) were identified. Metrics characterizing the locomotion, e.g. joint/segmental angles, position of the centre of pressure (CoP) and its distance from the centre of mass (CoM) and ground reaction force components, were calculated from the raw data for every gait cycle. We also used an inverse dynamics model to evaluate the forces and moments acting on the joints.

3 Results

The measures $m_i(t)$, such as segmental angles and force data were stored as time functions. The scalar values at stance and flight transitions and extremes were extracted: $m_i(t_{IC})$ at IC, $m_i(t_{TO})$ at TO, 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, which could identify the cost-functions for the different tasks. We also made a correlation analysis to determine, whether there is a correlation between the speed and measures (for constant velocity running) or between the running type (deceleration, constant speed and acceleration) and the measures. Fig. 2 shows plots related to the data analysis. Based on the resuls of the Wilcoxon signed-rank test, we can state that 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. Those differences are also visible on the time-functions. For constant speed running, we found that there is a strong correlation between the velocity of the participants and the elevation of the toe and the ankle, therefore the foot, shank, thigh and knee angles also show correlation. Angular acceleration and the CoP-CoM distance also correlate with the velocity. For the deceleration-constant speed running-acceleration comparison there is a strong correlation between the running types and the thigh angle, trunk angle and the x-components of the forces acting in the joints (x axis shows the direction of the locomotion).

4 Conclusions

Metrics, taken from the literature, were used to observe quantitative changes caused by different cost functions in case of different velocities, acceleration or deceleration. We could also observe some trends regarding the changes caused by the different locomotion types or velocity difference. These results help 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.

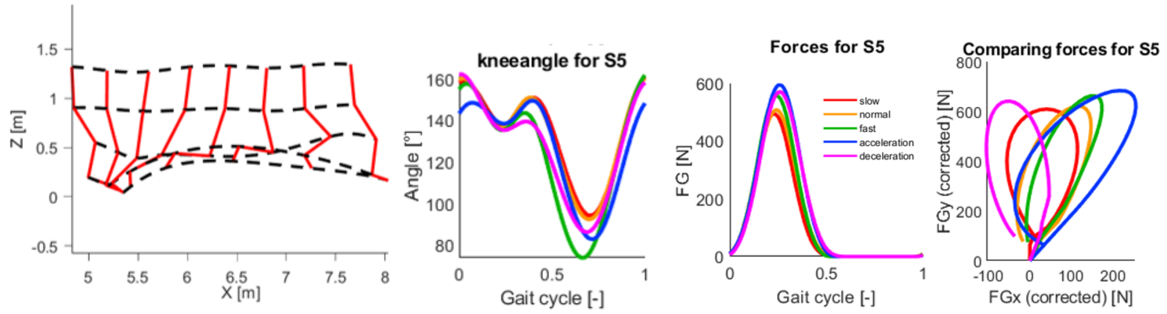

Figure 1: Tools for data visualisation and statistics: stroboscopic visualization of the motion (first panel); knee angle changes during a gait cycle; measured vertical ground reaction force (third panel); path of the ground-reaction force vector [1] (fourth panel).

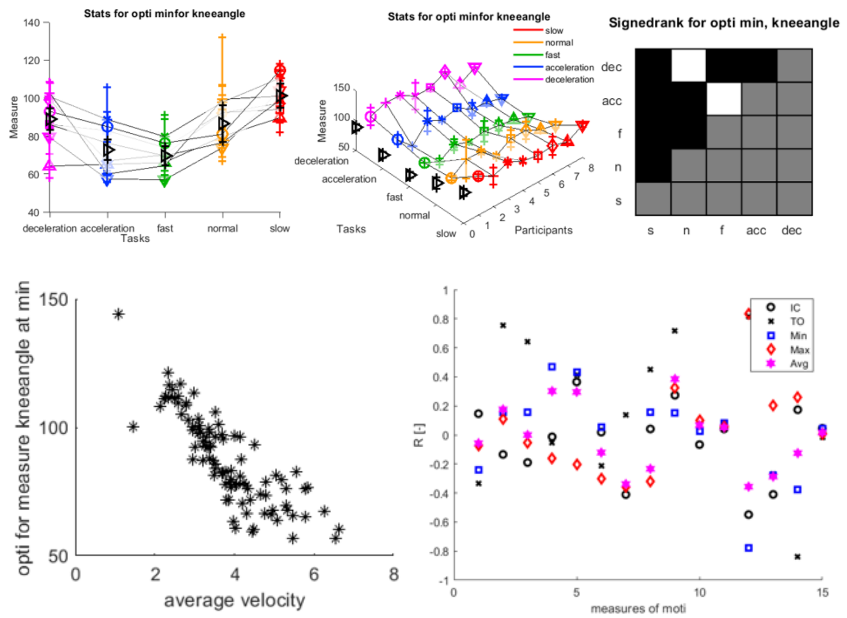

Figure 2: Tools for statistics: confidence intervals for each task in case of each scalar measure (top left panel); confidence intervals for each task and each subject in case of each scalar measure (top middle panel); matrix plot of the signed-rank test, where black / white tiles indicate significant difference / not proven difference for each scalar measure (top right panel); example data plotted for the knee angle minimum to calculate correlation (bottom left panel); correlation coefficients for the measures taken from Moticon (bottom right panel).

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