LEG STIFFNESS IN WALKING AND RUNNING

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INTRODUCTION

There is a good deal of published research available on the mechanics of running regarding leg stiffness and stability [2, 4]. A simple spring-mass model for running had been proposed [1, 5], which provides a basis for further investigations. The work of Seyfarth et al. (2002) exposes spring-like leg operation, minimum running speed, and adjusted leg stiffness and angle of attack as prominent requirements of mechanically self-stabilized running. For walking, however, it seems to be a much greater challenge when attempting to propose respective simple templates. This study targets the leg stiffness, to determine whether running and walking patterns are stable. Aims of this study therefore were a) calculating the correlation coefficients of leg stiffness in running and walking, and b) comparing leg stiffness of both gaits. We hypothesized that vertical ground reaction forces (GRFs) and displacement of the center of mass (CoM) would correlate significantly in a positive linear way for running as well as for walking. We also hypothesized no significant intra- or inter-individual differences for leg stiffness.

METHODS

9 healthy subjects (4 women and 5 men) were randomly selected from an athletic population. Subjects had a number of reflective markers placed over anatomical landmarks to calculate positions of body segments. Ground reaction forces (GRFs) during running and walking were measured on a special split-belt treadmill, where each belt covered a Kistler force plate (2000Hz). 3D coordinates of the reflective markers were recorded simultaneously via six high-speed (150Hz) video cameras (Qualisys). Subjects were required to perform 13 gait transitions (6 x walking, 6x running) at their individual transition speeds, determined in a pretest. Time of transition was signalized by an acoustical signal occurring every 10 seconds. Raw force plate data was processed using custom software (Matlab, Mathworks Inc.). For each stance phase (heel-strike to toe-off), the vertical CoM displacement was calculated by numerically integrating the vertical force. Total vertical GRF (right GRF + left GRF) was then plotted over CoM displacement for each stance phase in running and walking to represent leg stiffness. Correlation coefficients between vertical GRF and CoM displacement and regression lines were calculated on individual stance phase data. A simple analysis of variance (ANOVA) was conducted to determine for significant differences within and between subjects. Both, walking and running were analyzed.

RESULTS AND DISCUSSION

High correlation coefficients of over 0.95 were observed for all data. The results also showed that neither intra-individual nor inter-individual stance phase data did differ statistically with p values being near zero (Figure 1).

Given the fact that stance phase data of both, running and walking, was collected at the same forward speed, it is well justified to compare leg stiffness across both gaits. Two main observations emerged from our comparisons: the vertical stiffness of the leg can be considered as a linear spring not only for running but also for walking. While not exactly the same regressions, there is still a close proximity of the spring-like leg behaviors apparent. The observed smaller vertical excursions of the CoM in walking correspond to the absence of flight phases, where instead single support occurs as opposed to double support.

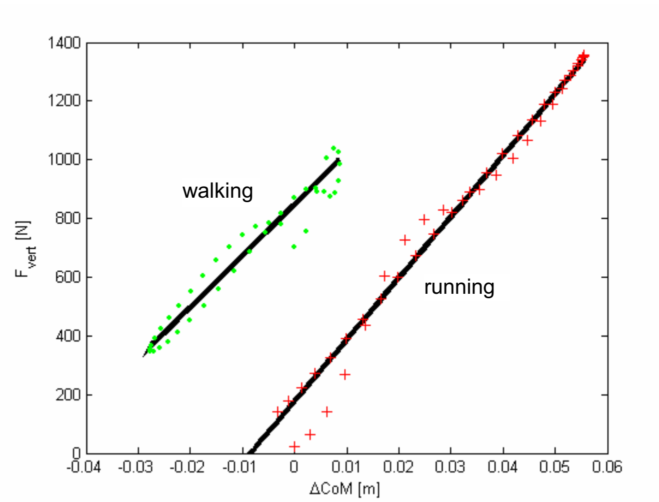

Figure 1 Mean vertical GRFs and CoM displacement data shown as scatter plot and regression line representing leg stiffness in walking (left) and running (right).

CONCLUSION

Mathematical models have already been successfully applied to describe experimentally observed GRFs for running [3, 6]. Further research is currently done to extend these models by a second spring-like leg.

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