ISB 2013
BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL
SOCIETY OF BIOMECHANICS

XV BRAZILIAN CONGRESS
OF BIOMECHANICS

REALTIME BIOFEEDBACK OF THE MECHANICAL STRESS ON THE LEGS DURING RUNNING

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SUMMARY

We evaluated the effects of real-time biofeedback of the mechanical stress on the legs during running. We used an instrumented treadmill for biofeedback. Initial peak of the ground reaction force and the leg stiffness value calculated based on the mass-spring model was visually shown to the subjects. The subjects were instructed to reduce these values while running. Running motion was captured using an optical motion capture system. The data were processed through inverse dynamic analysis, out of which joint motion, moments, reaction forces and muscular tensions were obtained. It was found that initial peak of the ground reaction force as well as joint stiffness can be effectively adjusted using visual biofeedback. It was also clarified that some major muscles of the leg contribute to this change.

INTRODUCTION

Running is a popular form of exercise that people can start relatively easily. Although there are quite a few people who enjoy running as a regular exercise, there also exist a certain percentages of running injury. It is assumed that these injuries partly come from the lack of knowledge regarding the mechanical stress loaded on the legs during running.

Figure 1. The instrumented treadmill used in this study.

During running, approximately twice to three times of body weight is loaded on a single leg, and this is repeated for thousands of times. Therefore it is quite important to give a serious consideration to the mechanical stress loaded on the legs during running [2].

In this study, we had three specific aims. (1) We aimed at analyzing the mechanical stress loaded on the legs real-time, using an instrumented treadmill. Specifically, we calculated the initial peak of the ground reaction force, and the stiffness of legs derived based on the mass-spring model. (2) We constructed a system of real-time visual biofeedback of the above mentioned variables. In addition, we instructed the subjects to adjust the values with the clue of visual feedback. (3) We analyzed the change of musculoskeletal behavior associated with the visual biofeedback. We used a three-dimensional musculoskeletal simulation model for this analysis.

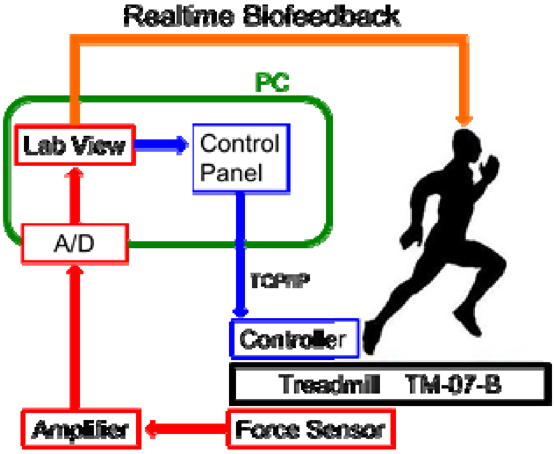

Figure 2. The experimental system developed in this study.

METHODS

We performed data collection in two areas of the laboratory. One is a corner in which an instrumented treadmill is installed. The other is an open-space floor in which motion capture system is installed.

Biofeedback on the treadmill: For the biofeedback, we used a split-belt instrumented treadmill (ITR3017, Bertec; Figure 1). The treadmill has built-in force sensors and can output 6 force components (3 force components and 3 moment components) for each leg real time. The data were taken into a personal computer using an A/D converter and house-made computer programs (LabView, National Instruments; Figure 2). The sampling was performed at 1000 Hz. Initial peak of the ground reaction force [3] and the stiffness of the leg based on the mass-spring model [1, 4] were calculated from the force platform data (Figure 3). These data were presented on a large monitor placed in front of the subject.

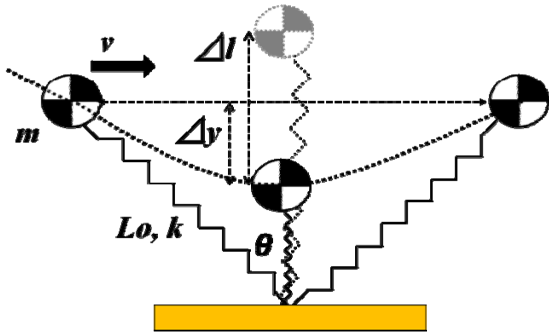

Figure 3. The mass-spring model used in this study.

Open-space motion capture: For the motion capture system, we used an eight cameras whole body capture system (MAC3D, Motion Analysis Corporation) and four force platforms (Advanced Mechanical Technology, Inc.). The data were sampled at 200 Hz. Inverse dynamic analyses were performed on the data to obtain the values of joint moments and reaction forces. In addition, tension values of individual muscles were calculated using an optimization procedure. A commercial simulation software package of human musculoskeletal system (nMotion musculous, nac Image Technology, Inc.) was utilized.

Experimental procedure: The experiment was performed in six phases. (1) The subjects ran on the treadmill at constant speeds for a few minutes, without visual feedback. They got used to running at the specific speed through this phase. (2) The subjects immediately moved to the open space and ran at the same speed. The motion was captured, and the data were further analyzed using the musculoskeletal model. (3) The subjects ran on the treadmill at constant speeds with visual feedback. Their task was to reduce the initial peak value of the ground reaction force. (4) The subjects immediately moved to the open space and ran in a similar manner. The motion was captured, and the data were further analyzed using the musculoskeletal model. (5) The subjects ran on the treadmill at constant speeds, with visual feedback. Their task was to reduce the stiffness value of the leg. The stiffness of the leg was calculated based on the data of constant belt speed and ground reaction force. (6) The subjects immediately moved to the open space and ran in a similar manner. The motion was captured, and the data were further analyzed using the musculoskeletal model.

RESULTS AND DISCUSSION

Initial peak of the GRF: We found that the initial peak value of the ground reaction force was reduced with visual feedback. The effect was consistent in all the subjects. The average value changed from 1.50-1.71 body weight to 1.32-1.38 body weight during 2.0-3.0 m/s of running.

Stiffness of the leg: We found that the stiffness of the leg was also reduced with visual biofeedback (Figure 4). The effect was consistent in all the subjects. The average value changed from 18.08-19.50 to 6.80-14.36 during 2.0-3.0 m/s of running (the unit of the value is normalized by [body weight]/[leg length]).

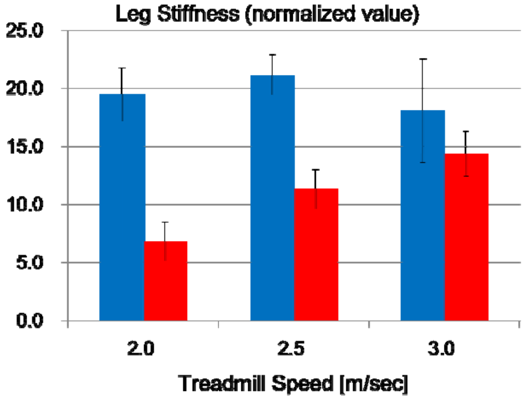

Figure 4. The change of leg stiffness with biofeedback. The left, blue bars correspond to no biofeedback. The right, red bars correspond to with biofeedback.

Changes of the muscular activity: There were clear differences in the activities of some major muscles around the leg joints. Changes were also observed in joint motion patterns, which reasonably explained the reduction of the mechanical stress considered in this study.

Contribution of this study: It is hoped that this study contributes to reducing the cases of running injury. It was made clear that the initial peak of the ground reaction force as well as the stiffness of the leg can be adjusted with the clue of visual biofeedback. It was also found that the joint motion and the activity of some major leg muscles change with feedback. This knowledge as well as the system developed in this study will have a great contribution in future studies.

Future plans: We still have not found the "optimal" values for the initial peak of ground reaction force and the leg stiffness. Therefore we still do not know to what values these parameters should be adjusted. This issue needs to be addressed in future studies.

CONCLUSIONS

We found that visual biofeedback can be used to adjust the values of mechanical stress such as initial peak of ground reaction force and leg stiffness. We also found that the activities of some major muscles change. We aim to address the limitations of this current study and contribute to reducing the cases of running injuries in the future.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Number 24680067, and the Descente and Ishimoto Memorial Foundation for the Promotion of Sports Science.

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