Prediction of 3D GRF during running from a single sacral measurement using artificial neural network.

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***Abstract*— In order to monitor the risk of injury, many studies have been conducted to estimate the ground reaction force (GRF) from motion data using machine learning. However, at least three sensors were required. Recently, in walking, GRF could be estimated from a single sacrum-mounted IMU using spring-loaded inverted pendulum (SLIP) model and feed forward artificial neural network (FFNN) [3]. Since running can also be interpreted using SLIP model, this study proposes a method for estimating 3D GRF during driving using FFNN from sacrum displacement. Sacrum displacement and GRFs were measured on treadmills of seven subjects, and the GRFs was estimated using three-layered FFNN. As a result, it was possible to estimate all three-axis GRFs. Among them, vertical GRF (VT) and anteroposterior GRF (AP) were estimated with high accuracy (NRMSE: 8 ~ 12% and r: 0.96 ~ 0.99). In conclusion, we could reduce the number of measurements required for estimating GRF by using the idea of mechanical model and machine learning.**

Keywords—Running, Estimating GRF, Artificial neural network

I. Introduction

Many studies have been conducted to estimate the ground reaction force(GRF) from motion information to monitor injury risk, but they need more than three sensors [1]. Recently, GRF was estimated from a single sacrum-mounted IMU using spring-loaded inverted pendulum (SLIP) model and feed forward artificial neural network (FFNN) [2]. Since running can also be interpreted as a SLIP model, this study proposes a method of estimating 3-axis GRFs from sacrum kinematics based on SLIP mechanics during running.

II. Method

The 3-axis sacral displacement and time measured from the optical motion capture system were used as input data. The FFNN used was a three-layered feedforward neural network consisting of input layer, hidden layer having 10 hidden nodes, and output layer. To ensuring generalization of methods, leave-one-subject-out cross validation was used. Seven subjects participated in the experiment, which ran at 2.85 m / s on a treadmill with a built-in force plate. 10 steps of sacrum trajectory and GRF data were used.

III. Results

The results of estimation GRF are shown in Fig.1 and Table 1. Vertical GRF (VT) was most accurately estimated (NRMSE: 8.72 ± 4.16%, r: 0.99 ± 0.02) and mediolateral GRF (ML) was estimated with the lowest accuracy (NRMSE: 44.44 ± 6.91%, r : 0.68 ± 0.32).

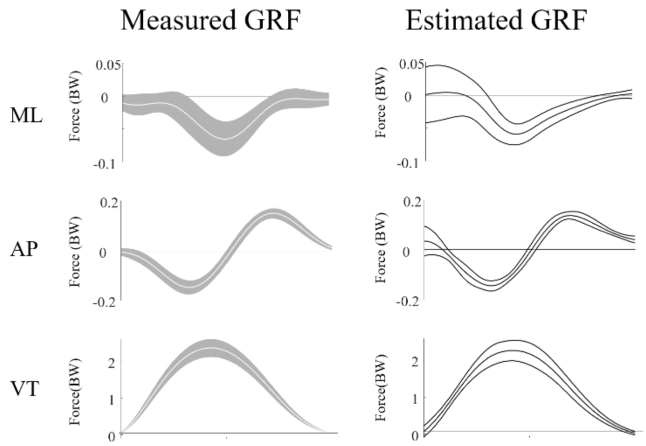

Fig 1. Measured GRF(left column) and estimated GRF (right column). Each row denotes three directions of GRF, mediolatral(ML), anteropostrior(AP) and vertical(VT). The unit of force is body weight (BW)

TABLE I. Prediction result

	RMSE(BW)	*NRMSE(%)*	*r*
ML	0.03±0.01	44.44 ± 6.91	0.68 ± 0.32
AP	0.04±0.01	12.44 ± 2.98	0.95 ± 0.03
VT	0.20±0.09	8.72 ± 4.16	0.99 ± 0.02

IV. Conclusion

In this study, based on SLIP dynamics simulating running, we estimate the 3D GRF when running through a simple FFNN from a single measurement. Since the GRF can also be estimated as sacrum kinematics, it is expected to expand the information obtainable by the user from the sacrum-mounted wearable device by integrating previous research methods.

Acknowledgments

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References

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