Predicting Running Vertical Ground Reaction Forces Using Wavelet Neural Network Model Based on an IMU Sensor

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Summary

To predicting running vertical ground reaction force (vGRF) using wavelet neural network (WNN) based on an inertial measurement unit (IMU) sensor. Acceleration data and vGRF values of running were collected by a single IMU and an instrumented treadmill. Sliding time window synchronization (STWS) algorithm was developed to sync IMU data with vGRF data. After synchronization, mean absolute errors (MAEs) for stride time of the IMU data and vGRF data were less than 11.2 ms. WNN model was adapted to predict vGRF. The normalized root means square errors (NRMSEs) between measured and predicted curves were 4.58 ~ 6.79%. For peak vGRF, the NRMSEs were 1.60 ~ 6.25%. STWS algorithm can effectively achieve the data synchronization between IMU and force plate during running. WNN model using sagittal-axis acceleration data may be an ideal model with good prediction accuracy and less input data.

Introduction

Running is a popular sport, but it may result in running-related injury (RRI). VGRF parameters are important biomechanical factors during running associated with greater RRI. IMUs are widely used wearable sensors to capture human motion in an unconstrained environment. Predicting biomechanical variables with IMUs using WNN models may be used to daily monitor biomechanical RRI risk factors without expensive force-measuring equipment. The purpose of this study was to predict running vGRF using WNN models of different data types (three-axis or sagittal-axis acceleration data) based IMU data.

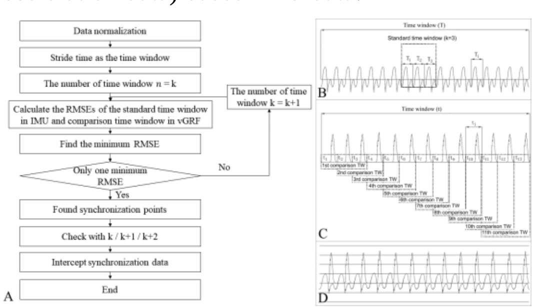

Figure 1: Illustration of STWS algorithm.

Methods

Fifteen high-level runners were recruited. Running acceleration data and vGRF values were collected by one IMU of the medial malleolus (Lpms-B2, ALUBI, China, 200Hz) and an instrumented treadmill (h/p/cosmos Gaitway II, 250 Hz, Germany), at 12, 14, and 16 km/h running speeds. Based on the variability of the running gait cycle, STWS algorithm has been developed to synchronize IMU data with vGRF data (figure 1). One participant's data was randomly selected as the test set, and the other participant's data was selected as the training set. Training set data was used to learn and adjust the model parameters such as weights, the number of neuron nodes, and batch size, and test set data was used to evaluate the predictions and the model's generalization ability. The WNN models were built using the three-axis or sagittal-axis acceleration data, and the activation functions of the hidden layers was the Morlet function.

Results and Discussion

The results showed that the MAEs of the time parameters of IMU data and vGRF data were less than 11.2 ms. For FFS and RFS runners, The NRMSEs between measured and predicted curves were 4.58 ~ 6.25% and 5.60 ~ 6.79%. For peak vGRF, the NRMSEs were less than 3.85% and 6.25%, respectively.

Study showed that a synchronization delay between IMU and kinetic data of 50 ms is acceptable [1]. The synchronization error in this study showing a relatively high accuracy. STWS algorithm can overcome the application limitations of IMU, and provide a novel idea to solve the synchronization problem between IMU and other measurement systems.

The vGRF and its peak value are the key monitoring indexes for injury prevention in running. Our data indicate that WNN models based on three-axis or sagittal-axis acceleration data of IMU, can successfully predict vGRF with very few errors and with good agreement between predicted and measured data. Using uniaxial accelerometers can simplify the estimation of vGRF and reduce the amount of computation, and reduce the sensor weight and size. The results can be further used for daily monitoring of vGRF outside of the lab.

Conclusions

The STWS algorithm is effective in synchronization between IMU and force plate of the running data. WNN model demonstrated good accuracy and agreement in predicting vGRF. Using sagittal-axis acceleration may be an idea model with less input data. This work provides foundation for personalized monitoring of lower limb load.

Acknowledgments

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References

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