Variability of step parameters measured by IMU during a long run

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Summary

Thirteen female distance runners ran 16 km at a pace of 15 km/h while their step parameters during the run were measured using IMUs. Among these parameters, vertical oscillation exhibited the greatest extent of change and variation.

Introduction

The long run is one of the most common training methods for distance runners. For elite runners, low intensity running accounts for up to 80 % of their total running distance. However, the rate of overuse injury has been reported to be very high. Hamill et al. (2012) hypothesized that a certain level of variability - not too high and not too low - might help maintain a healthy state. Recently small and wireless inertia measurement units (IMUs) have been developed, allowing for long-term measurement of running motion.

The purpose of this study is to investigate variability of step parameters during a long run measured using IMUs.

Methods

Thirteen female distance runners agreed to participate in the study as part of their training, organized by a university women's distance running team. Their mean (SD) age, height, and body mass were 20.5 (1.0) years, 160.0 (4.6) cm, 46.7 (4.2) kg. The participant's total weekly running distance before the measurement was 94.8 (31.5) km. Only three of them had never experienced a running-related injury.

The participants ran 16 km at a pace of 15 km/h. IMUs developed by CASIO were clipped onto the back of their running tights. Three-dimensional acceleration and gyroscope data were recorded at 200 Hz and stored in the internal memory of IMUs. The data were then downloaded to a PC after the measurements. The IMU coordinate system was converted to the runner's coordinate system using a Kalman filter. Step parameters including step length (SL), step frequency (SF), contact time (CT), and vertical oscillation (VO) were calculated for each step using vertical acceleration and GPS data.

The mean absolute percentage error (MAPE) was calculated for step parameter to evaluate variability;

$$\mathrm{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{y_t - \hat{y}_t}{y_t}\right| \times 100$$

where n is the total number of steps, y_t is the parameter value at step t, $\hat{y}_t$ is the moving averaged of y_t.

Results and Discussion

The mean (SD) values of SL, SF, CT and VO during the long run were 1.33 (0.04), 188.6 (3.2) steps/min, 197.8 (5.8) ms, and 8.34 (0.40) cm. The average range (maximum - minimum) of each step parameter during the run were 0.28 m for SL, 22 steps/min for SF, 38.9 ms for CT, and 2.6 cm for VO. The largest variation was observed in VO.

Figure 1 presents an example of step-by-step VO data along with its moving average during the long run. The large deviations from the average indicate notable variations in VO throughout the run.

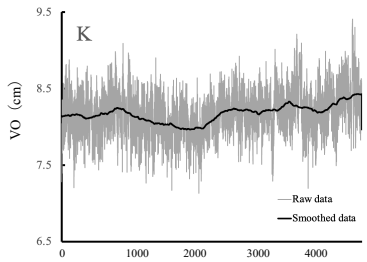

Figure 1: Example of step-by-step and averaged VO data during the long run. The horizontal axis represents the number of steps.

Figure 2 illustrates the MAPE value for SL, SF, CT, and VO. MAPE evaluates deviations from the averaged data for each parameter. VO exhibited a significantly higher MAPE compared to SL, SF, and CT. Since SL and SF are adjusted to maintain a constant running speed, and CT and flight time vary interdependently to regulate SF, the relatively high MAPE of VO suggests that its variability could result from accumulated variations in step parameters. Additionally, VO showed notable differences between right and left steps, further contribution to its variability.

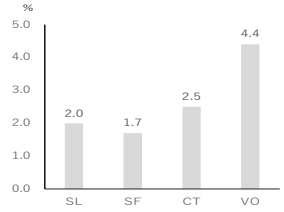

Figure 2: Average MAPE during long run for SL, SF, CT and VO..

Conclusions

The high variability in VO suggests that it may result from accumulated variations in step parameters.