CHANGES IN SPRING-MASS CHARACTERISTICS DURING 400M SPRINT

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INTRODUCTION

For the biomechanical analysis of running, the whole body is often modeled with a spring-mass model composed of a body mass and a linear leg spring (Butler et al., 2003). Vertical stiffness (K_{vert}), which is defined as the ratio of the vertical leg spring compression at a given force during ground contact, is known to strongly influence the running performance (Butler et al., 2003).

How the K_{vert} during running changes with fatigue is still a matter of debate. Morin et al. (2006) clearly showed that the K_{vert} decreased with repetitive 100-m sprint running. However, Dutto and Smith (2002) failed to see a consistent change in K_{vert} during treadmill running to exhaustion.

The purpose of the present study was to investigate whether the fatigue induces the change in K_{vert} during 400 m sprinting, because it requires runners to run till the full exhaustion at the goal (Nummela et al. 1992).

METHODS

Eight male athletes participated in the study. Before the start of experiment, the subjects warmed up for 20 min. Then, each subject was instructed to run for 400 m with a maximal effort on an outdoor field track.

According to the previous study (Morin et al., 2005), the K_{vert} was calculated as the ratio of the estimated peak force (F_{max}) and the estimated vertical center of mass displacement (Δy_c):

$$K_{vert} = F_{max} \cdot \Delta y_c^{-1}$$

$$\text{with } F_{max} = mg\pi/2\ (t_f / t_c + 1)$$

where m is the total body mass, t_f the flight time and t_c the ground contact time

$$\text{and } \Delta y_c = F_{max}\, t_c^2 / m\pi^2 + g t_c^2 / 8$$

The t_f and t_c were determined by the output waveform of the accelerometer, which was attached to the subject's right heel with sampling frequency at 1 kHz. Obtained signals were averaged over each interval of 50 m during the entire running period.

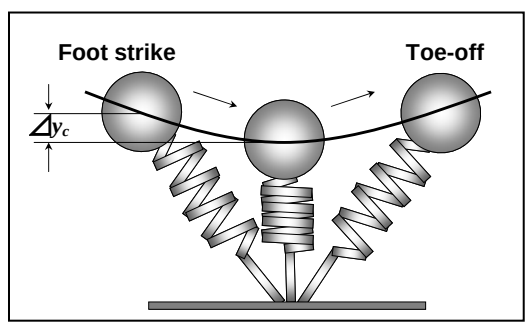

Figure 1: Spring-mass model in running. The leg spring is compressed during the first half of the stance phase and rebounds during the second half. Δy_c represents the vertical displacement of the center of mass.

The effect of fatigue on the K_{vert} was analyzed with the one-way repeated measures ANOVA. Dunnet's post-hoc multiple comparison test were performed if a significant main effect was observed.

RESULTS AND DISCUSSION

The subjects ran 400 m in 52.67 ± 0.92 s. Running speed peaked at 50-100 m period, and it consistently decreased from the middle to the later part of the entire running period (Fig. 2). This result is in line with the earlier findings that the running performance began to decrease during the first quarter of the 400 m sprint, due to the fatigue (Nummela et al. 1992).

Figure 2 also shows the consistent decrease in K_{vert} over an entire 400 m sprinting. The K_{vert} peaked at 50-100 m period, and it gradually decreased until the last interval. Because the K_{vert} during sprinting depends on the knee joint stiffness (Kuitunen et al., 2002), observed changes in K_{vert} would be due to the decrease in knee stiffness.

SUMMARY/CONCLUSIONS

During 400 m sprinting, vertical stiffness peaked at 50-100 m interval and then gradually decreased towards the end of the race, which is in parallel with the change in running speed.

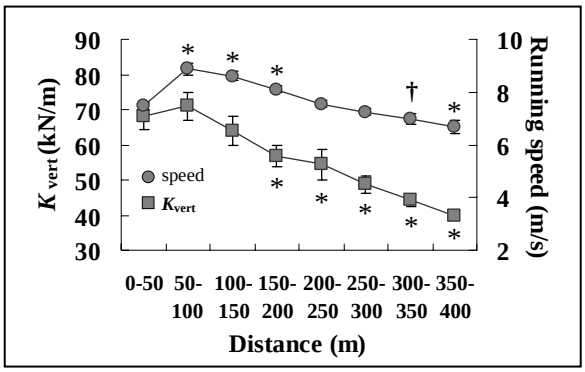

Figure 2: Changes in K_{vert} through an entire running period. A dagger (†) and an asterisk (*) indicate significant differences between two conditions; $p < 0.05$ and 0.01, respectively.

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