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INFLUENCES OF THE SHOE SOLE HARDNESS AND SPEED ON STRIDE FREQUENCY AND STRIKING POSITION VARIABILITY DURING TREADMILL RUNNING WITHOUT AWARENESS OF SPEED CHANGE

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The purpose of this study was to investigate the influences of wearing soft or hard soled shoe on the runner’s stride frequency and striking position variability, while the runner was not aware of the treadmill speed changing by visual or auditory information. The positions of the right ankle markers on the twenty subjects were captured to determine the stride frequency and striking position variability from ten strides at different speeds during six minutes of treadmill running. The results showed that the runner’s stride frequency significantly increased as the treadmill speed increased ($p<0.05$). However, sole hardness did not significantly affect the stride frequency under the four different speed conditions. Furthermore, the shoe sole hardness and speed seemed to have no influences on the striking position variability in this study.

KEY WORDS: Treadmill running; sole hardness; striking position; stride frequency

INTRODUCTION: Many previous studies have identified the relationship between the stride frequency and running speed. A recent study of treadmill running showed that the runners’ stride frequency increased as the running speed increased (Brughelli, Cronin, & Chaouachi, 2011). In this study, the subjects were asked to run at 40, 60, 80 and 100% of their maximum speed on a non-motor driven treadmill. Similar to the previous studies about treadmill running, the data were collected for several seconds as the subject running at a given speed. In addition, the subjects were aware of the belt speed from a screen in front of them for maintaining the constant running speed. However, there is no study to investigate the influence of the belt speed on the stride frequency without awareness of speed change during treadmill running.

Shoes have been assumed to be concerned with motion control of the runners. Previous Studies have showed that the soft shoe sole decreased the stability of foot and reduced the consciousness of the joint location. The hard shoe sole that has been assumed to increase plantar sensitivity needed less muscle activity to keep the static stability. Therefore, the elderly has been suggested to wear the hard soled shoes to reduce the risk of fall. (Perry, 2007; Robbins, 1995). However, Lord et al.(1999) suggested that the sole hardness had no influence on the ability of dynamic balance, such as running on a motor-driven treadmill.

The purpose of this study was to investigate the influences of wearing soft or hard soled shoe on the runner’s stride frequency and striking position variability during treadmill running, while the runner was not aware of the belt speed changing by visual or auditory information.

METHODS: There were twenty-three male participants (age: 21.4 ± 1.6 yrs, height : 170.9 ± 6.5 cm, mass : 66.8 ± 7.1 kg) included in this experiment. Due to the miss data, the results of three subjects were excluded, and only 20 participants’ data were analyzed. All subjects did not have any sport injury within past six months. Moreover, they were experienced in treadmill running. This investigation was approved by the Human Experiment and Ethics Committee of National Cheng Kung University Hospital. All subjects in this study were informed of the experimental risks and signed an informed consent before their test.

Two sizes (US 9 and 10) of shoes with different sole hardness (Shore C 45，70) were used in this study. Except for the sole hardness is different, the appearance and the material of the shoes are all the same (see Figure 1). The subjects cannot distinguish the differences of shoes with soft or hard soles. A motor-driven treadmill (FUNA-7310, Tonic Fitness Technology) was used in this study. The subjects had to finish six minutes of treadmill running with wearing different hardness of shoes. A motion tracker (200Hz, Phoenix Technology Inc., Canada) which contains three sensing eyes was set on right side of the treadmill to capture the position of a LED active marker attached on the right lateral ankle of the subject. The three-dimensional coordinates of the marker were analyzed by VZsoft software.

Figure 1: Testing shoes for this study

In order to avoid the subject noticing the speed change of the treadmill from any visual and auditory information, the console of the treadmill was covered by a black cloth and the subject was asked to wear an earphone to isolate any external sound (see Figure 2). The subject would not be notified that the speed would change to slower or faster speed, and the changing times would not be mentioned before the experiment. The subject wore his own jogging shoes to do three to five minutes of treadmill running at their preferred speed for warm-up. After that, the subject was asked to wear randomly the shoes with hardness of shore 70C (hard) and 45C (soft) to finish six minutes of treadmill running. At the beginning, the subject would run at the speed of 10 km/hr, then after three, four and five minutes, the experimenter would change the speed to 11, 12 and 13km/hr, respectively.

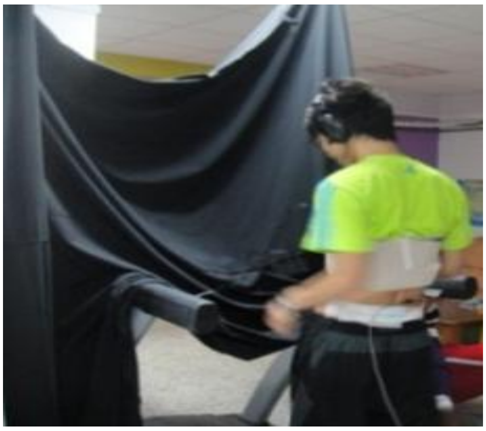

Figure 2: The set-up of the experiment. The console of the treadmill was covered by a black cloth. The subject had to wear the earphone with music playing in order to isolate any external sound.

The ten seconds of data before each speed change were recorded and the runner’s mean stride frequency were analyzed from ten strides. Heel striking position was defined as the anterio-posterial coordination at the moment of lowest vertical position of the ankle marker after the foot swing to maximum forward. The standard deviation of the ten heel striking positions indicated the variability of the striking position. All data assessment and analysis were done by MATLAB program.

Two-way repeated measure ANOVA was done by SPSS 17.0 to examine whether there were significant differences ($p<0.05$) in the stride frequency and heel striking position while wearing shoes with two different hardness at four different speeds.

RESULTS: Table 1 shows that the runner's stride frequency significantly increased when the treadmill speed increased with the two different hardness of shoes ($p<0.05$). However, sole hardness did not significantly affect the stride frequency. The least variability (one standard deviation = 21.8mm) of striking position occurred when wearing 45C hardness of shoes at the speed of 12km/h and the greatest variability (32.1mm) occurred when wearing 70C at 10km/hr. However, there are no significant differences between any testing conditions ($p>0.05$).

Table 1: Stride frequency and striking position variability at four different speeds under the two different hardness of shoes

n=20	10km/hr		11km/hr		12km/hr		13km/hr	
	45C	70C	45C	70C	45C	70C	45C	70C
Stride frequency(s^{-1})	1.38 (0.08)	1.39 (0.08)	1.42 (0.10)	1.42 (0.08)	1.44 (0.09)	1.43 (0.08)	1.45 (0.13)	1.46 (0.08)
Striking position variability (mm)	21.8 (7.9)	32.1 (14.7)	28.1 (10.8)	28.3 (8.8)	27.2 (6.7)	29.3 (11.1)	28.8 (11.0)	27.4 (8.5)

DISCUSSION: This study was to investigate the influences of the hardness of shoe sole and belt speed on stride frequency during treadmill running. However, the subjects were not aware of treadmill speed change during whole testing session, which is different from the protocols of previous studies of treadmill running. The previous study showed that the runners, who could see the treadmill speed displayed on the screen, performed greater stride frequency as the speed was faster (Brughelli, Cronin and Chaouachi, 2011). In present study, the same result was found, even the runner were not aware of the treadmill speed change from external information. This result means that the runner could adjust their gait, for example increased stride frequency, as detecting the belt speed change to faster from the plantar sensitivity or other incoming information. Furthermore, the hardness of shoe sole seemed to have no effect on the adjustment of the runner's stride frequency during the treadmill speed change.

The sole hardness of shoe and belt speed was found to have no influence on the striking position variability in this study. According to the results, the striking position variability (one standard deviation) of the subjects who are running on the treadmill is between 22 to 32 mm and the range of striking position of each stride at a given speed was from about 60 to 90 mm. It indicates that the runners' gait is unstable when running on the treadmill under the four different speeds.

CONCLUSION: In conclusion, no subject was failed to catch up the belt speed or even fall because of the increase of treadmill speed under the situation that the runners were not aware of the speed change. It represents that the runners could adjust their gait faster, for example the greater stride frequency in this study, for the increased belt speed that the subject cannot detect from visual or auditory information. And this adjustment ability is not affected by the hardness of the shoe. In addition, the runner's range of striking position of each stride at a given speed was from about 60 to 90 mm during running on a motor-driven treadmill.

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