EFFECTS OF SHOES MASS ON RUNNING GAIT ANALYSIS

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The purpose of this study was to investigate the running gait analysis between different mass of shoes. Eleven male college runners from the physical education department participated in this study. The mass of experimental shoes of this study were 175 g, 255 g, 335 g and 415 g. When the weight of shoes increased, the maximum vertical ground reaction force increased, and the footstrike patterns changed to mid-foot strike (MFS). The center of pressure shifted forward, and the runner changed to MFS. The strike index of the strike patterns change to MFS pattern that is self-protection mechanism. Heavy shoes increase ground reaction force, thus might increasing lower extremity injuries risk.

KEY WORDS: shoes, injury prevention, strike index.

INTRODUCTION: Running is a popular physical activity that can improve physical health, mental health, and reduce the pressure of everyday life (Hafstad et al., 2009; Haskell et al., 1993). However, runners also sustain many sports injuries. Of the sports injuries reported every year, 79% are attributed to running (Lun, Meeuwisse, Stergiou, & Stefanyshyn, 2004; van Gent et al., 2007). A high proportion of injuries are to the lower extremity, especially the knee joint.

Past studies indicate that running shoes are implicated in such injuries (Cheung, Ng, & Chen, 2006; Milner, Davis, & Hamill, 2006; Stefanyshyn, Stergiou, Lun, Meeuwisse, & Worobets, 2006; Taunton et al., 2002). Rear-foot strike (RFS) runners had impact transient of vertical ground reaction force, and that sudden change in types of force may increase the risk of a running injury. The impact force affects running strategies. Although various types of running shoes exist, most studies only discuss different types of running shoes. There is not research on different mass of shoes. The purpose of this study was to investigate the different mass of shoes during running.

METHODS: Eleven male subjects (21.21±1.04 years; 174.91±5.73 cm; 67.45±4.22 kg) participated in this study. All subjects were habitual RFS runners and free of lower extremity injury at the time of data collection. Subjects performed a uniform warm-up of 10 minutes on the treadmill. The experimental protocol consisted of four different mass of shoes: 175 g, 255 g, 335 g and 415 g. In this study were used the same shoes and add lead weights to sew of four edges for increaseing mass of shoes. Subjects ran their baseline speed in each of the four differently weighted shoes. The order of weight conditions was changed using the counterbalancing technique to prevent an order effect. The data from three complete successful running trials were collected. Before data collection, subjects were allowed practice trials to become acquainted with the different mass of the shoes.

An eight-camera motion analysis system (Qualisys Track Manager, Oqus 100, Sweden) was used to collect whole body motion with a total of 40 reflective markers placed on bony landmarks. Marker trajectories were sampled at 200 Hz using a low-pass filtered, fourth order Butterworth filter with a cutoff frequency of 12 Hz. Two AMTI force plates (BP600900, AMTI Inc., Watertown, MA, USA) were used to collect the ground reaction force. The kinetics data were sampled at 1000 Hz using a low-pass filtered, fourth order Butterworth filter with a cutoff frequency of 50 Hz. Kinematics and kinetics data were synchronized with a Qualisys

64-Channel to synchronize the collected data.

During the complete running cycle, the first toe-off was defined when the heel and PSIS marker were at the maximum displacement of the sagittal plane (Smith, Preece, Mason, & Bramah, 2015). The footstrike and second toe-off were identified by applying a 20 N threshold to the vertical ground reaction force (VGRF). The strike index (SI) was used to characterize footstrike patterns (Cavanagh & Lafortune, 1980). A custom written Matlab program (version 7.0; The Mathworks Inc., Natick, MA) was used to calculate the following variables: strike index, step length, step rate, running velocity, peak VGRF, peak load rate, and impulse (Bonacci et al., 2013). Statistical comparisons were made using repeated measures; one-way ANOVA was used to compare the differences between the parameters of different mass of shoes. The Fisher's least significant difference (LSD) test was used for pair-wise comparisons ($\alpha = 0.05$).

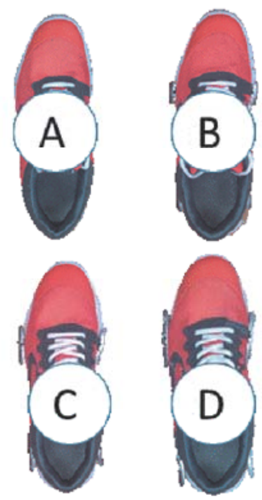

Figure 2. Experiment shoes. a) Shoe175g, b) Shoe255g, c) Shoe335g, and d) Shoe415g.

RESULTS: According to the strike index the footstrike patterns were divided into RFS, MFS and fore-foot strike (FFS) (Figure 1). There were six subjects with RFS (55%) and five subjects with MFS (45%) during the Shoes175g condition (55%). There were four subjects with RFS (36%), five subjects with MFS (46%), and two subjects with FFS footstrike (18%) during the Shoes255g condition. There were three subjects with RFS (27%), six subjects with MFS (55%), and two subjects with FFS (18%) during the Shoes335g condition. During the Shoes415g condition, there were eleven subjects with MFS (100%).

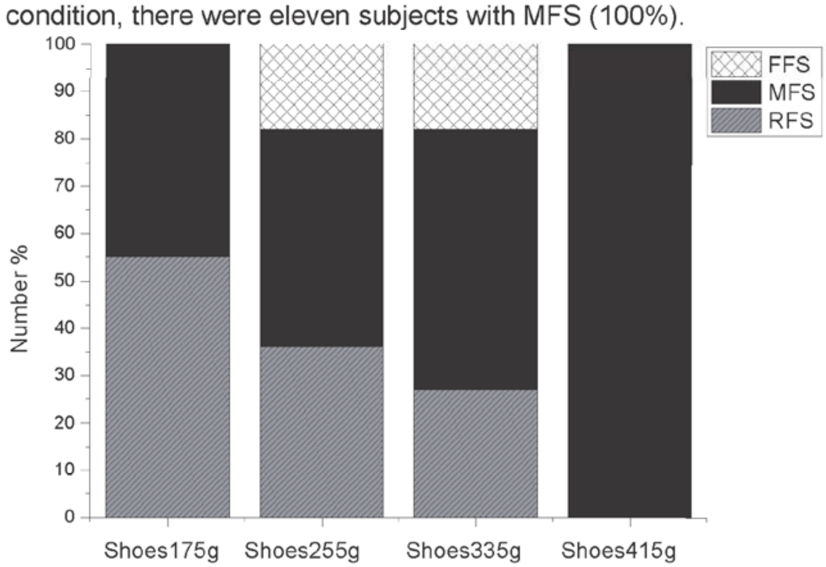

Figure 1: Different mass of shoes with strike index

Comparison of the different shoe mass with the respective step length, step rate and running velocity statistical results are shown in Table 2. The results show that step length, step rate and running velocity did not have significant differences (*p*>0.05).

Table 1： Effect of different shoe mass on runing kinetics parameters

	Shoes175	Shoes255	Shoes335	Shoes415	*p* -value
Peak VGRF (N/BW)	27.16 ±2.45	27.38 ±3.18	27.64 ±3.04	28.35 ±2.87	0.012*
Peak load rate (N/BW/sec)	299.81 ±15.10	343.94 ±42.63	359.81 ±60.42	367.84 ±65.9	0.344
Impulse (N*ms/BW)	1865.42 ±73.92	1898.82 ±99.61	1895.83 ±79.16	1867.69 ±82.99	0.880

Note: * Means significant difference between different mass of shoes condition, significant difference at *p*<0.05.

DISCUSSION: It was found that footstrike patterns change according to the different mass of shoes. Previous studies found that when running with different types of shoes, the different shoe structures alter running strategies. Comparison of the fivefinger shoes (148 g) and standard running shoes (341 g) demonstrates that the strike index (SI) of the fivefinger shoe is significantly larger than that of the standard running shoe. When increasing the shoe mass, the center of pressure tended to move forward (Squadrone & Gallozzi, 2009). The fivefinger and standard running shoes' mass and structures are both different. The soles of the fivefinger shoes are thin and thus could not buffer landing. When compared with being barefoot, the fivefinger shoe had a layer of protection for the foot. The fivefinger shoe running strategy was different from that of the standard shoe. Footstrike parameters were similar to barefoot running. In this study, we only changed the shoes' mass. It was found that the footstrike pattern was RFS in 55% of runners when wearing the shoes175g shoes. With increasing mass of shoes, the subjects changed to MFS patterns. With the increasing weight of the shoes415g shoes, all subjects developed an MFS pattern. Therefore, when wearing the lightest shoes, the habit of having an MFS does not change to an FFS. However, wearing the heaviest shoes tends to move the center of pressure forward.

When subjects wear the Shoes175g shoes, the peak GRF was reduced during running. Past studies comparing minimalist and fivefinger shoes demonstrated that the lighter fivefinger shoes had a lower peak GRF (Squadrone & Gallozzi, 2009). Therefore, the results of this study show that in sole structure, the peak GRF did not change when comparing Shoes175g and Shoes255g; because of this, the strike index did not change. Past studies revealed that the fivefinger changed the footstrike to a forefoot strike, and a forefoot strike has reduced force benefits. This may be related to protection from lower extremity injuries (Lieberman et al., 2010). In this study, we found that when wearing the Shoes415g shoes, the peak GRF increases, . In past studies, when there is rear footstrike with shoes, the impact generated was transient. The larger GRF and loading rate increase lower extremity injuries (Shih, Lin, & Shiang, 2013).

CONCLUSION: Dynamical systems theory generally consists of several perspectives were including tasking inividual adaptation and environment (Hamill, van Emmerik, Heiderscheit, & Li, 1999). In this study, the mass of shoes were different. Heavier shoes increase impact force during running, thus might increasing lower extremity injuries risk. The strike index of the strike patterns change to MFS pattern. MFS pattern might more comfortable strike patterns than RFS pattern. That may self-protection mechanism of human movement. Too big ground reaction force causing muscle vibration and may cause muscle injury or discomfort. FFS or MFS landing technology reduces ground impact forces (Giandolini et al., 2013). When the runners wear heavy shoes the impact force will increase. In order to reduce discomfort, runners shift to MFS.

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