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Effect of the cushioning running shoes in ground contact time of phases of gait

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ABSTRACT

The main objective of this research was to know how five different cushioning shoes may interfere in ground contact times of each gait phase of walking and running in contrast with barefoot condition. Thirty healthy sport recreational male runners participated in this study. They played over a treadmill wearing minimalist, Boost®, Ethyl-vinyl-acetate (EVA), Air® chamber and pronation-control cushioning shoes technologies and under barefoot condition, recording the last 30 s of walking and running at 5.17 km/h and 9 km/h respectively, while ground contact time duration of each phase of gait was recorded with circular standard pressure sensors located on plantar feet. During walking, the heel contact phase was the station that increased significantly ground contact times wearing all sole cushioning shoes ($p < 0.001$), excepting no sole shoes (minimalist), versus barefoot condition, being Air® chamber the model that showed the highest times of contact floor versus barefoot (0.28 ± 0.08 ms and 0.23 ± 0.12 ms vs 0.12 ± 0.07 ms and 0.18 ± 0.07 ms in heel contact during midstance phases, respectively). During running, propulsion phase was the station that showed the highest spent times on ground contact with the floor under all shoe conditions, even with minimalist, being again Air® chamber the model with higher significant times in two of three phases versus barefoot (0.11 ± 0.04 ms and 0.16 ± 0.11 ms vs 0.09 ± 0.03 ms and 0.10 ± 0.02 ms in midstance and propulsion phases respectively). Air chamber® was the model too with the most switch ratio to forefoot strike pattern (0.07 ± 0.10 ms to 0.16 ± 0.11 from heel contact to propulsion phase, respectively). In conclusion, a ground contact times increase using all cushioning running shoes compared with barefoot condition was shown in both walking and running test.

1. Introduction

Regarding recreational and competitive running, the reduction of time and effort in order to perform a concrete distance may be a key focus defined as running economy (RE) (Conley and Krahenbuhl, 1980). Indeed, RE may be influenced by many intrinsic and extrinsic factors such as the ground contact time (GCT) and shoe surface-interaction (Moore, 2016). Running biomechanics during GCT seemed to play an important role on RE, especially during the propulsion phase, according to several authors who have shown an association between a shorter RE and longer contact times (Di Michele and Merni, 2014). Consequently, a high metabolic cost could be generated by an incremental reactive muscle strength during the propulsion phase and the variation of the learned sporting gesture of runners (Roberts et al., 1998). In addition, preventing the energy lose on deceleration speed during GCT may be another key aspect to improve RE (Kong and de Heer, 2008; Nummela et al., 2007).

Sports footwear characteristics have been related to RE

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Table 1
Demographics data for total population and gender.annao. Anthropometric characteristics of the runners.

Variable	Male n = 30 mean ± SD (95% CI)
Age (years)	36.20 ± 8.50 (33.16–39.24)
Height (cm)	177.20 ± 4.25 (175.68–178.62)
Weight (kg)	72.10 ± 6.39 (69.81–74.39)
Foot Size (EC)	43.43 ± 0.82 (43.14–43.73)
BMI (Kg/m^2)	23.03 ± 1.73 (22.41–23.66)
FPI	2.5 ± 0.9 (2.18–2.82)

Abbreviations: EC = Europe countries; BMI = Body mass index; SD= Standard Deviation; CI= Confidence Interval; FPI= Foot posture index.

biomechanical positive effects, due to body mass impact to the ground may be dissipated by plantar shoe´s sole whilst in minimalist or barefoot conditions these ground reaction forces have to be actively cushioned by the tendons and muscles, increasing the metabolic cost and reducing RE (Tung et al., 2014). Some prior studies using traditional sports footwear and minimalist or barefoot conditions suggested that there was a influence on kinetic and kinematic data, which may modify the foot strike pattern (Bishop et al., 2006; Fredericks et al., 2015; Lieberman et al., 2010; Squadrone and Gallozzi, 2009), although the effects on GCT derived of these different foot strikes remain unclear.

In addition, there is a lack of knowledge about GCT modifications on phases of gait during walking neither running under the effects of the particular kinds of typical cushioning soles of sports footwear. Therefore, the aim of the present study was to know how could influence Boost®, Ethyl-vinyl-acetate (EVA), Air® chamber, pronation-control cushioning technologies and minimalist versus barefoot condition on the duration of each phase during walking and running gait, hypothesizing that increasing cushioning, GCT would be higher.

2. Materials and methods

2.1. Design and sample

The sample size was calculated with the software from Unidad de Epidemiología Clínica y Bioestadística. Complexo Hospitalario Universitario de A Coruña. Universidade A Coruña (www.fisterra.com) to detect difference in ground contact times between wearing different cushioning sports shoes during walking and running, which were 0.228 ± 0.009 s and 2.422 ± 0.01 s, respectively (Di Michele and Merni, 2014) with 80% statistical power (β = 20%) and an interval of confidence 95% (α = 0.05) and 2-tailed test, at least 7 participants were required. Furthermore, assuming a loss to follow up rate of almost 43%, at least 10 participants would be included in the present study.

Thirty healthy sports recreational male runners participated in a human movement laboratory of the Universidad Rey Juan Carlos of Madrid, (Spain) during the months from April (2017) to January (2018). An observational cross-sectional research design according to the Strengthening The Reporting of OBservational Studies in Epidemiology (STROBE) criteria (von Elm et al., 2007) and a non-random consecutive sampling technique (Roca-Dols et al., 2018b, 2018a) were used. The inclusion criteria were being between eighteen and twenty five years old; running practice around 30 km per week with neutral sports shoes; neutral foot and rearfoot strike pattern; to have normal dorsiflexion in ankle joint complex with at least 10° with the knee fully dorsiflexed; normal range of motion in subtalar joint of 30°; normal range of motion in non-weight-bearing in the first metatarsocuneiform joint with 4 mm in dorsiflexion and 4 mm in plantarflexión of first metatarsal bone; normal unrestricted motion along the longitudinal axis of the midtarsal joint of 15°; to have more than 82° in first MPJ mobility according to Buell technique (Buell et al., 1988) and written informed consent. To select foot individuals, foot posture index (FPI) (Redmond et al., 2006) was used, considering values from 0 to +5 as neutral in the examination. This is a validated and moderate to good reliability screening tool to assess foot posture (Evans et al., 2003).

2.2. Kinematic data collection

In order to select each gait and duration phase, circular standard pressure sensors (SX230) of 0.5 in., assured to cutaneous surface with tape (Murley and Bird, 2006), were located on plantar medial and plantar lateral heel, and plantar first interphalangeal hallux joint, synchronizing the "switched on" sensor with ground contact time, and the "off" sensors with no GCT.

Before to data collection, participants walked continuously during three minutes over a motorized treadmill at speed 5.17 km/h (Boyer and Nigg, 2004) under 6 different shoe conditions (barefoot, minimalist, Boost®, Air® chamber, EVA and pronation control), to get use to treadmill where the test was performed; only during the last 30 s the activity was collected for each condition, with five minutes recovery with each subject remained at rest between experiments (De Cock et al., 2006); the order of data collection was randomized. Five trials of each condition was recorded and the lapse duration of each cycle of gait was determined selecting visually from the graph on computer screen by the researcher: if there were no sensors "on" (all sensors in "off" status), pre-activation phase (PAP) was identified; if only heel sensors were "on", heel contact phase (HCP) was identified; if hallux sensors was "on" plus heel sensors, midstance phase (MSP) was identified; and if heel sensors were "off" and hallux sensor was "on", propulsion phase (PP) was identified. The same protocol was used to running test over the same treadmill at speed 9 km/h (Nigg et al., 2003).

2.3. Ethical considerations

Research and Ethics Committee of Universidad Rey Juan Carlos, Spain, was the official entity that ruled the study, giving favorable authorization certificate n° 1001201701317. All volunteers gave written informed consent documentation before being part in this study. Human and ethical standards in experimentation were followed according to the Declaration of Helsinki and other organizations.

Table 2
Technical characteristics of the sport shoes included in the study.

Technical	Minimalist	Boost®	Ethyl-vinyl-acetate	Pronation control	Air® chamber
characteristics	sport shoe	sport shoe	sport shoe	sport shoe	sport shoe
Sole material	Rubber	Rubber	Rubber	Rubber	Rubber
Mid-sole material	Non-existent	Ethyl-vinyl-acetate	Ethyl-vinyl-acetate	Ethyl-vinyl-acetate	Ethyl-vinyl-acetate
Impact absorption system	Non-existent	Ethyl-vinyl-acetate	Ethyl-vinyl-acetate	Ethyl-vinyl-acetate	Air chamber
Control system	Non-existent	Non-existent	Non-existent	Postero-medial	Non-existent
Drop (mm)	0	11	9	9	16
Weight (g)	172	320	250	286	360

Abbreviations: mm, millimeters; g, grams.