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An investigation into plantar pressure measurement protocols for footwear research

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ABSTRACT

Many researchers investigate how footwear design affects plantar pressure (PP) and ask participants to walk in unfamiliar footwear as part of their studies. However, there are no clear guidelines for the required period of time or number of steps a healthy participant requires to acclimatise to unfamiliar footwear. Nor are there clear guidelines for how many steps should be collected to produce data that is representative of gait in each particular shoe being tested. There were therefore two aims to this study: (1) to investigate the number of steps required to produce an average step that is representative of normal gait; (2) to investigate the number of steps required for a participant to acclimatise to a range of footwear types. PP data were collected in 20 healthy participants whilst they walked for 400 m in a range of footwear. The results showed that the number of steps required for both acclimatisation and to ensure data quality are dependent on shoe type and the foot region being investigated. It is recommended that 30 steps from one foot are collected during data collection and an acclimatisation period of at least 166 steps is given for each shoe condition. The former recommendation is not met by most studies in the literature.

1. Introduction

The magnitude and distribution of pressure on the plantar surface of the foot has been associated with foot pain [1,2], comfort [1] and devastating clinical problems such as foot ulcers [3]. Footwear research has therefore sought to investigate specific footwear designs that might reduce plantar pressures (PP) [4–6]. A wide range of footwear styles have been investigated, including running shoes, high-heeled shoes, boots, rollover footwear and instability footwear [4,5,7–11].

Many aspects of gait (PP [4], lower limb kinematics [12], kinetics [13] and muscle activity [14]) are sensitive to footwear design choices. Therefore, footwear can be said to represent a potential perturbation in the mechanical conditions under which gait is performed. Like any perturbation in the conditions of walking, some period of acclimatisation to the footwear is likely necessary and this is widely acknowledged by researchers in their protocols. Footwear that is similar to that worn by a participant on a daily basis might represent a small or indeed no perturbation at all, and requires little acclimatisation. Investigation of some footwear styles, however, (e.g. stiletto, rollover footwear) might require more acclimatisation if participants are unfamiliar with their use.

Protocols used in prior research to acclimatise to footwear vary considerably and often only scant details are offered. Some studies require the participant to familiarise themselves with the study protocol rather than the footwear being tested [1,15–17] and others had participants acclimatise to footwear walking on a treadmill but collected data during overground walking [18]. Other investigators allow a period of time between conditions but do not explain the purpose of this period or what each participant did [19]. There are studies which allow the participant to acclimatise to each footwear condition [20,21] and 5 min is the most common period of time provided. The variation in methodologies highlights the lack of understanding of the acclimatisation effect. Furthermore, no previous studies have reported quantitative criteria to define when a participant has acclimatised to a specific shoe design.

A further issue regarding PP protocol design is how many steps are required to produce a valid representation of gait. Since no two steps during gait are the same [22] numerous steps must be

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measured and thereafter averaged to represent the individual participant and experimental condition. One study has suggested that 200 steps are required when walking on a treadmill [23] although this was based on ground reaction rather than PP data. In PP studies, it is typical to use fewer than 200 steps [17,19,21,24].

The only comparable study based on PP data focussed on people with diabetes wearing rocker profile footwear [25]. Based on data from 20 steps, just 12 were required for valid data. However, people with diabetes exhibit different gait patterns and rocker footwear has features that are distinct from many footwear styles (very stiff sole, distinct angular sole profile). Thus, the generalizability of these data is low.

The two aims to this study are:

1) To identify the minimum number of steps required to produce an average which accurately represents normal gait.
2) To identify the minimum number of steps required for participants to acclimatise to a range of footwear types.

Our purpose in meeting these aims was to offer recommendations for future studies concerned with footwear effects on PP.

2. Method

2.1. Participants

Twenty young adults (10 female, mean (SD) age = 28 (7.1) years, height = 1.692 m (0. 074); mass = 69.9 kg (14.9)) were each tested in one session. All were pain, injury and pathology free. The study was approved by the university ethics committee and all participants provided informed consent.

2.2. Footwear

Five footwear designs for females and three for males were selected to provide a range of perturbations and therefore possible acclimatisation periods and number of steps for valid data. For men: a Duna (Italy) diabetic rocker shoe with a 15° rocker angle, a 55% apex position and a 80° apex angle as defined by Chapman et al. [4]; Kalenji Ekiden 50 running shoe, and the Scholl Starlit instability shoe. In addition to the shoes worn by the males, the females also wore: a stiff upper high-heeled shoe (Scholl Flon, 55 mm heel and bovine leather upper); a soft upper high-heeled shoe (Scholl Flon, 55 mm heel and bovine suede upper) (Fig. 1).

2.3. Protocol

To familiarise themselves with the testing procedure, participants walked in their own shoes for a period of 5 min up and down a 27 m walkway. We requested that the participant attend wearing a stable sports shoe and most wore running shoes whilst the remainder wore converse style shoes. The walkway comprised of a hard flat laminated surface and included a 20 m central area and a 3.5 m acceleration/deceleration zone at each end. Participants were required to walk at a speed of 1.2 m s^{-1} ±5%, which was measured using optical timing gates (Brower Timing Systems, Draper, Utah, USA). If we had allowed the participants to pick their own speed they may have chosen a speed that was too fast to comfortably walk in all shoe types. Since we could not let participants wear the test shoes before data collection, as this would have affected our acclimatisation results, we had to choose a speed we were confident all participants could walk at in all shoes. The high-heeled shoes were thought most likely to affect walking speed and past studies had shown that participants are able to walk in excess of 1.2 m s^{-1}in high heels [5]. During the familiarisation period, verbal feedback was provided to the participant until they could consistently walk at the correct speed. The testing was conducted in a laboratory setting and therefore it was not possible to collect 400 m of continuous walking. However, this study was designed to inform future protocols which are typically performed on a walkway of a similar length.

The Pedar (Novel) system was used to collect PP; however, this device can be affected by the heat and moisture in shoes [26]. Therefore, during the protocol and walking speed familiarisation period the Pedar insoles were placed inside the participant's own shoes to enable measurement sensors to acclimatise. After familiarisation the test shoes were tested in a random order

Fig. 1. The shoes (top left: Scholl Flon, top right: Scholl Starlit, bottom left: Duna Diabetic Rocker, bottom right: Kalenji Ekiden 50).