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Full Length Article

Gait kinetics, kinematics, spatiotemporal and foot plantar pressure alteration in response to long-distance running: Systematic review

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ABSTRACT

The aim of this systematic review was to obtain an improved insight of the present state of knowledge regarding the effect of long-distance running on gait kinetics, kinematics, spatiotemporal and foot plantar pressure. Electronic databases were searched for articles relating to biomechanical modification following long-distance running, published in English between 1990 and 2016. All the studies presenting gait parameters before and after long-distance running were included. A modified Quality Index was used for assessing methodological quality. Thirteen studies met the eligibility criteria. Five of 13 studies measured plantar pressure, reporting that the loading under the metatarsal regions were shown to be the highest following long-distance running. Ten studies reported spatiotemporal changes; step and stride frequency were generally increased, while stride length and aerial time were decreased after running. Four studies measured kinetics, indicating that vertical ground reaction force (GRF) was generally decreased, whereas impact acceleration was increased. Four studies showed that the lower limb kinematics and the foot strike techniques were altered by long-distance running. Three studies performed a second follow-up, revealing that the changes were generally returned to baseline levels. This is the first systematic review to examine the effect of long-distance running on gait kinetics, kinematics, spatiotemporal and foot plantar pressure.

1. Introduction

Long-distance running, for example 5–42 km, has become a popular sport even at the amateur level. Plantar pressure, temporal-spatial kinematic and kinetic measurements have been widely used as metrics of overall running performance. For instance, spatial plantar pressure modifications have been associated with increased speed (Rosenbaum, Hautmann, Gold, & Claes, 1994), changes in muscle activity associated with treadmill and overground running (Baur, Hirschmüller, Müller, Gollhofer, & Mayer, 2007), and changes in plantar loading associated with different shod conditions during running (Wiegerinck et al., 2009). Changes in biomechanical parameters have been reported to be strongly associated with long-distance shod running in healthy participants (Degache et al., 2013; Dierks, Davis, & Hamill, 2010; Willems, De Ridder, & Roosen, 2012). However, there is no study synthesising gait changes after long-distance running in a single review paper.

A review of parameters for healthy shod runners may provide a better understanding for future injury studies that deviate from healthy baseline controls. For example, running with more central heel-strike, increased pronation along with high plantar pressure

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under the medial side of the foot and more lateral roll-off is linked with increased lower leg pain (Willems et al., 2006). Increased peak knee internal rotation during stance is associated with iliotibial band syndrome (Aderem & Louw, 2015), and high pronation velocity, greater peak plantar pressure can be associated with increased risk of Achilles tendinopathy, patellofemoral pain, and other non-specific overuse injuries (Dowling et al., 2014). While running has obvious health benefits, the lower limbs are often exposed to higher than normal joint stress levels, which may lead to gait modifications away from normal gait but does not necessarily explain the cause of injury.

Therefore, the objective of this systematic review was to obtain an improved insight of the present state of knowledge regarding the effect of long-distance running on gait patterns and plantar pressure distribution in healthy runners. An appreciation of biomechanics for 'high and repetitive loading' imposed on the lower limb joints would be of great value for informing running injury prevention. While different surface types (road and trail) and running duration will produce different grades of loading, we do not differentiate these factors in this study. We have been motivated by numerous MRI studies that have reported ankle (Kim, Fernandez, & Mirjalili, 2017) and knee cartilage degenerative changes in marathon running (Krampla et al., 2001), and short running such as 30-min on a treadmill (Boocock, McNair, Cicuttini, Stuart, & Sinclair, 2009), or asphalt running (Mosher et al., 2005), and 5–20 km track running (Kessler, Glaser, Tittel, Reiser, & Imhoff, 2006), that are all associated with initiating degenerative changes. Further, most long-distance runners are shod and there is a trend emerging towards unshod and minimalist long-distance running. We must fully understand the shod case before the benefits of unshod running can be fully realised.

2. Methods

2.1. Search strategies and selection process

This systematic review followed the guidelines of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol (Moher, Liberati, Tetzlaff, & Altman, 2009). Electronic databases of Scopus, Web of Science, SportDiscus, and Ovid Medline were searched for assessing gait parameters before and after long-distance running, with restriction for English language and published between 1990 and 2016. The final search was completed on 7th March 2016. The search terms used a combination of 1) biomechanic* OR kinematic* OR kinetic*; AND 2) running OR run OR jog OR jogging OR marathon OR long distance; AND 3) plantar pressure OR foot pressure. The reference lists of included articles were also looked through for additional relevant articles.

The study selection process was performed by a single reviewer (H.K.K) and this whole process was evaluated by another reviewer (S.A.M). After removed duplication, abstracts and titles were initially predetermined based on eligibility criteria as shown below. Full-text articles were retrieved from this initial screening and the full text was read for inclusion. If there were any disagreement for the study selection between two reviewers, a third reviewer (J.F) adjudicated.

2.2. Eligibility criteria

Studies were identified based on the following inclusion criteria: 1) healthy or asymptomatic adult populations were included; 2) the intervention running must be a continuous long-distance run or be a multi-days run but single case; 3) long-distance run should be at least 30-min; 4) the studies must report at least one of the following outcomes; kinetics (impact loading rate, GRF, impact acceleration), kinematics (hip kinematic, knee kinematic, ankle kinematic, foot strike), plantar pressure, and/or spatiotemporal parameters (contact time, contact area, stride length, stride frequency, step length, step frequency, aerial time, running velocity) during gait tests following long-distance running; 5) gait tests and/or plantar pressure measurement should be conducted before and after long-distance running; 6) OR the measurements were conducted simultaneously with long-distance running.

Studies were excluded based on the following exclusion criteria: 1) a short last run such as sprint or interval runs was excluded; 2) review, conference abstract, and press papers were excluded; 3) non-English articles were excluded.

2.3. Data extraction

Characteristics of studies (i.e. authors, year), characteristics of participants (i.e. sample size, demographics data, biometric data, training history, fitness level, injury history, if available), long-distance running types (i.e. speed, distance, environment, shoes, surfaces, if available) and study method (aim, study design, measurements, outcomes) were extracted. Inclusion and exclusion criteria were also noted. More details are presented in Table 1.

2.4. Methodological quality assessment

Selected articles were evaluated for methodological quality by using a modified version of a quality index (QI), originally developed by Downs and Black (Downs & Black, 1998). This QI tool allows assessing the quality of reporting, external validity, internal validity (bias and confounding) and power. In this review study, the power scale (question 27) was excluded due to its uncertainty (Deeks et al., 2003). Each question can be answered 'yes', 'no' or 'unable to determine'. If the answer was 'yes', it awarded one point, while scored zero. Question five was an exception where 'yes' was scored two, 'partially' was one and 'no' was zero. Thus, 27 was the maximum scores from the QI tool. The following cut-off was used for the current review which was adopted from previous studies (Carroll, Parmar, Dalbeth, Boocock, & Rome, 2015; Meyer, Karttunen, Thijs, Feys, & Verheyden, 2014; Weierink, Vermeulen, & Boyd, 2013): A high-quality study, ≥80%; a moderate quality study, ≥47% and < 80%; a poor-quality study, < 40%.