Approximating the relationship among the degree of the reaction forces and the nodes on footprint during a stance phase

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Introduction

This research involved an investigation of the foot biomechanics that are utilized when a foot is placed in contact with the ground during a stance phase. The purpose of the study was to investigate the normalized ground reaction forces that reacted on certain sections and points on the footprint and to attempt to identify patterns in the degree to which these forces occurred. In order to do this, it was necessary to measure the ground reaction forces. Measuring these forces using a force plate is one method that is commonly applied. However, a force plate system produces output charts that provide no depiction of the relationship between the ground reaction forces and the bones and joints involved. The reaction force patterns involved in human walking gait provide crucial information pertaining to the level of normality of the feet. If foot is abnormal, then the walking profile will follow a different pattern. Studying the reaction force patterns can be extremely beneficial because they can help to determine the level of foot normality [1], measure the gait biometrics [2], and allow an accurate reproduction of the foot in the form of prosthetic foot [3]. However, these benefits fall beyond the scope of the current study.

Background

The human foot has 27 bones [4]. The five digits called the phalanges are located at the extreme end of the foot, while the calcaneus, the largest bone, is located at the ankle. At the initial stage of a stance phase, sole-floor reaction force from the calcaneus dominates the distribution of reaction force, whereas the phalanges are effective towards the end. A stance phase has five sequences, which occur in the following order [5]:

(i) The initial contact (IC) with the ground,
(ii) Heel strike (HS),
(iii) Mid stance (MS),
(iv) Forefoot contacts (FC), and end with
(v) Push-off (PO).

The calcaneus is the first bone to bear the body weight upon contact with the ground. The body weight will then accumulate onto the navicular, the cuboid, and later onto the remaining bones. At the end of a stance phase, the last toe bears the body weight. The HS initiates the sequence in which specific bones will begin to have direct contact with the ground. The sequences of a stance phase apply to human locomotion; it is unknown if they also apply to other primates. However, a research has proven that the human foot has a lower total force in joints and muscles than that of an ape [6]. The kinematic pattern in human gait was proposed in [7].

Comprehensive gait analyses may be performed using a force plate system with special techniques, as suggested in [8]. The application of a force plate system to experiment with the walking patterns of healthy subjects that were wearing rocker shoes was reported in [9]. The function of gait analysis has been clinically evaluated [10], as too has the gait characteristics of persons with bilateral transtibial amputations [11]. However, the accuracy and reliability of the observational gait analysis data produced during this study was questionable [12,13]. As such, this work aims to approximate the reaction forces that act on the specific bones and joints by using an alternative measurement system to the force plate.

Methods

Proposition

In completing one gait cycle, the foot undergoes a distinct sequence that follows a unique path; this is shown in Fig. 1 and is commonly referred to as the gait path. The path has fourteen nodes, 12 of which contain areas where the forces react. This has been extensively studied, especially in the early work of Elftman [14]. However, at present, Bani Hashim et al. [3] is the only study that proves the existence of the 12 nodes on the footprint. The path in Fig. 1 depicts node N_0 as the start point along the path as the foot descends. Similarly, N_{13} is located along the path above the ground after the PO. The cycle begins at N_0 and ends on N_{13}. On the IC, N_1, the calcaneus experiences the first force reaction impulse.

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