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Short communication

Assessment of sub-division of plantar pressure measurement in children

J.A. Stebbins[a,*], M.E. Harrington[b], C. Giacomozzi[c], N. Thompson[b], A. Zavatsky[a], T.N. Theologis[a,b]

[a]*University of Oxford, Oxford, UK*
[b]*Oxford Gait Laboratory, Oxford, UK*
[c]*Istituto Superiore di Sanita, Rome, Italy*

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Abstract

Methods for the measurement of plantar pressure are poorly defined particularly when describing sub-sections of the plantar surface of the foot in the presence of deformity. The aim of this study was to assess foot pressure measurement in healthy children, using an automatic technique of sub-area definition that has the potential for objective evaluation of treatment of foot deformity. Twelve healthy children were examined on three occasions. Plantar pressure data were collected and time synchronised with force plate and stereophotogrammetric data. The footprint was divided into five sub-sections by using the position of the markers on the foot at mid-stance projected onto the pressure footprint. Repeatability for peak pressure and peak force was assessed. Automatic sub-area definition based on marker placement was found to be reliable in healthy children. A comparison of results revealed that peak vertical force was a more consistent measure than peak pressure for each of the five sub-areas. This suggests that force may be a more appropriate measurement for outcome studies.

Keywords: Plantar pressure; Foot; Reliability; Force

1. Introduction

Plantar pressure measurement is commonly used to determine specific loading characteristics at the sole of the foot. However, there is a lack of consistency in both measurement technique and reporting of results. Clinically, it is more relevant to examine pressure under specific areas of the foot rather than the foot as a whole [1]. Theoretically, the foot may be divided infinitely into smaller and smaller sections. While more precise information is gained by considering smaller areas, there is also a loss of information about global foot function [1]. Sub-divisions of the foot must be small enough to avoid confusion with function from a neighbouring area, but large enough to include all useful information about that particular area. Ideally, divisions should correspond to foot anatomy and function, and should, therefore, take into consideration position of joints in the foot.

Methods for defining sub-areas may be grouped into two categories. One is based on the geometry of the foot, while the other involves the identification of anatomical landmarks. If the first method is used, the footprint obtained from the pressure platform is rotated and translated to fit into the reference system of the platform [2]. It is then divided according to predefined geometric criteria. This method loses accuracy when foot deformity is present [3]. The second method involves visual examination of the footprint, and selection of sub-areas based on a subjective assessment and identification of areas corresponding to anatomical landmarks. The accuracy of this process depends on the spatial resolution of the platform, the anatomical knowledge of the clinician, and the clarity with which each landmark may be identified [1,4]. It is more valid in the presence of

* Corresponding author. Present address: Oxford Gait Laboratory, Nuffield Orthopaedic Centre, Windmill Road, Oxford OX37LD, UK. Tel.: +44 1865 227946; fax: +44 1865 227943.
E-mail address: julie.stebbins@ndos.ox.ac.uk (J.A. Stebbins).

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foot deformity than the first method, but the lack of automation reduces repeatability.

Another method by which the foot may be divided on the basis of anatomical landmarks involves the synchronisation of a pressure platform with a stereophotogrammetry system. Reflective markers are placed on relevant anatomical landmarks on the foot. The position of each marker is projected vertically onto the footprint at a point corresponding to mid-stance. Sub-divisions of the foot may then be automatically defined based on the position of the markers. Giacomozzi et al. [5] proposed this method and achieved encouraging results. It maintains the accuracy of using landmarks rather than arbitrary divisions of the foot, while improving repeatability by reducing human error in identification of these landmarks. However, the particular sub-divisions used in their paper relied on the subject achieving flat foot contact and therefore have a limited application to feet that have a significant deformity.

The current study utilises the approach of automated sub-area division suggested by Giacomozzi et al. [5]. However, the method of selecting sub-areas based on anatomical data was adapted to be suitable for foot deformities commonly seen in conditions such as cerebral palsy (CP). The aim of this study was to assess repeatability of plantar pressure measurement in healthy children to provide a baseline for comparison with children with foot deformity and to supply a tool for the objective assessment of the outcome of treatment.

2. Children and method

Twelve healthy children (mean 9.9 years, range 7–14 years) were examined on three separate occasions at the Oxford Gait Laboratory for the repeatability analysis. Two children with hemiplegic CP were also assessed (both aged 8 years) on one occasion only. Both CP children exhibited an equino-varus foot deformity, and walked with toe contact only. The results from the CP children were used for the purposes of normalisation discussed below. Visits were spaced a minimum of 7 days apart. Each child had reflective markers placed on specific anatomical landmarks [6] on their dominant (or affected) foot, as well as a conventional lower body marker set [7]. A 12 camera VICON 612 system (Vicon Motion Systems, Oxford, UK) was used to collect 3D kinematics of one foot and both lower limbs for each subject, sampling at 100 Hz. Data were also collected from a piezo-resistive pressure platform (Istituto Superiore di Sanita, Rome, Italy) with a spatial resolution of 5 mm, sampling at 100 Hz [5]. This was rigidly mounted to and time synchronised with an AMTI force plate, with a minimum sampling frequency of 500 Hz (OR6 platform, Advance Mechanical Technology Incorporated, Massachusetts, USA). Results were validated by comparing centre of pressure and total force output from the AMTI force plate with that of the pressure mat. Subjects were asked to walk at their usual walking speed along a 10 m walkway. Three representative footprints for each visit were used in the analysis.

The pressure footprint was divided into five sub-sections. These were medial heel, lateral heel, midfoot, medial forefoot and lateral forefoot. The positions of the markers on the foot were superimposed onto the pressure footprint at a time corresponding to mid-stance, defined by the instant when the summed vertical distance between all the markers on the foot and the floor was at a minimum. The medial/lateral and anterior/posterior co-ordinate of each marker was then projected vertically onto the footprint (Fig. 1). This provided the means to automatically divide the foot on the basis of anatomical landmarks (Table 1).

Peak pressure and peak force values (normalised to body mass) were obtained for each sub-area, for each gait cycle, and repeatability of these measurements was assessed using SPSS software (SPSS Inc., Version 11.0). ANOVA tables were used to define within subject standard deviations for the healthy children. To compare the repeatability of reporting

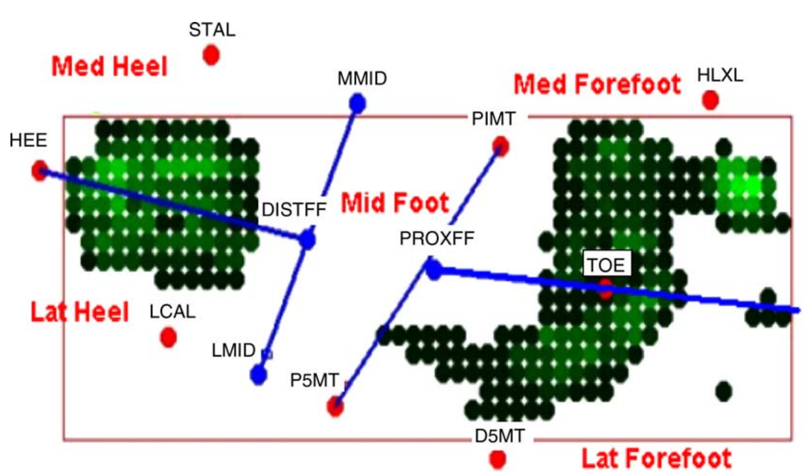

Fig. 1. Pressure footprint showing five sub-areas: medial heel, lateral heel, midfoot, medial forefoot, and lateral forefoot. The labelled circles represent the projected positions of markers on the foot. Table 1 lists the name and location of each of these anatomical landmarks.