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The use of the Podotrack in forensic podiatry for collection and analysis of bare footprints using the Reel method of measurement

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ABSTRACT

This small-scale study examined the role that bare footprint collection and measurement processes have on the Reel method of measurement in forensic podiatry and its use in the Criminal Justice System. Previous research indicated that the Reel method was a valid and reliable measurement system for bare footprint analysis but various collection systems have been used to collect footprint data and both manual and digital measurement processes were utilized in forensic podiatry and other disciplines. This study contributes to the debate about collecting bare footprints; the techniques employed to quantify various Reel measurements and considered whether there was asymmetry between feet and footprints of the same person. An inductive, quantitative paradigm used the Podotrack gathering procedure for footprint collection and the subsequent dynamic footprints subjected to Adobe Photoshop techniques of calculating the Reel linear variables. Statistical analyses using paired-sample t tests were conducted to test hypotheses and compare data sets. Standard error of mean (SEM) showed variation between feet and the findings provide support for the Reel study and measurement method.

1. Introduction

This article was the result of a study into bare footprint collection and started off as an initial idea based on the evidence from a short literature review and speaking with forensic podiatry colleagues that there appeared little to no scientific evidence on which techniques were used for collection, analysis and interpretation of bare footprints. The author had been instructed sometime previously by a police force to evaluate and systematically show that a person held in custody could be the perpetrator of a murder, where at the crime scene bloodied bare footprints had been left, which appeared to be either socked or bare footprints. The author had collected footprints from the suspect using Podotracks, a carbonized paper and collection system used in analysing pressure distribution and load in diabetic patients and which the author had used in clinical practise [1]. However, there was little to no evidence or standard collection system found in the literature and little evidence could be found as to which method of collection was appropriate and if there was likely to be any difference between measurements using differing systems.

The Gunn method of analysis [2,3] was used for the casework, but again there was scant evidence to support its use as a valid and reliable measurement and analysis system. Discussion between professionals and literature searching suggested no agreed protocol or standard for measurement or analysis in terms of a valid and reliable measurement system or one in which there was an agreed protocol to either manually or digitally measure the various foot measurements at that time. Subsequently the Reel system of measurement [4,5] has been shown to be a valid and reliable measurement system in bare footprint analyses.

Perpetrators of crime leave some form of trace evidence when they visit a scene [6]. The skill of the forensic expert is to match the physical or trace evidence to an individual, determining whether that individual, known by the investigators, visited that scene. Forensic podiatry uses the skills and attributes of the podiatric profession and applies these attributes and specialized knowledge to the development of evidence through scientific and technical investigation to assist courts in resolving questions of fact in civil or criminal trials. According to Vernon and McCourt [7] forensic podiatry is: “the application of sound and researched podiatry knowledge and experience in forensic investigations, to show the association of an individual with a scene of crime, or to answer any other legal question concerned with the foot or footwear that requires knowledge of the functioning foot”. Forensic podiatry is a relatively new forensic science discipline [8], starting in the 1970's in Canada and the United Kingdom. Podiatrists are employed to determine if identification of suspects is possible from foot impressions left at a crime scene. The role and scope of forensic podiatry has now been clarified and agreed by the International Association of Identification [9].

‘Footprints’ are the impressions or marks left behind by a person walking or standing, whereas ‘shoeprint’ is the specific term for prints made by shoes. Footprints can also allow the detective to find the approximate height by the length of the footprint. The footprint tends to be approximately 15% of the person's height [10,11,12].

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One of the most influential philosophies, behind modern forensic science, is commonly known as Locard's exchange principle, which simply states that "with contact between two items, there will be an exchange" [6].

This study used the exploratory and empirical research methodologies for its epistemological assumption, which was that the foot and its dimensions are open to measurement. Barefoot impressions whether left at a crime scene as latent prints or within a shoe, need to be 'dissected' first, i.e., broken-down into component parts, properties and characteristics, which are observed and measured. The findings are noted, then compared with known standards e.g., size of shoe, style, and manufacturer [13]. However, forensic podiatry is a young profession and the measurements and observations of feet and foot impressions have not been validated by large scientific studies [8,14–17].

2. Material and methods

2.1. Participants

Bare footprints were collected from a self-selected convenience sample of thirty-five participants (staff and students) using the Podotrack™ (PressureStat™ in some countries), in a test, re-test method, collecting the 4th step of a dynamic phase of gait and utilizing both feet of the participants. The 4th step was chosen as similar to that of previous studies [18,19] and justified in terms of previous research [20]. The sample size was deemed an appropriate number to be recruited in the time limits available and to maintain costs of materials.

2.2. Ethical approval

Ethical approval for the study was obtained from the xxxxxxxxxx xxxxxxxxxx xxxxxxxxxx Ethics Committee, informed consent was obtained from participants and an appropriate risk assessment was conducted using a simple pro-forma to ensure that the risk of injury to anyone taking part was minimized in line with Research Governance procedures. The following selection criteria were utilized for participants.

2.2.1. Criteria

The following criteria were applied in selecting the study participants.

2.2.1.1. Inclusion criteria.

- Two feet.
- Participants aged between 16 and 65 years of age.
- Either gender or any ethnic background.
- Able to walk a minimum of 10 m unsupported.
- Have no medical or surgical condition affecting their walking pattern.

2.2.1.2. Exclusion criteria.

- Any lower limb abnormality preventing 'normal' walking.
- Prosthetic limb(s).
- Persons who have difficulty standing steady or straight, and participants with hairstyle (e.g., Afro or Mowhawk) or head dress (e.g., turban) that prevents proper use of the height measuring equipment.
- Pregnancy.

A unique identity was assigned to the participant and preliminary checks undertaken to confirm participant suitability.

2.3. Collection protocols

Footprints were collected from each individual using a standard protocol. The footprints were collected using a dynamic footprint collection method.

The Podotrack is a carbon paper based system [21] consisting of:

A top transparent sheet, an antistatic plastic foil with an adhesive layer on the back, protected by a paper strip. Despite the adhesive layer, the foil is transparent.

A middle sheet, a modified DLA-colour carrier, which has a standard black colour. In order to remove this sheet after use, it is perforated both at the top and the bottom edges.

The third sheet is white cardboard, printed with a pattern of 1 mm squares. Two adhesive strips are attached to the underside which allows the Podotrack® to be fixed to the floor.

The protocol consists of:

Ask the participant to practise walking in their bare feet in the designated area to allow them to achieve their 'normal' gait and for them to be observed as to what might constitute 'normal' gait for them.

A starting point is marked on the floor with masking tape, the participant is asked to stand upright, with their eyes fixed on a point level with their eyes somewhere in the distance, which helps prevent targeting of the paper and the participant watching where they are walking. The participant stands behind the start line with their toes adjacent to the masking tape but not in contact with it. The participant is asked to walk normally at their own pace along the 'walkway', starting with their left foot for a right footprint collection foot (if taking a left footprint — start with right foot).

The investigator places the Podotrack adjacent to where the participant's right foot lands on second contact with the floor i.e., 4th step. The participant is asked to go back to the start line and again walk normally (See Fig. 1).

When the investigator is satisfied that the participant is walking normally and that the Podotrack is in the correct location, the Podotrack is prepared and taped to the floor with masking tape to prevent slipping, in the line of the walk. The participant then is asked to walk again, collecting the footprint data as they walk.

After the footprint has been collected, the carbonized paper is removed from the Podotrack and the clear film adhered to the underlying footprint (See Fig. 2). The paper is marked with participant identification number, time, location and date and initialled by investigator.

Reel [4] reported a system for the quantitative measurement of footprints. The Reel method uses a system of linear and angular measurements based on a validity and reliability study, which showed standard errors of means and other appropriate statistical analyses, which demonstrated the requirements for a valid, reliable method. Although conducted on a relatively small sample size, the methods were well described and well executed allowing someone else to repeat the process. Reel [4] reported statistically significant differences between paired static and dynamic linear measurements (df 60) with t values ranging from 3.08 to 23.17, $p < 0.01$. The highest correlations were reported to be associated with stature and were disclosed to be the linear measurement from the heel to fifth toe print in the dynamic footprints ($r = 0.858$, $p < 0.01$). A reliability analysis found high intra-rater agreement using intra-class correlation coefficient (ICC) 0.99 with a 95% standard error of measurement 0.84 mm, 95% limits of agreement (LOA) −0.91 to 0.65.

Reel [4] initially started with defining the inner and outer tangents of the footprint, which were identified [22–24] (see Fig. 3) and bisected to create the central axis. A grid was placed over the image, which was then rotated to ensure the central axis was vertically aligned. A horizontal mark was then introduced which would cross the most proximal pixel of the heel in this new alignment [4]. This determined how the mid-point of the rear most aspect of the heel was defined and determined and the original lines of the Gunn method were also employed in her study. From that point where the central axis and the heel