



The identification and reliability of static and dynamic barefoot impression measurements: A systematic review



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ABSTRACT

Objective: Barefoot impressions collected from crime scenes can be used in forensic analysis. The reliability of the measurement method employed during comparison of these foot impressions is paramount to prevent incorrect conclusions being made. A number of methods of obtaining measurements from barefoot impressions have been described in the research literature; however there has been no comprehensive review of their reliability. Therefore, the aim of this systematic review was to determine the reliability of measurements used to describe footprint morphology obtained from static and dynamic barefoot impressions.

Methods: Four electronic databases were searched from inception to 23 November 2017. Eligible studies were required to report either the test–retest, intra or inter-rater reliability of measurements taken from barefoot impressions for the purposes of identification or classification of foot morphology. Methodological quality was assessed using the COSMIN checklist.

Results: Eleven studies were identified that reported the reliability of 10 measurements (Reel method, arch index, Chippaux-Smirak index, footprint angle, Staheli index, contact area, Martirosov's K index, toe score and metatarsal ridge-to-toe measurement). High intra-rater reliability has been established for the Reel method (ICC = 0.98–0.99), arch index (ICC = 0.96–0.99), Chippaux-Smirak index (ICC = 0.98–0.99), footprint angle (ICC = 0.97–0.98), Staheli index (ICC = 0.98–0.99) and footprint index (ICC = 0.96–0.97). High inter-rater reliability has been established for the Reel method (ICC = 0.99) and footprint angle (ICC = 0.99). Overall methodological quality was rated as 'Poor' to 'Fair'.

Conclusion: The measurement developed by Reel et al. has both its intra- and inter-rater reliability established to be high. However, the findings of this review were unable to inform a recommendation of one specific technique based on reliability data due to a small body of research at this time. Furthermore, there is a lack of data on the reliability of footprint measurement and comparison techniques in real-world scenarios. Overall, the findings regarding reliability of the techniques covered in this systematic review are to be interpreted with caution due to the methodological quality of reliability testing conducted within the included studies.

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1. Introduction

Foot impression measurements are employed in forensic analysis, particularly for the comparison of foot impressions collected from crime scenes [1]. Parameters and indices can be obtained from a foot impression by geometrically charting it

according to landmarks. These measurements may also be used to make a prediction of the stature, sex and body weight of the individual [1,2]. The reliability of the measurements employed during forensic examination of foot impression evidence is crucial [3]. If the examiner were to use an unreliable measurement, there is a probability that the results obtained would be inaccurate and could lead to incorrect conclusions in evidence [3].

Multiple measurements have been proposed for the characterisation of barefoot impressions, ranging from simple linear distances between the margins of the footprint and anatomical locations [1,4], angular measurements between foot regions [5], to area based metrics that represent the three-dimensional morphology of foot structure, such as the medial longitudinal

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arch [6]. There is currently no standardised protocol or gold standard in the forensic analysis of barefoot impressions, in-part due to the paucity of scientific evidence which supports the reliability of one specific foot impressions measurement technique over another [5,7].

Due to the lack of reliability data on existing measurements and techniques underpinning the comparison of barefoot impressions, Reel et al. [5] developed a method based on features of heel and forefoot width and digit length relative to posterior calcaneus. Although some studies in the literature have further investigated the reliability of this method [7,8] and other selected measurements [9], no previous systematic reviews synthesising the published studies on all different measurements could be identified. Therefore, the aim of the systematic review was to identify which measurements have been described in the scientific literature for characterising footprint morphology obtained from static and dynamic barefoot impressions and determine their reliability.

2. Methods

2.1. Design and search strategy

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines [10]. The review protocol was registered on the international Prospective Register of Systematic Reviews (PROSPERO; registration number CRD42016049503).

A systematic search was performed using four electronic databases (Medline, Embase, CINAHL, and AMED) on 23 November 2017 (Table 1). Grey literature was not scrutinised.

2.2. Eligibility criteria

Studies were included if they met the following criteria:

- 1) Static or dynamic two-dimensional barefoot impressions collected from human participants with morphological measurements recorded.
- 2) Reliability testing (either test–retest, intra or inter-reliability) of any foot impression measurement performed and reliability statistics provided.
- 3) English language full-text article available.

Studies were excluded if:

- 1) The study was in the form of a literature review, opinion piece or case study.
- 2) Foot impressions were collected in forms other than two-dimensional or from plantar pressure platforms.

Although clinical foot impression measurements were not specifically developed for identification purposes, they may have the potential to do so, within the constraints of class characteristics. Thus, we expanded the eligibility criteria to capture measurements in the clinical field to provide a comprehensive review.

2.3. Selection process

Study selection was performed by two independent reviewers using covidence online review manager (www.covidence.org). Two reviewers (AH and SJ) screened the titles and abstracts of all studies identified. The full texts of all remaining studies were retrieved and assessed independently by the same reviewers. After each phase, reviewers met and discussed any disagreements. If disagreements could not be resolved, a final decision would be made by a third independent reviewer, however, this was not required. The reference lists of the final included studies were searched for potential studies not previously identified.

2.4. Extraction and analysis of data

Data from all included studies were extracted independently by two reviewers using a standardised data extraction form. The data extracted included sample characteristics (sample size, gender, age, health status, presence of foot pathologies), foot impression collection methods (instrument utilised, protocol, left/right foot, measurements) and reliability estimates.

Extracted data were evaluated for homogeneity and potential for meta-analysis. Data not suitable for meta-analysis would be presented in a narrative form.

The reliability of measurements were estimated with a range of indices, including correlation coefficients (Pearson's, intraclass correlation), mean differences, standard error of measurement (SEM) and Bland and Altman 95% LOA [11]. Intraclass correlation coefficient (ICC) values greater than 0.90, between 0.80 and 0.89 and less than 0.80 were interpreted as high, moderate and questionable reliabilities respectively [12]. Pearson's values greater than 0.70, between 0.50 and 0.69 and less than 0.50 were interpreted as high, moderate and low reliabilities respectively [13].

2.5. Quality appraisal

The methodological risk of bias for each study was assessed by two independent reviewers (AH and JA) using the COSMIN (Consensus-based Standards for the selection of Measurement Instruments) checklist (Appendix 1 of Supplementary material) [14].

As this systematic review focussed on the reliability of foot impression measurements, only the reliability section (box B) of the COSMIN checklist was used to evaluate the methodological quality of the reliability testing conducted within the included studies. As part of this section only considers whether an ICC was calculated as a reliability estimate, item 11 from box C (measurement error) was added to determine whether studies calculated other reliability estimates. Items 12, 13 and 14 from box B were removed as they assess ordinal data. The specific items that were evaluated when assessing the included studies are listed in Table 2. There are four response options for each assessed item: "Excellent", "Good", "Fair" and "Poor". As recommended by the checklist, the final methodological quality score of the study was decided based on the lowest rating of any item in the section.

Prior to independent appraisal of the studies, the reviewers discussed interpretation of the items in the tool to ensure

Table 1

Search strategy for systematic review.

| | | |
|--|-----|---|
| footprint* OR foot print* OR bare footprint* OR foot impression OR barefoot OR arch index OR arch indices OR Gunn method OR Hernandez-Corvo index OR Hernandez Corvo index OR Chippaux-Smirak index OR Chippaux Smirak index OR Staheli arch index OR Clarke angle OR Reel method OR overlay method OR forensic podiatry | AND | precise OR precision OR reliab* OR reproduc* OR accura* |
|--|-----|---|

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