CHAPTER 11

Forensic Podiatry: A Brief Compendium

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INTRODUCTION

In 1862, foot-related evidence linked Jessie McLachlan to a murder, eventually leading to her conviction (1). This was the first documented case of pedal evidence being used in a criminal investigation. The use of podiatrists in criminal cases in the US and Canada started in the 1970s with Dr. Gunn and continues to grow (2,3). One of the most substantial cases that used forensic podiatry was the O. J. Simpson trial (4). After obtaining a bloody shoeprint that was believed to be left by the perpetrator, a shoeprint analysis was performed. Investigators determined that the shoeprints came from relatively rare, imported Italian shoes in the size that OJ Simpson wears (4). The above-mentioned shoes were never found and O. J. Simpson insisted that he would never wear those shoes, even with pictures suggesting otherwise. Although this was insufficient to convict OJ Simpson in criminal proceedings, this evidence was used against him in a civil suit. He was ultimately convicted for the wrongful death of his ex-wife. By the turn of the millennia, a need to establish a forensic podiatry organization arose due to the exponential growth in the field.

In 2003, Dr. John DiMaggio founded the American Society of Forensic Podiatry, which promotes the utilization of podiatry within criminal cases, as well as maintaining high standards of practice. The demand for forensic experts within the field of podiatry is quickly rising, as is the amount of research and interest within the field among practitioners and students. Forensic podiatry clubs have been established at the New York School of Podiatric Medicine and Barry Universities School of Podiatric Medicine. Other schools, such as Temple University School of Podiatric Medicine, Scholl College of Podiatric Medicine, and the California School of Podiatric Medicine have plans to establish clubs as well.

Much of the research in the podiatric forensics field to date has been completed by forensic anthropologists and a variety of other disciplines. Although these fields laid a foundation, podiatrists have utilized their expertise in lower limb anatomy and biomechanics to expand on this research, leading to the development of the podiatric sub-discipline known as forensic podiatry. Forensic podiatry is defined as "the application of sound and researched podiatric knowledge and experience in forensic investigations, to show the association of an individual with a crime scene, or to answer any other legal questions concerned with the foot or footwear that requires knowledge of the functioning foot" (5). As of now, there are four fundamental scopes of practice within forensic podiatry: podiatric treatment records, footprint analysis, footwear, and gait analysis. Research focuses on these aspects of forensic podiatry so that evidence can be utilized effectively. It is important for forensic podiatrists to know how evidence is collected and what information can be extracted in order for the maximum efficiency and accuracy to be exhibited in expert testimony.

EVIDENCE COLLECTION

While most forensic podiatrists rarely participate in actual evidence collection, it is important to understand the different types of evidence collection, the technique of collection, and the advantages and disadvantages of each. This establishes an understanding on how to not only interpret evidence but also what can be gained by each ilk.

The technique used to collect evidence is dependent on the type of evidence left. In some cases, it may be possible for evidence technicians or other evidence personnel to remove the footprint. This would enable a forensic expert to examine the evidence at a later time to allow investigators to accumulate other information. It can also allow for direct comparison for evidence from the crime scene with characteristics or other evidence provided by potential suspects (6). One applicable example of removing a footprint would be if a footprint or shoeprint was found on a tile. The tile with the footprint can be removed and preserved for later inspection. Other examples of print extraction include impressions on a piece of paper, a shoe, or a small rug.

Print extraction in which the print cannot be removed can be accomplished by either lifting or casting techniques (6). Lifting is utilized when two-dimensional footprints or shoeprints are viable. Lifting techniques can be defined as "a way of transferring a two-dimensional impression from

its original surface to a surface that will provide better contrast" (7). There is a cornucopia of lifting techniques to extract dusty footprints including adhesive, electrostatic, and gelatin methods for lifting dusty prints. Silicone-based techniques that adhere to prints after being allowed to set may also be utilized (6,7). Each of these techniques has their advantages and disadvantages, but they all permit removal of footprints and shoeprints from the scene so they can be examined later.

Casting is a technique used for three-dimensional footprints and shoeprints. It is defined as "the filling of three-dimensional footwear impressions with a material that will acquire and retain the characteristics that were left in that impression by the footwear" (7). There are numerous casting materials, each having unique advantages and disadvantages, including dental stone, sulfur, paraffin wax, silicon-based materials, and alginates (6). The appropriate casting technique and material should be selected based on the environment and condition of the impression. For example, sulfur and paraffin wax are used for foot impressions in the snow (6). Before any casting or lifting technique is performed, the print should be photographed and documented extensively in the event that there is distortion or damage to the print.

ANALYSIS OF FOOTPRINTS

After a footprint has been collected, there are many quantifying characteristics. This can later be indications of the perpetrator. First, pedal evidence can express different levels of individuality. The amount of individuality allows for evidence to be variably weighted in a case based on how unique the characteristics are. They are categorized into two types: individualizing and class-level. Individual characteristics are defined as unique and identifying (7,8). Examples of an individual-level characteristic would be papillary ridges in a footprint or damage wear on a shoeprint. Class-level characteristics do not have a precise definition. However, all definitions commonly state that while these characteristics are not considered unique, they do have an undeniable compatibility between similar items (6). An example of a class-level characteristic would be shoe size or common pathologies like bunions or hammertoes. Although a single class-level characteristic may seem insignificant, a group may provide a strong foundation for individuality.

In spite of the fact that footprints are less common at crime scenes, there is a great deal of research done about them. This research allows forensic podiatrists to quantify several important aspects about the footprint. One prominent technique is measuring the length and breadth of a footprint. Footprint length is calculated from the most posterior point of the heel to the tip of the longest toe (9). The footprint breadth is determined from the most lateral obtrusion of the fifth metatatarsal bone to the most medial protrusion of the first metatarsal bone (9). Foot heel breadth is the unique distance from the most medially and laterally protruding points of the heel (10).

While these are fairly simple measurements to obtain, they can divulge detailed information about a person, such as a reliable estimation of their height, weight, and sex (11). For example, a subject's height and footprint length have been shown to give the highest correlation coefficients than any other foot dimension (12). In the mid 1800s, Topinard estimated a person's foot length to be about 15% of his or her stature (13). This number was cited by many, but was further investigated by Giles and Vallandigham in 1991. They discovered in a population of soldiers that a man's footprint was 15.346% of his height and woman's was 14.926% of her height (14). In 2012, however, Pawar and Pawar determined the footprint length was estimated to be in a range of 13.24–15.78% for males and 12.03–15.51% for females of a person's total height (15). Regression analyses have been performed and have given very strong estimations of height based on footprint length and the sex of the subject. Pawar and Pawar (15) used the following equations to estimate height:

Height = 15.690 + 6.342 x (left foot length in cm) in men

Height = 87.906 + 3.165 × (left foot length in cm) in women.

Jaiswal used the regression stature (mm) = 989 (trochanteric height) x 1.10 +737.03(constant) and found a small standard error less than 7 cm (15). Many regression equations and percentage estimations have been researched, but there has not been a consensus on an exact number or equation. Each report does show that there is a small standard error and a high correlation between footprint length and body height.

In addition to footprint length, information can be extracted from a footprint breadth. It has been found that forefoot width will provide a more accurate estimation of stature than heel breadth (17). Weight is also a prominent characteristic obtained from analysis of the footprint width. The ratio of the width of the foot (measuring from the first to the fifth metatarsals) to weight ranges from 67% in men to 71% in women (13). It has also been stated that the ratio changes depending on which foot is measured. In general, the percentage was 66.751% of footprint width to body weight ratio for a right foot and 66.920% of footprint width to body weight ratio (13). Additionally, footprint breadth and length increases significantly per every 20kg of weight that is added (18). This indicates that footprint length and width have the same relationship with body weight (18). Atamturk and Duyar stated that heel breadth is a stronger

predictor of body weight than foot width (19). They noted that age, sex, foot breadth, and heel breadth allowed for more successful predictions of body weight (19).

Through utilization of foot length and width, investigators can estimate a person's sex. The average foot shape, including a pedal width-to-length ration, shows sexual dimorphism (20). It was also demonstrated by several studies that foot dimensions, in general, were greater in males than females in addition to the left foot being more accurate in determining sex than the right foot (12,15,16,21). On average, male feet are longer, have a larger width-to-length ratio, a lower-arched foot, longer toes, and larger distal toe elements than females (20). In sectioning point analysis, the heel breadth and length compared to the fifth digit were the most accurate in the left foot; foot breath, heel breadth, and the foot length from the heel to the anterior point of the first digit were most accurate in the right foot (21). Another study stated that the heel-ball index on the right foot alone was enough to discriminate between sexes (22). The sectioning point method is accurate, allowing for 69.3–80.3% of cases to be accurately categorized (21). A regression model was developed for sex determination for both the left and right foot (23). For the right foot, sex = 69.169 + 0.173 (maximum foot length) - 0.368 (maximum foot width) - 0.820 (shoe length) + 0.224 (shoe width) - 1.280 (shoe number). For the left foot, sex = 69.551 + 0.276 (maximum foot length) - 0.504 (maximum foot width) - 0.739 (shoe length) + 0.344 (shoe width) - 1.360 (shoe number). While sectioning point analysis is accurate, a regression model has demonstrated a higher level of precision in sex prediction (21).

In addition to quantitative measurements and ratios that can be taken from a footprint, qualitative characteristics of the skin and foot shape can also be extracted. Features such as shape of the toe print, shape of the toe line, accidental marks like cuts, and the lack of toe prints allow investigators to extrapolate useful evidence from the digits of a footprint. Toe lines can also exhibit humps, which are defined as a protruding curvature in the ball line. The number of humps found can vary between sexes and range from 0-3. Phalange mark and crease mark sizes, shapes, and positions are often unique. Other skin marks, such as corns, pits, crack marks, and deformities are also considered distinctive to a particular person. A class-level qualitative characteristic is a foot type seen in a footprint. Historically, pes planus foot types were considered to be of greater importance because of the lack of frequency seen in footprints.

All of the previously mentioned analytical techniques used with footprints allow for a combination of both individual and class-level characteristic examination. This combination provides a strong representation of the person who left pedal evidence. Footprints can also give important information about how a crime took place and how a person entered and exited the scene (4). Sets of footprints can clue investigators into what the entrance and exit areas of the scene were used. It can also help the investigators determine if the victim or perpetrator were running, walking, or even changing their pace. Investigators and practitioners are able to develop a strong profile to not only aid in criminal justice cases, but many other realms as well. Footprints establish a vivid picture of an individual if the evidence can be correctly extracted and interpreted.

SHOEPRINTS

Frequently, shoe prints are present at crime scenes and can also present identifying information about a subject (4). They allow analysis of gait and biomechanics based on the wear patterns seen in shoeprints and to linking a person to a place. Brand name and style of shoes are also extracted from a shoeprint and can provide information.

Shoe length have been shown to be useful in estimating height and sex. In Ozden's study, there was a strong correction between foot and shoe dimensions (23). The shoeprint lengths could be used in the same formula as the foot measurements to give accurate results (23). In a study comparing a person's foot, footprint, and shoe, the shoe length was found to be the single most reliable variable to determine a person's sex, with 90% accuracy (24). In a multivariable model, foot length, shoe length, shoe breadth, and shoe size were included to give the most reliable model (24). It was further concluded that even partial shoeprints can be valuable and give identifying information.

Although some researchers proclaimed accuracy from shoeprint length, others expressed contradicting ideas and evidence. Some researchers report that shoe length is a less reliable predictor of height, but shoe size can be somewhat valuable (14). They suggest that estimating height from shoeprint length is a "best-effort" approach and that shoe fit needs to be factored into the height estimation (14). Shoe fit affected the way a person walked and compensated for the misfit shoe. This accommodation affects width measurements of the print and thus the conclusions drawn from these measurements (14). Shoe size was a more reliable method to estimate height because of the underlying foot length/width measurements taken into account with sizing (14). It has also been recently reported that beyond size and make, there have not been any reliable methods to extract anything from shoeprints and footwear.

Despite criticisms of the reliability of information extracted from shoeprints, technology has been developed to analyze partial shoeprints. After analysis, the program can give a make and size estimation of the shoeprint. The advantage of this method is that it allows for the matching of low quality shoeprints accurately and effectively (25). Automatic recognition of low quality shoeprints is still an unresolved

issue in all algorithms (26). Additionally, shoeprints left in sand, mud, or snow are difficult to match when compared to shoeprints taken directly from shoe soles (27).

While there is skepticism about the use of shoeprints to obtain information about a person, there has been some research highlighting possible uses. Shoe size and make can be reliably abstracted from either a full or partial print. This information has been used to determine height and sex in suspects, but there is still very little research on this aspect of pedal evidence. There is still an extensive amount of work to be done if shoeprints are to be analyzed and valued as much as footprints.

In conclusion, the foot, footprints, and shoeprints give a wealth of information about a person. There are clinical advantages for knowing how to analyze a foot and its markings, such as seeing pathologies and biomechanic function. However, the forensic value of a foot, footprint, or shoeprint may not be so obvious. Footprints can give individual-level characteristics, such as papillary ridge markings, corns, calluses, and humps, or class-level characteristics, which may not be able to definitively identify an individual, but can give a very strong individualizing picture when these characteristics are combined. Footprints can also be used to determine the height, weight, and sex with good reliability.

Shoeprints, while there is skepticism concerning their value, are frequently found at a crime scene and can provide valuable data. The shoe make and size can be reliably

Figure 1. Members of Barry University School of Podiatric Medicine Forensic Podiatry Club participating in a workshop where they extracted wet footprints from a piece of paper.

Figure 2. Hardened casting of a shoeprint (28).

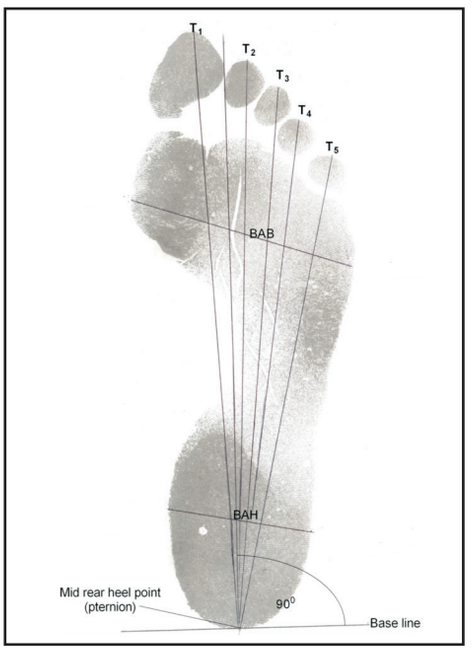

Figure 3. Foot print dimensions (29).

Figure 4. Measuring foot dimensions.

determined, but height, sex, and individualizing wear marks need to be further researched to determine their reliability.

Although forensic podiatry is still a young field, the principles behind them have been noted throughout many cases. These have been utilized in cases that date back to 1862, in addition to being utilized to analyze footprints and shoeprints from ancient cultures to evaluate human development. Forensic research-based approaches are being introduced, evaluated, and improved to give forensic podiatrists more tools to give accurate and reliable information about pedal evidence. Forensic podiatry is also gaining more recognition within the general public. The field is constantly continuously developing and becoming a substantial sub-discipline in the realm of podiatry.

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