Forensic Podiatry:

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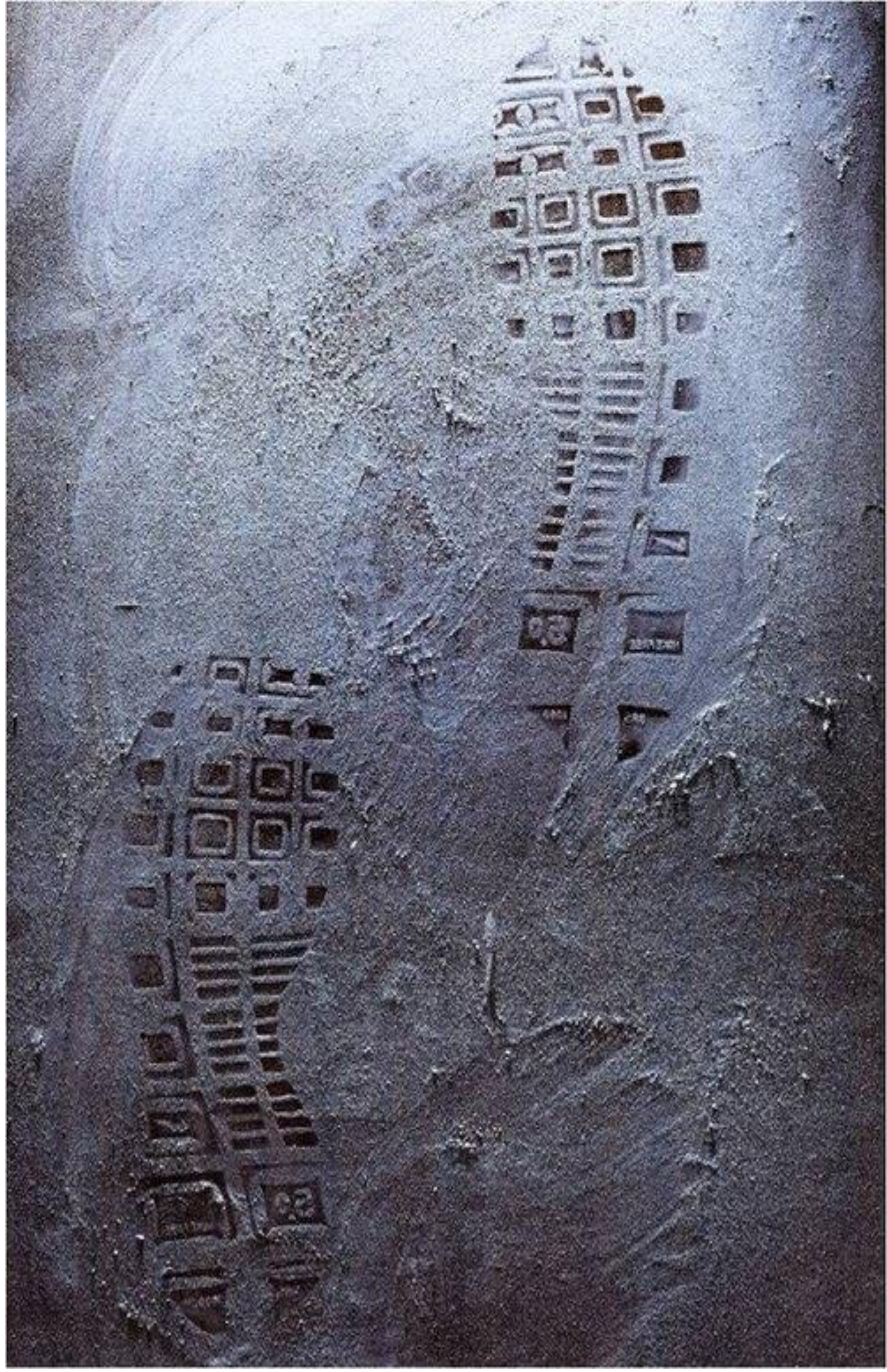
The Unseen Evidence Beneath Your Feet

Dr. Japheth Lumadede

Wherever he steps, whatever he touches, whatever he leaves even unconsciously, will serve as silent witness against him. Not only his fingerprints or his footprints, but his hair, the fibers from his clothes, the glass he breaks, the tool marks he leaves, the paint he scratches, the blood or semen he deposits or collects -- all of these and more bear mute witness against him. This is evidence that does not forget. It is not confused by the excitement of the moment. It is not absent because human witnesses are. It cannot perjure itself. It cannot be wholly absent. Only its interpretation can err. Only human failure to find it, study and understand it, can diminish its value.

Paul L. Kirk
Crime Investigation, 2nd ed., J. I. Thornton, ed., 1974, p. 2.



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Topics to be Covered

- Overview
- Investigative Value
- Formation of Footwear Impressions
- Location and Recovery of Transportable vs. Non-Transportable Impressions
- Comparative Examination Methods
- Conclusion and Way forward

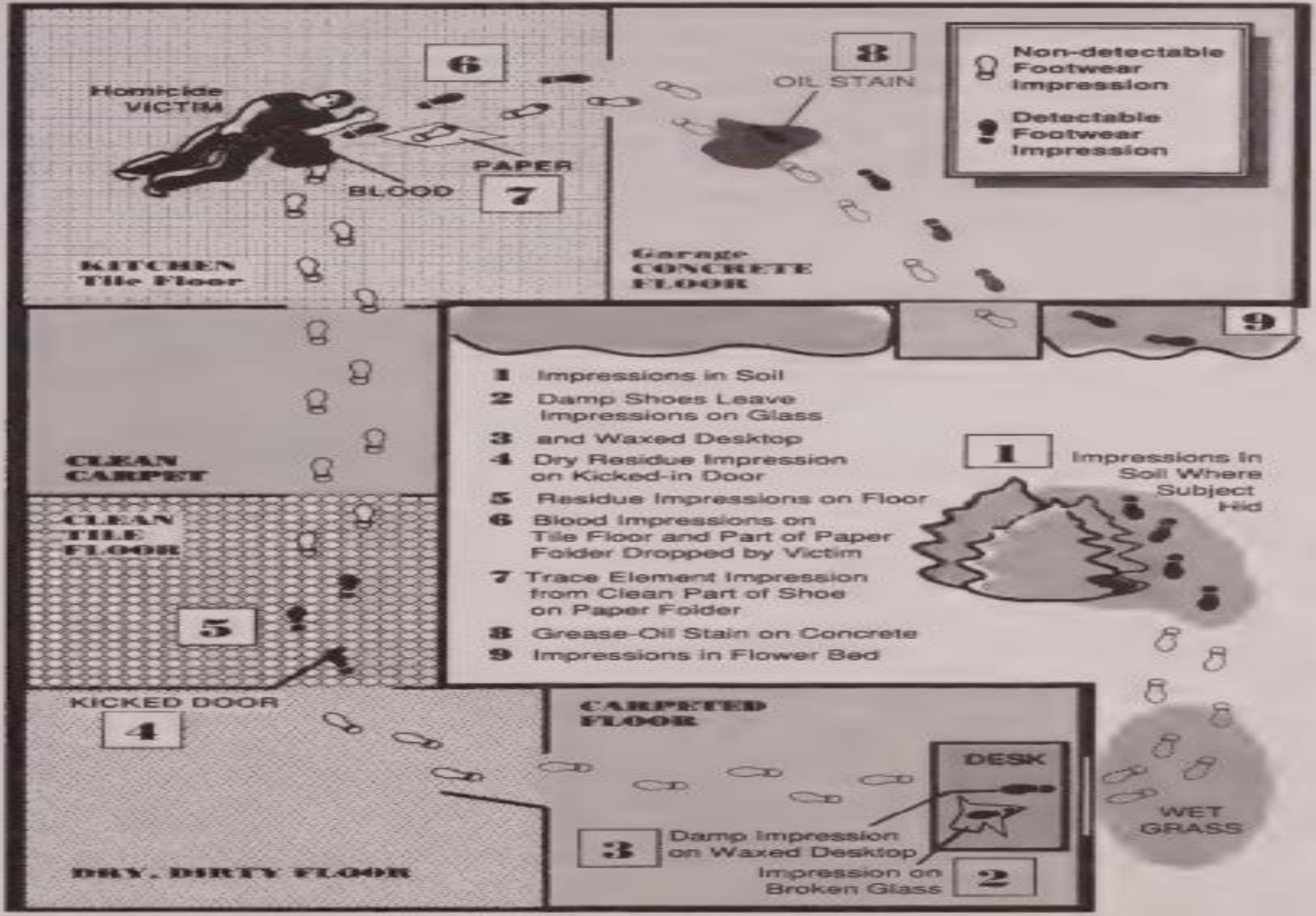

Figure 1.9 A hypothetical crime scene illustrates some of the many ways in which footwear impressions can occur at a crime scene.

Overview

Forensic Podiatry is a specialized discipline that applies the knowledge of the human foot, ankle, and lower limb to legal investigations and judicial proceedings. This document provides a structured overview of the elements, collection, analysis, and judicial considerations of forensic podiatry evidence for law enforcement and judicial personnel.

It focuses on the analysis of pedal evidence:

- barefoot prints,
- footwear (shoeprints),
- insole impressions,
- and gait

—to assist in human identification, crime scene reconstruction, and the evaluation of evidence.

Overview

Forensic podiatry primarily operates within four key areas of practice [1]:

1. Podiatric Treatment Records: Analysis of medical records to establish identity or medical history relevant to a case.
2. Footprint Analysis: Examination of static and dynamic impressions of the bare foot.
3. Footwear Analysis (Shoeprints): Examination of impressions left by shoes, including the shoe itself and its wear patterns.
4. Gait Analysis: Analysis of an individual's walking pattern, often from video evidence.

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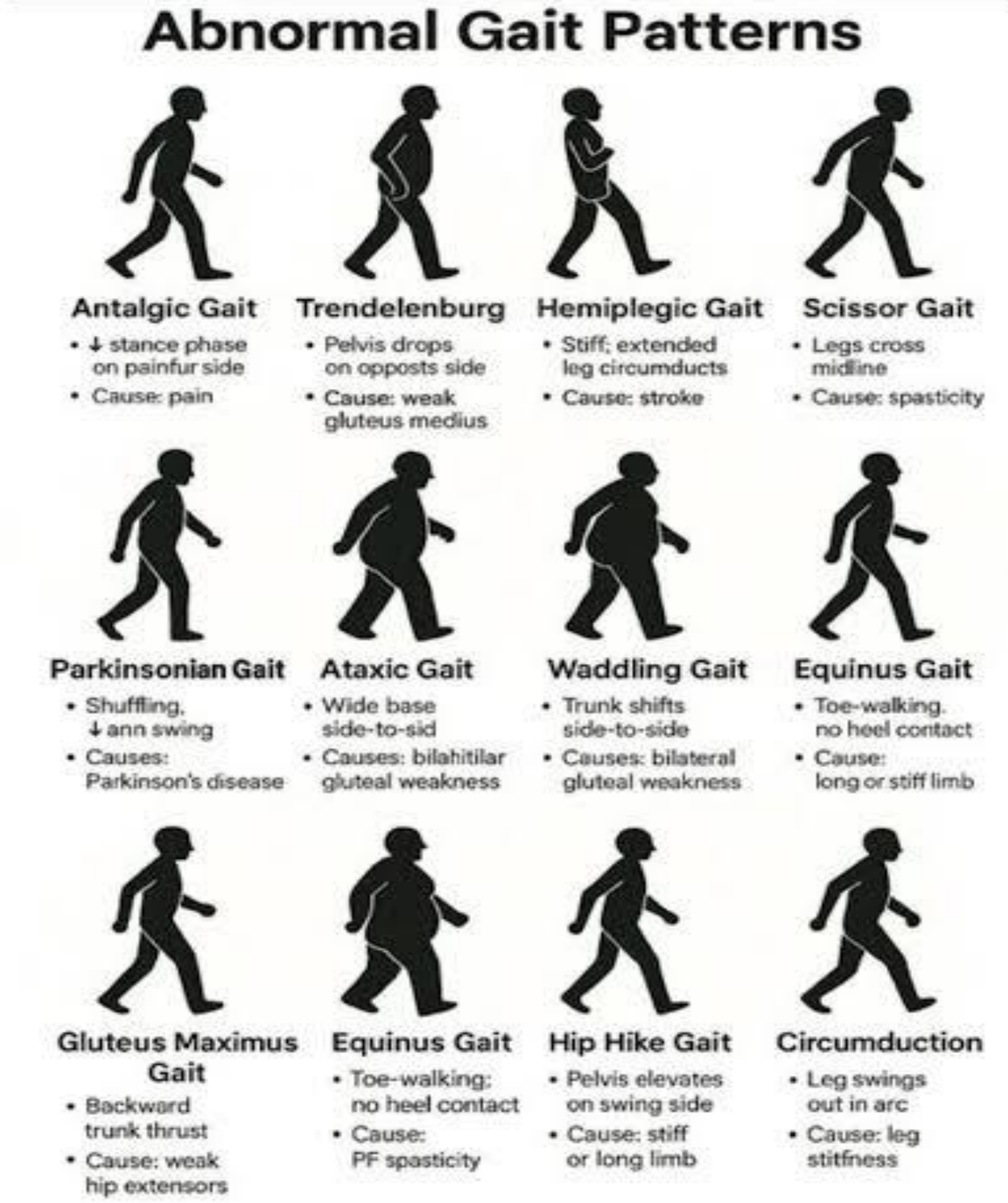
Overview

Podiatric Treatment Records: Analysis of medical records to establish identity or medical history relevant to a case.



Investigative Value of Footwear Impressions

A. Identification and Elimination of Footwear

Class characteristics: Shoe make, model, size, tread design are used to associate or eliminate footwear.

Elimination relevance: Can serve as exculpatory evidence if confirmed.

B. Establishing Suspect Presence and Participation

Impressions at entry/exit points, on stolen or assaulted items, or in victim's blood confirm suspect presence and sometimes participation in the crime.

C. Crime Scene Reconstruction

Impression locations help to locate other evidence (e.g., discarded weapons).

Tracking impression sequences can reconstruct movement paths.

Investigative Value of Footwear Impressions

D. Additional Information Derived –

Shoe size estimated from impression dimensions and known brand sizing.

Number of perpetrators inferred from differing shoe styles or sizes at a scene.

Height estimation possible via foot length and stride analysis.

Activity analysis: Depth and distribution can indicate walking, running, or carrying weight.

4. Gait Characteristics - Though gait (stride length, step width) may differ with speed or surface, it is unreliable alone for personal identification due to variability.

5. Tracking - Following a trail marked by footwear impressions and other physical disturbances (displaced debris, crushed plants). Common use by law enforcement, border patrol, and search teams to locate suspects or missing persons.

Investigative Value of Footwear Impressions

Footprints give information about:

- The number of criminals
- Points of entry and exit
- Position of the suspects
- Direction of movement through the crime scene.
- Time period (eg short-lived impressions in frost, snow and dew)
- Sequence and manner (walking, running, limping, staggering).
- The type, size and areas of wear on the shoes.

Investigative Value of Footwear Impressions

Wear Pattern Gradual alteration of the outsole surface caused by **repeated contact and friction** during use.

Characteristics:

- Each individual walks differently (pronation/supination), creating unique pressure and wear zones.
- Common wear zones: heel edges, forefoot ball area, toe region.

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Investigative Value of Footwear Impressions

Class and Identifying Characteristics:
Class characteristics are features shared by a group of shoes, such as the design of the outsole pattern or the size and shape of the shoe. Identifying characteristics are unique features that distinguish one shoe from another within the same class, such as scratches, cuts, or embedded debris on the outsole.

Forensic experts compare the known impressions obtained from the suspect's shoes with the questioned impressions found at the crime scene. They look for similarities in wear characteristics, class characteristics, and identifying characteristics to determine whether the impressions are a match.

Investigative Value of Footwear Impressions

Class Characteristics of Shoe Impressions:

Outsole Pattern: Each shoe has a unique outsole pattern, which is the most common feature examined. It includes the design, arrangement, and dimensions of the treads.

Size and Shape: The size and shape of the shoeprint can provide clues about the type and size of the shoe.

Material Composition: The material of the outsole can vary and leave distinct impressions.

Individual Characteristics: Unique Wear and Tear: Over time, shoes develop unique wear patterns due to factors like gait, weight distribution, and the surfaces they're used on.

Formation of Footwear Impressions

As people walk, their shoes collect materials like dust, dirt, grease, blood, and moisture from different surfaces and then transfer them to new locations, leaving behind shoe impressions. These can be either: Patent impressions — visible marks on hard surfaces, or Latent impressions — invisible and requiring enhancement techniques.

On soft surfaces (like soil, sand, or snow), shoes can leave three-dimensional impressions that record the shoe's class characteristics (brand, pattern, size) and individual characteristics (wear, cuts, defects).

Forensic footwear examiners detect, collect, and enhance these impressions, create known test prints from suspect shoes, and compare them to the crime scene impressions to determine if they match or can be excluded.

Footwear evidence is often crucial in linking suspects to crime scenes, especially in homicides, assaults, robberies, burglaries, and sexual offenses, where proving a suspect's physical presence is key.

Formation of Footwear Impressions

1. Types of Footwear Impressions

A. Three-Dimensional (3D) Impressions - Impressions created when a shoe physically deforms a soft or malleable surface, leaving depth and shape.

Common substrates: Sand, soil, snow, clay-based soils, mud.

Importance: Highly detailed 3D impressions can often be linked to a specific piece of footwear.

B. Two-Dimensional (2D) Impressions - Impressions made on hard, non-giving surfaces like tiles, linoleum, wood, paper, plastics, clothing, glass, countertops, or carpet.

Formation: Occurs when soles deposit materials like dust, grime, dirt, blood, or oils onto these surfaces.

Visibility: Can be visible (e.g. bloody prints) or latent (invisible without enhancement).

Materials transferred: Dust, residue, oily substances, blood, dirt, etc.

Detail paradox: Lighter, latent prints often contain more nuanced sole detail than heavier, more visible prints due to less smudging.

Formation of Footwear Impressions

Creation of Static Charges

•**Mechanism:** When a shoe contacts a surface, friction creates an **electrostatic charge** (Davis, 1988).

•**Demonstration:** Applying light blower powder or small polystyrene beads to a charged area will visualize the impression as the materials are **attracted to the residual static charge**.

•**Forensic Utility:**

- •**Not Practical for Crime Scenes:** The residual charge **does not last long** and is rapidly lost in **high-humidity** or **damp environments**.
- •**Secondary Role:** Static charges are thought to aid in the **strong adherence of residue, dust, and other trace materials**, contributing to the formation of transfer impressions.

Deformation of the Surface

Subtitle: Retaining the Shoe's Characteristics

•**Mechanism:** When the ground surface is **soft or yields**, the pressure exerted by the shoe causes the material to **deform**, retaining the shoe's characteristics.

•**Types of Deformation:**

- •**Permanent (3D):** Occurs in **non-resilient, soft substrates** (e.g., **snow, sand, soil**). These impressions are **durable** and require **casting (Dental Stone)** for recovery.
- •**Temporary (2D):** Occurs on **resilient surfaces** (e.g., **carpet, grass, skin**). The surface slowly **returns to its original shape**.

•**Associated Evidence:** Even with temporary deformation, associated evidence like **stains, contusions (on skin), or transfer of residue** may occur.

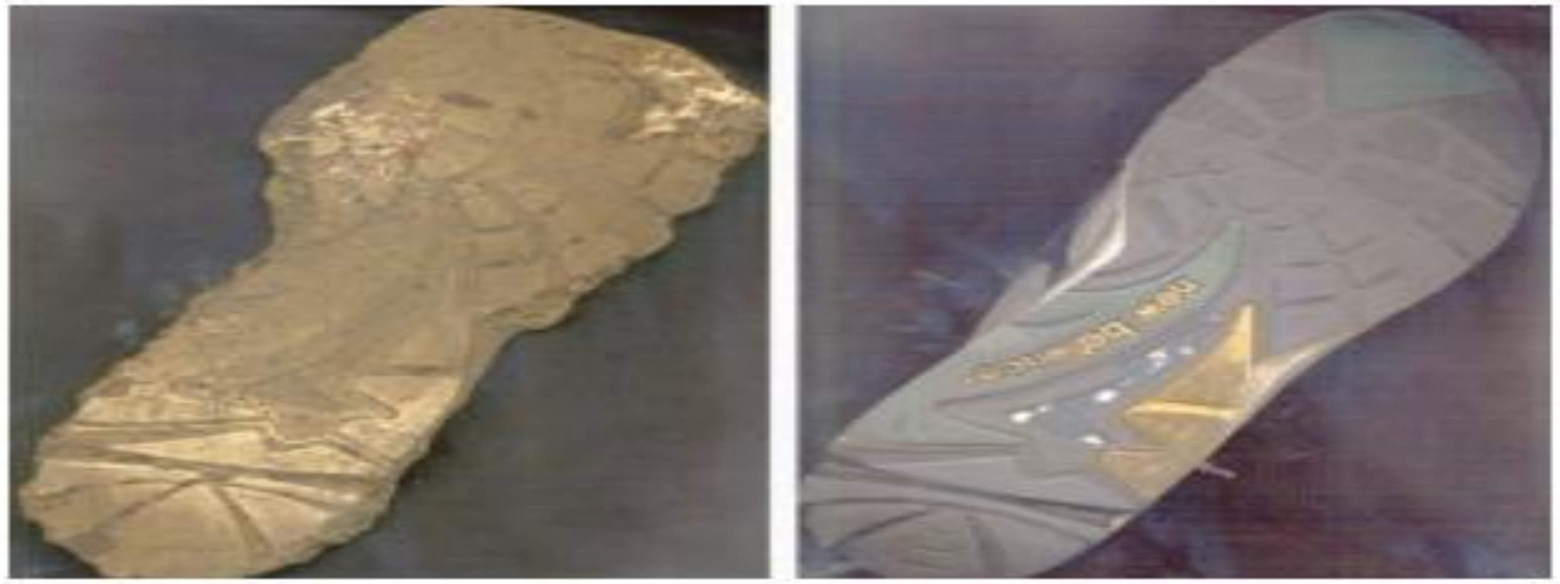

Figure 16.7 A cast of impression #7 in Figure 16.3 recovers the three-dimensional information in excellent detail. A cast should *always* be made after three-dimensional impressions are photographed. Alongside the cast is the suspect shoe.

Formation of Footwear Impressions

Transfer of Trace or Residue Impressions

Subtitle: The Physical Contact Mechanism

•**Mechanism:** The physical contact between the shoe and substrate results in a **transfer of material** (trace materials, dust, dirt, blood, water) **either to or from** the shoe.

•**Positive Impression (Deposition):**

- •The shoe **deposits material onto the substrate**. The deposited residue visually represents the **areas of the sole that actually came in contact** with the ground surface.
- •**Frequency:** Constitutes the **most common form** of two-dimensional impressions

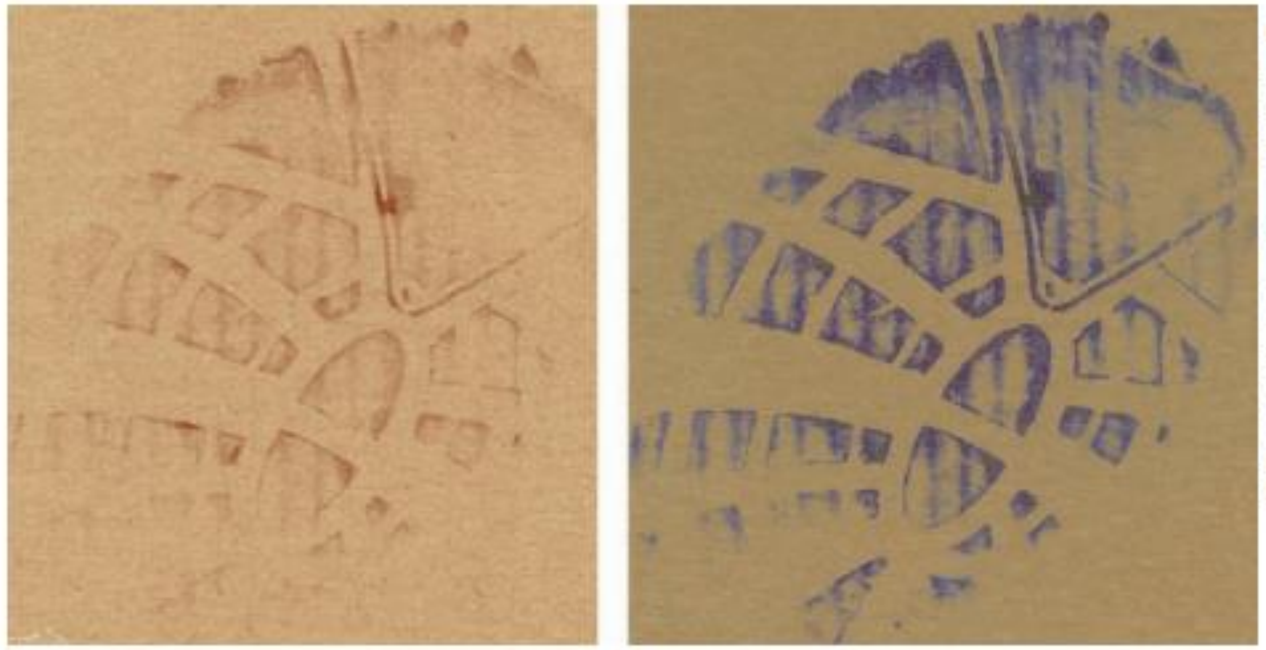

Figure 16.8 A faint bloody shoe print on a piece of corrugated cardboard and the same impression after it has been enhanced with a spray of leuco crystal violet (LCV). The LCV provides excellent enhancement with no background coloration. It is used extensively on floor surfaces at crime scenes where bloody impressions need to be enhanced or developed.

Transfer of Trace or Residue Impressions

Negative Impression (Removal/Lift Off)

Subtitle: Absence of Residue

•The shoe **removes residue from the surface**. The remaining visual image is formed by the **residue that remains where the sole did not come in contact** (i.e., the grooves and recessed areas of the sole pattern).

•**Frequency:** Occurs **less frequently** than positive impressions.

- Mechanism (Lift-Off): This occurs frequently on non-porous and polished surfaces (flooring, glass, countertops) that carry a film of accumulated residue or dirt. The shoe's contact area lifts (removes) the film from the surface.
- Result: The visible impression is negative; the print is formed by the absence of the film where the sole made contact, contrasting with the remaining film on the rest of the surface.
- Examples: A dry, clean shoe stepping on glass with a dirt film will lift the film, creating a clear image of the sole's contact areas.
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Location and Recovery of Footwear Impressions: Forensic Best Practices

Importance of Proper Technique

- Proper identification, documentation, and recovery methods are critical to maximize evidentiary value.
- Failure to aggressively seek and correctly recover footwear impressions often results in lost or diminished evidence.
- Even partial impressions can hold sufficient detail for identification or elimination.

Securing the Scene

- Footwear impressions can be found both inside and outside the crime scene perimeter.
- Immediate scene security prevents contamination, e.g., by other individuals' shoes.
- Search procedures must be thorough and deliberate, using slow visual scans and enhanced lighting methods.

Locating Impressions

- Obvious impressions include visible bloody shoe prints on light surfaces.
- Many impressions are latent or faint, requiring specialized detection methods:
- Darkened room inspection with high-intensity oblique lighting.
- Use of electrostatic lifting devices to reveal dry or dusty impressions on porous and nonporous surfaces.
- Items stepped on (paper, glass, magazines, broken glass, rugs) should be examined carefully for latent dust or blood impressions.

Location and Recovery of Footwear Impressions: Forensic Best Practices

Securing the Scene

- Methods of Searching (Systematic & Light-Dependent)
- Subtitle: Moving from the Obvious to the Subtle
- Principle: The search must be methodical, moving from the obvious to the subtle.

Phase 1: Initial Visual Search
Subtitle: Detecting the Obvious Prints
•**Technique:** Methodical visual search using **existing room light**, focusing on one small area/room at a time.
•**Rationale:**
 •To detect the **obvious, highly visible prints** (blood, grease, heavy residue).
 •To establish a general layout, identifying **areas to avoid walking over**.

Phase 2: Latent Detection
Subtitle: Using Oblique Lighting
•**Technique: Darken the area completely.** Use a bright **oblique light source** (halogen floodlight or high-intensity flashlight).
•**Position:** Light must be held **just off and parallel to the ground** (Figure 1.4A).
•**Focus:** Best for **smooth surfaces** (tile, wood) to reveal latent residue or dust prints via **shadowing**.

Phase 3: Substrate-Specific Search
Subtitle: Employing the EDPL
•**Technique:** Use the **Electrostatic Lifting Device (EDPL)**.
•**Focus:** Used to search specific areas for **dry residue prints**, especially where oblique light failed.
•**Surfaces:** Ideal for **carpeting** or other rough/porous surfaces.

Documentation

- Detailed notes on the location, orientation, and description of each impression are essential.
- Use numbered placards adjacent to impressions to facilitate photographic linkage and accurate record-keeping.
- Obtain general crime scene photographs (medium & close range) to show impression context.
- Impression numbering must be maintained through lifting, casting, and examination.

Figure 3.3 An even impression in a firm surface.

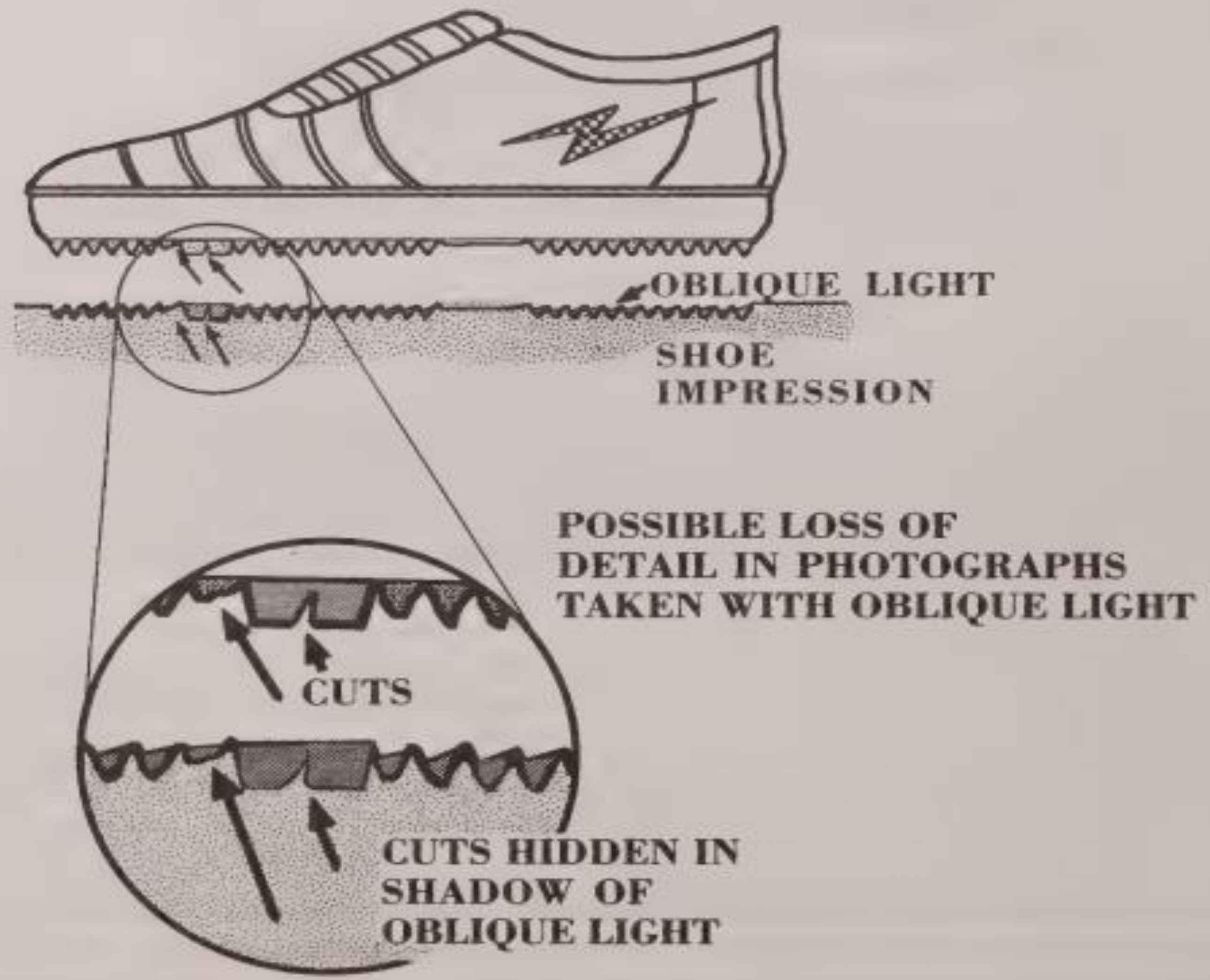

Figure 3.4 Shadows caused by oblique light photography can obscure some characteristics in the impression.

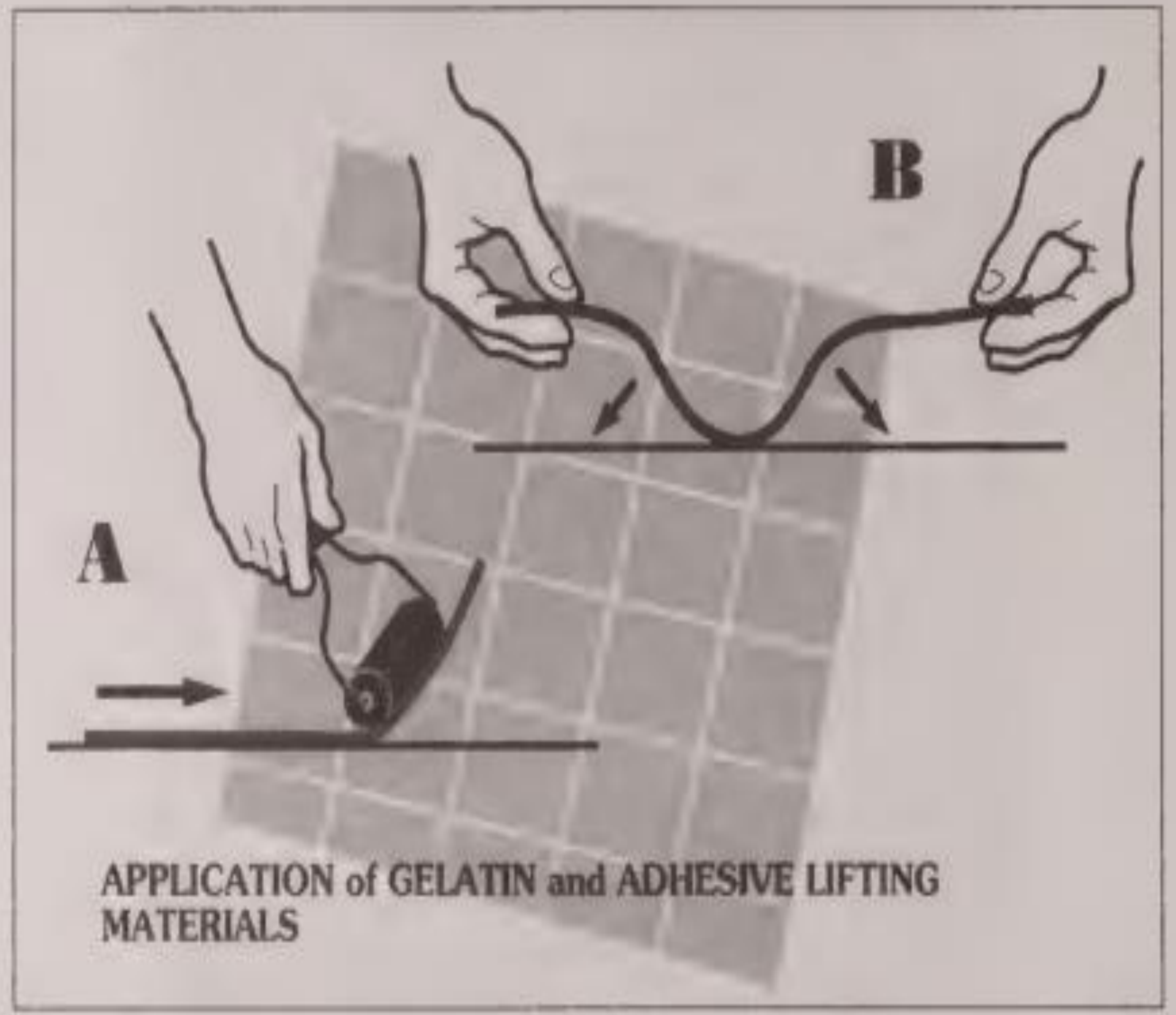

Figure 4.11 Gelatin and adhesive lifts may be applied either (A) with a roller or by (B) touching the center of the lifting material to the center of the impression area and allowing the sides to roll across the impression. With either choice, try to avoid air pockets, and avoid using excessive pressure, which might distort the impression.

Recovery of Transportable vs. Non-Transportable Impressions

Transportable Impressions

When an impression occurs on a **movable surface** (e.g., paper, cardboard, carpet, linoleum tiles, glass fragments, or plastic sheets):

- ✓ **Do not touch or alter** the impression directly.
- ✓ **Secure the item** in a rigid evidence box to prevent smudging or distortion.
- ✓ Label orientation (top/bottom, direction of travel) for reconstruction.
- ✓ Record with **photography before movement** to preserve context.

Examples:

•Bloody footprint on torn magazine paper.

•Dusty shoe mark on a broken glass panel.

Non-Transportable Impressions

For impressions on **fixed surfaces** (floors, walls, pavements, vehicle exteriors):

Step 1: Photography (Before Disturbance)

- ➢ Use **examination-quality photography** to capture every detail.
- ➢ Recommended: **35mm DSLR** or **mirrorless camera** with manual controls.
- ➢ Use **tripod and scale ruler** placed **in the same plane** as the impression.

•Maintain **perpendicular angle** to avoid parallax distortion.

•Employ **oblique lighting (20–45°)** to cast shadows that enhance texture.

Step 2: Documentation

•Record environmental conditions (light, temperature, moisture).

•Sketch or note impression location and orientation relative to fixed points (walls, furniture, blood pools).

Photography Techniques

Always photograph using a **perpendicular setup** and include **three sequential scales** (overview, mid-range, close-up

Enhancement Techniques

Method	Purpose	Key Tools	Example Use
Oblique Lighting	Reveals texture and depth	Flashlight/angled lamp	Dust impressions on tile
Ultraviolet (UV)	Detects biological traces	UV lamp (365 nm)	Semen or saliva impressions
Infrared (IR)	Reveals impressions under blood stains or dark backgrounds	IR-sensitive camera	Footprint on dark carpet
Alternate Light Source (ALS)	Detects latent or weak impressions	ALS filters, goggles	Mixed residue prints

Physical Enhancement Methods

Technique	Description	Suitable Surfaces	Notes
Powder Dusting	Lightly apply contrasting fingerprint powder (black, white, gray, magnetic).	Nonporous, smooth	Avoid over-application; fix with transparent lifting tape.
Gelatin Lifts	Soft gelatin sheets pick up powdered or moist impressions.	Smooth, curved, vertical	Ideal for delicate or flexible surfaces.
Adhesive Lifts	Transparent adhesive films lift powdered residues.	Nonporous	Provides clear photographic backing.
Electrostatic Lifting	Uses an electrostatic charge to attract dust particles onto conductive film.	Tile, linoleum, paper, metal	Nondestructive, effective for faint prints.

Chemical Enhancement Methods
Used when impressions are in **biological fluids or residues**.
Blood-Based Impressions
Residue/Non-Blood Impressions

Chemical	Function	Surface
Physical Developer	Enhances oily/waxy residues	Porous (paper, cardboard)
Potassium Thiocyanate	Reveals metallic trace residues	Nonporous

Reagent	Effect	Caution
Leuco Crystal Violet (LCV)	Turns blood prints purple-blue	Fix image immediately (photograph).
Amido Black	Stains protein in blood dark blue-black	May be permanent; photograph before use.
Diaminobenzidine (DAB)	Brown stain; high sensitivity	Toxic; handle under hood.
Luminol	Chemiluminescent blue glow in dark	Transient; photograph immediately.
Fuchsin Acid	Pink staining	High contrast but not for dark surfaces.

Casting of 3D Impressions

Purpose:

To preserve the **depth, shape, and fine detail** of impressions in soft materials like **mud, soil, sand, or snow**.

Material: Dental Stone (Calcium Sulfate Hemihydrate)

- Preferred over Plaster of Paris for **strength (7000–8000 psi)** and **detail reproduction**.
- Cures within **20 minutes**, hardens fully in **24–48 hours**.

Procedure:

1. Photograph the impression from multiple angles before casting.
2. Mix **Dental Stone powder with water** in a resealable bag (2:1 ratio).
3. Knead until lump-free; **pour gently along a spatula or stick** to avoid erosion.
4. Allow to set (20–30 min); lift cast carefully once hardened.
5. Label, air-dry, and store securely for lab analysis.

Special Considerations: Snow Impressions

Challenge	Solution
Fragility and melt risk	Spray light coat of Snow Print Wax™ or fixative paint before casting.
Poor contrast	Add colored dye or wax to improve visual edges.
Temperature sensitivity	Cast using pre-cooled dental stone to prevent melting.

Digital Enhancement

After photographic capture, **digital processing** refines visibility and detail using software such as:

- **Adobe Photoshop®**, **Amped FIVE**, or **ImageJ**.
- Techniques include **contrast stretching**, **color channel isolation**, **filtering**, and **digital overlay** comparison.

Purpose:

- Clarify tread pattern edges.
- Reveal faint impressions not visible to the naked eye.
- Prepare scaled digital images for side-by-side comparison with known footwear exemplars.

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Comparative Examination and Identification

Footwear impression analysis is a **core forensic comparison discipline**, bridging **trace evidence, pattern recognition, and individualization principles**. Every shoe–surface contact transfers measurable **class and individual characteristics,** which, when properly documented and compared, can link a suspect directly to a crime scene.

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The Forensic Principle: Transfer and Uniqueness

When footwear contacts a surface (e.g., floor, kicked door, soil, paper):

- It transfers **class characteristics** (pattern, size, shape) and **individual characteristics** (unique damage, wear, and foreign matter).
- Each impression represents a **dynamic physical record** of contact force, movement, and surface composition.

•Examiners compare **crime scene impressions (questioned)** with **known exemplars (suspect shoes)** to evaluate their degree of correspondence.

This process aligns with **Locard's Exchange Principle** — *"Every contact leaves a trace."*

Comparative Examination Methods

. Observation & Comparison Techniques

•**Side-by-Side Examination**

- •Physical or photographic comparison of crime scene impression and known shoe print side by side.
- •Allows real-time assessment of pattern alignment, proportionality, and distinctive wear areas.

•**Superimposition Technique**

- •Transparent overlays or digital software (e.g., **Forensic Comparison Imaging System, Photoshop**) superimpose the impression and exemplar.
- •Used for evaluating spatial consistency of tread blocks, cuts, and marks.

•**Instrumentation Aids**

- •**Low magnification microscopes (5×–20×)** for wear and damage analysis.
- •**Specialized lighting** (oblique, polarized, or coaxial) to accentuate fine details.
- •**Digital microscopy** for non-destructive magnified comparisons.

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Footwear Comparison

The tread design or outsole pattern manufactured into the shoe sole, typically defining its brand, type, or model

Analytical Focus:

- Arrangement of tread blocks, siping (grooves), logos, and texturing.
- Comparison begins by assessing **pattern congruence** across the suspect's shoe and scene impression.

Significance:

- Design is the **first and broadest eliminative feature** — if the pattern differs, the shoe is excluded.
- Because thousands of outsole designs exist globally (and change annually), a **pattern match already narrows the pool substantially**.
- Slight variations can exist even within a single model line due to manufacturing tolerances.

Example:

A Nike Air Max tread with visible "waffle" patterning and swoosh logo is identified in a dusty footprint at a burglary scene. If the suspect's shoe displays the same configuration of design elements, further detailed comparison continues.

The Four Pillars of Footwear Comparison

The Four Pillars of Footwear Comparison

Manufacturer, model and size: - general outsole patterns, shapes, features and markings can help examiners identify the manufacturer, model and size of the footwear. Can be used to profile the suspect and provide leads on who may have bought or worn the footwear.

Approximate height: Investigators refer to statistical data to approximate the height of the person. Height can also be approximated by stride length.

Refers to the **actual measured length, width, and proportional configuration** of the outsole pattern — not the manufacturer's labeled size.

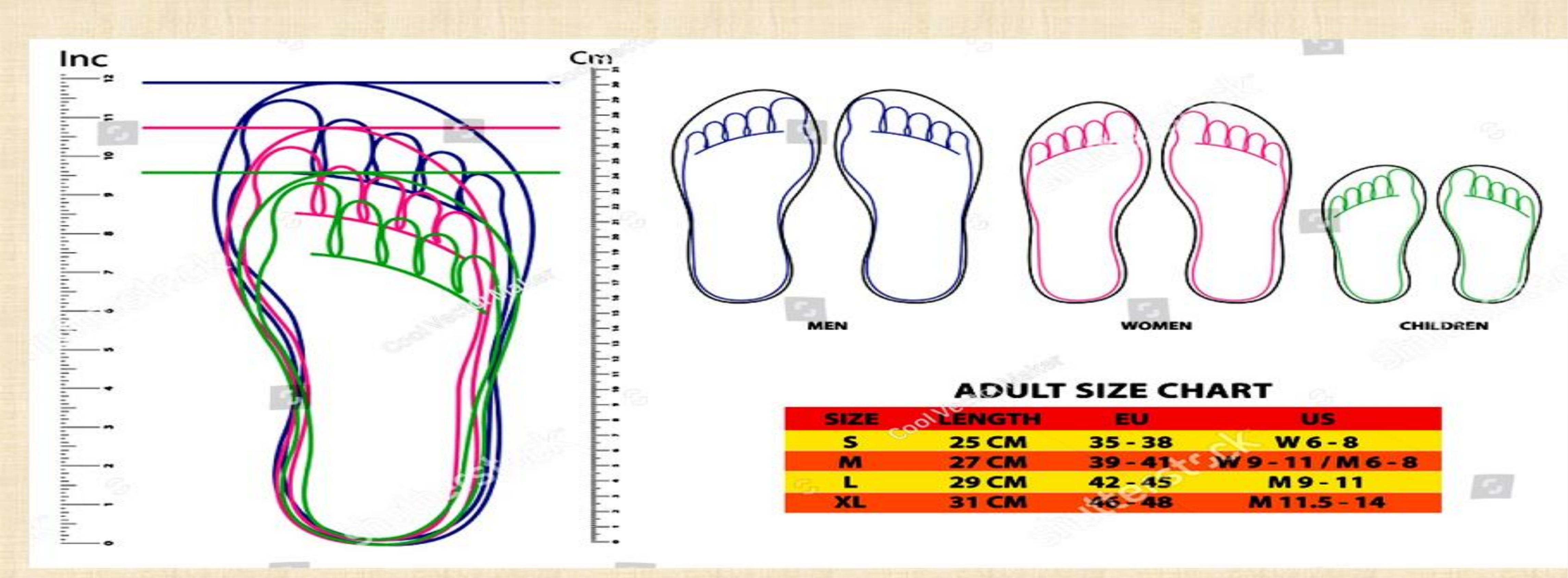
- Each design is produced across several sizes; proportions vary with size and sometimes width category (e.g., 8 vs. 9½).
- Physical size measurement is done using scaled photography or direct measurement from cast impressions.
- Even slight mismatches in length or tread spacing can rule out a suspect shoe.

Significance:

- Matching both **design and physical dimensions** gives strong evidentiary value.
- Given the vast number of possible design-size combinations, a precise correspondence represents **a minute statistical probability** within the global shoe population.

Example:

If a partial shoe impression measures 28.3 cm in length and 9.8 cm in width, corresponding precisely to the outsole size of a size 10 Adidas Superstar, it strengthens the linkage.



Wear Pattern

Gradual alteration of the outsole surface caused by **repeated contact and friction** during use.

Characteristics:

- Each individual walks differently (pronation/supination), creating unique pressure and wear zones.
- Common wear zones: heel edges, forefoot ball area, toe region.
- Wear pattern depends on gait, weight distribution, walking surface, and activity type.

Analytical Considerations:

- **Position of wear** — where the sole shows smoothing or abrasion.
- **Degree of wear** — how deeply the tread is eroded.
- **Symmetry** — differences between right and left shoe.

Wear Pattern

Time lapse between crime and shoe recovery affects evaluation (wear evolves).

Evidentiary Value:

If the wear pattern corresponds in both location and degree, it adds additional discriminating power, eliminating most other shoes of the same make/size.

Wear alone cannot confirm identity, but it strengthens association when combined with design and size.

Example:

A shoe recovered from a suspect has a worn right heel and smoothed forefoot—matching the pattern in a dusty crime scene print.

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Individual Identifying Characteristics — Unique to One Shoe

Random, accidental features acquired during use that make one shoe **distinct from all others**, even of identical model and size.

Examples:

- •Cuts, gouges, nicks, tears, holes, and embedded objects (nails, stones, tar, gum).

•These randomly distributed marks alter the shoe surface permanently.

Analytical Significance:

- These features are **non-reproducible** and **randomly located**, giving them **high individualizing power**.
- The chance of identical placement, shape, and size of such defects on two different shoes is **statistically negligible**.
- Identification Standard:
- No set number of individual features required for positive identification.
- Examiners assess **quality, clarity, and correlation** of visible features.
- A single, well-defined individual characteristic may suffice if it uniquely matches between the shoe and impression.

Gait Analysis)

The **systematic study of human locomotion** (walking).

- **Forensic Gait Analysis/Comparison:** The **assessment and evaluation of a suspect's gait patterns and features** compared with scene-of-crime evidence

(e.g., a series of footprints or video footage) for the purpose of identification.

Status: Currently defined as a **contributor to the identification process** rather than a sole method of identification, as **individualization of gait has not yet been fully scientifically proven**.

C. Historical Context

Early Use: Gait evidence entered court as early as **1839 (Thomas Jackson case in London)**, where a witness identified a suspect by his **bowed left leg and limp**.

Admissibility as Scientific Evidence: First used as admissible **scientific evidence** in the UK case of **R v. Saunders** by Dr. Haydn Kelly

Spatio-Temporal Parameters

:Metrics used to quantify gait:

- **Stride Length:** Distance between two successive steps of the same foot.
- **Step Length:** Distance between opposite feet (may be unequal).
- **Stride Width (Walking Base):** Transverse distance perpendicular to travel.
- **Foot Angle:** Angle of foot midline to direction of travel (toe-in/out).

Forensic Application & Podiatric Contribution

Forensic Application:

•Primarily used for **Tracking individuals** (e.g., Border Patrol) and **Associative Analysis**.

•Gait is, at best, a **class characteristic** used to distinguish a person's path or to corroborate/refute a suspect's statement about their movement.

•Podiatric Contribution:

•Understanding **how and why gait changes**: Linking changes in stride/step to temporary (e.g., carrying a heavy load) or permanent (e.g., neurological deficit, limb length difference) factors.

•The podiatrist **interprets gait changes** in the context of human limitations and functional anatomy.

Variability (The Critical Limitation)

Variability Factors: Gait characteristics **vary normally within the same individual** based on:

- **Speed:** (e.g., increased speed increased stride length/width).
- **Surface:** Type/friction (slippery surface \ altered kinematics).
- **Footwear:** Flexibility.

•Limitation: "Cannot be used to establish the personal identity of a subject." (Per the text). A reliable succession of impressions representing normal gait is rarely recovered at crime scenes.

Location and Recovery of Footwear Impressions: Forensic Best Practices

Human gait measurements

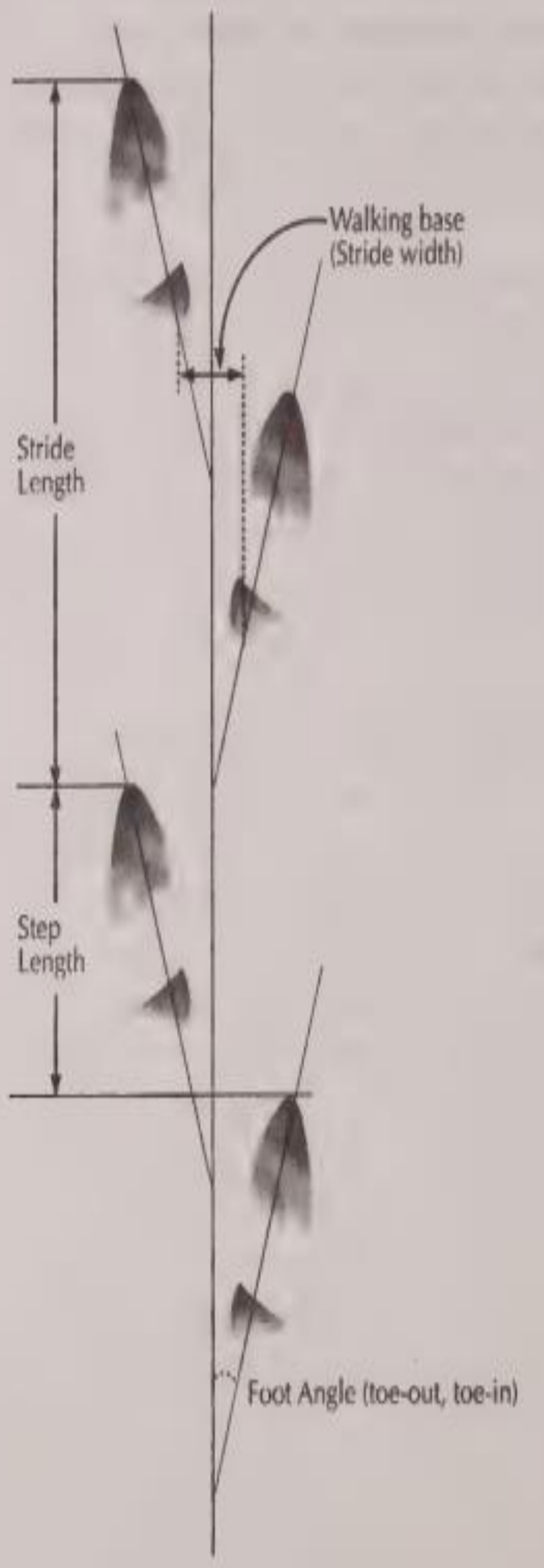


Figure 1.1 Human gait measurements.

II. The Gait Cycle and Analysis Methodology

A. The Gait Cycle

Human walking follows a specific pattern consisting of two primary phases:

1. **Stance Phase (Approx. 60% of cycle):** When the foot is on the ground. Includes: initial contact, loading response, mid-stance, terminal stance, and pre-swing.
2. **Swing Phase (Approx. 40% of cycle):** When the foot is moving forward in the air. Includes: initial swing, mid-swing, and terminal swing.

B. Standardized Methodology

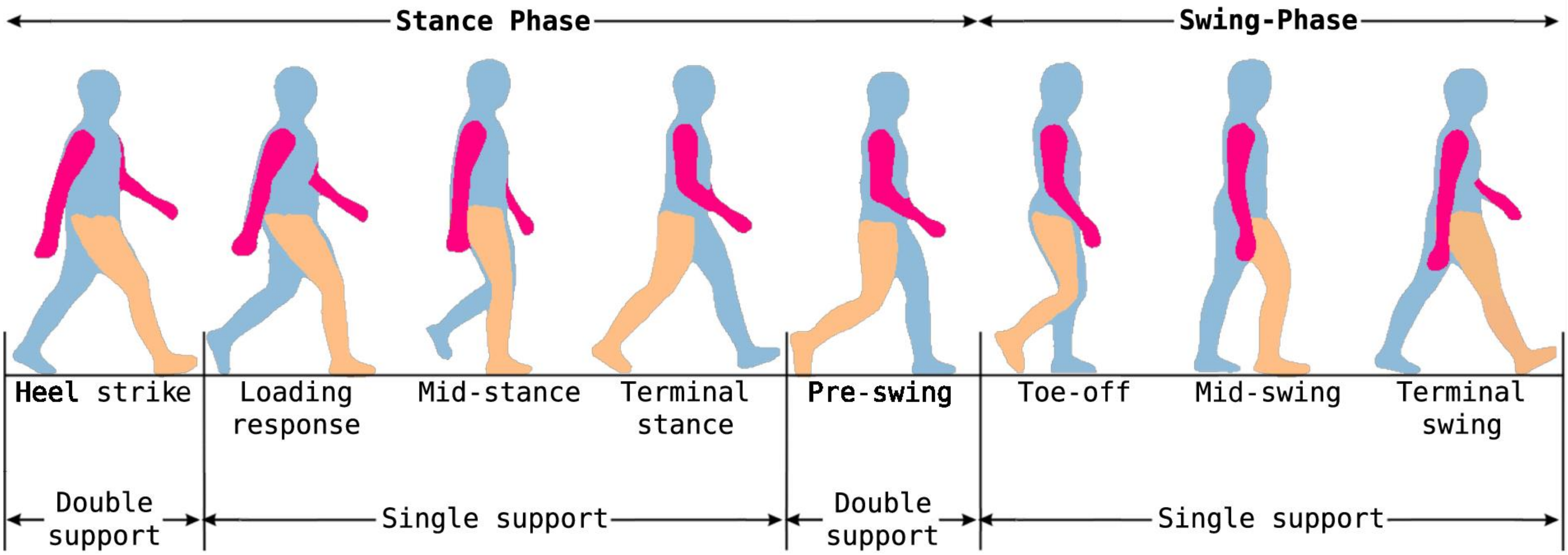
Forensic gait analysis utilizes the **ACE-VR** methodology, aligning it with other forensic disciplines:

- **A**nalysis
- **C**omparison
- **E**valuation
- **V**erification
- **R**eport

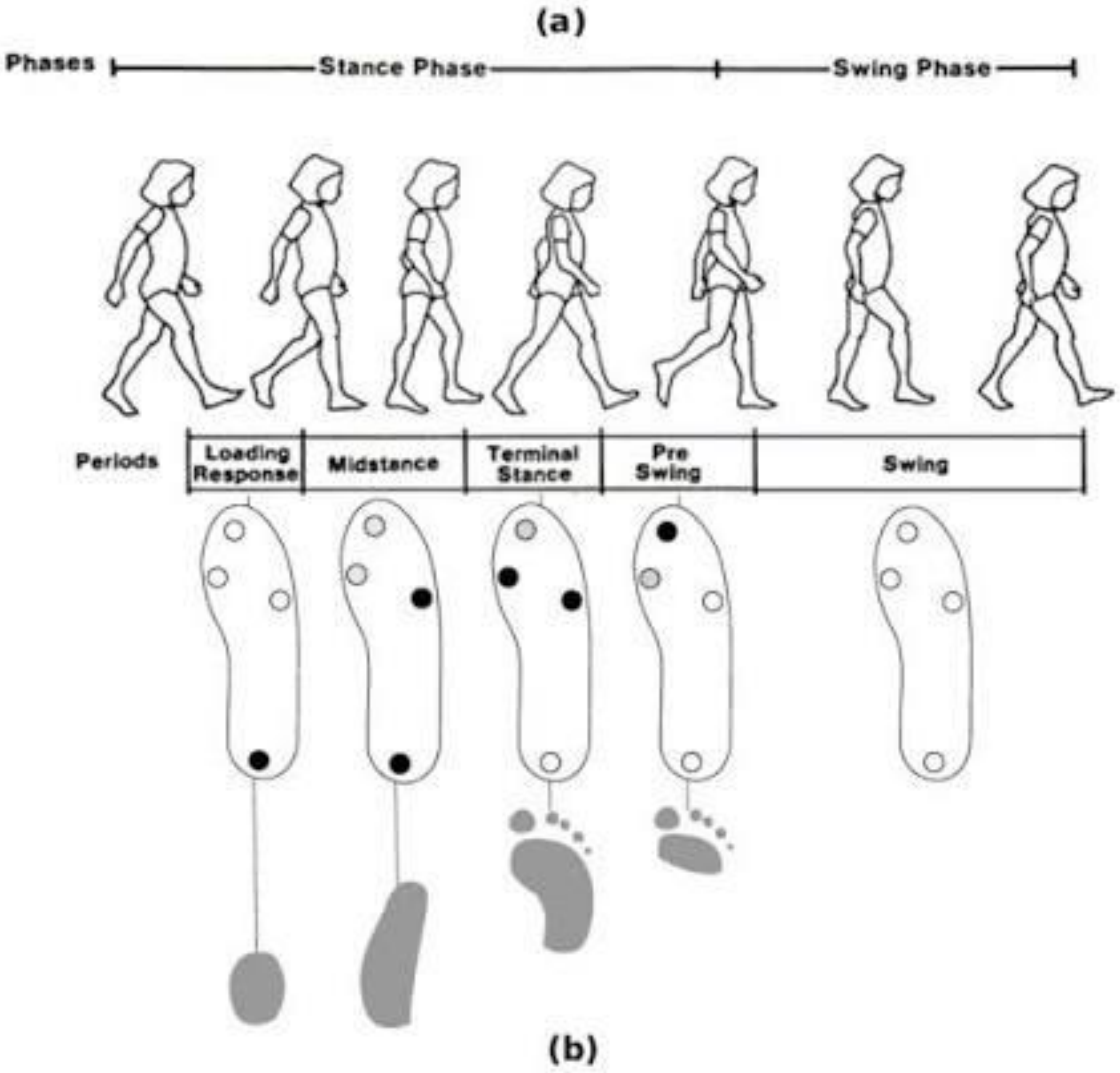
C. Sources of Evidence

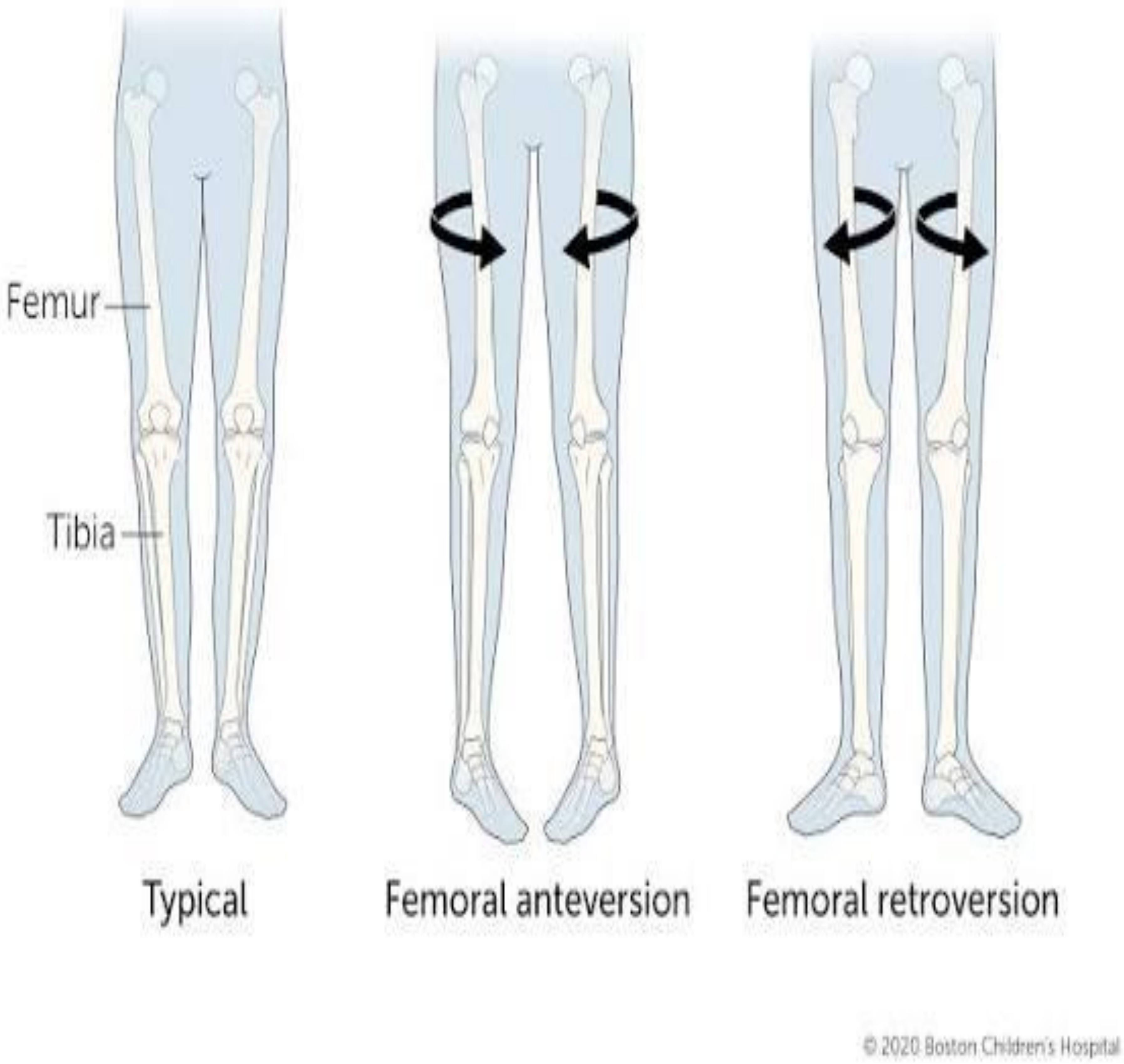
1. **Gait Analysis on the Surface (Footprints/Shoeprints):**
   - Requires a minimum of **3 to 4 consecutive prints** for analysis.
   - Parameters include dimensions, margins, toe marks, and general print shape.
   - Used to measure **step length** and **stride length** to approximate **stature, sex, age, and body weight**.
2. **Gait Analysis from CCTV Footage/Video Recording:**
   - The primary source in modern cases due to surveillance proliferation (CCTV, dash-cams, mobile phones).
   - Replaces the less reliable **eye witness** testimony of walking style.

Crucial Step: Digital evidence must be collected following established protocol, including securing a copy, calculating the **hash value**, and maintaining a strict **chain of custody**.

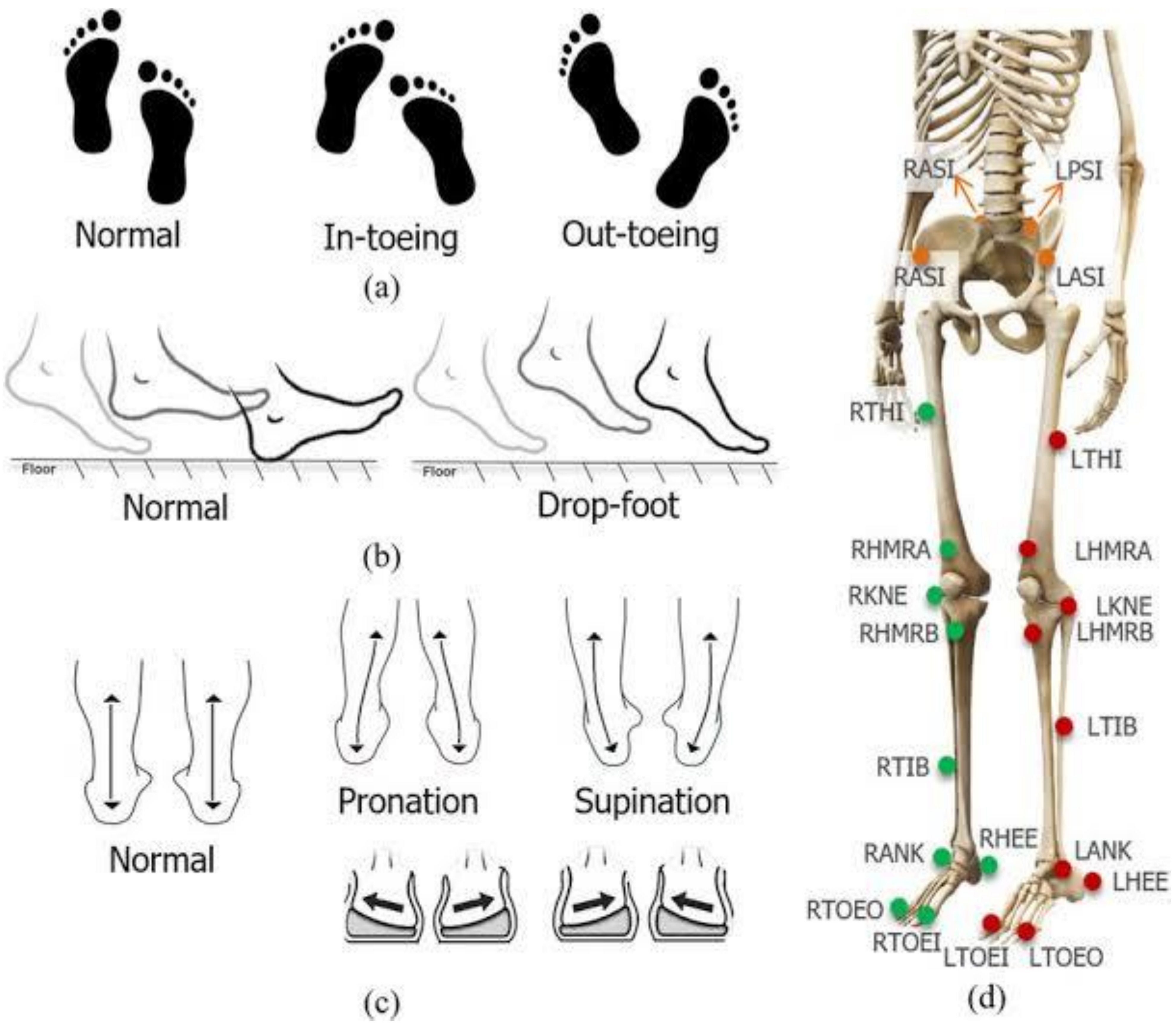

Stance Phase
Swing-Phase
Heel strike
Loading response
Mid-stance
Terminal stance
Pre-swing
Toe-off
Mid-swing
Terminal swing
Double support
Single support
Double support
Single support

Location and Recovery of Footwear Impressions: Forensic Best Practices





Location and Recovery of Footwear Impressions: Forensic Best Practices



A. Foot Types and Wear Patterns

The human foot generally falls into three main structural categories, each resulting in a predictable primary wear zone:

Neutral Foot (Normal Arch):

- **Movement:** The ankle rolls slightly inward (pronation) to absorb shock, distributing pressure evenly.
- **Wear Zone:** Typically concentrated near the **center/lateral (outer) edge of the heel** and the **center of the forefoot** beneath the second and third toes.

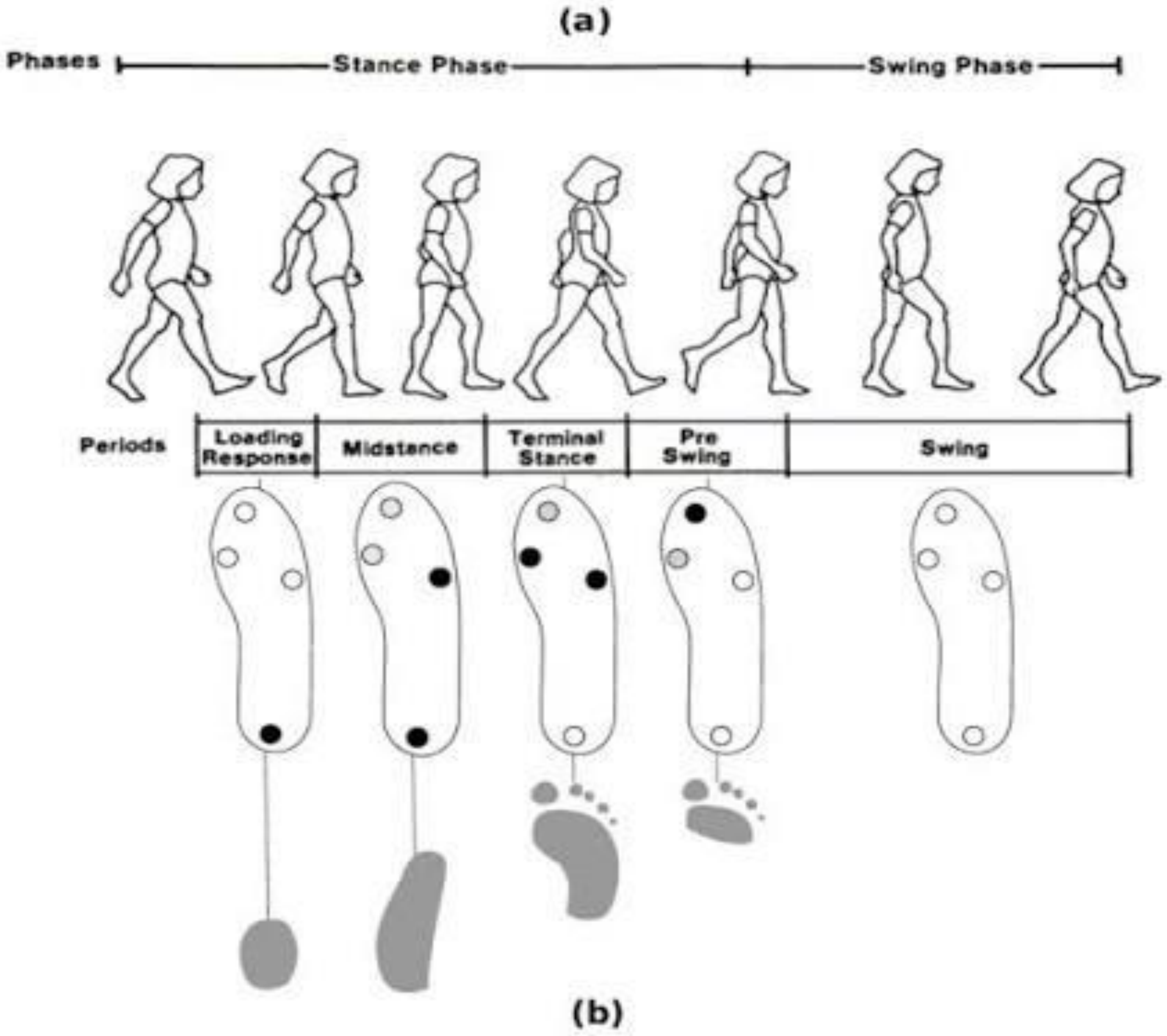
Overpronation (Flat Arch):

- **Movement:** The ankle rolls excessively inward, resulting in the foot bearing weight primarily along the inner edge.
- **Wear Zone:** Heavy, pronounced wear on the **medial (inner) edge of the heel** and the **medial forefoot** (under the big toe).

Supination (High Arch/Underpronation):

- **Movement:** The ankle rolls outward, failing to adequately absorb shock and placing stress on the outer edges.
- **Wear Zone:** Heavy, pronounced wear on the **lateral (outer) edge of the heel** and the **lateral forefoot** (under the little toe).

Location and Recovery of Footwear Impressions: Forensic Best Practices



Analytical Application: Position of Wear

•The **Position of Wear** is used by the examiner to help match the impression to a potential **foot type**.

•For example, a shoeprint showing extreme wear on the inner heel strongly suggests the suspect is an overpronator (flat feet).

•This eliminates individuals with a high arch (supinators), adding discriminatory power to the evidence.

Approaches and Issues of Concern

A. Analysis Approaches

Internal Factors	External Factors	Intentional Factors
Disease/Disorder (e.g., Parkinson's gait, choreiform gait)	Footwear (alters stride length/hip movement)	Directed Gait (walking under instruction, e.g., marching)
Fatigue (decreases speed and alters the cycle)	Speed (changes between walking and running)	Intentional Alteration (deliberately changing gait to avoid recognition)
Age (muscle strength changes)	Location/Surface (affects walking consciousness)	Emotional Mind State (stress, fear)
Sex (assessable from pattern)	Camera (angle, positioning, quality)	Load Carriage/Attire

Factors Affecting Gait (Variability)

Gait is a biological characteristic that shows high **intra-individual variability** (a person's gait varies on different occasions) and is highly influenced by **internal and external factors**

Approach	Description	Issues
Human-Based (Observer-Based)	Involves direct measurement, photo-anthropometry (landmark measurements), or superimposition. Motion analysis involves running videos in reverse/pause.	High error/bias risk and significant inter-observer and intra-observer variability.
Computer-Based Human-Assisted	Uses algorithms (model-based or appearance-based) to extract gait features and provide a match score.	Model-Based: Fixed landmarks predefined by a human model. Appearance-Based: Extracts silhouette sequences without a model.

Limitations and Admissibility

A. Limitations of Forensic Gait Analysis

- **Reliability and Accuracy Questionable:** The method remains questionable regarding reliability, reproducibility, and accuracy.
- **High Variability:** High intra-individual variability makes it difficult to establish a pattern unique enough for identification.
- **Lack of Standardization:** Experts often lack a prescribed, standard protocol, leading to variations in methodology and confusion for judges/jury.
- **No Databases:** Unlike fingerprints or DNA, there are currently **no standard, large-scale databases** for gait comparison.
- **Observer Error:** Human observation is subject to error, though experienced experts show more precise decisions than inexperienced analysts.

B. Conclusion on Admissibility

Forensic gait analysis remains a **weak method of identification**. Any resulting forensic evidence must be treated with caution in forensic scenarios due to error rates, and the lack of fully recommended **codes of practice and standardization** of procedures. It should be viewed as a **supportive role** in the absence of other biometric identifiers.

Approaches and Issues of Concern

A. Analysis Approaches

1. **Biomechanical and Physiological Factors**

Factor	Effect on Gait	Forensic Implication
Foot Type (Pronation/Supination)	Directly determines the forces transmitted through the foot and leg. **Overpronation** (flat feet) causes the foot to roll inward, often reducing stride efficiency and altering the angle of the foot line. **Supination** (high arch) causes rolling outward, leading to a stiff gait with less shock absorption.	Directly corresponds to the **wear pattern** on the shoe and can alter the **foot angle** (toe-out/in) in a series of prints.
Disease/Disorders	Creates **pathological gaits** that are highly distinctive. Examples include: **Parkinsonian Gait** (small, shuffling steps, reduced arm swing, forward stoop) or **Choreiform Gait** (irregular, jerky, involuntary movements).	If a suspect has a diagnosed condition, their gait may be highly individualized, strengthening the identification process.
Age	As muscle strength and joint flexibility naturally decrease, the gait becomes **slower**, with **shorter stride length** and **wider step width** (walking base) to maintain stability.	Must be considered when estimating age from gait parameters recovered at a scene.

Approaches and Issues of Concern

A. Analysis Approaches

1. **Biomechanical and Physiological Factors**

Factor	Effect on Gait	Forensic Implication
Sex	Due to differences in the pelvis (generally wider in females), studies show slight variations. Females often exhibit greater hip adduction and a smaller angle of progression, resulting in a different **stride length/leg length ratio**.	Can be used as a **class characteristic** to help establish a suspect's profile.
Fatigue	Causes a depletion of energy, leading to a **decrease in walking speed and cadence**. Steps become less controlled, and the overall gait cycle becomes less efficient and more variable.	Can explain discrepancies between a suspect's controlled exemplar gait and the crime scene footage (e.g., if the perpetrator was running from the scene).
Use of Knee Brace / Pregnancy	Directly imposes an external constraint. A knee brace restricts normal joint movement, creating a compensatory walking pattern. Pregnancy (especially 1st trimester) alters the **center of gravity** and changes the **foot angle** and stance width.	Creates a temporary, yet identifiable, abnormality that should be matched to the time frame of the crime

Approaches and Issues of Concern

A. Analysis Approaches

1. **Environmental Factors**

Factor	Effect on Gait	Forensic Implication
Footwear	Different footwear significantly alters the gait cycle. High heels increase stride length and change the angle of the foot. Heavy boots reduce flexibility and may shorten the stride.	The forensic podiatrist must match the crime scene impression to the known shoes and understand the biomechanical impact of that *specific* type of footwear on the wearer's gait.
Speed	A **running gait** is fundamentally different from a **normal walking gait**. Running involves a **flight phase** (both feet off the ground) and a much longer stride length, higher cadence, and greater impact force.	Must be analyzed carefully. If a series of prints shows long stride lengths, the analysis must use parameters correlated with running, not walking.
Location/Surface	Walking on an unusual or unstable surface (e.g., ice, sand, rocky terrain) causes the person to walk **consciously**, focusing on placement. This often results in a **slower, shorter, and wider step** to maximize stability.	The exemplar comparison must account for the crime scene substrate. A suspect's gait on a flat treadmill is not comparable to their gait on a slippery slope.
Load Carriage	Carrying a heavy load (e.g., a large backpack, a box) changes the center of mass and requires the body to compensate. This typically results in a **shorter stride, slower speed**, and sometimes a forward lean.	Must be considered if crime scene footage or witness accounts indicate the perpetrator was carrying an object.

Approaches and Issues of Concern

A. Analysis Approaches

1. **Environmental Factors**

Factor	**Effect on Analysis Reliability**	**Mitigation**
Camera Angle/Quality	**Angle and positioning** of the CCTV camera critically affect measurements. Low-quality, pixelated, or poorly lit footage makes angular and temporal measurements difficult or impossible.	Digital evidence must be secured correctly. The analyst must declare the limitations imposed by the video quality in their report.
Emotional Mind State	**Stress, fear, or panic** can cause an involuntary change in movement, often resulting in a quicker, less rhythmic, or uneven gait. Conversely, a highly controlled or **Directed Gait** (e.g., marching) masks individual features.	The expert must look for evidence of deliberate **intentional alteration** of gait to escape recognition and factor in the likely emotional state of the perpetrator during the crime.
Time Lapse	**Wear patterns** used in the analysis are **evolving**. The wear on a shoe recovered months later may be significantly different from the wear present at the time the impression was left.	The expert must perform a comparative analysis, estimating the rate of wear and how the pattern would have appeared at the date of the crime.

Location and Recovery of Footwear Impressions: Forensic Best Practices

Forensic Gait Parameters and Features

For features to be forensically useful, they should ideally possess **universality, permanence, and uniqueness**. Gait features are classified as follows:

A. Static Measurements (Geometrical)

- Measurements of the body at rest or in a fixed position (e.g., whole leg length, knee-foot height).

B. Dynamic Measurements (Movement-Related)

- **Spatial Parameters (Distance):** Measured using a **progression line** (imaginary line in the direction of walking). Includes: **step length, stride length**, stride width, foot angle, and gait line.
- **Temporal Parameters (Time):** Measured using stopwatches or software from video footage. Includes: **step time, stride time, cadence** (steps per minute), stance duration, and speed.
- **Angular Displacement Parameters (Angle):** Angles of joints during the gait cycle (e.g., hip angle, knee angle).

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(A)

Figure 1.2 A footwear impression in a dry environment will create a static charge that can be visualized by applying a fine powder or toner across the surface. This impression (A) was a latent static charge on a floor over which several puffs of blower fingerprint powder were applied. The powder adhered to the charged areas of the footwear impression.

(B)

Figure 1.2 (continued) (B) A piece of paper was stepped on with clean shoes. No impressions were visible on the paper before processing with physical developer.

(A)

Figure 1.3 (A) A piece of glass with a film on it which was stepped on at a crime scene. The film, which consisted of accumulated dirt and residue, was removed in the area where the clean shoe made contact with it, resulting in a negative impression. When photographed with a dark background, the impressioned area shows up dark.

(B)

Figure 1.3 (continued) (B) An impression resulting from a clean shoe stepping on a residue-covered cabinet and resulting in a negative impression.

Integration of Digital and Modern Methods

- **3D scanning and photogrammetry** for precise depth and volume capture of impressions.
- **Computer-Aided Overlay Systems (CAOS)** for digital comparison and measurement.
- **AI-assisted outsole databases** (e.g., SICAR®, SoleMate®) assist in rapid pattern identification across brands.

Levels of Identification and Conclusion

Conclusion Type	Description	Evidentiary Meaning
Positive Identification	Crime scene impression and shoe share sufficient corresponding class and individual characteristics.	That specific shoe made that impression.
Probable Association	Strong similarity, but not enough individual detail for certainty.	Likely made by that shoe or same model.
Inconclusive	Insufficient quality or quantity of features.	Cannot confirm or exclude.
Elimination	Significant differences in class characteristics (pattern, size, etc.).	Shoe did not make the impression.

Your Company Logo

Thank You

End quote

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