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Medico-Anthropological Characteristics of Flatfoot and Its Clinical Significance

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Flatfoot (pes planus) is the reduction or collapse of the foot's medial longitudinal arch, with both clinical and anthropological significance. It may be flexible or rigid, congenital or acquired, and its prevalence varies by age, sex, body mass, footwear, and occupation. Anthropological studies reveal wide population differences, from under 5% in some European adults to over 20% in Asian and African groups. Clinically, flatfoot ranges from asymptomatic to causing pain, altered gait, and musculoskeletal problems. Diagnosis combines footprint indices, radiographs, and modern 3D scanning. From a medico-anthropological view, flatfoot reflects both evolutionary adaptation and a condition needing early recognition and management. Standardized diagnostic criteria and integration of anthropological insight are essential for accurate assessment and care.

Key words: foot, flatfoot, pes planus, anthropology, medial longitudinal arch, footprint analysis

Introduction

The human foot is an evolutionary innovation central to bipedal locomotion. Its complex skeletal and ligamentous architecture allows efficient propulsion, weight distribution, and shock absorption. A key element of this structure is the medial longitudinal arch, whose presence and height are often considered hallmarks of foot morphology.

Flatfoot, or pes planus, is defined as the reduction or collapse of the medial longitudinal arch of the foot, leading to excessive plantar surface contact with the ground [10]. It is among the most frequently observed morphological variants in human populations. While often benign, in some cases it contributes to pain, functional limitation, and predisposition to musculoskeletal disorders. From an anthropological perspective, flatfoot is an important marker of developmental and evolutionary variation [1, 21]. The human foot arch evolved as an adaptation to bipedal locomotion, and its collapse has both biomechanical and cultural implications. This paper provides a medicoanthropological review of flatfoot, focusing on diagnostic methods, prevalence, and clinical significance. Recent studies highlight updated prevalence rates and functional impacts, such as reduced balance, agility, and core strength in young females [8], as well as prevalence data from Chinese adolescents [18].

Anthropometric approaches for study footprint

This review was conducted between January and July 2023 using PubMed, Scopus, and Web of Science. Search terms included 'flatfoot', 'pes planus', 'foot arch', 'footprint analysis', 'anthropometry', and 'epidemiology'. Reference lists were manually screened. Both English- and Bulgarian-language studies were considered. Studies included had to report prevalence, diagnostic criteria, or clinical outcomes. Exclusion criteria were case reports with fewer than 10 participants, surgical series without anthropometric data, and reports without clear definitions of flatfoot.

Data extracted included population characteristics, diagnostic methods used, prevalence, and clinical consequences. Anthropometric approaches primarily included footprint indices such as the, Staheli Arch Index (SAI), Chippaux – Smirak Index (CSI), and Clarke's Angle (CA) which remain widely used for their simplicity. Radiographic evaluation focused on the Calcaneal Pitch Angle, Meary's Angle, and the Talocalcaneal Angle, which are considered gold standards in clinical orthopedics. Modern methods such as 3D foot scanning, dynamic plantar pressure analysis, and gait analysis were also reviewed, providing detailed biomechanical insights but with limited availability for large-scale studies. Their methodological robustness has been reaffirmed in recent reviews [3], with studies showing correlations between CSI and clinical assessment [17].

The Staheli Arch Index (SAI) is obtained by dividing the minimum width of the midfoot by the maximum width of the heel in a footprint. Values greater than 1.0 are indicative of flatfoot. This index is especially useful in pediatric studies due to its simplicity, but it may overestimate prevalence in young children where the plantar fat pad obscures the arch (**Fig. 1**).

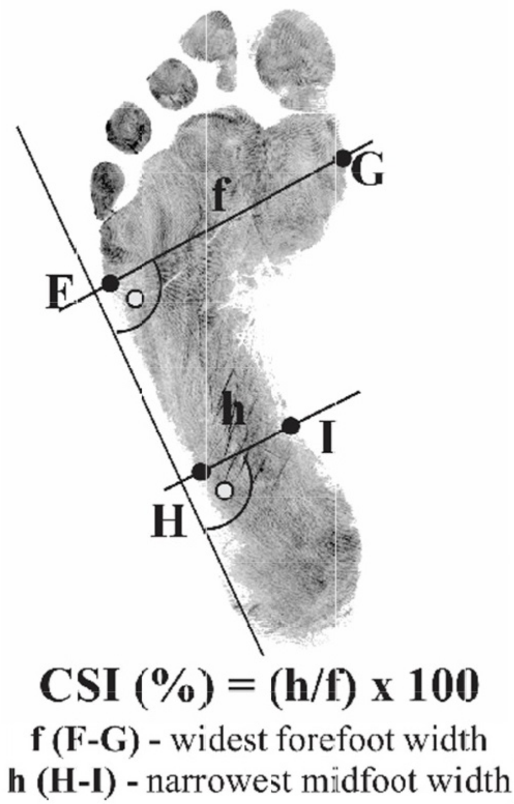
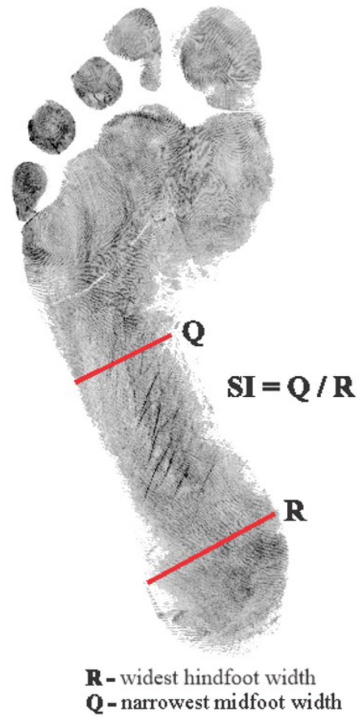


Fig. 1. Staheli Arch Index (SAI). The ratio of the minimum width of the midfoot to the maximum width of the heel; values >1.0 indicate flatfoot

Fig. 2. Chippaux–Smirak Index (CSI). Calculated as the ratio of the narrowest midfoot width (**h**) to the widest forefoot width (**f**) ×100; values >45% indicate flatfoot



The Chippaux–Smirak Index (CSI) is calculated by dividing the narrowest width of the midfoot by the widest part of the forefoot, multiplied by 100. A value above 45% is diagnostic of flatfoot, while values below 25% suggest a high arch. This index is considered highly sensitive and reliable for epidemiological surveys **(Fig. 2**).

Clarke's Angle (CA) is formed by the intersection of a tangent drawn along the medial border of the footprint and a line connecting the most medial point of the forefoot to the heel. Angles less than 31° indicate flatfoot, while values greater than 45° indicate a high arch. This method is easy to apply in clinical practice but can be influenced by body weight and the position of the foot during measurement (**Fig. 3**).

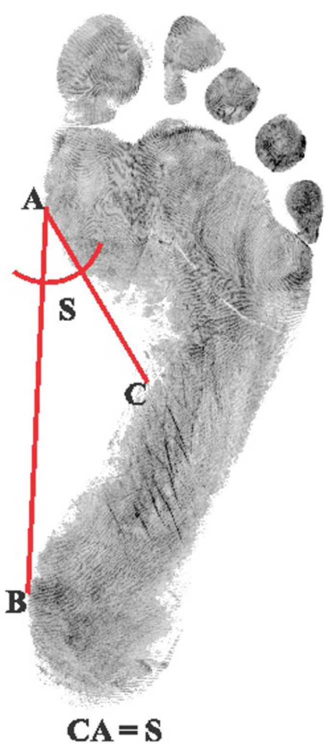


Fig. 3. Clarke's Angle

The review analyzed children and adolescents separately due to natural arch development, adults for persistence of flatfoot, and occupational groups such as military recruits and athletes where prevalence may be influenced by load-bearing demands. Barefoot versus shod populations were also compared, highlighting the role of culture and environment. Findings were synthesized from a medico anthropological perspective, integrating biological, cultural, and clinical insights.

Clinical Significance of flatfoot

Flatfoot prevalence was highest in early childhood, affecting 40–50% of children aged 2-5 years, largely due to the plantar fat pad and immature arches [14,23]. By 6–10 years, prevalence dropped to 15-25%, and by adolescence stabilized at 10-15% [4, 7] **(Fig. 4).** In adulthood, prevalence was 2-6% in European cohorts and 13-20% in Asian populations [21, 13]. African barefoot populations showed prevalence below 5%, while urbanized, shod groups had higher rates, reaching up to 15% [15] (**Table 1**). Indigenous communities demonstrated naturally low arches without associated pathology, underscoring the importance of cultural context [19]. In addition, Shen et al. [18] reported a prevalence of approximately 5.5% among Chinese adolescents, with slightly higher rates in girls than boys. Birhanu et al. [18] observed a notable prevalence in Ethiopian children, highlighting regional differences. Giuca et al. [9] demonstrated correlations between severity of flatfoot and risk factors such as BMI and physical inactivity in children and adolescents.

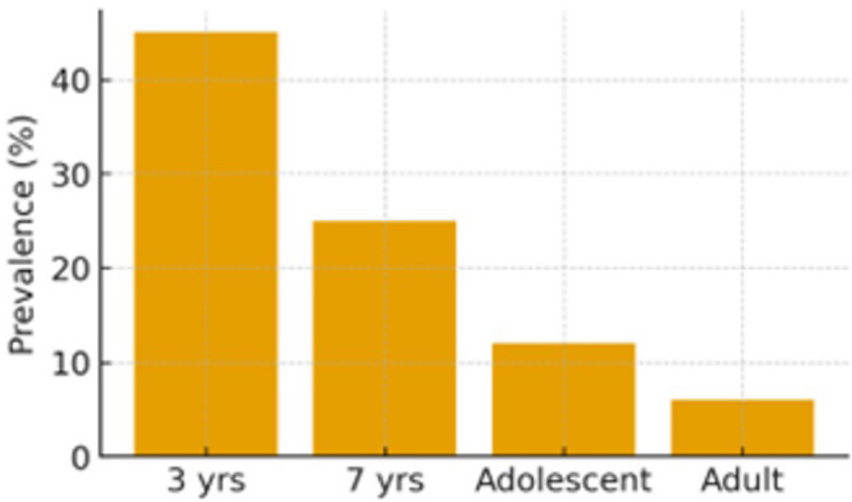


Fig. 4. Prevalence of Flatfoot Across Age Groups

Sex differences were inconsistently reported: some studies suggested higher prevalence in females, potentially linked to ligamentous laxity, but these often diminished after adjusting for BMI [13]. Overweight and obese individuals consistently demonstrated higher prevalence, reflecting mechanical overload of the medial arch [5,23]. Lifestyle also played a role: barefoot groups showed stronger arches, while urban, shod populations exhibited greater collapse [15] **(Table 1).** Occupational influences were significant. Military recruits showed prevalence of 10-20% due to load carriage and training demands [10]. Athletes displayed divergent patterns: runners and dancers had lower prevalence, likely due to strengthening of intrinsic muscles, while gymnasts and weightlifters had higher rates (12-20%) due to repetitive stress and ligamentous strain [16, 6]. Symptomatic flatfoot was associated with pain, altered gait, and higher risk of plantar fasciitis, tibialis posterior dysfunction, knee malalignment, and low back pain [4, 14, 23]. Recent evidence further emphasizes functional outcomes: Ghorbani et al. [8] reported that young females with flatfoot showed reduced balance, agility, and core strength. Yu et al. [24] found impaired jump height performance in athletes with flatfoot, while Jia et al. [11] demonstrated that exercise therapy could improve arch function in adults.

Table 1. Prevalence of flatfoot across populations and age groups.

Population	Prevalence (%)	Method	Notes
Children (2-5 yrs)	40–50	Footprint indices	Physiological flatfoot
Children (6-10 yrs)	15–25	Footprint indices	Arch development
Adolescents	10–15	Footprint + radiography	Mature arch
European adults	2–6	Radiographic	Lowest prevalence
Asian adults	13–20	Mixed	Higher prevalence
African barefoot	<5	Footprint	Protective effect
African urban	Up to 15	Mixed	Urban lifestyle risk
Military recruits	10–20	Radiographic + clinical	Load effects
Athletes (runners/ dancers)	2–8	Mixed	Protective sports
Athletes (gymnasts/ weightlifters)	12–20	Mixed	Stress-related risk

The findings confirm that flatfoot is largely developmental in children, with spontaneous resolution in many cases [7, 22]. Persistent flatfoot into adulthood, however, may indicate structural abnormality or predispose to clinical symptoms (**Fig. 4**). Evolutionary perspectives highlight the human arch as a recent adaptation for efficient bipedal locomotion [1, 21]. Barefoot populations demonstrate stronger arches and lower prevalence, while shod, urban groups exhibit higher rates [19, 15]. These findings emphasize the cultural and environmental role in foot morphology.

BMI and lifestyle strongly influence prevalence, with overweight individuals consistently more likely to present with flatfoot [5, 22]. Occupational load-bearing, such as in military service, is another strong predictor [10]. Athletic training demonstrates dual effects, with some sports protective and others predisposing. Symptomatic flatfoot is clinically relevant, associated with pain, altered gait, and comorbidities such as plantar fasciitis, posterior tibial tendon dysfunction, and back pain [4, 14, 22].

Methodological diversity complicates prevalence estimates. Footprint indices, radiographic parameters, and modern 3D measures often yield different thresholds, limiting cross-population comparison [20, 4] **(Table 2).** Standardization and creation of normative population-specific databases would improve both clinical and anthropological assessments. Preventive approaches should emphasize early detection, strengthening of intrinsic muscles, and culturally sensitive interventions. Footprint indices such as the SAI, CSI, and Clarke's Angle remain invaluable in large-scale anthropological surveys due to their low cost and ease of application. The CSI generally provides higher diagnostic accuracy, the SAI is most widely used in pediatric populations, and Clarke's Angle, while simple, can be subject to variability based on foot posture and observer interpretation. For comprehensive evaluation, these indices are best applied in combination with radiographic or modern digital techniques. Recent studies confirmed their continued relevance and diagnostic value in both children and adults [12, 18, 11, 23, 8, 9].

From an anthropological perspective, flatfoot is not only a pathology but also a morphological variant reflecting the interplay of biology and culture.

From a public health standpoint, screening programs in school-aged children may allow early identification of persistent flatfoot, particularly in populations with high BMI or limited physical activity. Occupational health also requires attention: prevalence rates among military recruits remain elevated [10, 6], reinforcing the need for preventive conditioning and supportive footwear.

Clinically, however, recognition of risk factors and appropriate treatment are essential to prevent long-term disability.

Table 2. Diagnostic approaches for flatfoot

Method	Parameter	Threshold	Notes
Staheli Arch Index	Midfoot/heel width	>1.0	Anthropometric
Chippaux–Smirak Index	Midfoot/forefoot ratio	>45%	Anthropometric
Clarke's Angle	Medial footprint angle	<31°	Anthropometric
Calcaneal Pitch	Radiographic angle	<15°	Skeletal measure
Meary's Angle	Talus–metatarsal axis	>4° deviation	Structural collapse
Talocalcaneal Angle	Hindfoot alignment	Increased	Valgus correlation
3D Scanning	Arch height index	Low volume	High precision

Conclusion

Flatfoot represents both a normal morphological variant and a condition of clinical significance. In childhood, it is largely physiological and self-correcting, but persistent or adult flatfoot can result in pain, gait alteration, and secondary musculoskeletal problems. Its prevalence varies by age, sex, body weight, occupation, and culture, underscoring the combined influence of biology and environment. While barefoot populations tend to have stronger arches, urban lifestyles and overweight contribute to higher prevalence. Symptomatic flatfoot requires tailored management, ranging from conservative treatment to surgery. Methodological inconsistencies in diagnosis remain a challenge, highlighting the need for standardized criteria. Future research should focus on longitudinal studies, cross-cultural comparisons, and integration of digital imaging to refine understanding and improve prevention and treatment. By adopting a medico anthropological approach, clinicians and researchers can better appreciate the dual role of flatfoot as a reflection of human variation and as a clinical entity requiring intervention. Recent studies underscore that beyond structural prevalence, functional consequences such as impaired balance, agility, and jump performance are clinically significant [23, 8]. Furthermore, regional surveys [18, 2, 9] highlight the variation of prevalence and risk factors across populations, while interventional research confirms that exercise therapy may improve arch stability and function [11]. These findings reinforce the importance of integrating preventive exercise programs, population-specific screening, and culturally adapted interventions into both clinical and anthropological practice.

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