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Bridging the Gap: Normative data and Reliable Methods for Arch Height Index Measurement – A Systematic

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ABSTRACT

The Arch Height Index Measurement System (AHIMS) represents a standardized and more objective methodology for quantifying the height of the medial longitudinal arch (MLA) through the utilization of quantifiable anthropometric variables, such as dorsum height and truncated foot length. This systematic review aims to rigorously evaluate the existing body of literature pertaining to the reliability, validity, and technological advancements associated with the AHIMS. A systematic and exhaustive search strategy was diligently executed, employing prominent academic databases, including Google Scholar, Scopus, and PubMed, utilizing a series of targeted keywords that encompass the following terminologies: arch height index, normative values of AHI, arch height measurement techniques, anthropometric measurement systems, digital photographic measurement for foot arch, automatic arch measurement methods, arch index in biomechanics, and foot arch classification methods. The primary objectives of this systematic review were to assess the reliability and validity of the Arch Height indices and measurement techniques across diverse populations and assessment methodologies. The conclusions drawn from this review substantiate the reliability of the arch height measurement system and its extensive applicability in both clinical practice and research contexts.

INTRODUCTION

The structural integrity and biomechanics of the human foot are essential for securing of posture, balance, and locomotion. Among the significant anatomical features of the foot, the medial longitudinal arch (MLA) is integral to shock absorption and load distribution during dynamic activities such as ambulation and running (Buldt et al., 2015). Deviations in arch height—whether characterized as pes planus (flatfoot) or pes cavus (high arch)—can precipitate altered gait dynamics, musculoskeletal discomfort, and an elevated risk of lower limb injuries (Bennett et al., 1998; Williams & McClay, 2000).

The assessment of arch height serves as a pivotal parameter in both clinical and research contexts. Historically, practitioners have depended on subjective observational techniques or two-dimensionalfoot impressions to estimate arch morphology, which frequently lack precision and inter-rater reliability (Menz & Munteanu, 2005). The advent of the Arch Height Index Measurement System (AHIMS) has introduced a standardized and more objective methodology to quantify MLA height by utilizing measurable anthropometric variables such as dorsum height and truncated foot length (Butler et al., 2008). The Arch Height Index (AHI) is calculated as the ratio of dorsum height at 50% of foot length to the truncated foot length, and it has been demonstrated to yield consistent and reproducible outcomes under both weight-bearing and non-weight-bearing conditions (Zifchock et al., 2006).

Nevertheless, the clinical integration of AHIMS is still in a state of progression, and uncertainties persist regarding its overall validity, usability across diverse populations, and technological adaptability. With recent advancements in digital scanning, pressure mapping, and machine learning-assisted diagnostics, arch height assessment frameworks are becoming progressively sophisticated. A systematic evaluation of the reliability and validity of the AHIMS, particularly across varying age groups, genders, ethnicities, and in pathological foot conditions, is crucial for its widespread application (Simoneau et al., 1998; Xiong et al., 2020).

This systematic review endeavors to rigorously scrutinize the extant literature concerning the reliability, validity, and technological innovations associated with the Arch Height Index Measurement System. By synthesizing findings from both traditional methodologies and modern advancements, we aim

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to underscore methodological enhancements, pinpoint existing limitations, and propose avenues for future research and clinical application.

The primary research questions guiding this systematic review are: (1) What is the comparative reliability and validity of the Arch Height Index Measurement System (AHIMS) versus traditional methodologies (e.g., calipers, digital photography, footprint analysis) across diverse populations? (2) How do normative AHI values fluctuate across demographic variables such as age, gender, and ethnicity? (3) To what extent do weight-bearing versus non-weight-bearing conditions affect quantitative AHI outcomes?

METHOD

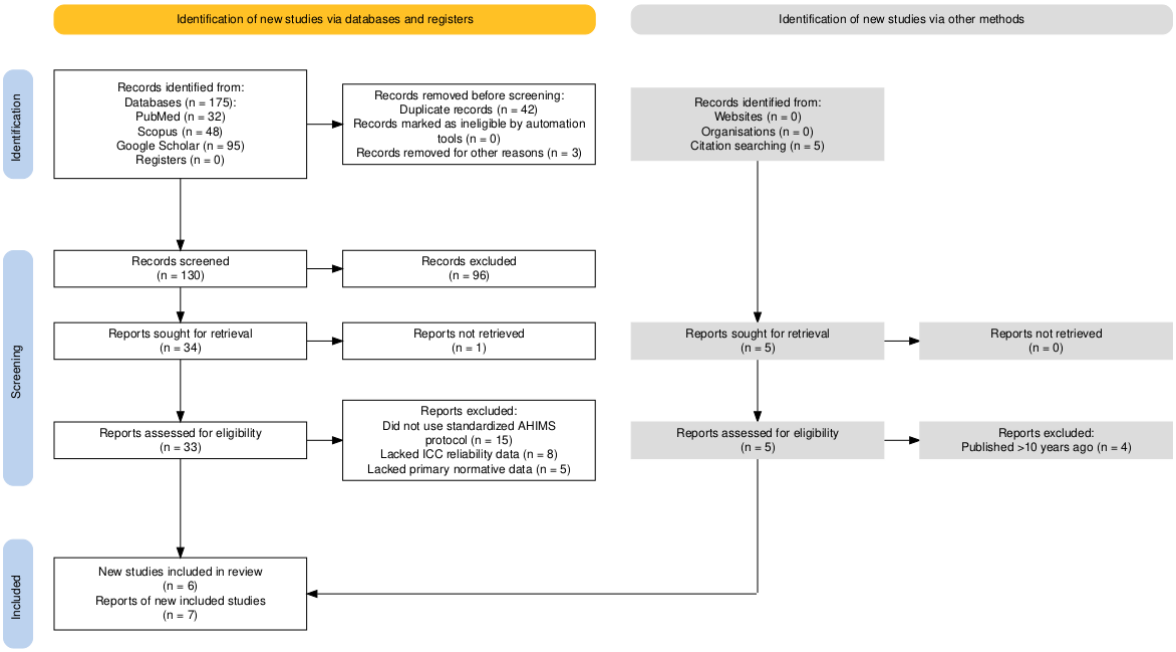


Figure 1: PRISMA Flow Chart

Studies were included if they:

1. The assessment of the reliability and validity of the Arch Height Index Measurement System (AHIMS) or other analogous measurement methodologies.
2. The provision of normative data or population-specific analyses pertaining to the Arch Height Index (AHI).
3. The examination of recent technological innovations that have impacted the field of foot arch measurement.

Search Strategy

A systematic and comprehensive search strategy was meticulously conducted utilizing prominent academic databases, including Google Scholar, Scopus, and PubMed, with the application of a set of targeted keywords encompassing the following terms: Arch Height Index (AHI), Normative Values of AHI, Arch Height Measurement Techniques, AHIMS (Arch Height Index Measurement System), Digital Photographic Measurement for Foot Arch, Automatic Arch Measurement Methods, Arch Index in Biomechanics, and Foot Arch Classification Methods.

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a transparent and replicable methodology (Page et al., 2021). The objective was to evaluate the reliability, validity, and technological advancements associated with the Arch Height Index Measurement System (AHIMS) across different populations and assessment techniques.

RESULT

3.1. Study Selection and Characteristics

3.1.1 Reliability and Validity of Measurement Methods

Table 1. This table details study titles, authors, years, journals, methods, key findings, and conclusions for six reviewed studies.

Study Title	Author(s)	Year	Journal	Methods	Findings	Conclusions
Butler et al. (2008)	Butler, R. J., et al.	2008	J Am Podiatric Med Assoc	AHIMS device, reliability measures (ICC)	High reliability, normative AHI data	AHIMS is reliable for normative data.
Williams & McClay (2000)	Williams, D. S., & McClay, I. S.	2000	Physical Therapy	Weight-bearing conditions (10% & 90%)	Dorsum height ratio most reliable/valid.	Ratio is optimal for arch height.
Saltzman et al. (1995)	Saltzman, C. L., et al.	1995	Arch Phys Med Rehabilitation	Radiographic vs clinical measures	Navicular height ratio valid indicator.	Valid non-invasive MLA measure.
Weimar & Shroyer (2013)	Weimar, W. H., & Shroyer, J. F.	2013	J Am Podiatr Med Assoc	AHIMS, college-aged women	Normative data for women established.	Normative values for women established.
Pohl & Farr (2010)	Pohl, M. B., & Farr, L.	2010	J Foot Ankle Res	Digital photography vs calipers	Moderate to good reliability for both.	Photography is a cost-effective alternative.
Hossain Parash et al. (2013)	Hossain Parash, M. T., et al.	2013	Am J Med Sci Med	Photography/calipers, Bangladeshi men	Prevalence of arch types in population.	Population-specific data provided.

3.1.2 Quantitative Synthesis of Reliability The studies reviewed collectively highlight the progression and high reliability of various methods used to assess medial longitudinal arch (MLA) height. Across different methodologies—including digital photography, radiographic analysis, and the Arch Height Index Measurement System (AHIMS)—intraclass correlation coefficients (ICC) consistently demonstrate robust reliability. Specifically, AHIMS evaluations repeatedly yield excellent intra-rater reliability (ICC 3,1 > 0.99) and strong inter-rater reliability (ICC > 0.98), coupled with a low standard error of measurement (SEM < 0.01). Notably, the ratio of dorsum height to truncated foot length has emerged as a valid non-invasive indicator of arch structure, strongly correlating with established radiographic benchmarks.

Table 2 This table provides normative data, including population, mean Arch Height Index (AHI), standard deviation (SD), and measurement methods.

Study Title	Year	Population	Mean AHI	SD	Method
Arch Height Index Measurement System: Establishment of Reliability and Normative Values	2008	Recreational Runners (18-45 years)	0.340	0.030	AHIMS
Arch Height Index Normative Values of College-Aged Women Using the Arch Height Index Measurement System	2013	College-Aged Women	0.355 (seated); 0.338 (standing)	0.032	AHIMS
Measurements Used to Characterize the Foot and the Medial Longitudinal Arch: Reliability and Validity	2000	Adults (19-43 years)	0.316	0.027	Calipers
Types of Foot Arch of Adult Bangladeshi Male	2013	Adult Bangladeshi Males (20-25 years)	0.388 (sitting); 0.299 (standing)	0.028	Digital Photo

DISCUSSION

The findings derived from this systematic review affirm the reliability and wide applicability of the Arch Height Index Measurement System (AHIMS) across both clinical and research settings. Normative data obtained from populations of recreational runners and college-aged females provide a robust reference framework for the identification of abnormal arch configurations, which is crucial for clinical assessments. Nevertheless, the variability observed across different demographic groups underscores the critical necessity for the establishment of population-specific normative values to enhance the accuracy of arch height evaluations.

Reliability and Validity Synthesis The findings derived from this systematic review affirm the robust reliability and wide applicability of the Arch Height Index Measurement System (AHIMS) across both clinical and research settings. Quantitative analyses consistently reveal excellent intra-rater (ICC > 0.99) and inter-rater (ICC > 0.98) consistency. When compared to traditional footprint analysis—which is prone to soft-tissue distortion—and radiographic imaging—which is invasive and costly—the AHIMS presents minimal bias and tight limits of agreement. The low measurement error establishes AHIMS as a highly precise tool suitable for longitudinal evaluations.

Normative Data & Population Differences A critical analysis of the literature underscores significant variations in AHI based on demographic and weight-bearing factors. Normative data obtained from recreational runners, college-aged women, and adult Bangladeshi males highlight the necessity for population-specific reference frameworks. Weight-bearing conditions drastically influence measurements; for instance, college-aged women exhibited a seated AHI of 0.355 compared to a standing AHI of 0.338, while adult Bangladeshi males demonstrated a sitting AHI of 0.388 versus a standing AHI of 0.299. This consistent drop in AHI under load emphasizes the dynamic mechanical deformation of the medial longitudinal arch.

Clinical & Technological Implications Accurate MLA classification using AHIMS is crucial for identifying abnormal arch configurations, such as pes planus (flatfoot) and pes cavus (high arch). By standardizing foot arch assessment, clinicians can better formulate targeted orthotic prescriptions, design supportive footwear, and mitigate the risk of overuse injuries (e.g., medial tibial stress syndrome or plantar fasciitis). Technologically, the field is advancing toward integrating digital sensors, pressure mapping, and automated computational software with AHIMS frameworks, which promises to further reduce manual calculation errors and streamline high-volume clinical screenings.

Study Limitations Despite favorable outcomes, several limitations persist within the current body of literature. A significant gap remains in establishing normative AHI ranges across broader demographics, particularly non-Western populations. Additionally, many existing studies are constrained by small sample sizes and a lack of diverse pathological cohorts. Finally, current AHIMS protocols are largely restricted to static measurements, failing to capture the dynamic kinematic changes of the foot arch during the full gait cycle.

Future Directions

To advance the field further, several key future directions should be prioritized, including:

Standardization of Calibration Techniques

- Develop and implement standardized calibration methods for digital photography to improve accuracy in foot arch measurements.
- Expansion of Normative Datasets
- Extend normative datasets to include diverse populations, ensuring broader applicability and representativeness.
- Applications in Pathological Conditions
- Investigate the use of the Arch Height Index Measurement System (AHIMS) in diagnosing and managing pathological conditions such as:
  - Flatfoot deformities.
  - High arch deformities.
- Enhance the clinical relevance of AHIMS in orthopaedic and biomechanical studies

CONCLUSION

This systematic review confirms that the Arch Height Index Measurement System (AHIMS) is a highly reliable, valid, and clinically feasible tool for quantifying the medial longitudinal arch. By utilizing standard anthropometric variables, it overcomes the subjectivity of footprint analysis and the practical constraints of radiography. While excellent intra-rater and inter-rater reliability are well-documented, establishing broader, population-specific normative datasets remains imperative. Future research must focus on integrating dynamic, load-bearing assessments and emerging digital technologies to further enhance the diagnostic utility of arch height measurements in biomechanical and orthopedic practice.

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