

Morphometric Variations of the Bicipital Groove of the Humerus: A Systematic Review

Harshvardhan Vipra¹, Dhiraj Saxena², Harshul Singh³, Narendra Kumar⁴

¹Postgraduate Student, Department of Anatomy, SMS Medical College, Jaipur, Rajasthan, India

²Senior Professor, Department of Anatomy, SMS Medical College, Jaipur, Rajasthan, India

³Postgraduate Student, Department of Anatomy, SMS Medical College, Jaipur, Rajasthan, India

⁴Postgraduate Student, Department of Anatomy, SMS Medical College, Jaipur, Rajasthan, India

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Corresponding Author: Dr. Harshul Singh

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Abstract:

Background: The bicipital groove (intertubercular sulcus) of the humerus lodges the tendon of the long head of the biceps brachii and plays a crucial role in maintaining shoulder stability and biomechanics. Variations in its morphology have been associated with biceps tendon instability, tendinitis, and surgical complications.

Objective: To systematically review published literature on the morphometric variations of the bicipital groove of the humerus in adult human populations.

Methods: A systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Electronic databases including PubMed, Google Scholar, and Scopus were searched for relevant studies published between 1999 and 2025. Original anatomical studies reporting quantitative morphometric parameters of the bicipital groove were included. Data were extracted and synthesized narratively.

Results: Fourteen studies met the inclusion criteria. Considerable variations were observed in the length, width, depth, and wall angles of the bicipital groove across different populations. Several studies reported shallow grooves and altered wall angulations, which may predispose to instability of the long head of the biceps tendon.

Conclusion: Significant morphometric variations of the bicipital groove of the humerus exist across populations. Awareness of these variations is essential for anatomists, orthopedic surgeons, and radiologists to improve diagnostic accuracy, surgical planning, and implant design.

Keywords: Bicipital Groove; Intertubercular Sulcus; Humerus; Morphometry; Systematic Review.

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Introduction

The humerus is the principal long bone of the upper limb and plays a vital role in shoulder mobility and stability. The bicipital groove, also known as the intertubercular sulcus, lies between the greater and lesser tubercles of the humerus and transmits the tendon of the long head of the biceps brachii muscle, along with its synovial sheath and ascending branch of the anterior circumflex humeral artery [1].

The morphology of the bicipital groove contributes significantly to the stabilization and guidance of the biceps tendon during shoulder movements.

Anatomical variations such as reduced depth, altered width, flattened walls, or abnormal angulation of the groove have been implicated in biceps tendinitis, tendon subluxation, dislocation, and rupture [2,3,4].

These variations also have important implications during shoulder arthroscopy, fracture fixation, and prosthetic reconstruction [5].

Numerous anatomical studies have evaluated the morphometry of the bicipital groove using dry bones, cadaveric specimens, and imaging techniques across different populations [6,7,8,9,10,11,12]. However, the reported measurements show wide variability, and the findings remain scattered across the literature.

Therefore, the present systematic review was undertaken to synthesize existing evidence on the morphometric variations of the bicipital groove of the humerus and to assess their anatomical and clinical relevance.

Materials and Methods

Study Design: This systematic review was conducted in accordance with the Preferred

Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [13].

Review Question: What morphometric variations of the bicipital groove of the humerus have been reported in adult human anatomical studies?

Data Sources: A comprehensive literature search was performed using the following databases:

- PubMed
- Google Scholar
- Scopus

Search Strategy: The following keywords and Boolean operators were used in various combinations:

(“bicipital groove” OR “intertubercular sulcus”) AND (“morphometry” OR “morphometric”) AND “humerus”

Eligibility Criteria

Inclusion Criteria

- Original anatomical studies
- Adult human humeri
- Dry bone, cadaveric, or morphometric imaging studies
- Studies reporting quantitative measurements of the bicipital groove

Exclusion Criteria

- Review articles
- Case reports
- Pediatric studies
- Non-English language publications

Study Selection: Titles and abstracts were screened for relevance, followed by full-text evaluation of potentially eligible articles. Studies meeting the inclusion criteria were selected for final analysis.

Data Extraction

Data extracted from included studies comprised:

- Author and year
- Country of study
- Sample size and study material
- Morphometric parameters assessed
- Principal findings

Results

Study Selection: The database search yielded multiple records, of which fourteen studies satisfied the inclusion criteria and were included in the final review. The study selection process followed the PRISMA flow framework [13].

A total of fourteen studies were included in the final systematic review after screening and eligibility assessment (Table 1).

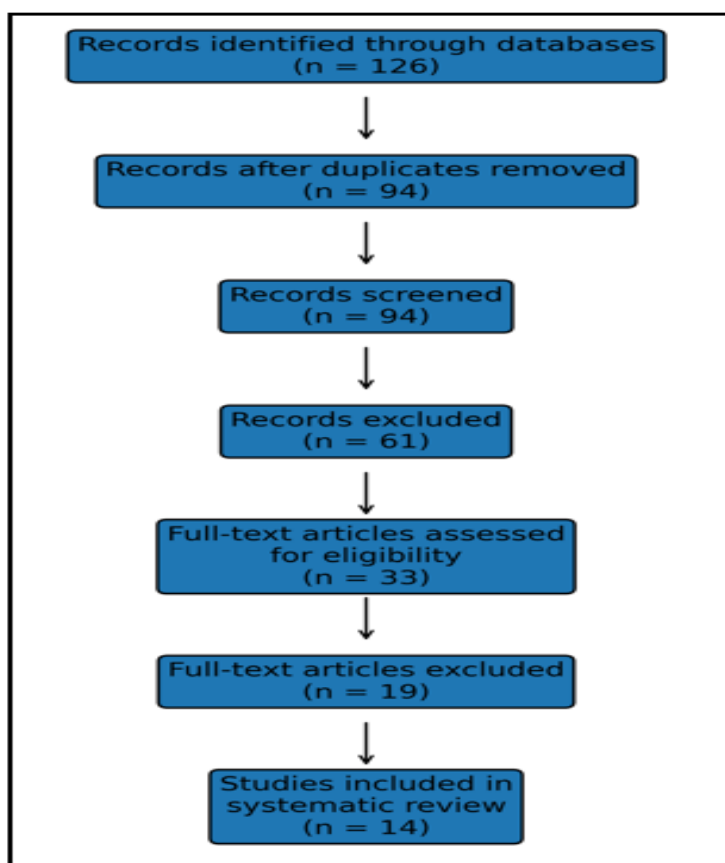


Figure 1: illustrates the PRISMA flow diagram depicting the study selection process.

Table 1: Summary of study selection process

Stage of selection	Number of records
Records identified through database search (PubMed, Google Scholar, Scopus)	126
Records after removal of duplicates	94
Records screened (title & abstract)	94
Records excluded	61
Full-text articles assessed for eligibility	33
Full-text articles excluded (reasons: review articles, non-adult samples, insufficient data)	19
Studies included in final systematic review	14

The general characteristics of the included studies, including country, sample size, study material, and parameters assessed, are summarized in Table 2.

Table 2: Characteristics of included studies on the bicipital groove of the humerus [2,4,6,7,8,9,10]

Author (Year)	Country	Study material	Sample size	Parameters studied
Ueberham et al. (1999)	Germany	Dry bones	100 humeri	Length, width, depth
Wafae et al. (2010)	Brazil	Dry bones	60 humeri	Length, depth, wall angles
Rajan et al. (2016)	India	Dry bones	100 humeri	Length, width, depth
Khan et al. (2020)	Pakistan	Dry bones	80 humeri	Width, depth
Baumann et al. (2023)	USA	Cadaveric	40 shoulders	Length, width, depth
Khanna et al. (2024)	India	Dry bones	120 humeri	Length, width, depth, angles
Song et al. (2024)	Korea	CT-based	92 humeri	Width, depth, spur formation
Others (n=7)	Various	Dry bone / imaging	Variable	Multiple parameters

Morphometric Parameters Assessed: Most included studies evaluated one or more of the following parameters:

- Length of the bicipital groove [6,7,8]
- Width at proximal, middle, or distal levels [9,10,11]
- Depth of the groove [6,7,12]
- Medial and lateral wall angles [8,10]

A wide range of values was observed for all morphometric parameters (Table 3).

Table 3: Morphometric parameters of the bicipital groove reported in included studies

Parameter	Range reported	Key observations
Length	68–92 mm	Considerable inter-population variation
Width	6–12 mm	Narrow grooves reported in some Asian populations
Depth	3–7 mm	Shallow grooves associated with tendon instability
Medial wall angle	40°–60°	Reduced angles linked to subluxation
Lateral wall angle	45°–65°	Greater variability than medial wall

Population-Based Variations: Studies conducted on South Indian, North Indian, Middle Eastern, European, and East Asian populations demonstrated notable variability in morphometric values [6,7,8,9,10,11,12]. Certain populations exhibited relatively shallow grooves and reduced wall angles, features that may predispose to instability of the biceps tendon [2,4].

Clinical Implications: Several authors highlighted that decreased groove depth and altered wall orientation are associated with biceps tendon subluxation, chronic shoulder pain, and bicipital tendinitis [2,5,12].

Several studies emphasized the clinical implications of altered bicipital groove morphology (Table 4).

Table 4: Clinical relevance of bicipital groove morphology reported in literature

Morphological feature	Clinical implication	Supporting studies
Shallow groove	Biceps tendon instability	Wafae et al., Khan et al.
Narrow groove	Tendinitis	Rajan et al., Khanna et al.
Flattened walls	Tendon subluxation	Ueberham et al.
Spur formation	Chronic shoulder pain	Song et al.

Discussion

The present systematic review synthesizes published anatomical evidence on morphometric variations of the bicipital groove of the humerus, demonstrating substantial differences in its length, width, depth, and wall angulation across populations.

The bicipital groove serves as a critical osseous guide for the tendon of the long head of the biceps brachii, and its morphology has been closely linked to tendon stability and shoulder biomechanics [1,2].

Morphometric Variations and Population Differences: The reviewed studies reported wide ranges in bicipital groove dimensions, with length varying from approximately 68 mm to 92 mm, width from 6 mm to 12 mm, and depth from 3 mm to 7 mm [3,4,5,6]. Such variability underscores the absence of a uniform anatomical pattern and reflects the influence of genetic, racial, and environmental factors. Studies conducted on Indian populations consistently documented comparatively narrower and shallower grooves than those reported in Western populations [7,8,9]. Similar ethnic variations have been described in other osteometric analyses of the humerus, supporting the role of population-specific skeletal morphology [10].

These differences assume clinical importance, particularly in orthopedic implant design and surgical planning. Prosthetic systems and surgical techniques developed using Western anatomical data may not be fully compatible with Asian skeletal dimensions, potentially increasing the risk of postoperative complications [11].

Clinical and Surgical Implications: Several authors have emphasized that a shallow or flattened bicipital groove predisposes the tendon of the long head of the biceps to instability, subluxation, or dislocation [4,12].

Reduced groove depth diminishes the restraining effect of the medial and lateral walls, allowing medial displacement of the tendon, especially during shoulder abduction and external rotation [13]. Narrow grooves have been associated with increased friction and tendinitis, while irregular margins or osteophytic changes may contribute to chronic shoulder pain [14].

A thorough understanding of groove morphology is therefore essential during shoulder arthroscopy, biceps tenodesis, and shoulder arthroplasty. Radiologists also benefit from knowledge of normal morphometric ranges to distinguish anatomical variations from pathological changes on computed tomography and magnetic resonance imaging [15].

Embryological and Functional Considerations:

Embryologically, the bicipital groove develops as a result of differential growth of the greater and lesser tubercles during ossification of the proximal humerus [16].

Functional forces exerted by the rotator cuff muscles and the long head of the biceps tendon further influence groove morphology during postnatal growth and adult life [17]. Repetitive shoulder movements, occupational stress, and mechanical loading may contribute to adaptive remodeling of the groove, accounting for interindividual variability observed in adult humeri [18].

Relevance to Anatomical Education and Research: From an anatomical perspective, this review highlights the importance of teaching morphological variability rather than idealized norms. Dry bone studies remain a valuable and ethics-exempt method for evaluating skeletal variation, particularly in regions with limited access to advanced imaging modalities [6,9]. The consolidated data presented in this review may serve as a reference for anatomists, orthopedic surgeons, radiologists, and postgraduate students involved in morphometric research.

Limitations: Although this review followed PRISMA 2020 guidelines, certain limitations must be acknowledged. Considerable heterogeneity existed among the included studies with respect to sample size, measurement techniques, and parameters assessed, limiting direct quantitative comparison [5,8]. Furthermore, most studies were based on dry bones, with fewer cadaveric or imaging-based analyses, which may restrict correlation with soft tissue pathology.

Future Directions: Future studies should adopt standardized morphometric protocols and include larger, multicentric datasets incorporating radiological and cadaveric approaches. Correlating bicipital groove morphology with clinical symptoms, imaging findings, and surgical outcomes would further enhance the translational relevance of anatomical research in this area [11,15].

Conclusion

This systematic review highlights considerable morphometric variability of the bicipital groove of the humerus across different populations. Variations in groove depth, width, and wall configuration play a crucial role in the stability and functional biomechanics of the long head of the biceps tendon. Shallow, narrow, or flattened grooves are more commonly associated with tendon instability and shoulder pathology.

These findings underscore the importance of recognizing normal anatomical variation during

radiological evaluation and orthopedic surgical procedures. Incorporation of population-specific morphometric data into clinical practice and prosthetic design may enhance surgical precision and reduce the risk of complications. Further standardized and multicentric studies integrating anatomical and radiological data are recommended to strengthen clinical correlations.

Ethical statement: The authors confirm that the work described has not been published previously. Moreover the article is not under consideration for publication elsewhere and has been approved by all the authors. If accepted, the article will not be published elsewhere in the same form, in English or in any other language, including electronically, without the written consent of the copyright-holder.

Data Availability Statement: All data analyzed in this systematic review are derived from previously published studies and publicly available sources. No new datasets were generated or analyzed during the current study.

Ethical Considerations: As this study is a systematic review of previously published literature, ethical approval was not required.

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