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Comparative Morphology and Morphometry of the Scapula in Humans (*Homo sapiens*) and Sclater's Monkey (*Cercopithecus sclateri*)

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ABSTRACT

The scapula is a key anatomical structure reflecting locomotor adaptation in primates. Humans exhibit bipedalism with non-weight-bearing upper limbs, whereas arboreal primates such as *Cercopithecus sclateri* rely on forelimb-assisted locomotion. Forty adult dry scapulae (20 humans, 20 Sclater's monkeys) were analyzed. Morphological features were assessed qualitatively, while morphometric parameters including spine length, acromion length and width, glenoid diameter, and coracoid process length were measured using digital calipers. Data were recounted as mean ± standard deviation and assessed by an independent t-test ($p < 0.05$). All parameters were significantly higher in humans: spine length (13.02 ± 0.62 cm vs. 6.35 ± 0.48 cm), acromion width (4.62 ± 0.41 cm vs. 0.52 ± 0.09 cm), glenoid diameter (2.01 ± 0.15 cm vs. 0.81 ± 0.07 cm), and coracoid length (4.38 ± 0.27 cm vs. 1.52 ± 0.12 cm) ($p < 0.001$). The suprascapular notch was present in all human specimens but absent in monkeys. The scapula demonstrates significant structural divergence between species, reflecting functional adaptation to mobility in humans and stability in arboreal primates.

Keywords: scapula, morphometry, primate anatomy, locomotor adaptation, shoulder biomechanics

INTRODUCTION

The primate shoulder girdle exhibits remarkable structural diversity, reflecting adaptation to different locomotor and functional demands [1]. The scapula, as a major component of this complex, plays a critical role in upper limb mobility, muscle attachment, and force transmission across the shoulder joint [2]. Its morphology has been widely used in evolutionary and functional studies to infer locomotor patterns among primates [3,4].

In arboreal primates, the scapula is adapted to facilitate overhead limb use and climbing, with structural features that enhance joint mobility and allow a greater range of humeral movement [5,6]. Conversely, in humans (*Homo sapiens*), the adoption of obligate bipedalism has resulted in the functional liberation of the upper limb from locomotion. This transition has enabled enhanced manipulative capabilities, tool use, and fine motor coordination [7,8]. These functional distinctions are evident in the morphology of key scapular features, including the spine, acromion, and glenoid cavity.

The glenoid cavity is particularly important in determining the balance between movability and stability at the shoulder joint. Arboreal primates typically exhibit relatively shallow glenoid cavities that allow increased humeral mobility necessary for climbing and suspensory behaviors [6,9]. In contrast, humans display modifications that enhance joint stability during controlled upper limb activities [10]. Similarly, the acromion process contributes significantly to deltoid muscle function and influences shoulder biomechanics [11].

Previous reports have shown that scapular structure is shaped by both functional demands and allometric scaling, emphasizing the importance of careful morphometric analysis in interspecific comparisons [12,13]. Although extensive research has been conducted on primate shoulder evolution, data on regionally endemic species such as Sclater's monkey (*Cercopithecus sclateri* Pocock, 1904) remain limited [14].

This study, therefore, aims to compare the morphology and morphometry of the scapula in humans and Sclater’s monkey, with emphasis on functional and evolutionary implications.

MATERIALS AND METHODS

Ethical approval

This comparative study was conducted in strict accordance with the principles of the Declaration of Helsinki on the ethical use of human osteological materials and animal ethics guidelines for non-human primate specimens. Ethical approval for this study was granted by the Health Research Ethics Committee, Department of Human Anatomy, Olabisi Onabanjo University, Ogun State, Nigeria (Approval No. OOU/HREC/2026/022).

Specimen selection

A total of forty dry scapulae comprising twenty human (*Homo sapiens*) and twenty Sclater's monkey (*Cercopithecus sclateri*) specimens were systematically selected for this study. To ensure morphometric accuracy, only adult scapulae exhibiting complete, intact anatomical landmarks were included. Specimens displaying signs of pathological deformity, congenital anomalies, or post-mortem fractures were rigorously excluded to preserve morphological integrity.

Source and handling

All specimens were ethically sourced from the skeletal archives of the Department of Anatomy Museum, Faculty of Basic Medical Sciences, Olabisi Onabanjo University. Official academic utilization of the bone collection was authorized by the designated legal custodian. All human specimens were fully anonymized. Respectful handling protocols, adhering to international osteological curation standards, were meticulously maintained throughout the analytical phases.

Morphological evaluation

Qualitative morphological evaluations were performed systematically across the posterior, anterior, and medial aspects of each scapula. Key anatomical features, including the acromion process, spinous process, supraspinatus fossa, infraspinatus fossa, subscapularis fossa, suprascapular notch, glenoid cavity, and coracoid process, were visually assessed, compared, and documented.

Morphometric analysis and statistical framework

Anthropometric measurements of defined scapular components were obtained using digital vernier calipers (Mitutoyo, Japan) calibrated to 0.01 mm precision. The parameters assessed included: Spine Length, Acromion Length, Acromion Width, and Coracoid Process Length.

Statistical analyses were performed using IBM SPSS Statistics version 26.0. Descriptive data were presented as mean ± SD to account for sample variance. Independent samples t-tests were employed to estimate the statistical significance among the two species, with the threshold for significance established at $p < 0.05$.

RESULTS

Morphological findings

Visual observation of the scapulae across both species revealed distinct structural variations reflecting their varied biomechanical adaptations.

Scapular Fossae: Both species presented well-defined supraspinatus, infraspinatus, and subscapularis fossae. However, the human fossae were substantially broader, accommodating larger muscle bellies.

Suprascapular Notch: A prominent morphological divergence was the suprascapular notch; it was clearly identifiable in the human scapulae but entirely absent in all Sclater's monkey specimens.

Glenoid Cavity: The articular surface of the glenoid cavity was observed to be distinctly shallower and more elongated in the Sclater's monkeys compared to the deeper, more pyriform structure in humans.

Processes: The acromion and coracoid processes were highly robust and expansive in humans, whereas they appeared slender and restricted in the monkey specimens.

Morphometric findings

The morphometric comparative analysis yielded significant dimensional differences between the human and Sclater's monkey scapulae across all measured parameters. The human scapula demonstrated overwhelmingly larger dimensions, particularly in the structural width of *muscle attachment* sites.

Table 1 shows comparative scapular morphometry across both groups. All values are expressed as mean ± standard deviation (SD). Measurements were obtained using digital vernier calipers. Data analysis was carried out using IBM SPSS version 26.0. Differences between groups were analyzed using an independent samples t-test. All parameters were significantly higher in humans compared to monkeys ($P < 0.001$).

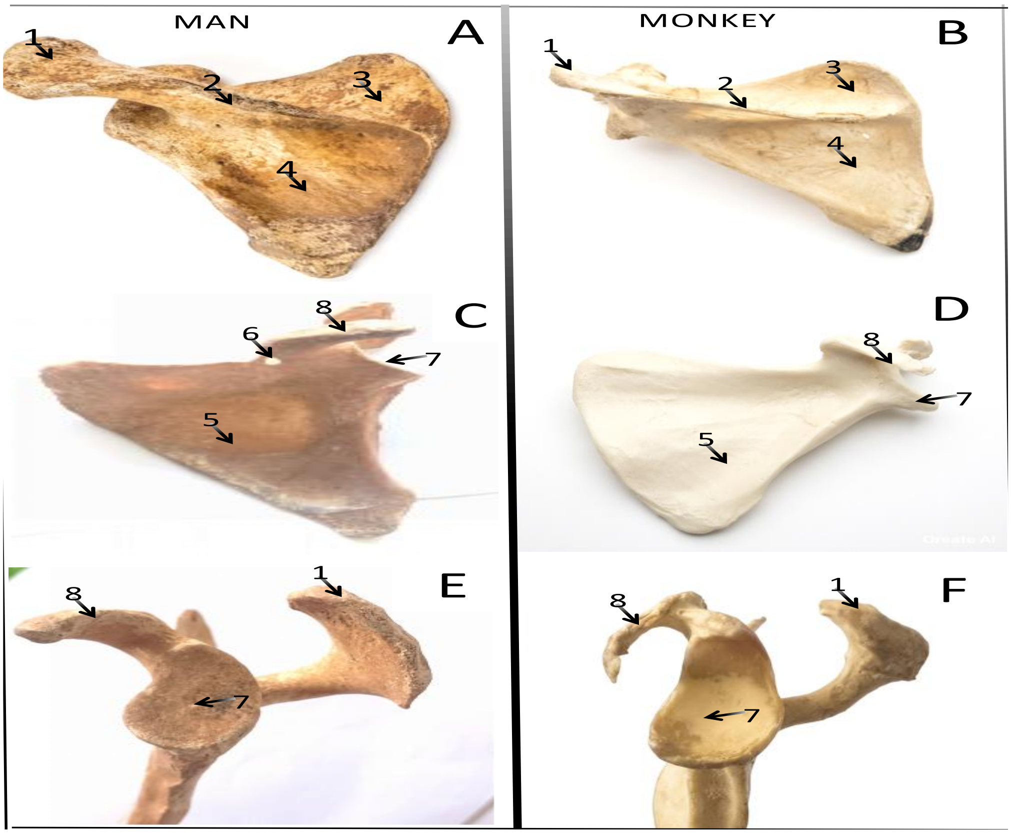

Figure 1: Morphological Comparison of the Scapulae in Humans and Monkeys (A) Posterior view of the human scapula; (B) posterior view of the monkey scapula; (C) anterior view of the human scapula; (D) anterior view of the monkey scapula; (E) medial view of the human scapula; and (F) medial view of the monkey scapula. Key anatomical features identified include the acromion process (1), spinous process (2), supraspinatus fossa (3), infraspinatus fossa (4), subscapularis fossa (5), suprascapular notch (6; absent in monkeys), glenoid cavity (7; shallower in monkeys), and coracoid process (8).

Table 1: Morphometric comparison of the scapula in humans and Sclater's monkeys

Parameter (cm)	Humans (Mean ± SD)	Monkeys (Mean ± SD)	t-value	p-value	Evolutionary Implication
Spine Length	13.02 ± 0.62	6.35 ± 0.48	35.12	<0.001	Expanded trapezius/deltoid attachment in humans.
Acromion Length	5.12 ± 0.36	1.92 ± 0.21	31.45	<0.001	Increased leverage for shoulder abduction.
Acromion Width	4.62 ± 0.41	0.52 ± 0.09	38.27	<0.001	Massive lateral deltoid stabilization in humans.
Glenoid Diameter	2.01 ± 0.15	0.81 ± 0.07	33.84	<0.001	Deeper joint congruence for human manipulation.
Coracoid Length	4.38 ± 0.27	1.52 ± 0.12	36.09	<0.001	Enhanced the short head biceps/pectoralis minor origin.

DISCUSSION

The present study revealed substantial morphological and morphometric differences between the scapulae of humans and Sclater's monkeys, indicating marked divergence in shoulder function and locomotor adaptation between both species. These differences are likely associated with the contrasting biomechanical requirements of bipedal manipulation in humans and arboreal quadrupedal locomotion in monkeys. Similar relationships between scapular architecture and locomotor behavior have been widely documented in comparative anatomical studies of primates [3,5]. The generally larger scapular dimensions observed in humans, including spine length, acromion dimensions, glenoid diameter, and coracoid length, suggest a broader surface area for muscular attachment and improved mechanical advantage for muscles involved in *upper limb* mobility and stabilization [11].

The scapular fossae were noticeably broader in humans than in Sclater's monkeys. Enlargement of the supraspinatus, infraspinatus, and subscapular fossae may indicate increased development of the rotator cuff musculature, which plays an important role in maintaining glenohumeral stability during precision movements and repetitive *upper limb* activities. In humans, the upper limb is frequently involved in reaching, lifting, and manipulative functions that require coordinated muscular control. Conversely, the narrower fossae observed in the monkey scapulae may reflect muscular adaptations favoring rapid limb movement and climbing efficiency during arboreal locomotion. Previous comparative investigations have similarly reported that scapular shape and fossa proportions correlate strongly with locomotor specialization among primates [18].

One of the most pronounced findings in this study was the marked enlargement of the acromion process in humans. Both acromion length and width were significantly greater in humans compared with Sclater's monkeys. The acromion serves as an important attachment site for the deltoid and trapezius muscles, and its expansion likely improves leverage during shoulder abduction and elevation. Earlier studies have demonstrated that acromial morphology contributes significantly to shoulder biomechanics and influences the efficiency of *upper limb* movement [15]. Recent biomechanical analyses also indicate that variations in scapular spine orientation and acromial projection affect muscle force generation and glenohumeral loading patterns in primates [19]. The relatively small and slender acromion observed in Sclater's monkeys may therefore represent an adaptation for forward limb excursion and climbing activities rather than extensive lateral arm elevation. Reduced acromial projection may additionally minimize obstruction during quadrupedal progression through trees.

The glenoid cavity demonstrated clear interspecific variation in both shape and size. Human scapulae possessed a larger and deeper glenoid cavity, whereas the glenoid surface in Sclater's monkeys appeared shallower and more elongated. These findings suggest functional differences in shoulder joint mechanics between the species. In humans, a deeper glenoid cavity may improve congruence between the humeral head and scapula, thereby enhancing joint stability during manipulative activities and weight transmission through the upper limb. In contrast, the shallower glenoid cavity in monkeys may permit a wider range of humeral motion required for climbing and suspensory behavior [9]. Previous studies have similarly emphasized that glenoid morphology reflects a balance between stability and mobility within the shoulder joint [10]. Comparative three-dimensional investigations of hominoid scapulae further support the view that glenoid orientation and scapular form are closely associated with locomotor patterns and functional shoulder loading [3, 20].

The coracoid process was also significantly longer and more robust in humans than in Sclater's monkeys. This structure provides attachment for muscles such as the pectoralis minor, coracobrachialis, and short head of the biceps brachii, all of which contribute to stabilization and coordinated movement of the shoulder complex. Increased coracoid dimensions in humans may therefore reflect enhanced muscular development associated with precision handling and *upper limb* control. Similar observations have been reported in musculoskeletal modeling studies that demonstrated a close relationship between scapular morphology and shoulder muscle performance [22].

An additional anatomical difference observed in this study was the absence of the suprascapular notch in all examined Sclater's monkey scapulae. In humans, the suprascapular notch normally transmits the suprascapular nerve beneath the superior transverse scapular ligament. Variations in this structure have been documented in both humans and non-human primates and may reflect differences in ligamentous arrangement or neural pathway organization [22]. The absence of the notch in Sclater's monkeys may therefore represent a species-specific anatomical adaptation, although its exact functional significance remains uncertain.

The significant differences recorded in spine length, acromion dimensions, glenoid diameter, and coracoid length collectively indicate major divergence in shoulder mechanics between humans and Sclater's monkeys. Human scapulae appear structurally adapted for stability, controlled *upper limb* movement, and manipulative efficiency, whereas monkey scapulae retain characteristics favoring mobility and arboreal locomotor flexibility. These findings support evolutionary interpretations suggesting that scapular morphology in primates reflects adaptation to species-specific functional demands and ecological behaviors [23,24].

The findings of this study support the notion that skeletal morphology is influenced not only by functional demands, but also by body size, evolutionary history, and developmental processes [13,17]. Recent morphometric analyses have further demonstrated that scapular form may be shaped by a combination of locomotor behavior, growth patterns, and phylogenetic inheritance acting simultaneously throughout evolution [25]. Consequently, some observed variations between humans and Sclater's monkeys may reflect inherited evolutionary divergence in addition to functional adaptation.

CONCLUSION

This study demonstrated significant morphological and morphometric differences between the scapulae of humans and *Cercopithecus sclateri*. These variations reflect functional adaptations associated with manipulative *upper limb* use in humans and arboreal locomotion in monkeys.

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