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The third head of the biceps brachii muscle exhibiting variable shape presentation: Prevalence, variability and clinical considerations

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ABSTRACT

Introduction: The third head of the biceps brachii is the predominant variation of the arm muscles. Awareness of muscular variations is essential for the management of upper limb pathologies. Variations in the shape of the muscles are rarely explored. This study aimed to describe the prevalence and anatomical presentation of the third head of the biceps brachii muscle (origin, insertion and innervation) with an emphasis on the shape and form variations.

Materials and methods: Biceps brachii of eighty-nine cadavers were examined. The presence of the third head, its origin, shape patterns, blood supply, and nerve innervation were determined and recorded.

Results: The third head of the biceps brachii was present in 20.2 %, with a prevalence of 22.2 % in males and 18.2 % in females. Half (50 %) of these were bilateral presentations. Most (92 %) of the third head of the biceps brachii variations were flat, thin and straight in shape. All the shape variation patterns were observed in males and on the left arm. The third head originated from the humerus on its anteromedial aspect in 92 % of cases. The musculocutaneous nerve innervated the third head of the biceps brachii in 96 % of the cases, and a nerve anomaly of musculocutaneous and median nerves innervated it in a single (4 %) case. The muscular branches of the brachial artery supplied the third head of the biceps brachii in all cases.

Conclusion: Studies on the variation of arm muscles may assist in identifying new patterns of morphological variations like the shape of the muscle and may aid in the accurate diagnosis and management of arm pathologies.

1. Introduction

The biceps brachii muscle is an important muscle of the anterior compartment of the arm that enables flexion of the arm and flexion and supination of the forearm at the elbow joint [1,2]. Typically, it presents two heads, a short and a long head. The short head originates from the coracoid process of the scapula, whereas the long head originates from the supraglenoid tubercle of the scapula [3,4]. The two bellies of both the short and long heads of biceps brachii merge distally into a tendon that inserts on the radial tuberosity and also as the bicipital aponeurosis. The bicipital aponeurosis fuses with the deep fascia of the forearm and extends to attach to the posterior border of the ulna bone [3]. The biceps brachii muscle variations are common, with supernumerary heads ranging from three to five in number having been reported in various populations [1,3,5,6]. The prevalence of the third head of the biceps brachii variation shows population specificity ranging between 2.08 % and 37.5 % in different populations [6–13].

The extra heads of the biceps brachii muscle were previously categorized based on their origin on the humerus. The most common origins are from the anteromedial, anterolateral and superior aspects of the humerus shaft [12]. The variations may also be based on the insertion point [3,14]. Clinically, the presence of the third head of the biceps brachii may be linked to idiopathic symptoms of neurovascular compression in the upper limbs and can be radiologically misdiagnosed as a soft tissue tumour and may complicate surgical interventions of the upper limb [3].

The description of the variations of the shape of the third head of the biceps brachii is unclear from previous studies [6,10–13]. Variations in

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the shape of the muscle may suggest different biomechanical functions and may also have important diagnostic and therapeutic implications [3, 14]. Morphological variations of the musculoskeletal system often present with population specificity. The purpose of the current study was to describe the prevalence and anatomical presentation of the third head of the biceps brachii muscle (origin, insertion and innervation) with an emphasis on the shape and form variations in South African cadavers of European descent. In addition, a review of the literature on the morphological variations, embryological, evolutionary and clinical application of the third head of the biceps brachii is also discussed.

2. Materials and methods

2.1. Study population

The current study examined 178 upper limbs, from 89 (45 males, 44 females) 10 % formalin-fixed adult human cadavers. The age of specimens ranged from 46 to 105 years, mean age of 75.11 ± 12.57 years. The current study was conducted under the ethical clearance number W-CBP-210401-01 granted by the human ethics committee of the University of the Witwatersrand. Cadavers that presented with evidence of trauma or surgical interventions to the shoulder joint, arm, and elbow joints were excluded from the study.

2.2. Dissection protocol

To reveal the anterior arm muscles, a vertical incision was made from the level of the acromion to the elbow 10 cm below the skin crease. Horizontal skin incisions were made perpendicular to the lower and upper end of the vertical skin incision. The skin of the arm was then reflected laterally, followed by the removal of the subcutaneous fat and fascia, and the biceps brachii muscle was exposed together with the neurovasculature of the arm. The origin, insertion, presence of the extra head, shape of the extra head, innervation patterns and blood supply of each biceps brachii muscle were observed and documented.

2.3. Statistical analysis

The descriptive statistics for the observed categorical variables were presented as percentages. The Pearson Chi-square tests were done to determine the existence of statistically significant associations between the number of each observed parameter (origin, insertion, shape and nerve supply) with sidedness and or sex. A p-value of less than 0.05 was used to infer significant associations. All the data analyses were done using IBM SPSS Statistics for Windows ver. 23.0 (IBM Corp., Armonk, NY, USA).

3. Results

The short and long heads of the biceps brachii exhibited the normal anatomical course in all the 89 cadavers (178 upper limbs) examined. The third head of the biceps brachii was present in 20.2 % (18/89) of the cadavers examined (Table 1). Except for the third head of the biceps brachii, no other supernumerary heads of the biceps brachii were observed. The prevalence of the third head of the biceps brachii was 22.2 % (10/45) in males and 18.2 % (8/44) in females and there were no statistically significant associations (Right $p = 0.778$, left $p = 0.547$). The third head of the biceps brachii was bilateral in 50 % of the cases. In total, 15.1 % (27/178) of upper limbs had the third head of the biceps brachii of which 14 of the upper limbs were in males (8 bilateral, 5 left side only, 1 right side) and 13 of the upper limbs were in females (10 bilateral, 2 left side only, 1 right side). The third head of the biceps brachii muscle belly presented with three different shapes that were not reported before; flat and thin straight shape (rectus) in 92 % (25/27) of

Table 1
Distribution of the third head of biceps brachii.

Sex	Side of the body			Total
	Right	Left	Bilateral	
Male (n = 45)	1	5	4	10 (22.2 %)
Female (n = 44)	1	2	5	8 (18.2 %)
Total (n = 89)	2 (11.1 %)	7 (38.9 %)	9 (50 %)	18 (20.2 %)

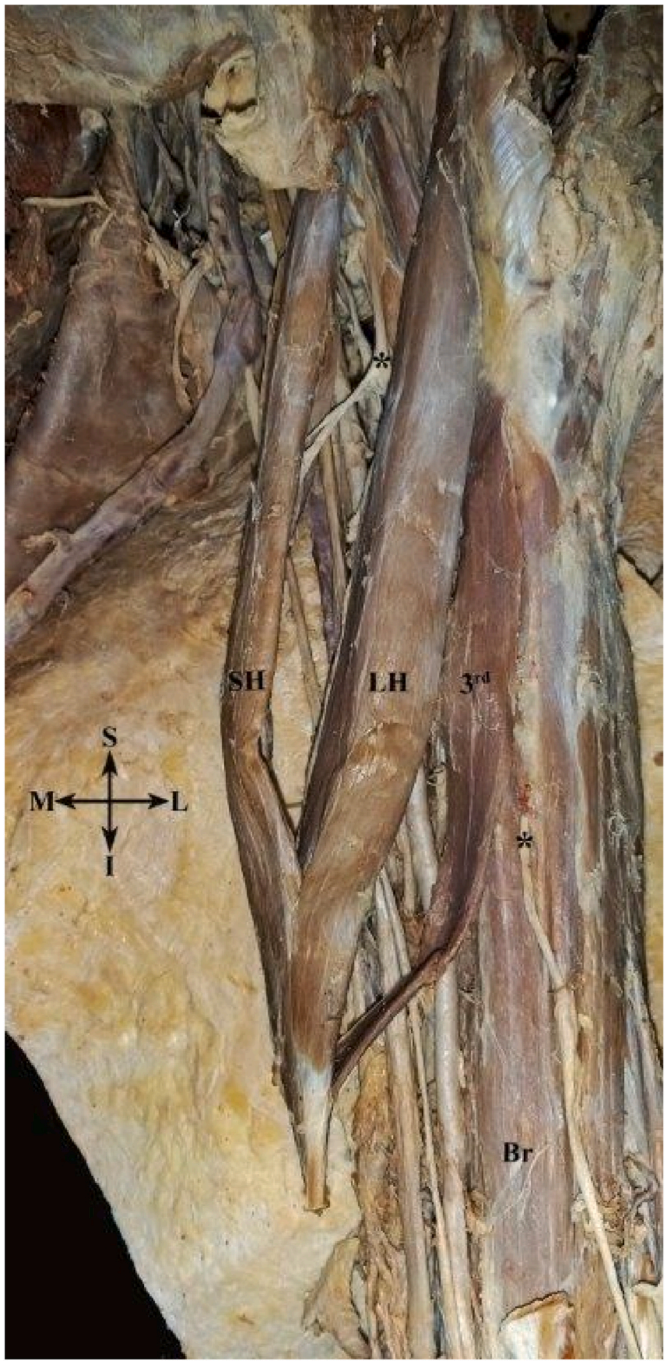


Fig. 1. A photograph of the anterior aspect of the arm, showing a rectus morphology of the third head of the biceps brachii on the left side in a male cadaver. The third head of the biceps brachii originates from the anteromedial surface of the humerus and courses anterior to the brachialis muscle and inserts onto the tendon of the biceps brachii muscle. The musculocutaneous nerve emerges between the third head and the brachialis muscle. **Br**= Brachialis muscle, **LH** = Long head of biceps brachii, **SH**= Short head of biceps brachii, **3**rd = Third head of biceps brachii, **S**= Superior, **I**= Inferior, **M** = Medial, **L** = Lateral, * indicates musculocutaneous nerve.

the variations (Fig. 1), triangular shape in 4 % (1/27) (Fig. 2), and round (teres) shape in 4 % (1/27) (Fig. 3) (Table 2). The triangular and round (teres) shaped third heads of the biceps brachii were observed in males and on the left side only.

Most (92 %) of the third head of the biceps brachii muscles originated from the humerus on the proximal anteromedial surface, between the origin of the brachialis muscle and the insertion of coracobrachialis muscles (Fig. 4). There was no significant side of the body associations between males and females regarding the origin of the third head of the biceps brachii as shown in (Table 2). In 8 % of cases, the third head of the biceps brachii muscle originated from the humerus on its proximal anterolateral surface, above the origin of the brachialis muscle and medial to the insertion of the deltoid muscle (Fig. 5) (Table 2). The third head of the biceps brachii muscle was inserted into the common muscle belly of the biceps brachii in 92 % of the cases (Figs. 2 and 3) and into the tendon of the biceps brachii in 8 % of cases (Fig. 1). No significant associations were observed regarding the insertion of the third head of the biceps and sex and side of the body (Table 2). The third head of the biceps brachii was innervated by the musculocutaneous nerve in 96 % (26/27) of the cases. The musculocutaneous nerve was more associated with the left side than the right side ($P = 0.048$), with no associations between sex (Table 2). On the right side in one female, the innervation was by a branch from the union of the median and musculocutaneous nerves. In all cases, the musculocutaneous nerve coursed posterior to the third head and anterior to the brachialis muscle. The muscular branches of the brachial artery supplied all the cases of the third head. In 4 % (1/27) of the cases, the third head of the biceps brachii covered the distal part of the brachial artery.

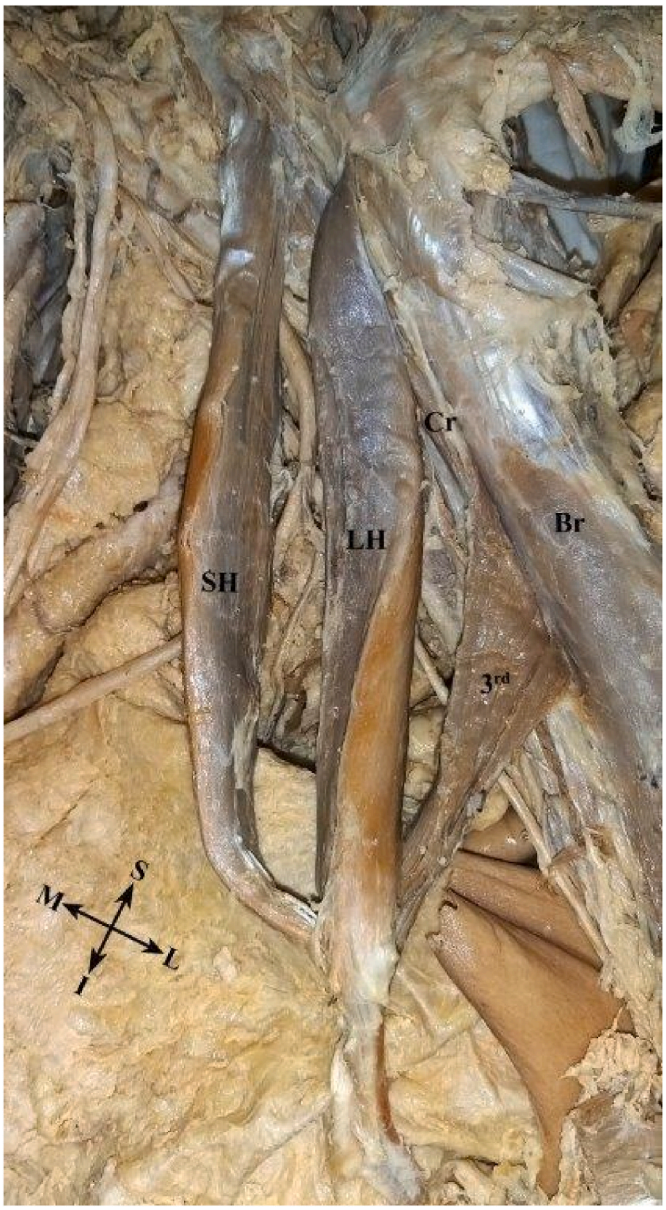


Fig. 2. A photograph of the anterior aspect of the arm showing a triangular-shaped third head of the biceps brachii on the left side of a male cadaver. The muscle originates from the anteromedial surface of the humerus at the level of insertion of the coracobrachialis muscle and inserts into the common belly of the biceps brachii muscle. **Br**= Brachialis muscle, **Cr**= Coracobrachialis muscle, **LH** = Long head of biceps brachii, **SH**= Short head of biceps brachii, **3**rd = Third head of biceps brachii, **S**= Superior, **I**= Inferior, **M** = Medial, **L** = Lateral.

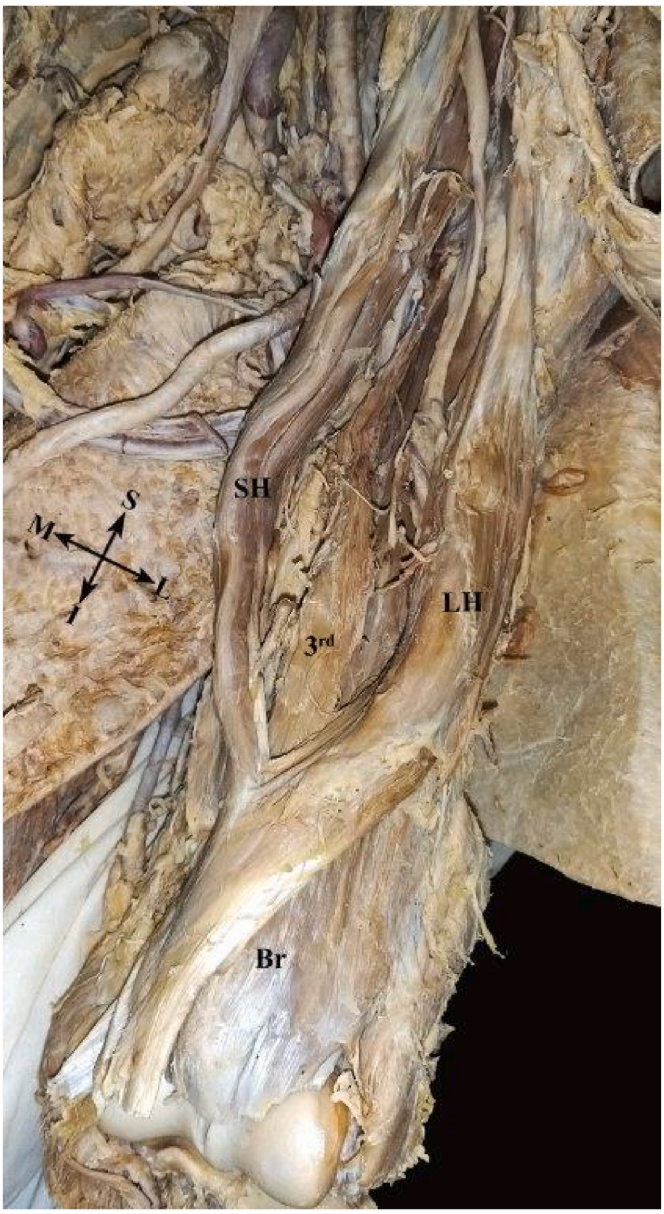


Fig. 3. A photograph of the anterior aspect of the arm showing a round (teres) shaped third head of the biceps brachii in between the long and short heads on the left side of a male cadaver. The third head originates from the anteromedial surface of the humerus and courses medial to the brachialis muscle and inserts into the common belly of the biceps brachii muscle. **Br**= Brachialis muscle, **LH** = Long head of biceps brachii, **SH**= Short head of biceps brachii, **3**rd = Third head of biceps brachii, **S**= Superior, **I**= Inferior, **M** = Medial, **L** = Lateral.

Table 2
Distribution of the variations of the third of the biceps brachii according to sex and side of the body.

Sex and Side		humerus bone origin		Insertion on biceps brachii muscle		Shape of the muscle			Nerve supply	
		Antero-medial surface	Anterolateral surface	Belly	Tendon	Flat	Round	Triangular	MCN	MCN-MN
Male	R	5	-	4	1	5	-	-	5	-
	L	8	1	9	-	7	1	1	9	-
Female	R	6	-	6	-	6	-	-	5	1
	L	6	1	6	1	7	-	-	7	-
Both sex	R	11	1	10	-	11	-	-	10	1
	L	14	1	15	2	14	1	1	16	-
	P	0.198	1.00	0.079	-	0.198	-	-	0.048[a]	-
Total		25 (92 %)	2 (8 %)	25 (92 %)	2 (8 %)	25 (92 %)	1 (4 %)	1 (4 %)	26 (96 %)	1 (4 %)
Grand total		27 (100 %)		27 (100 %)		27 (100 %)			27 (100 %)	

MCN = Musculocutaneous nerve, MCN-MN= Communication branch between musculocutaneous nerve and median nerve, R= Right side of the body, L = Left side of the body, P=P value (level of statistically significant differences).
[a] Statistically significant difference.

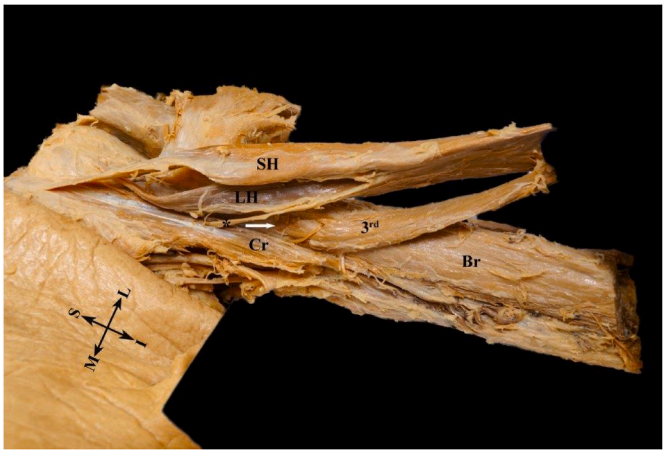


Fig. 4. A photograph of the anteromedial aspect of the left arm in a male cadaver, showing the origin of the third head of the biceps brachii. The third head of the biceps brachii originates from the anteromedial surface of the humerus between the insertion of the coracobrachialis muscle and the origin of the brachialis muscle, as indicated by the arrow. **Br**= Brachialis muscle, **Cr** = Coracobrachialis muscle, **LH** = Long head of biceps brachii, **SH**= Short head of biceps brachii, **3**rd = Third head of biceps brachii, **S**= Superior, **I**= Inferior, **M** = Medial, **L** = Lateral, * indicates musculocutaneous nerve.

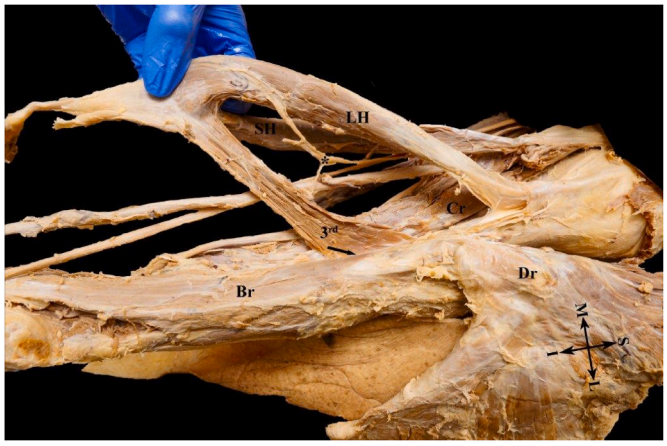


Fig. 5. A photograph of the anterolateral aspect of the left arm in a male cadaver, showing the origin of the third head of the biceps brachii. The third head of the biceps brachii originates from the superior surface of the humerus above the origin of the brachialis muscle and medial to the insertion of the deltoid muscle, as indicated by the arrow. **Br**= Brachialis muscle, **Cr** = Coracobrachialis muscle, **Dr** = Deltoid muscle, **LH** = Long head of biceps brachii, **SH**= Short head of biceps brachii, **3**rd = Third head of biceps brachii, **S**= Superior, **I**= Inferior, **M** = Medial, **L** = Lateral, * indicates musculocutaneous nerve.

4. Discussion

4.1. Variable shape presentations of the third head of the biceps brachii

The morphological variations of the third head of the biceps brachii are well known and exist with different classifications based on the number of heads and the point of origin [6,12]. Notably, previous studies on the variations of the third head of the biceps brachii did not describe the shape of the third head muscle slip [14–19]. The results from the current study have shown that the third head of the biceps brachii muscle also varies in shape and form, with the rectus shape being the most predominant. Illustrative figures from other authors show a thin flat muscle resembling the rectus shape observed in the current study [12]. The current findings also show that males presented with variable muscle shapes than females indicating sexual dimorphism. Additionally, the variable shapes of the third head of the biceps brachii were only on the left side, potentially suggesting laterality. The reason for the positive association between the shape variation of the third head of the biceps brachii with side and or sex remains to be elucidated. Similarly, there is no available information from the literature to suggest population specificity. Szewczyk et al. [6] have classified the possible variations of the biceps brachii muscle into four types (I-IV) based on the number of heads. Type I has two heads, type II has three heads, type III has four heads and type IV has five heads. Notably, the current study population group presented with the type II classification of the biceps brachii only. Thus, the variations of the shape in the other classification types of the biceps brachii are yet to be established.

4.2. Embryological and evolutionary aspects of the third head of the biceps brachii

Developmentally, aberrant muscles may arise due to altered separation of the myotome masses [11,20–22]. Separation of myotomes may be influenced by developing blood vessels and nerves, for example, the primordium of the brachialis muscle may undergo early splitting by the musculocutaneous nerve resulting in additional muscle slips [2,21, 23–25]. During the evolution from tetrapods to bipeds' major muscles of the fore/upper limb were retained, and minor muscles were lost due to disuse [20,26–30]. Normally, these atavistic muscles briefly appear during early embryonic developmental stages and disappear with maturation, usually before birth [29]. However, some may persist after birth and present as supernumerary muscle heads and or aberrant muscles exhibiting different shape patterns. Previous studies have shown evidence of atavistic muscles in modern human musculoskeletal anatomy [29,31]. Homologies of the forelimb limb muscle morphology

exist between phylogenetic classes of mammalians, avians, and reptilians [26,32,33]. Similarities may exist on the point of origin, orientation, function and insertion of homologous muscles. For instance, in reptiles, the biceps brachii muscles originate from the deltopectoral crest (proximal head) and coracoid process (distal head) and attach to the radial tuberosity. This is similar to the origin (for the short head) and insertion of the biceps brachii tendon in humans [34]. The presence of accessory muscles, like the third head of biceps brachii in humans, and their comparable anatomical structure with other animals, supports the evolutionary theory of a common ancestral lineage. This implies that these muscles in humans are evolutionary remnants [20].

Humans returned relatively fewer arm muscles than other extant non-human primates through the gracilization process, which is related to a decreased need for weight-bearing and locomotion [28,30,35]. In non-human primates, like the Cercopithecus (guenons), the coracobrachialis's long head may insert into the radial tuberosity together with the tendon of the biceps brachii [7]. Thus, the third head of the biceps brachii muscle in humans may be considered the remnant of the coracobrachialis muscle [3,7,29]. The population differences in the prevalence of the third head of the biceps brachii may be attributable to different functional adaptations and modified epigenetic factors during evolutionary and developmental processes which enables its continuous inheritance and spread within species [3,18,20,29].

4.3. Prevalence and morphological variation of the third head of the biceps brachii

The prevalence of the third head of the biceps brachii is estimated at 8.4 % globally [36], ranging from 2 to 37.5 % (Table 3). In the European populations, the prevalence of the third head of the biceps brachii ranged from 10 to 15.4 % [12,37,38]. The third head of the biceps brachii was observed in 20.2 % of the studied population in the current study. This finding is higher than the prevalence rates reported in other European populations [12,38], but corresponds to previous reports from the Brazilian (white) population (20 %) [39], American population (21.5 %) [40], and Japanese (21.3 %) population [9]. One study [7] reported that the prevalence of the third head of the biceps brachii is higher in black South Africans than in white South Africans, but the sample size for the white South Africans was very small to justify the comparisons (73 black South Africans compared to 12 white South Africans). On the contrary, the current study shows that the prevalence of the third head of the biceps brachii is similar to that reported previously in the in black South Africans [7]. This implies that there are no ethnic specific differences on this trait within the South African population groups, probably, due to shared geographic area. Low prevalences of the third head of the biceps brachii below 12 % were reported previously in the black Africans [37], black Brazilians [39], Indians [10,22], Sri Lankan [41], and Nepalese [4]. Human demographic history usually contributes to global genetic variations. The various prevalent numbers of the third head of the biceps brachii across the population indicate population specificity [7,12,38–40].

The occurrence of the third head of the biceps brachii did not show significant associations between sex in the current study ($P > 0.05$), and this is similar to previous studies [3,12,13,22]. However, other studies reported sexual dimorphism in the occurrence of the third head of the biceps brachii, with males having a higher incidence of the third head of the biceps brachii than females [7,12,23,41–43]. Bilateral presentations of the third head of the biceps brachii are reported to be rare [3,8,23,42], while unilateral presentations are more common, with the right side being more dominant [4,12,22,42]. On the contrary, the current study showed that the prevalence of the third head of the biceps brachii was high bilaterally, followed by the left side. Hence, the presence of the third of the biceps brachii should mainly be expected bilaterally and/or on the left side in the current population group. Bilateral presentations were also reported in white European and Indian studies [2,10,38,44] (Table 4).

The majority of the third head of the biceps brachii muscles originated from the proximal anteromedial surface of the humerus in the current study, similar to previous studies in different populations [1,2,7,12,21]. The muscle bellies originating from the proximal anterolateral surface of the humerus were all on the left side, potentially suggesting the laterality of the variation. Of note, the muscle bellies originating from the proximal anterolateral surface of the humerus do not fit into any of the type II classifications of the third head of the biceps brachii

Table 3
Comparison of prevalence of supernumerary heads of biceps brachii across populations.

Study	Population group	Sample size	Percentage	Variant	Origin (from the humerus)
Tubbs et al. [37]	Chinese	-	8	-	-
Tubbs et al. [37]	European Whites	-	10	-	-
Tubbs et al. [37]	African Black	-	12	-	-
Kosugi et al. [9]	Japanese	273	21.3	Third head	Anteromedial, pectoralis, deltoid
Asvat et al. [7]	South African Blacks	73	20.5	Third head	Anteromedial, superior, deltoid
Asvat et al. [7]	South African Whites	12	8.3	Third head	Anteromedial, superior, deltoid
Techataweewan et al. [13]	Thai	81	35	Third and fourth	Midshaft humerus, deltoid
Rincón et al. [11]	Columbians	16	37.5	Third head	Anteromedial
Ilayperuma et al. [41]	Sri Lankans	135	3.7	Third head	Anteromedial
Rodríguez-Niedenführ et al. [12]	European Whites	175	15.4	Third and fourth	Anteromedial, superior, anterolateral
Lee et al. [43]	Korean	107	13.1	Third head	Anteromedial
Poudel and Bhattarai [45]	Nepalese	16	12.5	Third and fourth	Anteromedial, anterolateral
Pathak et al. [4]	Nepalese	21	9.5	Third head	Anteromedial humerus
Nayak et al. [10]	Indian	48	2.08	Third head	Anteromedial, Superior
Kervancioglu and Orhan [8]	Turkish	24	8.33	Third head	Anteromedial, anterolateral
Paraskevas et al. [19]	Greek	56	5.4	Third, fourth, brachialis	Anteromedial, long head of biceps
Rai et al. [22]	Indian	42	7.1	Third head	Anteromedial
Ballesteros et al. [44]	Latin America	53	-	Third head	Anteromedial
Szewczyk et al. [6]	European	100	26	Third to fifth	Middle humerus, coracoid process, Psoas major, joint capsule
Bagoji et al. [51]	Indian	40	5.0	Third head	Midshaft humerus
Gupta and D'souza [42]	Indian	24	12.5	Third head	Anteromedial, supraglenoid tubercle
Santo Neto et al. [39]	Brazilian Whites	100	20	Third head	Anteromedial, Pectoralis major
Santo Neto et al. [39]	Brazilian Blacks	100	9	Third head	Anteromedial, Pectoralis major
Nasr and Hussein [3]	Saudi Arabian	50	10	Third and fourth	Anteromedial, middle humerus
Al-Kushi [38]	European Whites	40	15	Third head	Anteromedial
Greig et al. [40]	American	130	21.5	Third, fourth, Fifth	Anteromedial, pectoralis muscle
Duran and Arquez [23]	South Americans	14	14.3	Third head	Anteromedial, anterolateral
Current study	South African Whites	89	20.2	Third head	Anteromedial, Superior

Table 4
Comparison of the laterality of the third head of biceps brachii across populations.

Author and Year	Population	Prevalence	Bilateral (%)	Left side (%)	Right side (%)
Greig et al. [40]	American	21.5	35.7	-	-
Asvat et al. [7]	South African	20.5	60	33.3	6.7
	Blacks and Whites	8.3			
Rincón et al. [11]	Columbians	37.5	33.3	25	41.7
Rai et al. [22]	Indian	7.1	-	-	100
Nayak et al. [10]	Indian	2.08	100	-	-
Gupta and D'souza [42]	Indian	12.5	-	33.3	66.7
Kervancioglu and Orhan [8]	Turkish	8.33	-	-	100
Nasr and Hussein [3]	Saudi Arabians	10	-	70	30
Rodríguez-Niedenführ et al.[12]	European Whites	15.4	31.25	25	43.75
Poudel and Bhattarai [45]	Nepalese	12.5	-	-	100
Pathak et al. [4]	Nepalese	9.5	-	-	100
Al-Kushi [38]	European whites	15	66.7	-	33.3
Duran and Arquez [23]	South Americans	14.3	-	50	50
Ballesteros et al. [44]	Latin American	19.8	50	25	25
Current study	South African Whites	20.2	50	38.9	11.1

recently proposed [6], and this suggests the need for a more comprehensive classification that recognises all variant presentations. Other known possible sites of origin of the third head of the biceps brachii that were not observed in the current study include the humeral head, coracoid process, deltoid muscle, lesser tuberosity, greater tuberosity, intertubercular groove, tendon of pectoralis major and capsule of the shoulder joint [1,3,16,40]. In the current study the third head of the biceps brachii was inserted into the belly of the common biceps brachii and the biceps brachii tendon, however, other studies reported its insertion into the long and short heads of the biceps brachii [3,9,14,23].

The current findings show that the musculocutaneous nerve innervates the third head of the biceps brachii more consistently on the left arm than on the right arm *($P = 0.048$; $P \leq 0.05$)*. Other studies, however, reported the musculocutaneous nerve as the only nerve supply to the third head of the biceps brachii [2,3,17,23,45]. A single case in the current study was observed to be innervated by the communication branch from the merged trunk of the median and musculocutaneous nerves on the right side, similar to that reported on the right arm [44]. Some authors [4] reported a rare dual innervation of the third head of the biceps brachii by the median nerve and musculocutaneous nerve on the right arm. The presence of the third head of the biceps brachii may be associated with anomalies of the nerves in the arm. Nerve anomalies associated with the third head of the biceps brachii in the arm reported so far include the absence or duplicated musculocutaneous nerve, and communication/merger between musculocutaneous and median nerves [10,12,13,21,46–48].

4.4. Biomechanics and functions associated with the third head of the biceps brachii

The positions of the elbow and forearm affect the biomechanics of the biceps brachii muscles [3,8]. The biceps brachii muscle is only a flexor of the forearm when the elbow joint is in extension but assumes both a flexor and supinator roles of the forearm as the elbow joint approaches 90° of flexion and in pronation [8]. Apart from the combined functions of the biceps brachii, the individual functions of the third head of the biceps brachii may be difficult to demonstrate due to variations in the shape as observed in the current study. Individual functions may also be difficult to demonstrate due to other variations like the point of origin, orientation and size [3,6,24]. It is assumed that the third head of the biceps brachii plays minor roles in the elbow and proximal radioulnar joints [3,7,48]. The predominantly anteromedial origin of the third head of the biceps brachii as observed in the current study may suggest that supination of the forearm may occur from any position (flexion and or extension) of the elbow joint [3,7]. Thus, the third head of the biceps brachii may clinically induce and be implicated in the disorders of supination of the forearm or elbow flexion.

4.5. Clinical significance of the third head of the biceps brachii

An accessory muscle may lead to idiopathic pain through neurovascular bundle compression [1,5,12,14,18,49]. In the current study, the observed cases of the third head of the biceps brachii were close to the distal portion of the brachial artery and both the median and musculocutaneous nerves. Contraction of the third head of the biceps brachii during elbow movements may impinge on the nerves causing compression symptoms such as pronator syndrome (median nerve compression) and ulna nerve compression [3,14,24]. The proximity of the third head of the biceps brachii to the arm neurovascular bundle may induce pain during exercise [3,15,23,42]. Hence, it is imperative to consider the variations of the biceps brachii when assessing for compression syndromes [14,23]. Muscle anomalies are challenging to distinguish from soft tissue tumours on ultrasound scans [8,23]. During preoperative radiography, the third head of the biceps brachii may potentially be mistaken as a soft tissue tumour [3,8,24,48]. In ultrasound scans, muscles and tumours are observed as hypoechoic and anechoic images [50]. However, the accessory muscles may still be distinguished from tumours due to the continuous structure of the muscle. As demonstrated in the current study, knowledge of the variable muscle shape patterns may also aid in distinguishing accessory muscles from soft tissue tumours. Accessory muscles can be useful during reconstructive surgeries whereby muscle flaps can be utilized to enhance lost function and or cover soft tissue defects [8,24].

The current study has a limitation in that it could not elucidate the functional roles of the third heads of the biceps brachii muscles. This is because the variations were observed in formalin-fixed cadavers, which makes it difficult to carry out biomechanical tests due to reduced mobility. However, with ample technological modalities and suitable funding, it could be possible to perform a biomechanical analysis of the third head of the biceps brachii muscles following the methodology/framework described by Snow et al. on biomechanical analysis of cadaveric muscles [52]. Further studies on the third head of the biceps brachii based on in vivo clinical imaging/radiology could aid in better understanding the muscle's functional roles and its clinical presentation.

5. Conclusion

The current study has shown that new morphological variation patterns of the third head of the biceps brachii like the rectus, round and triangular shapes of the muscle belly exist in different populations. Awareness of the new variation patterns of the third head of the biceps brachii variations may help in the accurate diagnosis and management of upper arm pathologies. Further studies in distinct populations may be required to validate and expand on the shape and form of the muscle bellies to aid in accurate diagnosis.

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Ethical statement

The current study was conducted under the ethical clearance number W-CBP-210401-01 granted by the human ethics committee of the University of the Witwatersrand. The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research.

CRediT authorship contribution statement

Arthur Tsalani Manjatika: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Joshua Gabriel Davimes:** Writing – review & editing, Conceptualization. **Pedzisai Mazengenya:** Writing – review & editing, Conceptualization.

Declaration of competing interest

None.

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