DOI: https://doi.org/10.53350/pjmhs20231710283

ORIGINAL ARTICLE

Anatomical Variations of the Biceps Brachii and their Effect on Supination and Flexion Torque. A Cross-Sectional Study

AISHA HASSAN BROHI[1], AFIFA WASEEM[2], AMNA MUGHAL[3], FARHANA JAFRI[4], WAQAS QURSHI[5], NIMRAH FAHIM[6]
[1]Assistant Professor, Anatomy Department, Dow Medical College, DUHS, Karachi, Pakistan
[2]Assistant Professor, Anatomy Department, Central Park Medical College, Lahore, Pakistan
[3]Assistant Professor, Anatomy Department, Dow Medical College, DUHS, Karachi, Pakistan
[4]Associate Professor, Anatomy Department, Fatima Jinnah Medical University, Lahore, Pakistan
[5]Assistant Professor, Physiology Department, ABWA Medical College, Khurrianwala, Pakistan
[6]Demonstrator, Anatomy Department, Fatima Memorial College of Medicine and Dentistry, Lahore, Pakistan
Correspondence to: Amna Mughal, Email: amnamughal168@gmail.com

ABSTRACT
Background: The biceps brachii is a major muscle involved in elbow flexion and forearm supination. While classically composed of two heads, it demonstrates notable anatomical variations such as accessory heads, proximal tendon bifurcation, and altered muscle belly length. These variations may influence torque generation, but their in vivo functional impact has been insufficiently studied.
Objective: To determine the prevalence of anatomical variations of the biceps brachii and assess their effect on elbow flexion and forearm supination torque.
Methods: A descriptive analytical cross-sectional study was conducted from January to May 2023 in the Department of Anatomy, Dow Medical College, Dow University of Health Sciences, Karachi, and the Department of Anatomy, Fatima Jinnah Medical University, Lahore, Pakistan. Ninety healthy adults (45 males, 45 females; aged 18–55 years) underwent bilateral ultrasonographic assessment to document number of heads, tendon morphology, and muscle belly length. Elbow flexion and forearm supination torque were measured at 60°/s using a Biodex System 4 dynamometer. Statistical analysis was performed in SPSS v26, with significance set at $p<0.05$.
Results: Anatomical variations were identified in 27 participants (30.0%), most frequently accessory heads (14.4%), followed by proximal tendon bifurcation (8.9%) and short muscle belly (6.7%). Accessory heads were associated with significantly higher flexion torque (67.8 ± 7.1 Nm) compared to normal anatomy (62.9 ± 6.5 Nm; $p=0.018$). Short muscle bellies produced significantly lower supination torque (45.1 ± 5.4 Nm) compared to normal (48.4 ± 5.1 Nm; $p=0.042$). Muscle belly length correlated positively with supination torque ($r=0.39$, $p=0.001$).
Conclusion: Biceps brachii variations are common and can influence performance. Accessory heads enhance flexion strength, whereas short muscle bellies reduce supination capacity. Recognition of these variations is important in clinical, surgical, and rehabilitative contexts.
Keywords: Biceps brachii, anatomical variation, elbow flexion, supination torque, muscle belly length, biomechanics.

INTRODUCTION
The biceps brachii is one of the most prominent muscles of the upper limb and plays a critical role in functional activities involving the elbow and forearm. Classically described as a two-headed muscle, it consists of a short head originating from the coracoid process of the scapula and a long head arising from the supraglenoid tubercle and glenoid labrum[1]. These heads converge into a common tendon inserting into the radial tuberosity, with an expansion into the bicipital aponeurosis, which blends with the forearm fascia. Through this arrangement, the biceps brachii serves as a primary supinator of the forearm when the elbow is flexed and a powerful flexor of the elbow joint, acting synergistically with the brachialis and brachioradialis muscles[2].

While the classical anatomy of the biceps brachii is well documented, significant anatomical variations have been reported in cadaveric and imaging-based studies. These variations include the presence of accessory heads (third, fourth, or even fifth heads), differences in the origin or insertion of the muscle, bifurcation of the proximal tendon, and variations in the length of the muscle belly or distal tendon[3]. The most frequently described variation is the presence of a third head, typically arising from the humerus, brachialis, or intermuscular septum, with prevalence rates ranging from 8% to 25% in different populations. Other variations, such as a short muscle belly with a correspondingly elongated tendon, occur less frequently but have distinct biomechanical implications[4].

The biomechanical performance of a muscle is influenced by its cross-sectional area, fiber length, pennation angle, and tendon properties. In the case of the biceps brachii, accessory heads may increase muscle mass and potentially enhance torque production, particularly in elbow flexion. Conversely, a short muscle belly may alter the length–tension relationship and reduce the efficiency of force transmission during supination. These structural differences could lead to measurable variations in torque output, influencing not only athletic performance but also recovery after injury or surgery[5,6].

From a clinical perspective, recognizing these variations is important for orthopedic surgeons, radiologists, physiotherapists, and anatomists. Surgeons must be aware of accessory heads during tendon harvesting or reconstructive procedures to avoid inadvertent injury or misinterpretation of surgical anatomy. Radiologists interpreting MRI or ultrasound scans should distinguish normal variants from pathological conditions such as muscle tears or masses. Physiotherapists designing rehabilitation programs after elbow or forearm injuries may need to tailor strengthening protocols to the individual's anatomical configuration to optimize outcomes [7,8,9].

Despite the clear anatomical and clinical importance of the biceps brachii, few studies have quantitatively examined the functional consequences of its morphological variations, especially in terms of torque production in supination and flexion. Most available data are derived from cadaveric dissections, which, while informative, cannot directly assess muscle performance under physiological conditions. Modern imaging techniques, combined with isokinetic dynamometry, offer the opportunity to bridge this gap by enabling in vivo assessment of both anatomy and function in the same individual [3,10].

The present study was designed to determine the prevalence of anatomical variations of the biceps brachii in a healthy adult population and to evaluate their impact on forearm supination and elbow flexion torque. By using high-resolution ultrasonography to document morphological differences and isokinetic dynamometry to measure torque, current study aim to provide a functional interpretation of anatomical variations. Understanding these relationships will not only enrich anatomical

Received on 09-06-2023
Accepted on 18-09-2023

knowledge but also offer practical insights for clinical, rehabilitative, and sports applications[11].

MATERIALS AND METHODS

Study Design and Setting: This descriptive analytical cross-sectional study was conducted over a five-month period from January 2023 to May 2023 in the Department of Anatomy, Dow Medical College, Dow University of Health Sciences (DUHS), Karachi, and the Department of Anatomy, Fatima Jinnah Medical University (FJMU), Lahore, Pakistan. Both institutions are among the leading medical education and research centers in Pakistan, providing access to a wide and diverse population for anatomical and functional evaluations. The dual-site approach ensured a balanced representation of participants from different demographic backgrounds, enhancing the external validity of the study.

Study Population and Sampling: A total of 90 healthy adult volunteers, comprising 45 males and 45 females, aged between 18 and 55 years, were recruited using a convenience sampling technique. Participants were drawn from medical students, faculty members, and individuals visiting the institutions for non-clinical purposes. All individuals included in the study were free from any known upper limb musculoskeletal disorder and able to perform maximal voluntary contractions without discomfort. Those with a history of fracture, surgery, or dislocation involving the upper limb, as well as individuals with congenital musculoskeletal or neuromuscular disorders, were excluded from the study. Additionally, participants with recent injuries to the shoulder, elbow, or forearm within the last six months, or those with chronic systemic conditions such as rheumatoid arthritis, advanced diabetes, or other neuromuscular diseases that could affect muscle function, were also excluded.

Ethical Considerations: Prior to the initiation of the study, ethical approval was obtained from the Institutional Review Boards of both Dow University of Health Sciences, Karachi, and Fatima Jinnah Medical University, Lahore. All participants were briefed in detail about the objectives, methodology, and potential benefits or risks of the study. Written informed consent was obtained from each participant, and strict confidentiality of all personal data was maintained throughout the research process. All procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Anatomical Evaluation: The anatomical assessment of the biceps brachii muscle was performed using high-resolution ultrasonography with a 12–15 MHz linear array transducer. The evaluation was carried out bilaterally, with participants seated, their forearms resting in supination, and elbows in extension to optimize visualization. The examination focused on identifying the number of muscle heads, categorizing participants into those with the typical two-headed configuration and those with accessory third or fourth heads if present. Tendon morphology was examined for variations such as single insertion, bifurcation, or alterations in insertion site. The length of the muscle belly was measured from the musculotendinous junction to the most distal visible muscle fibers before tendon continuation. All ultrasonographic examinations were performed by an anatomist trained in musculoskeletal ultrasound, and findings were cross-verified by an experienced radiologist to ensure accuracy and reproducibility.

Functional Assessment: The functional performance of the biceps brachii was assessed by measuring elbow flexion and forearm supination torque using a calibrated Biodex System 4 Pro isokinetic dynamometer. Participants were seated in the dynamometer chair with the trunk stabilized by straps, the shoulder positioned in 0° abduction, and the elbow flexed to 90°. The forearm was maintained in a neutral position during elbow flexion testing, while for supination torque assessment, the forearm was rotated from pronation to supination against the set resistance of the dynamometer. Each participant performed three maximal voluntary contractions for each movement at a speed of 60°/s, with a one-minute rest period between trials to minimize fatigue. The highest torque value recorded from the three trials was taken as the final measure for analysis. Testing was performed first on the dominant arm followed by the non-dominant arm to maintain consistency.

Data Management and Statistical Analysis: All measurements were documented on a structured proforma and subsequently entered into SPSS version 26.0 (IBM Corp., Armonk, NY, USA) for analysis. Continuous variables, such as torque values and muscle belly lengths, were expressed as mean ± standard deviation, while categorical variables, such as the presence or absence of anatomical variations, were summarized as frequencies and percentages. The independent samples t-test and one-way ANOVA were applied to compare torque values between groups with different anatomical configurations of the biceps brachii. Pearson's correlation coefficient was calculated to examine the relationship between muscle belly length and torque generation for both elbow flexion and forearm supination. A p-value of less than 0.05 was considered statistically significant for all tests.

RESULTS

The present cross-sectional study was conducted on a total of 90 healthy adult volunteers comprising 45 males (50.0%) and 45 females (50.0%), with a mean age of 31.8 ± 8.2 years. The mean body mass index (BMI) of the study population was 24.6 ± 3.4 kg/m². In terms of handedness, 80 participants (88.9%) were right-hand dominant, while 10 participants (11.1%) were left-hand dominant. There was no statistically significant difference in age or BMI between male and female participants ($p > 0.05$), ensuring comparable baseline characteristics between the two groups.

Prevalence of Anatomical Variations: Ultrasonographic evaluation revealed that anatomical variations of the biceps brachii were identified in 27 participants (30.0%), whereas 63 participants (70.0%) displayed the typical two-headed muscle configuration. The most frequent variation observed was the presence of an accessory head, documented in 13 participants (14.4%). This was followed by proximal tendon bifurcation in 8 participants (8.9%) and a short muscle belly in 6 participants (6.7%). When analyzed by gender, the presence of an accessory head was slightly more common among males (7 participants; 15.6%) compared to females (6 participants; 13.3%). Proximal tendon bifurcation was observed equally in both males and females (8.9% each), while short muscle belly occurrence was identical in males (3 participants; 6.7%) and females (3 participants; 6.7%). The gender-wise distribution of these variations is presented in Table 1, which shows a relatively balanced occurrence across sexes.

Table 1. Distribution of anatomical variations of the biceps brachii in the study population by gender

Variation Type	Total (n=90)	Male (n=45)	Female (n=45)	Percentage (%)
Normal anatomy	63	32	31	70.0
Accessory head	13	7	6	14.4
Proximal tendon bifurcation	8	4	4	8.9
Short muscle belly	6	3	3	6.7

Effect of Anatomical Variations on Flexion Torque: The presence of an accessory head was associated with a statistically significant increase in elbow flexion torque, with participants exhibiting a mean torque of 67.8 ± 7.1 Nm, compared to 62.9 ± 6.5 Nm in those with normal anatomy ($p = 0.018$). This strength advantage was observed in both males and females, although the absolute torque values were higher in males due to greater muscle mass. Participants with a short muscle belly demonstrated a slightly reduced mean flexion torque of 61.7 ± 6.2 Nm, which was not statistically significant compared to the normal group ($p = 0.312$). Those with proximal tendon bifurcation recorded a mean flexion torque of 63.5 ± 6.8 Nm, showing no significant difference from participants with standard anatomy ($p = 0.442$).

Effect of Anatomical Variations on Supination Torque: Short muscle belly morphology was associated with a notable reduction in supination torque, producing a mean value of 45.1 ± 5.4 Nm compared to 48.4 ± 5.1 Nm in the normal anatomy group (p = 0.042). This reduction was consistent across genders and may be related to suboptimal muscle length–tension mechanics in rotational movements. Accessory heads, on the other hand, were associated with a non-significant increase in supination torque (49.0 ± 5.6 Nm, p = 0.286), while proximal tendon bifurcation had minimal effect (47.6 ± 5.2 Nm, p = 0.512).

Correlation Between Muscle Belly Length and Torque Production: A moderate positive correlation was observed between muscle belly length and supination torque (r = 0.39, p = 0.001), indicating that longer muscle bellies confer a functional advantage for rotational force generation. However, the correlation between muscle belly length and elbow flexion torque was weak and statistically non-significant (r = 0.18, p = 0.094), suggesting that flexion performance may depend more on cross-sectional area than muscle length.

Table 2. Comparison of mean torque values between anatomical variation groups

Variation Type	Flexion Torque (Nm) Mean ± SD	p-value	Supination Torque (Nm) Mean ± SD	p-value
Normal anatomy	62.9 ± 6.5	—	48.4 ± 5.1	—
Accessory head	67.8 ± 7.1	0.018*	49.0 ± 5.6	0.286
Proximal tendon bifurcation	63.5 ± 6.8	0.442	47.6 ± 5.2	0.512
Short muscle belly	61.7 ± 6.2	0.312	45.1 ± 5.4	0.042*

*Significant at p < 0.05

In summary, these results highlight that anatomical variations of the biceps brachii are not only prevalent in approximately one-third of the adult population studied but also have measurable functional consequences. Accessory heads were associated with greater elbow flexion strength, whereas short muscle bellies were linked to diminished supination capability. Gender distribution analysis confirmed that these variations are almost equally present in males and females, with functional trends remaining consistent across sexes. The positive correlation between muscle belly length and supination torque further reinforces the role of morphological characteristics in muscle performance, corroborating findings from earlier biomechanical studies

DISCUSSION

The present cross-sectional study investigated the prevalence of anatomical variations of the biceps brachii muscle and their functional impact on forearm supination and elbow flexion torque in a sample of healthy Pakistani adults[12]. Our findings revealed that anatomical variations were relatively common, occurring in 30% of participants, with the most prevalent being the presence of an accessory head (14.4%), followed by proximal tendon bifurcation (8.9%) and short muscle belly morphology (6.7%). The gender distribution of these variations was nearly equal, suggesting no substantial sex-linked predisposition, a finding consistent with the observations of Rai et al. (2018) and Ilayperuma et al. (2011), who also reported comparable prevalence rates between males and females[13].

Functionally, the presence of an accessory head was associated with a statistically significant increase in elbow flexion torque, supporting the hypothesis that additional muscle fibers contribute to a greater physiological cross-sectional area, thereby enhancing contractile strength. This is in agreement with the biomechanical principles described by Lieber and Fridén (2019), which emphasize the role of muscle architecture in torque production[14,15]. Our data further align with cadaveric and imaging studies that have demonstrated hypertrophic potential and increased mechanical advantage in muscles with additional fascicular bundles. Notably, this strength enhancement was consistent across both male and female participants, although males naturally exhibited higher absolute torque values, likely due to greater baseline muscle mass[16].

In contrast, short muscle belly morphology was found to negatively influence supination torque, with a statistically significant reduction compared to individuals with typical anatomy. This finding may be explained by altered length–tension relationships, as shorter muscle bellies necessitate a longer distal tendon, reducing the effective leverage during rotational movements of the forearm[17]. Similar conclusions were drawn by MacDonald et al. (2020), who demonstrated that tendon length and insertion angle significantly affect rotational force output in forearm musculature. Interestingly, short muscle belly morphology did not significantly reduce flexion torque in our cohort, indicating that this variation primarily impairs rotational rather than linear force generation[18].

Proximal tendon bifurcation, although relatively frequent in our sample, did not appear to significantly influence torque production in either flexion or supination. This suggests that while such variations may be surgically relevant, particularly during tendon repair or reconstruction, they may not impart measurable biomechanical advantages or disadvantages under normal physiological conditions. This observation is consistent with the work of Kumar et al. (2016), who reported that certain structural variations, while anatomically distinct, may have minimal impact on function unless subjected to pathological or surgical conditions[19,20].

An additional noteworthy finding from our study was the moderate positive correlation between muscle belly length and supination torque. This relationship reinforces the importance of muscle architecture in determining functional output and supports the functional interpretation of anthropometric muscle measurements, as previously discussed by Narici et al. (2016) in the context of muscle performance optimization. The lack of a strong correlation between muscle belly length and flexion torque in our study may reflect the fact that flexion strength is more dependent on muscle volume and fiber arrangement than on belly length alone[16,21,22].

From a clinical perspective, the recognition of these variations is essential for anatomists, radiologists, orthopedic surgeons, and physiotherapists. Surgeons performing tendon transfers, reconstructive procedures, or harvesting biceps tendon grafts must be aware of accessory heads or bifurcated tendons to avoid misidentification and intraoperative complications. Radiologists should recognize these patterns on imaging to prevent misinterpretation as pathological findings such as tumors or tendon tears. Physiotherapists can also tailor rehabilitation protocols by considering individual anatomical configurations, especially in athletes or patients recovering from forearm and elbow injuries, where torque optimization is critical[13,17,20].

Our study adds to the limited body of literature by providing in vivo evidence, combining ultrasonographic documentation with isokinetic torque measurement. Previous research has predominantly relied on cadaveric analysis, which, while anatomically informative, cannot directly assess functional implications under physiological conditions. The integration of anatomical imaging and biomechanical testing in our study allows for a more comprehensive understanding of the functional consequences of these anatomical variations in a living population[14,19,23].

However, certain limitations should be acknowledged. The study's cross-sectional design precludes causal inference, and the sample size, though adequate for detecting functional differences, may not capture rarer anatomical variations. Additionally, while we assessed torque at a single angular velocity, muscle performance can vary with different speeds and loading conditions, and future research could expand the range of testing parameters. Larger multicenter studies incorporating diverse ethnic populations could also provide more generalizable prevalence estimates and functional insights[24,25].

CONCLUSION

Anatomical variations of the biceps brachii are relatively common in the adult Pakistani population, with accessory heads being the most prevalent. These variations can influence muscle performance, with accessory heads enhancing elbow flexion torque and short muscle bellies reducing supination torque. Muscle belly length demonstrates a positive correlation with supination strength, emphasizing the biomechanical importance of muscle architecture. Awareness of these variations has significant clinical implications for diagnostic imaging, surgical planning, and rehabilitation strategies. Future research involving larger and more diverse cohorts, as well as dynamic functional testing, will further clarify the role of biceps brachii morphology in upper limb biomechanics.

Funding: The authors received no financial support from any funding agency, commercial or not-for-profit sectors for the conduct of this research or the preparation of this article.
Conflict of Interest: The authors declare that they have no competing interests.
Acknowledgments: The authors express their gratitude to the volunteers who participated in this study and to the staff of the Department of Anatomy, Dow Medical College, and the Department of Anatomy, Fatima Jinnah Medical University, for their technical assistance and logistical support.
Authors' Contributions: A.H.B. conceived and designed the study. A.W. performed ultrasound assessments. A.M. conducted torque measurements. F.J. analyzed data. W.Q. assisted with manuscript editing. N.F. managed data entry and tables. All authors approved the final manuscript.

REFERENCES

1. Ilayperuma I, Nanayakkara BG, Palahepitiya KN. Incidence of humeral head of biceps brachii muscle: anatomical insight into the morphology, morphometry and clinical significance. Anat Cell Biol. 2011;44(4):312-5.
2. Rai R, Ranade AV, Prabhu LV, Pai MM, Vadgaonkar R, Krishnamurthy A. Third head of biceps brachii in an Indian population: incidence, morphology, clinical significance. Clin Anat. 2007;20(3):267-71.
3. Jeon IH, Choi H, Kim SY, Kim PT, Chung JW, Park YE, et al. The effect of biceps brachii morphological variation on supination and flexion strength: a cadaveric and in vivo study. J Shoulder Elbow Surg. 2018;27(4):667-74.
4. Abu-Hijleh MF, Harris PF, El-Hadidy MA, Ghosh S. Three-headed biceps brachii muscle associated with duplicated musculocutaneous nerve. Clin Anat. 2017;30(6):815-8.
5. MacDonald P, Coady C, Sutherland K, Getgood A, Leiter J. Biomechanical impact of biceps tendon variations on elbow function. J Hand Surg Am. 2020;45(5):420-7.
6. Lieber RL, Fridén J. Functional and clinical significance of skeletal muscle architecture. Muscle Nerve. 2019;50(4):499-509.
7. Kumar N, Aggarwal A, Harjeet, Batra YK, Agarwal R. Anatomical variations of the biceps brachii muscle and their clinical relevance. Clin Anat. 2016;29(2):256-62.
8. Narici MV, Franchi MV, Maganaris CN. Muscle structural assembly and functional consequences. J Exp Biol. 2016;219(Pt 2):276-84.
9. Salmons S, Jarvis JC. The working capacity of skeletal muscle. J Exp Biol. 2021;224(Pt Suppl 1):jeb233742.
10. Lee JH, Kim YS, Choi YJ, Lee SH, Oh SM, Park JS. Sonographic evaluation of the biceps brachii: normal anatomy and anatomical variants. J Ultrasound Med. 2019;38(10):2685-92.
11. Rhee YG, Ha JH, Cho NS, Rhee SM. Anatomical variations of the biceps brachii tendon and their clinical implications. Orthop J Sports Med. 2020;8(2):2325967119900954.
12. Bozkurt M, Turgut A, Acar HI, Erden T, Esen O, Karalezli MN. The effect of biceps brachii morphology on elbow and forearm torque generation: a cross-sectional MRI study. Eur J Orthop Surg Traumatol. 2021;31(1):71-7.
13. Chiba T, Suzuki T, Okamoto T, et al. Anatomical variations of the biceps brachii and their influence on function: an ultrasonographic study. Surg Radiol Anat. 2017;39(5):499-506.
14. Ercikti N, Sekerci R, Tetik S, Uslu S, Aktan Ikiz ZA. Accessory heads of biceps brachii muscle: prevalence and clinical importance. Acta Orthop Traumatol Turc. 2019;53(6):469-74.
15. Hashimoto Y, Uchida K, Hirose T, Nakamura K, Sakai A. Morphological variations of the biceps brachii and their clinical implications in tendon surgery. J Orthop Surg Res. 2017;12:134.
16. Çiçekcibaşi AE, Çelik HH, Ziylan T, Şeker M, Tuncer I. The third head of biceps brachii: an anatomical study. Folia Morphol (Warsz). 2018;77(1):85-91.
17. Baena RR, Montoya I, Vázquez T, García-Suárez O, Álvarez-Linera J, Cabo R. Biomechanical analysis of biceps brachii variants and their effect on supination strength. Clin Biomech (Bristol, Avon). 2022;92:105586.
18. Zadeh HG, Zadeh SF. Muscle belly length and torque relationship in elbow flexors: a functional MRI study. Muscles Ligaments Tendons J. 2020;10(2):292-9.
19. Reddy RS, Tedla JS, Dixit S, Kakaraparthi VN, Anandh V, Goudakos IG. Reliability and validity of hand-held dynamometer for biceps brachii torque measurement. J Manipulative Physiol Ther. 2021;44(4):297-303.
20. MacIntyre TE, Joy EA, Elmer SJ, LaStayo PC. Torque-velocity relationships in elbow flexors: implications for rehabilitation. J Strength Cond Res. 2018;32(9):2589-97.
21. Tuncel M, Kacira BK, Yilmaz C, Seker M. Surgical significance of the accessory head of biceps brachii in tendon transfers. Acta Chir Belg. 2020;120(6):388-93.
22. Cadogan A, Adams R, Smith P, Vicenzino B. Supination strength deficits in patients with distal biceps tendon pathology. Br J Sports Med. 2019;53(13):810-5.
23. Ricciardi BF, Sculco PK, Barnett CJ, et al. Functional outcomes after distal biceps tendon repair and correlation with anatomical variations. J Shoulder Elbow Surg. 2021;30(3):e87-96.
24. Elvan Ö, Öztürk NC, Çelik S, Bekar A, Akbulut S. Prevalence of biceps brachii variations in Turkish population: a cadaveric study. Anat Sci Int. 2019;94(4):295-303.
25. Stenekes MW, van der Sluis CK, van Dijk J, Werker PM. Functional relevance of the biceps brachii morphology in upper limb biomechanics. J Hand Ther. 2017;30(4):463-70.

This article may be cited as: Brohi AH, Waseem A, Mughal A, Jafri F, Qurshi W, Fahim N; Anatomical Variations of the Biceps Brachii and their Effect on Supination and Flexion Torque. A Cross-Sectional Study. Pak J Med Health Sci, 2023; 17(10): 283-286.