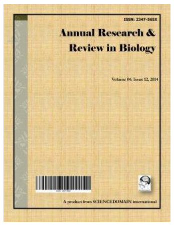

Annual Research & Review in Biology

16(4): 1-11, 2017; Article no.ARRB.31763
ISSN: 2347-565X, NLM ID: 101632869

Developmental Anatomic Studies on the *Triceps brachii* and *Biceps brachii* Muscles in Red Sokoto Goat (*Capra hircus*)

S. A. Hena[1*], A. Umar[2], M. L. Sonfada[2], A. Bello[2] and S. M. Atabo[2]

[1]*Department of Veterinary Anatomy, Faculty of Veterinary Medicine, University of Jos, Nigeria.*
[2]*Department of Veterinary Anatomy, Faculty of Veterinary Medicine, Usmanu Danfodiyo University, Sokoto, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author SAH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AB and SMA managed the analyses of the study. Authors AU and MLS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/31763
Editor(s):
(1) Xiao-Xin Yan, Department of Anatomy & Neurobiology, Central South University Xiangya School of Medicine (CSU-XYSM), Changsha, China.
Reviewers:
(1) Jianming liu, Harvard University, USA.
(2) Satheesha Nayak B., Melaka Manipal Medical College (Manipal Campus) Manipal University, India.
(3) Klaus Doelle, State University of New York, United States.
Complete Peer review History: http://www.sciencedomain.org/review-history/20844

Original Research Article

Received 23rd January 2017
Accepted 15th March 2017
Published 6th September 2017

ABSTRACT

Objectives: Triceps brachii and biceps brachii are important muscles for animal's functionality and useful to clinicians during intramuscular drug administration. This study investigated the gross, morphometric and histological developmental pattern of these muscles.
Methods: In this study nine wasted goat fetuses obtained at different trimesters, and three adult goat forelimbs making a total number of twelve animals were used, the study comprised of both male and female subjects, although sexual dimorphism was not considered. The triceps brachii and biceps brachii muscles were dissected out and gross, morphometric and histological evaluations were done.
Results: At the first trimester the two muscles were grossly observed to be small, thinner, soft and slimy on palpation. Progressive increments in muscle sizes and firmness on palpation as well as

Corresponding author: E-mail: sundayhena@yahoo.co.uk;

decreased slimy texture of the muscles were observed across advancement in ages from the second through the third trimester stages. At the adult stage the two muscles were larger in size, heavier and firmer on palpation. The morphometric values all showed significantly ($p<0.05$) increased values across chronological age advancement of the studied animals. Histologically muscle development was observed to commence by the laying down and condensation of mesenchymal cells which subsequently produced myoblast, and evidently the developing of muscle fascicles and muscle fibres, perimysial spaces and all other features of skeletal muscle were evident.

Conclusion: Knowledge on these studied muscles may not only bridge the gap on paucity of information on the developmental anatomy of these muscles, but could also find application in clinical practices.

Keywords: Anatomic; developmental; Triceps brachii; Biceps brachii.

1. INTRODUCTION

Goats are among the earliest animals to be domesticated and ranked among important livestock species used for meat production around the world, with the goats constituting a very important part of the rural economy in Nigeria, with more than 95% of the rural households keeping goats [1]. As a multipurpose animal, goats provide meat, milk, hides and skin and manure. Small ruminant sector plays an important role in the economic development of most West African countries. For example, in Nigeria, goats are kept by many rural dwellers in small herds to serve as sources of financial stability and supply of meat. In addition, some veterinary colleges/faculties use goats as a model for teaching gross anatomy practical class to undergraduate and postgraduate students. The most useful goat for these purposes is the Red Sokoto goat which is the predominant and most important breed of goat found mainly in the Sudan and Sahel savanna zone in the northwestern zone of Nigeria.

It was estimated that there are 570 goat breeds distributed across the world, although goats are found in all types of ecological zones, they are concentrated in the tropics, in dry zones and in developing countries [2]. Due to their ability to adapt to different environments, goats exhibit large diversity as a result of natural selection under different conditions [3]. The most common domestic breeds are the Angora, Cashmere, French-Alpine, Nubian, Saanen, Maradi and Toggenburg [2]. However, most breeds of goats in Nigeria are largely indigenous; and the common ones include the West African Dwarf (WAD) goat, Sahel/desert goat- known as West African Long-Legged goat; and Red Sokoto/Maradi goats [4]. According to FAO (Food and Agricultural Organization) in 2001, the WAD goats are more predominant in the southern part of Nigeria while the Red Sokoto goat is more largely found in the northern part of Nigeria. Goat meat is believed to be lowest in fat and cholesterol content when compared to other ruminants. While low fat content makes goat meat a healthy source for human nutrition, its low fat content is a disadvantage in terms of juiciness, flavour and tenderness [5].

Triceps brachii is a large and powerful muscle that fills the angle between the scapula and the humerus, it possesses three heads of origin: the long, lateral and medial heads [6]. This muscle is a powerful extensor of the elbow and a flexor of the shoulder. Biceps brachii is a strong fusiform-shaped muscle, which is composed of two short-fibred pennate muscle heads separated longitudinally by a thick internal tendon running continuously from the muscle's origin on the supraglenoid tubercle of the scapula to its insertion on the medial radial tuberosity [7,8]. It is a potential extensor of the shoulder and a flexor of the elbow.

Carroll et al. [9] investigated in vivo muscle strain and inverse dynamic estimates of muscle work and stress to understand how biarticular and monoarticular synergists of the goat (*Capra hircus*) triceps brachii might differ in their function across differing locomotor tasks. Several authors [10,11,12] have described the biceps brachii muscle as one of the muscles in the upper limb with the most frequent anatomic variations; variations are in the form of a supernumerary head, third, fourth or fifth heads. But there is paucity of information on the developmental anatomy of the Triceps brachii and Biceps brachii of Red Sokoto Goat, is evident judging by literature search on the subject matter. It is against this background that this research was conducted with the aim of providing relative morphometric data and histological findings on the developmental pattern of the triceps brachii and biceps brachii in this animal model studied. The results of these findings will be useful for teaching and research for undergraduate and postgraduate students of Veterinary Medicine and Animal Science, which could also be of advantage to anatomists, histopathologists and clinicians/surgeons.

2. MATERIALS AND METHODS

In this study nine wasted goat's fetuses were collected from slaughtered pregnant dams from Sokoto Metropolitan abattoir at different trimesters, and three forelimbs were bought at the Sokoto abattoir following the clinical examination and slaughter of adult Red Sokoto Goats, whose ages were determined by dentition. A total number of twelve (12) animals were used in the study comprising of both male and female subjects, although sexual dimorphism was not considered in this study. The collected fetuses and the adult forelimbs were wrapped in polythene materials containing ice pack while being transported to Veterinary Anatomy Laboratory of Usmanu Danfodiyo University, Sokoto, where further muscle sampling and processing were done.

The fetal ages were determined using the method adopted by Sivachelvan [13], the method involved the measurement of crown-vertebral-rump length (CVRL) which is a curved line along the vertebral column starting from the point of the anterior fontanel on the frontal bone and following the vertebral curvature to the base of the tail. Based on this, the fetal samples were divided into 3 main groups as follows: First trimester =1-51 days, Second trimester = 52-103 days and Third trimester =104 - 155 days.

The modified method of Chibuzo [14] was used for the dissection of the fetuses and the adult forelimbs, where animals are placed on lateral recumbency and the skin and superficial fascia covering each forelimbs were removed, this exposes the muscles of interest. Individual muscles of interest from the forelimb (triceps brachii and biceps brachii) were dissected out and their morphometrics determined thus: The weight of each of the fetus was taken using a sensitive Digital Electronic balance (CITIZEN Scales 1 PVT. LTD, Model MP-600, with a sensitivity of 0.01 g), the circumference of the muscles were measured using a measuring tape (Butterfly® with a sensitivity of 0.1 cm) in centimeters (cm); while the muscle lengths were measured using a measuring tape (Butterfly®) in centimeters.

For histological preparations, approximately about 2 cm^2 of muscle tissue samples were taken from both the triceps brachii and biceps brachii from all the sampled animals, the samples were taken from muscles' mid bellies. The obtained tissues were immediately fixed in 10% buffered formalin for 24 hours. The muscle tissues were then dehydrated in graded series of ethanol, cleared in xylene and embedded in paraffin wax, and the paraffin blocks prepared were sectioned at 5 µm thickness using a microtome, this were subjected to Hematoxylin and Eosin procedures for routine histomorphohology as adopted by Drury et al. [15]. After the histological preparation of the slides, the prepared slides were viewed using a microscope (Olympus® CH 23, Germany) at different magnifications (x40, x100, x400) and thereafter photomicrographs were obtained using a Digital Camera (Samsung® ES10, 8.1 Mega Pixels). The photomicrographs obtained were further transfered into a computer (Compac® Laptop, HDM, Presario CQ60) for further evaluation and detailed histological studies.

Numerical data obtained were presented in forms of Tables as means ± standard error of the mean (SEM). Student *t*-test and one-way ANOVA with Dunnett's post-test were performed using GraphPad Prism version 5.00 for Windows, GraphPad Software, San Diego, California, USA. The p values of less than or equal to 0.05 were considered statistically significant.

3. RESULTS

3.1 Gross and Morphometric Observations

At the first trimester the two muscles (triceps brachii and biceps brachii) were grossly observed to be small, thinner, soft and slimy on palpation (Fig. 1). At the second trimester both muscles were found to be relatively larger in size and less slimy on palpation in comparison to those obtained at first trimester (Fig. 2), at the third trimester the two muscles were larger in size and relatively harder on palpation (Fig. 3), and at the adult stage the two muscles were larger in size, heavier and hard on palpation (Fig. 4).

The morphometric values obtained in this study for both the triceps brachii and biceps brachii all showed significantly ($p<0.05$) increased values across chronological age advancement of the studied animals. Similarly there were progressive increments in body weights across all the ages (Table 1).

Table 1. Mean morphometric values for 1st, 2nd, 3rd, trimester fetuses and adult

Parameter	1st trimester	2nd trimester	3rd trimester	Adult
BW(g)	41.63±18.9^{a}	165.07±44.8^{b}	1437.33±71.^{c}	29666.67±2516.6^{d}
MWT (g)	0.77±0.15^{a}	1.27±025^{a}	6.00±0.72^{b}	147.90±10.11^{c}
MWB (g)	0.67±0.15^{a}	0.93±0.12^{b}	4.00±0.44^{c}	120.53±7.26^{d}
MCT(cm)	1.77±0.25^{a}	2.50±0.50^{a}	5.93±0.21^{b}	21.33±2.08^{c}
MCB (cm)	0.80±0.20^{a}	2.00±0.50^{a}	3.73±0.67^{b}	13.33±153^{b}
MLT (cm)	1.27±0.65^{a}	2.50±0.50^{a}	7.27±0.64^{b}	16.00±1.00^{b}
MLB (cm)	0.70±0.20^{a}	2.50±0.50^{a}	5.73±0.68^{b}	15.67±1.53^{b}

Note: Superscript (abcd) bearing different letters in a subclass differs significantly ($p<0.05$).
BW=Body weight; MWT=Muscle weight of triceps brachii; MWB= Muscle weight of biceps brachii; MCT= Muscle circumference of triceps brachii; MCB=Muscle circumference biceps brachii; MLT= Muscle length of triceps brachii; MLB= Muscle length of biceps brachii

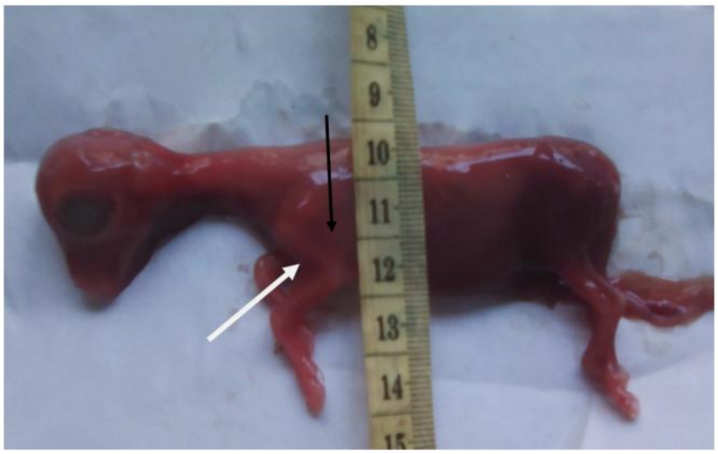

Fig. 1. A photograph of a first trimester Red Sokoto goat fetus showing the locations of biceps brachii (white arrow) and triceps brachii (black arrow), x125

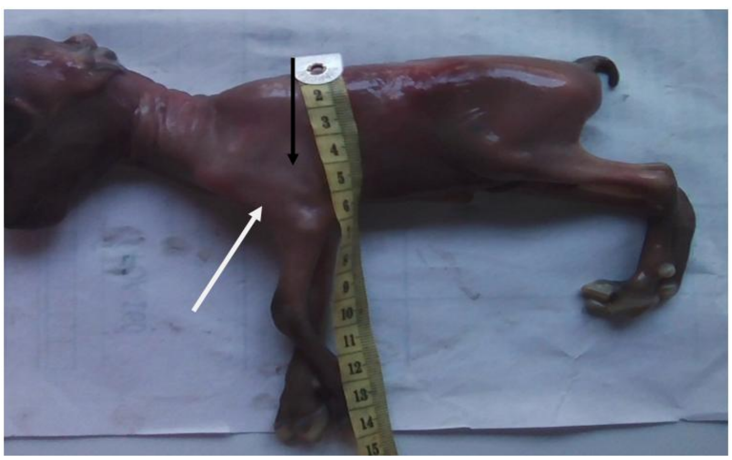

Fig. 2. A photograph of a second trimester Red Sokoto goat fetus showing the locations of biceps brachii (white arrow) and triceps brachii (black arrow), x125

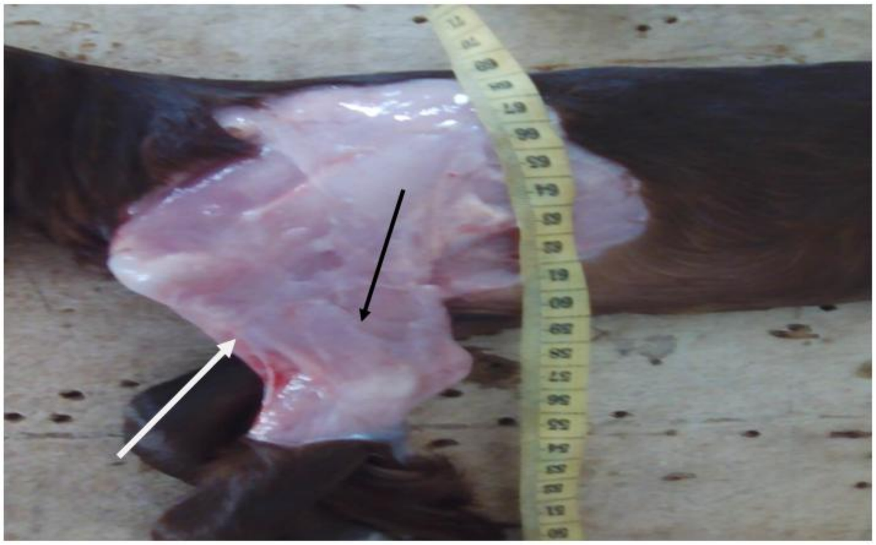

Fig. 3. A photograph of the forelimb of a Red Sokoto goat third trimester fetus, showing: Biceps brachii (white arrow) and triceps brachii (black arrow), x125

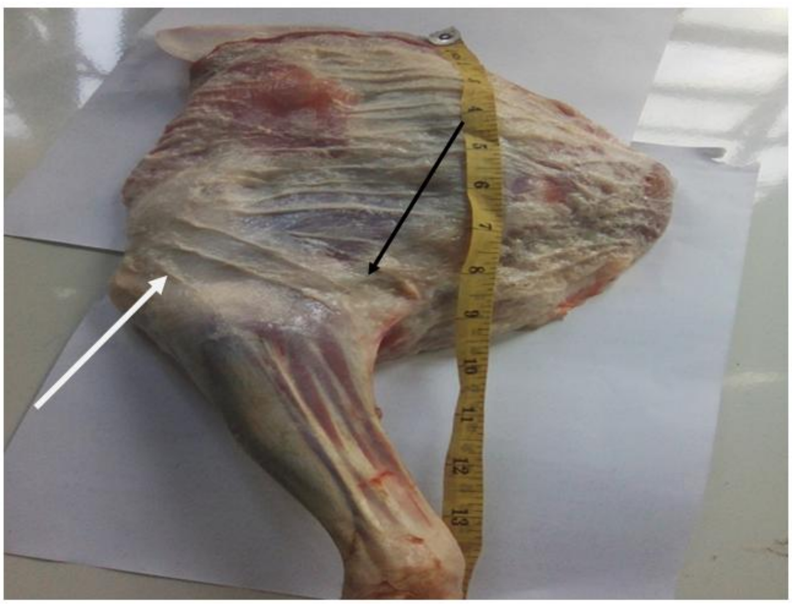

Fig. 4. A photograph of the forelimb of an adult Red Sokoto goat; showing the locations of biceps brachii (white arrow) and Triceps brachii (black arrow) x125

3.2 Histological Observations

Histologically muscle development in this work was observed to commence by the laying down and condensation of mesenchymal cells which subsequently produced myoblast (Figs. 5 and 6), further muscle development was observed at the second trimester stage (Figs. 7 and 8) where there was clear evidence of developing muscle fascicles and muscle fibres with a clearer perimysium.

At the third trimester stages there were organized muscular features such as the perimysial space, muscle fibre, clear endomysium and muscle nuclei (Figs. 9 and 10). At the postnatal stage all features of skeletal muscle were evident (Figs. 11 and 12).

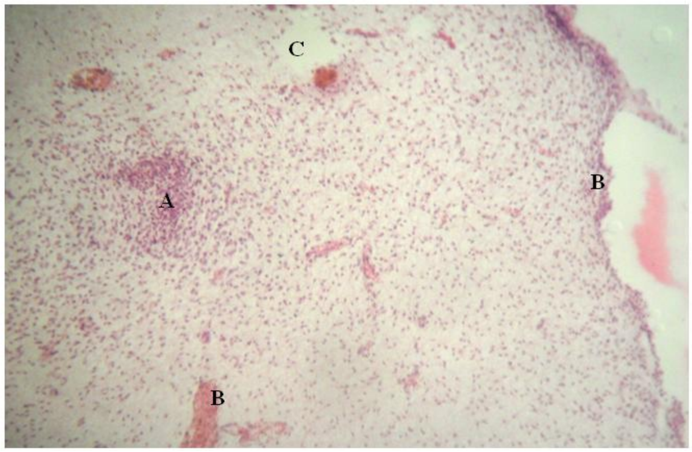

Fig. 5. Photomicrograph of biceps brachii muscle of first trimester fetus of Red Sokoto goat (showing: A= condensed mesenchymal cell; B= myoblast; C = developing perimysial space) H&E magnification x400

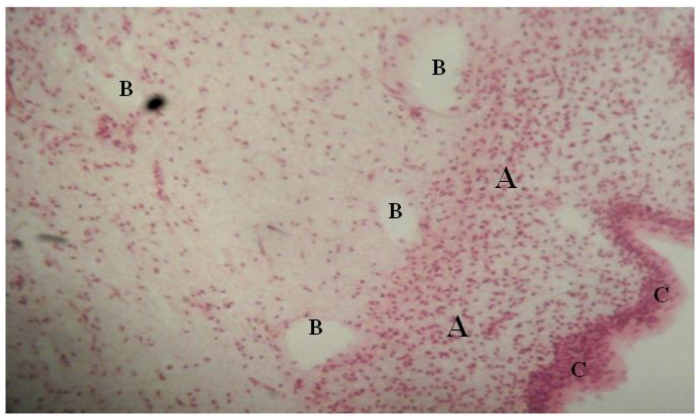

Fig. 6. Photomicrograph of triceps brachii of first trimester fetus of Red Sokoto goat showing (A = mesenchymal cell condensing; B = developing perimysial space; C= myoblast) H&E magnification x400

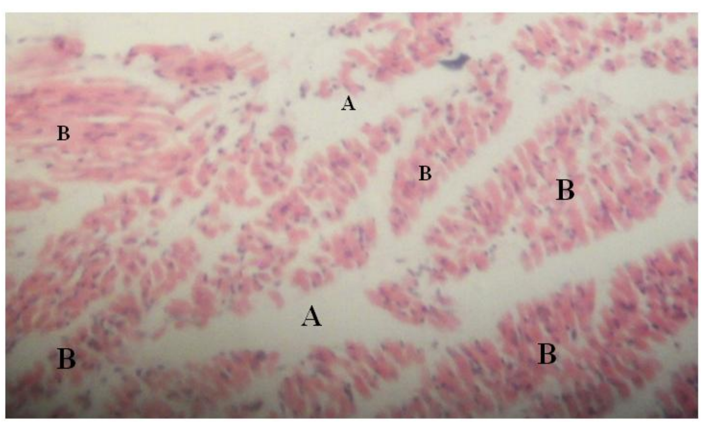

Fig. 7. Photomicrograph of biceps brachii of second trimester fetus of Red Sokoto goat showing (A = perimysial space; B = forming muscle fascicle) H&E, magnification x400

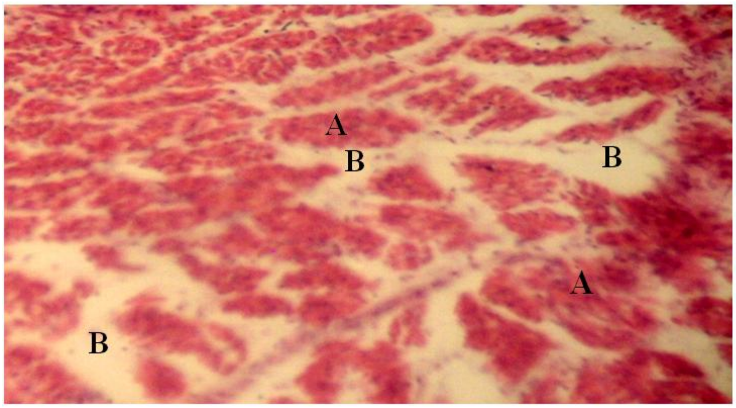

Fig. 8. Photomicrograph of triceps brachii of second trimester fetus of Red Sokoto goat showing (A= muscle fascicle forming, B = perimysial space) H&E, magnification x400

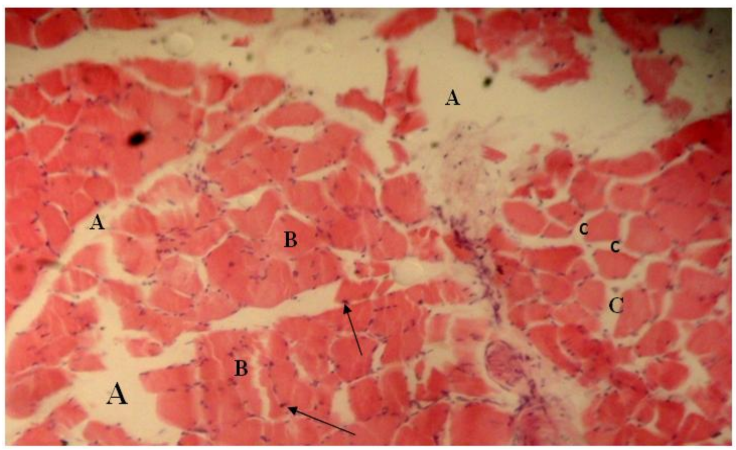

Fig. 9. Photomicrograph of biceps brachii of third trimester fetus of Red Sokoto goat (A= Perimysial space; B= muscle fibre; C= endomysium; arrow= muscle nuclei) H&E, magn. x400

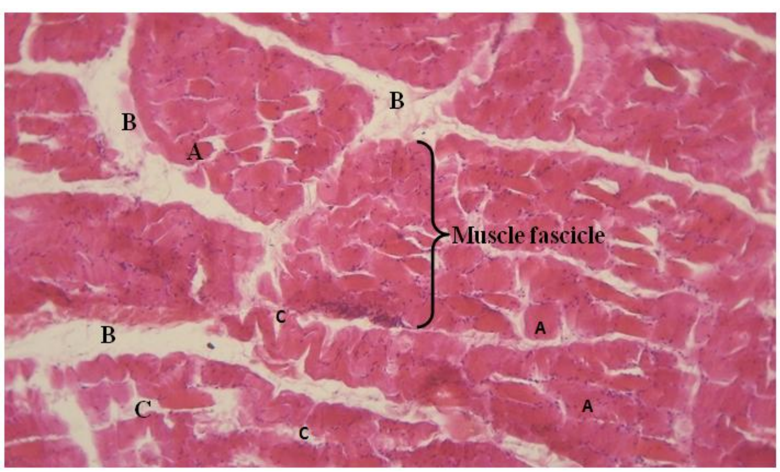

Fig. 10. Photomicrograph of triceps brachii of third trimester fetus of Red Sokoto goat showing (A= muscle fibre; B = perimysial connective tissue space; C= endomysium) H&E, magnification x400

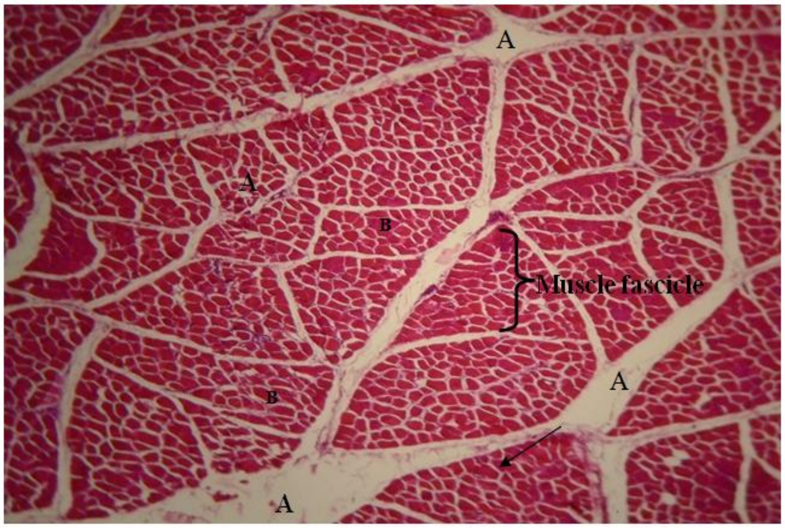

Fig. 11. Photomicrograph of biceps brachii of adult Red Sokoto goat showing: A clear and well developed muscular muscular features. Where: A= Perimysial spaces; B= Muscle fibre; C= Myofibres (muscle fibres); Arrow = Endomysium. H&E, magnification x400

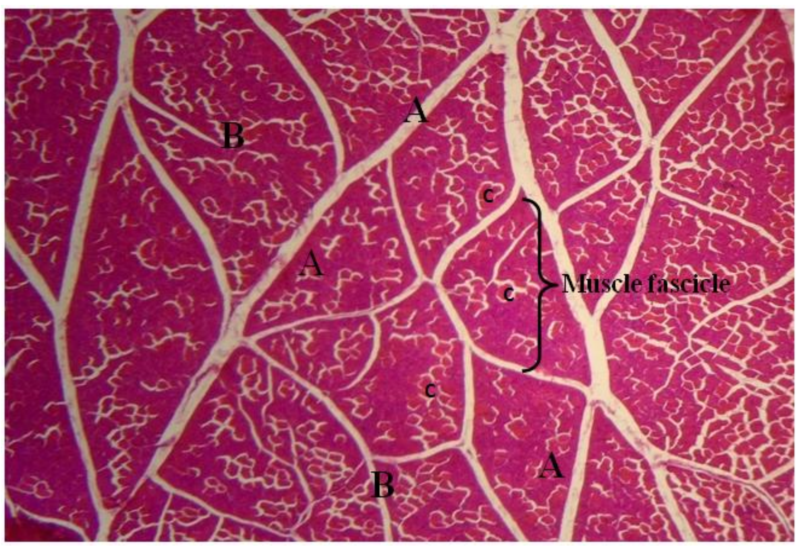

Fig. 12. Photomicrograph of triceps brachii of adult Red Sokoto goat's triceps brachii. Showing: A= Perimysial spaces; B= Muscle fascicles; C= muscle fibres (H&E, magnification x400)

4. DISCUSSION

The general observations made from this study showed that with advancement of gestation the morphometric data increased progressively across the various stages of development. This is in accordance with the findings of Bello et al. [16] on histomorphometric study on fetal development of Red Sokoto goat's kidney.

At the prenatal stage, the growth rate was least observed at first trimester which thereafter increased significantly at the third trimester with almost all the muscle growths being doubled between second and third trimesters. Similar increase in growth was observed in the adult animals. This may likely agree with Moore and Persaud, [17] who observed that muscles have to increase in length and width in order to grow with the skeleton and, that ultimate size depends on the amount of exercise performed.

Triceps brachii was observed with greater weight and circumference than the biceps brachii, this possibly could be because triceps muscle has three heads (long, lateral and medial heads) and appeared more bulky [6]. Additionally, in complex muscle, it is possible that tendinously inserted myofibres can continue to grow in length even after cessation of skeletal growth [18], although in this work skeletal growth was not evaluated. Muscle enlargement during the postnatal growth period is caused by hypertrophy and elongation of existing fibres coupled with the weight carrying capacity and exercises being performed by the muscle [19,20,21,22,23]. These may likely be responsible for the growth observed in the individual muscles, as it has been reported by Bezuidenhout and Hornsveld, [24] that the forelimb carries about 60% of the trunk weight in animals.

Skeletal muscle is involved in many biological processes and hence its quantification would provide new and important insights. In agreement with the work of Kuriyan et al. [25], the progressive muscle growths observed in the present study, more especially at the postnatal stage could be associated with muscle mechanical activity which could have induced a switch in the expression of myosin heavy chain genes, as these genes are directly related to myogenesis and subsequent growth. Other factors such as nutrition and environment might have played role in the developmental pattern, however, these have not been studied in the present work.

Histologically as seen in this work muscle development in the Red Sokoto goat appeared to be progressive according to chronological age advancement, right from the fetal stage to the postnatal level, this agrees with the work of Janqueira and Carneiro [26] on normal skeletal muscle architectures. The exposure to the knowledge of muscle histology may be of importance in advancing the course of anatomy and equally providing a basis for comparison during histopathological studies.

In vertebrates, according to Marini and Veicsteinas [27] the skeletal muscle is histologically characterized by several peculiarities that make it one of the more astounding tissues of the body. One of its unusual characteristics resides in its being highly heterogeneous in fiber arrangement, so that it may be looked at as a patchwork of rather different cells; another important feature is it's being made up of multinucleated cells, which is a sequela to cell fusion events occurring during development. Skeletal muscles are attached via tendons to bones, are the force generating elements, and exhibit a hierarchical structure. Analysing the hierarchical structure, one observes that muscles consist of fascicles, also known as muscle fibre bundles. These typically contain 50 to 400 muscle fibres depending on muscle type, age and species [28,29]. A fibre, in turn, consists of myofibrils, in which sarcomeres (the smallest contractile unit) are sequentially arranged. Force is generated through the interaction of actin and myosin filaments via cross-bridges and the resulting relative movement of these filaments, with the force transmission occuring through aponeuroses and tendons [30]. Therefore, all stimuli that determine an increase in the fibre cytoplasmic mass are likely to induce myonuclear addition by satellite cell proliferation and fusion to existing fibers.

5. CONCLUSION

Knowledge of these muscles' morphometrics may not only bridge the gap on paucity of information on the developmental anatomy of these muscles, but could also find application in veterinary clinical practices by quantifying the appropriate muscle mass needed for accurate estimation for the depth of needle penetration during administration of drugs intramuscularly, and this could also help during surgical interventions more especially when correcting fracture by internal fixation. Knowledge of the anatomy of these muscles may equally guide in avoiding some prominent nerves from possible damage during intramuscular drug administration or during surgical procedures. The researchers hereby recommend further studies on some certain hindlimb muscles such as the Hamstring group of muscles and biceps femoris which are also of great clinical significances. Equally further work is being recommended on the muscle fibre typing and ultrastructural study in this animal model.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ukpabi UH, Emerole CO, Ezeh CI. Comparative study of strategic goat marketing in Umuahia regional market in Nigeria. In: Proceedings of the 25th Annual Conference of Nigerian Society for Animal Production. 2000;364-365.
2. Galal S. Biodiversity in goats. Small Ruminant Research. 2005;60:75-81.
3. Morand-Fehr P, Boutonnet JP, Devendra C, Dubeuf JP, Haenlein GFW, Holst P, Mowlen L, Capote J. Strategy for goat farming in the 21st century. Small Ruminant Research. 2004;51:175-183.
4. Bourn D, Milligan K, Wint W. Tsetse, trypanosomiasis of cattle in a changing environment. In Von Kaufmann R, Chater S, Blench R, (Eds). Proceedings of ILCA/NAPRI Symposium, Kaduna, Nigerian. 1986;23-35.
5. Ciftci RM, Askin K. The effects of early castration on slaughter and carcass characteristics of Norduz male kids. Journal of Animal and Veterinary Advances. 2010;9:2382-2385.
6. Dyce KM, Sack WO, Wensing CJG. Textbook of veterinary anatomy. 4th Ed. Saunders Elsevier. 2010;54-57.
7. Watson JC, Wilson AM. Muscle architecture of biceps brachii, triceps brachii and supraspinatus in the horse. J. Anat. 2007;210:32–40.
8. Williams PL, Bannister LH, Berry MM, Collins P, Dyson M, Dussek JE, Ferguson MJ. Gray's anatomy. 38th Ed, ELBS Churchill Livingstone, London. 1995;843.
9. Carroll AM, Lee VD, Biewener AA. Differential muscle function between muscle synergists: Long and lateral heads of the triceps in jumping and landing goats (*Capra hircus).* J. Appl. Physiol. 2008;105: 1262–1273.
10. Kumar H, Das S, Rath G. An anatomical insight into the third head of biceps brachii muscle. Bratisl. Lek. Listy. 2008;109(2):76-78.
11. Poudel PP, Bhattarai C. Study on the supernumerary heads of biceps brachii muscle in Nepalese. Nepal Med. Coll. J. 2009;11(2):96-98.
12. Kervancioglu P, Orthan M. An anatomical study on three-headed biceps brachii in human fetuses, and clinical relevance. Folia Morphol. 2011;70(2):116-120.
13. Silvachelvan MN. Anatomical study of adaptive process in muscle. A Ph.D Thesis, Massey University; 1981.
14. Chibuzo GA. Ruminant dissection guide: A regional approach in the goat. 2nd Edition Beth-Bekka Academic Publishers Limited Maiduguri Nigeria. 2006;67-78.
15. Drury RAB, Wallington EA, Camara SR. Carleton's histological technique. 4th Ed. Oxford University Press. New York. 1967;48-66.
16. Bello A, Dabai DI, Umaru MA, Shehu SA. Histomorphometric study on fetal development of Red Sokoto goat kidney. Dir. Res. J. Agric. Food Sci. 2016;3:66-74.
17. Moore KL, Persaud TVN. The developing human (clinical oriented embryology). 6th Ed. W.B. Sounders Company. 1998;426-427.
18. Hammond JR, Masson IL, Robinson TJ. Intrafascicular termination of skeletal muscle fibers. In: Muscle Growth: The Problems of Muscle Fibers with an Intrafascicular Termination. J. Sci. 1971; 55:84-87.
19. Iwamato H, Morita S, Ono Y, Takahara H, Higashiuwatoko H, Kukimoto T, Gotoh S. A study on the fiber composition of breast and thigh muscles in Sanastsumador: Crossbred broilers. Japanese J. Zootechnical. 1984;53:34-37.
20. Timson BF, Dudenhoeffer M. Effect of severe dietary protein restriction on skeletal muscle fiber number, area and composition in weaning rats. J. Anat. Sci. 1985;61:418-424.
21. Herbert M, El-Roy RR, Edgerton VR. Influence of one week hindlimb suspension and intermittent high load exercise on rat muscles. Exp. Neurol. 1988;102:190-198.
22. Kandarian SC, White TP. Force deficit during the onset of muscle hypertrophy. J. Appl. Physiol. 1989;67:2600-2607.
23. Roy RR, Baldwin KM, Edgerton VR. The plasticity of skeletal muscle: Effects of neuromuscular activity: In skeletal muscle fiber cross-sectional area: Effects of freezing procedures. Acta Anatomica. 1991;155:131-135.
24. Bezuidenhout AJ, Hornsveld M. Veterinary anatomy. A study and dissection guide. 5th Edition. Published by University of Pretoria, South Africa. 2000;2.
25. Kuriyan R, Thomas T, Kurpad AV. Total body muscle mass estimation from bioelectrical impedance analysis & simple anthropometric measurements in Indian

men. Indian J. Med. Res. 2008;127:441-446.
26. Junqueira LC, Carneiro J. Basic histology. Text and Atlas. 11th Edition, Mc Graw Hill Medical Publishing Division. 2005;182-204.
27. Marini M, Veicsteinas A. The exercised skeletal muscle: A review. European Journal Translational Myology - Myology Reviews. 2010;20(3):105-120.
28. Grotmol S, Totland GK, Kryvi H, Breistol A, Essen-Gustavsson B, Lindholm A. Spatial distribution of fiber types within skeletal muscle fascicles from Standardbred horses. Anat. Rec. 2002;268:131–136.
29. Lexell J, Downham DY. The occurrence of fibre-type grouping in healthy human muscle: A quantitative study of cross-sections of whole vastus lateralis from men between 15 and 83 years. Acta Neuropathol. 1991;81:377–381.
30. Monti RJ, Roy RR, Hodgson JA, Edgerton VR. Transmission of forces within mammalian skeletal muscles. J. Biomech. 1999;32:371–380.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20844