P-ISSN: 2304-3075; E-ISSN: 2305-4360

International Journal of Veterinary Science

www.ijvets.com; editor@ijvets.com

Research Article

Geometrical Architectural Structure, Morphometrical and Physical Characteristics of the Biceps Brachial Muscle in the One-Humped Camel *(Camelus dromedarius)*

Allouch GM

Department of Veterinary Medicine, Faculty of Agriculture and Veterinary Medicine, Qassim University, Saudi Arabia,
Department of Anatomy, Faculty of Veterinary Medicine, Hama University, Syria
***Corresponding author:** gentle187@hotmail.com

Article History: Received: November 09, 2016 Revised: December 10, 2016 Accepted: December 15, 2016

ABSTRACT

The purpose of this study was to document of the geometrical architectural structure, morphometrical and physical characteristics of biceps brachii in the camel, which contributes in shoulder and elbow joints movements, muscle and lacerates fibrosus mass (LF) mas. The muscle, lacerates fibrosus lengths and fiber length of muscle were measured (biceps mass about was 1190g, mass was 75 g and lacertus fibrosus length about 35cm).The LF presents individual characteristics such as the length and width between the upper and lower parts. The maximum isometric force of this muscle was 1166200 x 10^6 Dyne. It was more than the force of lacerates fibrosus was 735 x 10^6 Dyne. The Physiological cross-sectional area (PCSA) was 62.5 cm^2, while the tendon CSA was 2.286. This study will enable us to know the interaction of the mechanical of absorption by the biceps muscle in the camel forelimb.

Key words: Biceps brachii, Lacertus fibrosus, Geometrical, Architecture, Camel

INTRODUCTION

The literature about the camel biceps brachaii and lacerates fibrosus geometrical and physical characteristics was not available for this study and not clear anatomically, morphometrically and physiogically. It has not mentioned the recent studies with regarding to the normal anatomy of architecture the biceps brachii muscle and lacertus fibrosus. The biceps brachii muscle of the camel that was involved in the movement of the shoulder and elbow joints, standing, weight and carrying the body, stress, kinetic energy generation and their storage. The origin, insertion and function biceps brachii muscle was anatomically descripted by (Smuts and Bezuidenhout, 1987) in camel, (Budras and Habel, 2011) in bovine, (Künzel and Forstenpointner, 1994) in sheep, goats and wild deer, (Payne and Veenman, 2005) in horse. Biceps was dynamic during the stance phase -when the foot is on the ground (Tokuriki *et al*., 1989; Tokuriki *et al.,* 1999). To the function across a lifetime of bestow, materials and structures must be designed to have suitable factors of safety to avoid failure (Biewener, 2005). The biceps muscle architecture was observed by (Hermanson and Hurley, 1990) and (Watson and Wilson, 2007) with different slightly from that was recorded.

Wilson *et al.,* 2003 had shown the energy was stored relatively slowly in elastic tissues (internal tendon of biceps brachii and lacertus fibrosus (LF) during limb loading but was released quickly at toe. In addition to (Watson and Wilson, 2007) mentioned that when biceps was stretched during the stance phase (due to shoulder flexion and elbow extension) the internal tendon was capable of withstanding very large forces, $3.2 \times 10^4 - 5.4 \times 10^4$ N. It has previously been shown that biceps used elastic energy stored in the internal tendon to initiate limb protraction (Wilson *et al.,* 2003). The previous studies had not included a detailed examination on the LF max proportionally with the physiological cross-sectional area. The purpose of this study determined the anatomical information, morphometric measurements and physical characteristics of the muscle and the lacertus fibrosus of the camel.

MATERIALS AND METHODS

Muscle architecture data were obtained from 16 camels, body mass ranged 350- 450kg) average about 400 kg and different ages between 4-6years of both sexes. The specimens of this study were collected from typical Burda Slaughterhouse, Qassim region and the veterinary

Cite This Article as: Allouch GM, 2017. Geometrical architectural structure, morphometrical and physical characteristics of the biceps brachial muscle in the one-humped camel *(Camelus dromedarius)*. Inter J Vet Sci, 6(1): 57-63. www.ijvets.com

teaching hospital of the faculty of agriculture and veterinary medicine in Qassim University K S A. The biceps brachii muscles were removed as soon as possible after the slaughter of the camel. Four muscles were preserved in 10% formalin for 3-4 days to study morphological of the muscle. The muscles fresh were removed with the tendons of origin and insertion, so that we could scale the muscle mass and the lacerates fibrosus to the body mass of the animal directly. Then we scaled the lengths of the muscle mass, the lacerates fibrosus and fiber of muscle to the belly mass too (Biewener, 2005).

An incision was made in the biceps muscle along the muscle length belly from the origin to the insertion to reveal the muscle fibers, where muscle length ratios were used to estimate fiber lengths. Measurements of muscle fiber length) were taken from different sections of the muscle belly. A mean value was calculated for the muscle. The physiological cross-sectional area (PCSA) and maximal isometric force were determined by (mass/density)/fiber length. Taking the density of muscle by Mass/Volume.

Maximum isometric force generation capacity of muscle was estimated by multiplying muscle PCSA * the maximum isometric stress of skeletal muscle (Payne et al., 2005) and was 0.3 MPa (Woledge *et al.,* 1985).The maximal isometric stress was 30^{-2} N cm . The cross-sectional area (CSA) of tendon was estimated by using Tendon CSA=(tendon mass/density) / Tendon length.

The theoretical force that the biceps tendon and lacertus fibrosus could hold out was estimated, taking the density of tendon to be 1.1 $^{-3}$ g cm and 'life stress' (stress resist in vivo) of the tendon to be 1×10^{4} Ncm^{-2} (Lichtwark and Wilson, 2005). The moment arms were determined by measuring the distance from the center of the shoulder joint rotation to the line of muscle action force vectors.

The muscle weight was estimated by (g) and the muscle volume was estimated by (cm^{3}). Linear measurements were estimated by cm such as longitudinal axis.

Noticing

Displacement = volume = Δd = df – dí = 3500-3000 = 500 cm^{3}
Density = Mass/Volume = P=M/V =1190/500=2.38 g cm-^{3}
Mass (m) = P. V= density x volume= P. V = 2.38 x 500 = 1190 g
Wight = Force =Mass x Gravity 1190 x 980 =1166200= 1.1662 x 10^{6} Dyne
Stress (p) = Force/Area,
Calculated Area of the biceps muscle:
P(1): Total surface Area = Lateral surface area + two circumference bases
$= \pi(R + r)h + \pi R^{2} + \pi r^{2} = 3.14\ (6+5).\ 13 + 3.14\ (6)^{2} + 3.14\ (5)^{2} = 640$
P(2): Total surface Area = Lateral surface area + circumference base
$1/2 \times 2\pi r \times h + \pi r^{2} = 1/2 \times 2 \times 3.14 \times 6 \times 7 + 3.14 \times (6)^{2} = 244$ cm^{2}
Total Area = 640+244= 884 cm^{2}
Calculated Area of the lacerates fibrosus:
P(1): Total surface Area (tringle) = 1/2. b. h = 1/2. 12. 15 = 90 cm^{2}
P(2): Total surface Area = Lateral surface area + total area of the two bases
= The base perimeter. h + 2 (L.W)
= 2(L+w). h + 2(L.w) = 2(20+2). 0.3 + 2(20.2) = 17.5+80 = 93 cm^{2}
Total area = part (1) + part (2) = 90+93 = 183 cm^{2}
PCSA = (mass/density)/fiber length, Stress (p) = Force/ Area, Force (F) = P.A
Strain (e) = ΔL/L= 1/20 = 0.05
Young module = Stress/ Strain .
The energy storage =1/2 × force × strain × distance.
Where P = stress, F = force, A = area, e = strain, ΔL = length change, L = original length, E = Young's modulus. If Density is stationary then an increase in mass will increase volume. Increased volume results from increased area (Area and Length) or both. An increase in area (Area or Length) increases the Energy stored.

We take the average values as there are difficulties in the anatomical measurements between the different muscles that have been taken from camels, because they have different sizes and weights.

RESULTS

Most of muscles bodies have a belly and two tendons, origin and insertion, but the biceps brachii muscle has special architecture structure. It has belly which is composed of two heads, and three tendons: origin tendon, insertion tendon and has lacertus fibrosus. The biceps brachii muscle helping in controlling the motion of both extensor of shoulder and flexor of elbow joints. Moreover; it plays minor function in the moving of the arms forward and upward. The biceps brachii muscle arises from the supraglenoid tubercle of the scapula, extending on the cranial surface of the humerus to insert in the medial redial tuberosity of the radius bone except its lacerates fibrosus (which inserts) with tendon of extensor carpi radialis. It extends to the distal part of the radius and carpal bones.

The biceps brachii muscle of the camel is large and is located at about 45 of the long axis of the muscle with long obliquely fibers. It has a cone shape. It composes of two parts superior part which has truncated cone shape and inferior part which has cone shaped. The biceps muscle has two heads, which are lateral and medial belles, between them there is a thin tendinous synthesis which is formed by the muscle fascia. They heads merge together to form a common compressed tendon distally terminates in the medial redial tuberosity of the radius bone. It is covered completely by the laceratus fibrosus. The fleshly part of the biceps brachii muscle connects the extensor carpii radialis muscle laterally.

The biceps brachii mass was about 1190 (1140-1240) g. The biceps lateral head is longer than the medial one. It had mass 850 g (800-900) g. While the medial head is short (shorter than the lateral one, it has mass about 265 (235-295)g. The length of the biceps brachii with the lacertus fibrosus were average about 55 cm except the lacerates fibrosus was 20 cm. The length of the muscle body were 8±2 cm cranio-caudally, 12±2 cm medio-laterally and 22±4 cm superior posterior. The muscle fibres direction was oblique (Fig 5). The biceps fibers are usually rather long relative to the muscle volume. The length of muscle fiber of the lateral head is about 8±2 cm, while the fiber muscle length of the medial head is 6±2 cm.

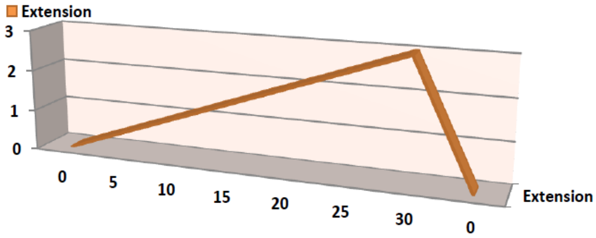

Fig. 1: The curve shows the relationship between the strain and stress of the muscle.

The biceps muscle that indicates the physical characteristics of the biceps brachial muscle are: The volume of the biceps muscle is calculated according to displacement, the volume was 500 cm^3 is the space and the place occupied by the muscle of the body.

The mass, density, fiber length and PCSA data for fresh biceps are calculated by

Density of muscle is 2.38 g/cm^3. (g cm^{-3})

Mass (m) of the muscle is 1190 g**.**

PCSA = (mass/density)/fiber length.

Maximal isometric force = PCSA *maximal isometric stress

The estimated combined isometric force that the biceps brachii could generate was (Mass. Gravity = 1190.980 = 1166200 = $1.1662.10^6$ Dyne (1.19x9.8 = 11.662 N)

The physiological cross-sectional area (PCSA) is the area of the cross section of a muscle perpendicular to its fibers. It is typically used to describe the contraction properties of pennate muscles, because it has a greater PCSA and isometric force-generating capacity:

PCSA = (mass/density)/fiber length, PCSA = 1190/2.38) / 8 = 62.5 cm^2

Maximum isometric muscle stress of biceps brachii muscle is estimated by dividing the Maximum isometric muscle force with the corresponding physiological cross-sectional area.

Maximum isometric muscle stress= Maximum isometric muscle force/physiological cross- sectional area = 1166200/62.5 =1.8659 x 10^4

The stress of biceps is physical force or pressure to the response of stretching

This force causes shoulder extensors and elbow flexor. The main function of the biceps brachii is to stabilize the shoulder joint rather than extending it.

The stress calculated Force/Area; P=F/A: where area = 603cm^2

Stress = Force/Area; P=F/A =

Stress (p) = 1166200 /884= 1319 Dyn/cm^2 (Dyn $\text{cm}^{-2)}$

When muscle stretching biceps during Phase stopping (due to the flexion of the shoulder and elbow extension needing a very large forces which calculated by Force (F) = Stress x Area =P x A = 1319.884 =1165996=1166200 N

The strain muscle fiber or tendon is the starting of tendon or muscle fibers tearing as a result of over-stretching. It was 0.054 which was calculated through Strain (e) = ΔL/L is 0.05

Young module is the relationship between stress (force per unit area) and strain. It determines modulus of elasticity that describes the elastic properties of a muscle undergoing tension or compression in only one direction, as in the biceps muscle case, that after being stretched or compressed lengthwise, it returns to its original length. Young modulus is the measure of the ability of a muscle to withstand changes in length under lengthwise tension or compression

Young module = stress/strain = p/e

Young module= 1319 / 0.05 = 26380 (3 x $10^{4)}$ Dyne cm^2.

due to calculation of the young module of biceps muscle was 3x 10^4 Dyne cm^2

Elastic energy storage is considered to be an important source of increasing power for many high-powered movements of shoulder and elbow joints.

The elastic energy storage capacity biceps was estimated from

1/2 × force × extension where force is derived from a maximum ‘life stress

= 1/2× 1166200× 1 = 583100 erg = 58 x10^4

the energy storage calculations are carried out only where biceps muscle data was available from the same camel by:

1/2×force×strain × distance = 1/2 x force × e × L = J (Nm)

1/2×1166200 ×0.05 × 20 =5831000 J= 583 x 10^4 N cm^{-2}

The biceps moment arm at the elbow joint where the elbow angle is calculated at the caudal aspect of its joint. It is and zero, when the joint is fully extended, The elbow angle increases, when the elbow joint flexes and the limb extends forward.

The moment arm is calculated by: Moment arm = Area stress distance

= 884 x 0.01 x 20 = 176.8 due to the direction which to increment the arm's moment of inertness by pulling the humerus in line with the trunk rotation and shoulder flexion torques.

The lacertus fibrosus of the biceps brachial has an obviously fibrous radial shape. The Radial taps emergence from the fascia of the fleshy segment in the middle of the biceps muscle. They mix together to have a band shape. Its aponeurotic expansion of the biceps brachii muscle. It extends posterior on the cranial face of the distal part of the biceps brachii forming the lacerates fibrosus tendon part of the muscle to intermingle with the cranial fascia antebrachii respectively. It attaches with the tendon of the extensor carpi radialis muscle at the distal part of antebrachii then to the intermediate tubercle of the intertubercular groove of the cranial face of radius bone. Then, it merges with the antebrachial fascia covering the tendon flexor muscle.

The lacertus fibrosus is a mass about 75 g average (70-80 g). Its length is about 35cm. A considerable difference in the tendon diameter between the proximal segment LF and the central and distal segments LF diameter is observed. It is about 12 cm in the proximal part and about 2 cm in the middle and 2.5 cm in the distal parts.

The cranial antebrachial facial is a thin transparent lamina covers lacertus fibrosus along its length, and it continues covering the tendon of extensor carpi redialis distally. However; lacertus fibrosus can only safely withstand force in the range about 735 Dyn. It is calculated by Force =Mass x Gravity = 75 x9.8 = 735N.

The possible role of LF in force transmission during flexion process.

Density (p) = Mass/Volume =75/80 =0.937 g/cm^3.

The cross-sectional area (CSA) of tendon was estimated by using Tendon CSA = (tendon mass/density)/Tendon length = (75/80)/35 = 0.026

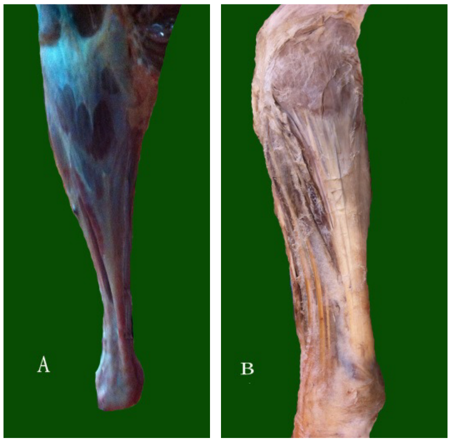

Fig. 2: A photograph shows the normal biceps brachii muscle in its position (A) as its formalized (B)

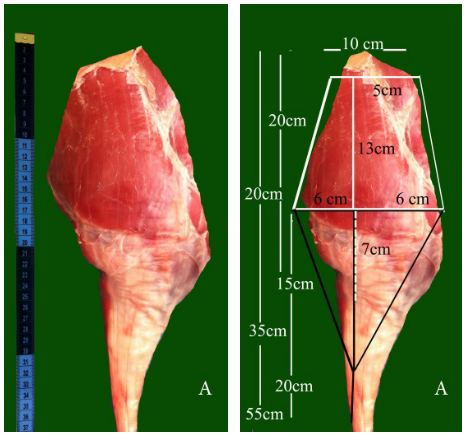

Fig. 3: A photograph shows the measurements of the biceps brachii (A), (B) in camel.

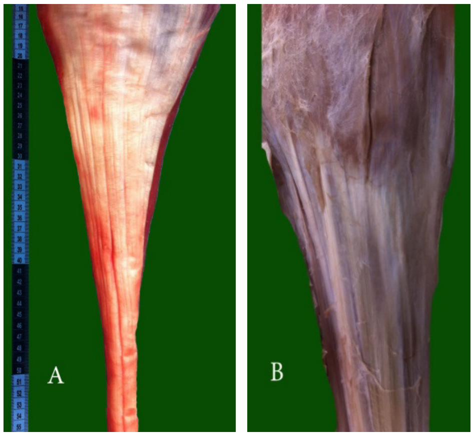

Fig. 4: A photograph shows the architectural of normal lacerates fibrosus and its length in camel (A) as its formalized (B).

Force = Mass x Gravity = 75 x 9.8= 735 N

Stress (p) = Force/Area, (calculated of Area of the lacerates fibrosus: formula for the surface area of a rectangular prism we can find the formula for the surface area of a rectangular prism as follows:

Surface area of a rectangular prism are

Calculated Area of the lacerates fibrosus:

P(1): Total surface Area (tringle) = 1/2. b. h = 1/2. 12. 15 = 90 cm^2

P(2): Total surface Area = Lateral surface area + total area of the two bases

= {The base perimeter. h = (2 (L+w) .h}+{2(L.w)}

2(L+w).h + 2(L.W) = 2(20+2). 0.4 + 2(20. 2) = 17.5+80= 93 cm^2

Total area = part (1) + part (2)= 90+93= 183 cm^2

Stress (p) = 735/183 =4 = N/cm^2

Strain (e) = $\Delta L/L$ = 2/35 = 0. 057

Young module = Stress/ Strain =4 / 0. 057= 70

The laceratus fibrosus has an ability of storage of energy flexibility that the elastic energy storage capacity biceps is estimated from

1/2 × force × extension = 1/2 x 735 x 2 = 735

Energy storage: 1/2 × force × strain × distance = 1/2×735 ×0. 057×35 =733 J the energy storage calculations are carried out only where lacertus fibrosus data are available from the same camel from 1/2 × force × strain × distance, 1/2 × P × A × e × L = 1/2×735 × 0. 057× 35 = 733 J (Nm)

Finally the laceratus fibrosus is considered as an important association in the passive stay in the camel.

DISCUSSION

The camel was adapted itself physiologically and anatomically (Yagil, 1984). So this study determined the geometrical architectural structure and the morphometric and physical characteristics of biceps brachii and lacerates fibrosus in camel.

This study revealed that the biceps brachii muscle had a special architecture structure. It had two heads: lateral and medial, and three tendons: origin, insertion tendons and lacertus fibrosus. It arised from the supraglenoid tubercle of the scapula, extending on the cranial surface of the humerus to insert in the medial redial tuberosity. Our results agree with (Smuts M, Bezuidenhout 1987) in camel, (Payne and Veenman, 2005, Watson and Wilson 2007, Dyce *et al.,* 2010 and Klaus *et al.,* 2013) in horse and (Künzel and Forstenpointner, 1994) in sheep, goats and wild deer. In the contrary of the lacerates fibrosus(LF) was described as a "fibrous lamina emerging from the medial border of the distal tendon of the biceps brachii in human (Snoeck *et al.,* 2014). This is disagrees with our results where the LF arose from the fascia of the fleshy segment in the middle of the biceps muscle.

The location and description of the biceps brachii muscle in the current study as well as those observed in previous studies. This agrees with our results. On the other hand; the description of the lacerates fibrosus in other studies that disagree with our results in this work. The lacertus fibrosus intermingles in sheep, goat and deer with the cranial fascia antebrachii respectively with the tendon of the m. extensor carpi radialis. While in sheep and goat its emergence from the m. biceps brachii is obviously bipartite (Künzel and Forstenpointner 1994).

According to this study, the biceps brachii was weight with lacertus fibrosus. These were about 1190 g and without with lacertus fibrosus was about 1115 g; It s lateral head mass was about 850 g, while the medial head was about 265. Its volume was about 500 cm^3 and without lacertus fibrosus was about 80 cm^3. The different measurements of the different muscles in this study showed that there was no significant differences.

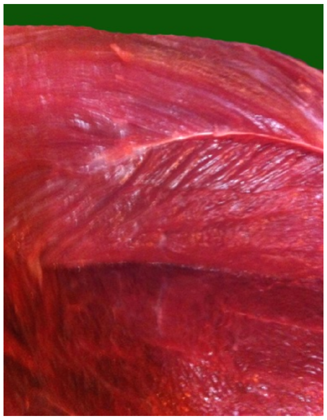

Fig. 5: A photograph shows the direction of the muscle fibers of the biceps brachii in camel.

The dimensions of the biceps brachii of the camel were 55 cm in length with the lacertus fibrosus and without with lacertus fibrosus was about 20 cm and 8±2 cm cranio-caudally, 12±2 cm medio-laterally and 50±4 cm superior posterior directions. Moreover, the length of fiber of the lateral head is about 8±2 cm. and fiber length 6±2 cm. However; (Hermanson and Hurley, 1990). They found that fibres in the medial head were between 1.5 and 2.0 cm as opposed to the larger fiber lengths found here (2.2–4 cm).

However, this is probably because the biceps muscle mass in (Hermanson and Hurley's 1990) search was 630 g (horse mass 386 kg) compared with the larger muscles dissected with (Watson and Wilson 2007) in Horse (576–1068 g, horse mass 388–650 kg).

(Snoeck *et al.,* 2014) indicated that the LF presents individual characteristics such as length and width. Measurements of the lacerates fibrosus of this work showed that the dimensions of the lacertus fibrosus of the camel was35 cm without the biceps brachii length. It was about 12 cm in the proximal part and about 2 cm in the middle and 2.5 cm in the distal parts. The results of the present study were in agreement with the above statement. The difference in these results measurements might be due to the differences in the type of the studied animals.

In the present findings, the fiber length of the lateral head was about 8±2 cm. and the fiber length was about 6±2 cm. On the other hand; the biseps fibers were usually rather long relative to the muscle volume, thus potentiating its force potential. Where was in the mammalian muscle fiber lengths generally scale∝ W0.23 (Alexander RM, 1979*).* On other hand; (Pollock and Shadwick, 1994) recorded that the muscle fiber-length and fiber-area scaling exponents can vary substantially between different muscle groups.

The density of the biceps brachii muscle of the camel in this study was 2.38 g cm^{-3}, whereas the density of lacerates fibrosus was 0.937 g cm^{-3}, while was the density 1.06 g cm^{-3} in mammalian muscle (Mendez & Keys, 1960) and was 1.1 g cm^{-3} in biceps brachii muscle of horse (Watson and Wilson, 2007) in horse.

According to our study, the estimated isometric force that the biceps brachii could generate was 1.1662 x 10^6 Dyen or (11.66 N), with little of laceruts fibrosus estimated isometric force range 0.392/10^6 Dyne, (Watson and Wilson, 2007) in horse mentioned that the force of biceps could be generate was between 10.6 × 10^3 and 21.4 × 10^3 N and the force of lacertus fibrsus was 3.6 × 10^3–7 × 10^3 N in horse. This force causes shoulder extensors and elbow flexor.

The results showed that the physiological cross-sectional area (PCSA) of the biceps brachii in camel was 62.5 cm^2. Using the relationship between PCSA and fiber length to represent the maximum force-potential of a muscle and assuming a similar moment. Where the PCSA was 366 cm^2 according to (Watson and Wilson, 2007) in horse. The difference in PCSA measurements can be attributed to variations in the muscle mass and the type of the comparative studied animals (Fukunaga *et al.,* 1992).

Our findings, showed that the maximum isometric muscle stress of biceps brachii muscle is estimated by Maximum isometric muscle force/ physiological cross-sectional area= 1166200/62.5 cm^2 =18.65, this agree with the results of (LiL *et al.,* 2007) investigated that maximum isometric muscle stress was not significantly from each other. Thus it appeared that it was reasonable to assume the same value for maximum isometric muscle stress for elbow flexors muscles studies.

To determine the material properties of the constituent tissues, it is necessary to measure cross-sectional area (CSA) of which lacerates fibrosus (LF) was 2.286 cm^2. This result disagree with (Goodship and Birch, 2005) that had been provides accurate values (within 0.8%) for CSA which are reproducible (coefficient of variation = 1.42%).

The stress of the biceps muscle in camel was calculated by dividing the force and Area. It was 1319 Dyn cm^{-2} = 0.01 N and the stress of lacerate fibrosus about was 2 Dyn/cm^2. This result disagree with (Biewener and Roberts, 2000) has been mentioned that the maximal isometric stress as was 30 N cm^{-2} and were constant in all muscles and tendons.

The strain muscle or tendon is the point of starting tearing of tendon or muscle fiber as a result of over-stretching. It was 0.05= 0.54 of muscle and 0.028 of lacerates fibrosus in this study.

The present work showed that the young module of the biceps brachii muscle was 2.6 x 10^3 Dyne cm^{-2}, which was more than lacerates fibrosus that was taken as 0.07 Dyne cm^{-2} compare with approximately half the ultimate stress withstood by tendon, 1.9 × 10^4 N cm^{-2} (Herzog and Gal, 1998) and the Young's modulus of tendon is taken as 2 × 10^5 N cm^{-2} (Alexander, 1983).

According to (Bramble *et al.,* 2004) there were morphological features in the camel. It played a major role in storing and releasing elastic energy as tall. Moreover; (Astley and Roberts 2012 and Patek *et al.,* 2012) The elastic energy storage has been shown to be an important source of power amplification for many high-powered movements. In the present findings the elastic energy storage capacity biceps brachii was 58.10^4 erg, which was estimated from 1/2 × force × extension, while the lacerates fibrosus was 735 J, whereas the force of the muscle and its tendon were derived from a maximum stress (Herzog and Gal, 1998). Moreover; the energy storage calculation [(1/2 x force x strain x distance) showed that the biceps muscle has the ability to store about 583 J(N) whilst lacertus fibrosus (LF) has the potential to store about 733 J (elastic energy of muscle an average of 18 times more than the lacerates fibrosus, whereas the energy storage of muscle was about 9 of more than energy storage of lacerates fibrosus). This demonstrates that biceps has major spring-like properties but the lacertus fibrosus has much less capacity for energy storage. Our finding similar to (Watson and Wilson 2007) revealed that the biceps muscle has the ability to store about 590 J(N) whilst lacertus fibrosus has the potential to store about 28 J (an average of 26 times less energy) in horse.

The biceps moment arm of the elbow joint was 2.6 due to the orientation, which allowed to increase the arm moment of inertia by pulling the humerus in line with the trunk rotation and shoulder flexion torques, maximizing renitence to both. These results correspond with (Neil *et al.,* 2003; Murray *et al.,* 1995), who mentioned that the anatomical measurements revealed that the flexion/ extension moment arms varied by at least 30% over a 95 degrees range of motion. The anatomical studies that the biceps flexion moment arm peaks in a more extended elbow position and has a larger peak when the forearm is supinated. Also, the peak biceps supination moment arm decreases as the elbow is extended.

Finally, this present study confirms the exchange of kinetic, potential and elastic strain energy and reduce the amount of work that muscles must perform in order to move an animal's limbs and center of mass (Alexander, 2002).

Conclusion

The present study appeared distinct variations in the gross anatomy of the biceps brachii with some variations due be structural adaptability to structure of the camel. Results of this paper indicate that the LF presents individual characteristics such as length and width and the possible role of LF in force transmission during flexion. This study aims to collect functional data to high light on the relationships between this structure and the shoulder and elbow joints kinematics.

Acknowledgements

The author thanks Mrs Hala Fatouh for Linguistic revision. The author also thanks Dr. Fathi Goumaa Professor of Medical Physics Department of Basic Science Qassim University, KSA.

REFERENCES

Alexander RM, 2002. Tendon elasticity and muscle function. Comp Biochem Physiol A Mol, Integr Physiol 133: 1001–1011.

Alexander RM, 1983. Elasticity and viscosity. Anim Mechanics. 3: 71.

Alexander RM, 1979. Allometry of the limb bones of mammals from shrews (Sorex) to elephant *(Loxodonta)*. J Zool, 189: 305-314.

Astley HC and TJ Roberts, 2012. Evidence for a vertebrate catapult: elastic energy storage in the plantaris tendon during frog jumping. Biol Lett, 8: 386–389.

Biewener AA, 1998. Muscle-tendon stresses and elastic energy storage during locomotion in the horse Comp. Biochem. Physiol B Biochem Mol Biol, 120: 73–87. Biewener AA, 2005. Biomechanical consequences of scaling. J Exp Biol, 208: 1665–1676.

Biewener AA and TJ Roberts, 2000. Muscle and tendon contributions to force, work, and elastic energy savings: a comparative perspective. Exerc Sport Sci Rev, 28: 99–107.

Bramble DM and DE Lieberman, 2004. Endurance running and the evolution of Homo. Nature, 432: 345–352.

Dyce KM, WO Sack and CGG Wensing, 2010. Textbook of Veterinary Anatomy. London: Saunders.

Fukunaga T, TRR Roy, SFG Shellock, TJA Hodgson, MK Day, IPL Lee, IIH Kwong-Fu, and IVR Edgerton, 1992. Cross- Sectional Area of Human Leg Muscles Based on Magnetic Resonance Imaging, J Thopaedic Res, Raven Press, Ltd, New York.

Goodship AE and HL Birch, 2005. Cross sectional area measurement of tendon and ligament in vitro: a simple, rapid, non-destructive technique. J Biomech, 38: 605-608.

Hermanson JW and KJ Hurley, 1990. Architectural and histochemical analysis of the biceps brachii muscle of the horse. Acta, Anat (Basel), 137: 146–156.

Herzog W and JT Gal, 2005. In: Nigg BM, Herzog W, editors. Biomechanics of the Musculo-Skeletal System. 2. John Wiley and Sons Ltd; 1998 pp: 127–144. J Experim Biol, 208: 1665-1676.

James G, 1986. Energy stored and dissipated in skeletal muscle basement membranes during sinusoidal oscillations. J Biophysical Soc, 50: 1127-1138.

Klaus D, WO Budras and SR Sack, 2013. Anatomy of the Horse Fifth, revised Edition, Schlütersche Verlagsgesellschaft mbH & Co KG, Hans-Böckler-Alle 7, 30173 Hannove, Printed in Germany.

Künze l and G Forstenpointner, 1994. Comparative studies on looking into lacertus fibrosis and aponeurosis of the bicipitis brachii muscle as well as assessment of the biceps brachii and bracialis muscles in sheep, goats and wild deer. Ann Anat, 176: 549-54.

Li L, K Tong, K, R Song, and TK KOO, 2007. Is maximum isometric muscle stress the same among prime elbow flexors? Clin Biomech (Bristol, Avon). 22: 874-883. Epub.

Lichtwark GA and AM Wilson, 2005. In vivo mechanical properties of the human Achilles tendon during one-legged hopping. J Exp Biol, 208: 4715.

Maganaris CN and V Baltzopoulos, 2000. In vivo mechanics of maximum isometric muscle contraction in man: Implications for modelling- based estimates of muscle specific tension. In Herzog W (Ed). Skeletal muscle mechanics: from mechanisms to function. Wiley & Sons Ltd, pp: 267-288.

Mendez J and A Keys, 1960. Density and composition of mammalian. Muscle Metabolism, 9: 184–188.CAS, Web of Science Times Cited: 396

Murray WM, SL Delp and TS Buchanan, 1995. Variation of muscle moment arms with elbow and forearm position.Nature. 2013 June 27; 498: 483–486. doi:10.1038/nature12267.

Neil T, I Roach, M Venkadesan, MJ Rainbow, E Daniel, DC Osbahr, DL Cannon and KP Speer, 2002. Retroversion of the humerus in the throwing shoulder of college baseball pitchers. Am J Sports Med, 30: 347-353.

Patek SN, BN Nowroozi, JE Baio, RL Caldwell and AP Summers, 2012. Linkage mechanics and power amplification of the mantis shrimp’s strike. J Exp Biol, 210: 3677–3688.

Payne RC and P Veenman, 2005. The role of the extrinsic thoracic limb muscles in equine locomotion, J Anat 206: 193–204.

Pollock CM and RE Shadwick, 1994. Allometry of muscle, tendon, and elastic storage capacity in mammals. Am J Physiol, 266: R1022-R1031.

Smuts M and A Bezuidenhout, 1987. Anatomy of the Dromedary. Clarendon:Oxford University Press.

Snoeck O, P Lefèvre, E Sprio , R Beslay, V Feipel, M Rooze and JS Van Sint, 2014. The lacertus fibrosus of the biceps brachii muscle: an anatomical study. Surg Radiol Anat, 36: 713-9.

Tokuriki M, O Aoki and Y Nikim, 1989. Electromyographic activity of cubital joint muscles in horses during locomotion. Am J Vet Res, 50: 950-957.

Tokuriki M, R Ohtsuki and M Kai, 1999. EMG activity of the muscles of the neck and forelimbs during different forms of locomotion. Equine Vet J Suppl, 30: 231-234.

Woledge RC, NA Curtin and E Homsher, 1985. Energetic aspects of muscle contraction. Monogr Physiol Soc, 41: 1–357.

Watson JC and AM Wilson, 2007. Muscle architecture of biceps brachii, triceps brachii and supraspinatus in the horse, J Anat, 2007 Jan; 210: 32–40. PMCID: PMC2100266.

Wilson AM, JC Watson and GA Lichtwark, 2003. A catapult mechanism for rapid limb protraction. Nature, 421: 35–36.

Yagi R, 1984. The camel: Self-sufficiency in animal protein in droughts-stricken areas in the right to food. International Conference Hunger, Montreal, Proceeding, pp: 28.