Original Article

Effect of Training on Stiffness of Distal Biceps Tendon: A Pilot Study

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ABSTRACT

Objective: Exercise can cause physiological and anatomical changes in muscle and its adjoining structures. Established imaging techniques are present to diagnose the changes. However, this data is focused more on muscle rather than tendons. The objective of this study was to determine changes in stiffness of distal biceps tendon caused due to training via elastography.
Design: Retrospective cohort study
Setting: College of Applied Medical Science, King Saud University, Riyadh, KSA
Subjects: Twenty healthy male subjects of Middle Eastern descent were studied. Subjects were divided according to their training activity. Individuals undergoing bicep training for 4 or more days in a week for at least a year were considered to be trained, while untrained individuals never went for biceps training during the last 1 year.
Intervention: Ultrasound elastography performed on biceps tendon
Main outcome measure: Stiffness of distal biceps tendon
Results: It was observed that training caused anatomically thicker distal biceps tendon while furthermore, it also caused the tendon stiffness to increase.
Conclusion: Stiffness and thickness of distal biceps tendon is dependent upon training. On the other hand, body mass index has no relationship with thickness or stiffness.

Keywords: elastography, exercise, strain ratio, ultrasound

INTRODUCTION

Biceps brachii muscle, more commonly known as biceps, is the muscle in the upper arm. It is of vital importance for biceps muscle to function optimally. The most imperative function of biceps muscle is supination of forearm and flexion of elbow[1]. Biceps brachii muscle has 3 tendons: short and long tendon in the proximal part of the muscle and one at the distal end. The former is commonly involved in pathological condition of shoulder pain[2]. Rupture of distal biceps tendon is rather an uncommon phenomenon that accounts for a mere 3% of all biceps-related tendon tears[3,4]. However, this may involve complete or partial tear. Complete tears are usually determined with excellent clinical outcomes by simply retracting the muscle belly and tendon[5]. However, in case of partial tear, the diagnosis is uncertain. Various methods are utilised to determine partial tears, ranging from magnetic resonance (MR) imaging[6] to ultrasound[7]. Results of conservative treatment of rupture of distal tendon of the biceps are far from excellent and surgical treatment is usually recommended.

Due to the extensive function of biceps muscle, the tendons associated with the biceps muscle are directly affected. Research suggests that exercise can cause muscle damage that can be inferred by imaging techniques like MR imaging, MR elastography and ultrasound elastography[8,9]. Mostly, the research is focused on muscle stiffness and scarce data is available for stiffness of tendon[10]. Although literature is available on the effect of changes in tendon stiffness before and after exercise for Achilles tendon[11], calcaneal tendon[12] and patella tendon[13], there is no data that suggests the effect of training on distal biceps tendon stiffness.

Furthermore, conventional methods to determine tendon stiffness include MR imaging or ultrasound.

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MR imaging is expensive and time consuming while plain ultrasound does not provide quantification to the problem. A quicker, safer and inexpensive approach is imaging via ultrasound elastography.

Elastography is an enhanced form of ultrasound. It follows the principle of palpation to detect difference in tissue stiffness before and after a minor manual compression of the tissue. Elastography is a novel imaging modality that provides quantitative results by evaluating Young's modulus or strain ratio among target and surrounding tissue[14].

It is known that exercise keeps the body in shape and regular exercise helps maintain a good fitness level[15]. However, the long term effects of weight training on the distal biceps tendon are not documented. This is a pilot study which determines the distal biceps tendon stiffness and thickness among trained and untrained individuals. Therefore, the results revealed here will serve as a guide to clinicians and as a reference to researchers.

SUBJECTS AND METHODS

Study design

This is a retrospective cohort study and subjects were divided according to trained and untrained individuals. Untrained individuals were selected as controls.

The current study was performed at the Department of Biomedical Technology, College of Applied Medical Science, King Saud University, Riyadh, KSA from January 2016 to April 2016.

This study was approved by the ethical review board vide letter no. CAMS 146-36/37 at King Saud University, Riyadh, KSA. All subjects were informed regarding the study aims, examination procedures and safety concerns. A signed consent was taken from each subject individually before the examination.

Selection criteria for participants

Individuals who had prior history of hormone therapy, tendon injury, hypothyroidism, having corticosteroids treatment, with any metabolic or inflammatory diseases and with shoulder pain were excluded from the study.

Twenty healthy male subjects of Middle Eastern descent volunteered for this cohort study. All subjects were studying at the same university where this research was undertaken. Subjects were screened with a questionnaire.

Subjects were divided according to their training activity. Individuals undergoing biceps training for 4 or more days in a week for at least a year were considered to be trained while untrained individuals never went for biceps training during the last 1 year.

All subjects were evaluated for their age, weight, height and body mass index (BMI). Moreover, their dominant hands were also recorded.

Examination

All ultrasound examinations were performed with Ultrasonix SonixTouch Q+, ultrasound unit (Analogic Corporation, 8 Centennial Drive, Peabody, MA, USA) having a linear transducer L14-5/38.

Examination was performed only on distal biceps tendon of dominant hands of each respective subject. Ultrasound examination was performed on each subject with their arm extended 180^0 lying on the table (as shown in Fig 1) while their forearm was maximally supinated.

Fig 1: Position of forearm to observe distal biceps tendon. The green marking shows the probable tendon length as observed through B-mode imaging. The region of interest for obtaining strain ratio was within the box as marked on arm.

A generous amount of gel was applied in order to increase coupling efficiency of ultrasound and to minimise error in stiffness. Normal gray scale image was initially used to identify the distal biceps tendon longitudinally as longitudinal scans have higher probability of reproducibility than transverse scans[16]. The transducer was placed over the proximal forearm longitudinally while the orientation marker was towards the patients shoulder to determine the location of tendon. The transducer was adjusted so that tendon fibers were visible. The distal biceps tendon appears as a hyperechoic fibrillar patterned structure. Once an optimal image was obtained, the transducer was used to manually generate pulsations. After a series of pulsations, the loop was frozen and measurements were taken by selecting best images from a pool of more than 100 images. Elastographic strain ratios were obtained for only the central part of tendon above the humeral caputellum and anterior fat pad. Three images per subject were selected and in each single image, 3 strain ratios were determined. To determine strain ratios at 3 different locations, one area within the tendon while another area in the surrounding muscle was selected as shown in Fig 2.

The BMI of each individual was calculated using formula stated in equation 1. However, the volunteers were not categorized according to BMI.

$$BMI = \frac{Weight}{Height^2} \text{ -------------- Equation 1}$$

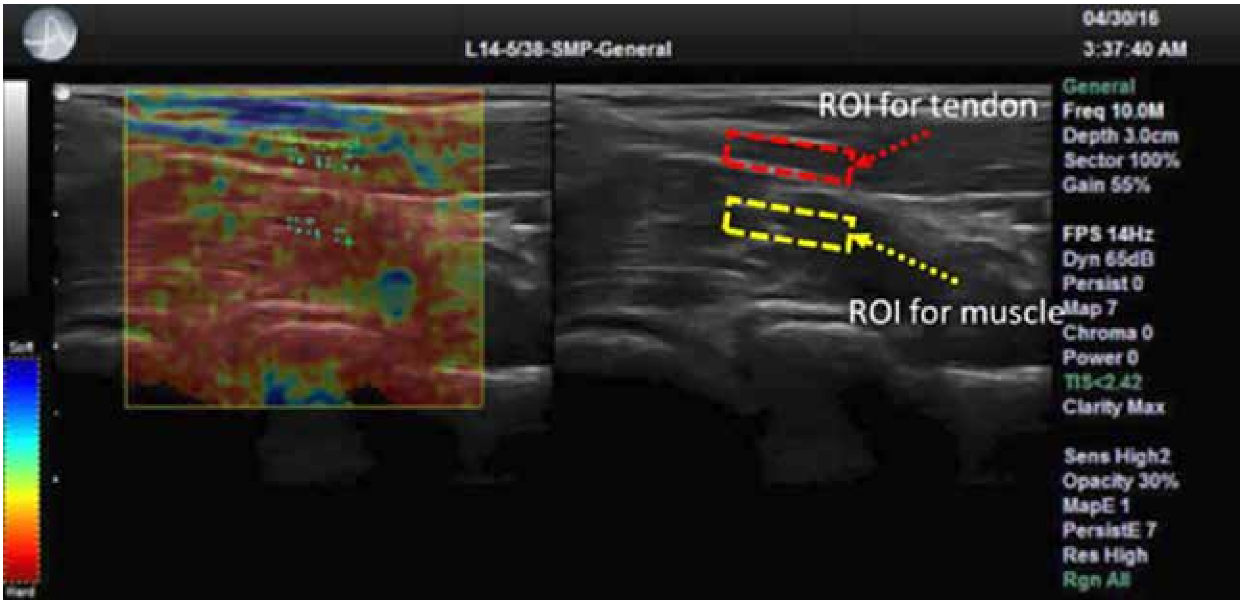

Fig 2. Two different areas for observing the strain ratio. Right panel shows B-mode image while left panel shows superimposed elastographic view over B-mode images where the selection has to be made.

- Where:
  a. Weight is in kg
  b. height is in meters

The demographic data for all the subjects is present in Table 1.

Table 1: Demographic data of subjects in untrained and trained study groups

Demographic Data	Untrained	Trained	p-value
Male, (n)	10	10	-
Dominant hand (Left), (Right)	(0), (10)	(2), (8)	-
Age	22.50 ± 0.97	21.90 ± 1.10	0.21
Body weight (kg)	71.58 ± 15.13	72.07 ± 13.53	0.94
Height	175.15 ± 3.95	172.75 ± 5.95	0.30
BMI	23.28 ± 4.53	24.09 ± 3.96	0.67

BMI: Body mass index

Statistics

All statistical analysis was performed on SPSS v21 (SPSS 21.0 for Windows, Chicago, IL, USA). Data is represented as mean ± standard deviation. Unpaired t-test was performed to determine the level of significance among groups at a p-value of less than 0.05. All parameters in ultrasound unit were kept constant, except depth and focus, as they both were changed according to each subject to obtain optimal image.

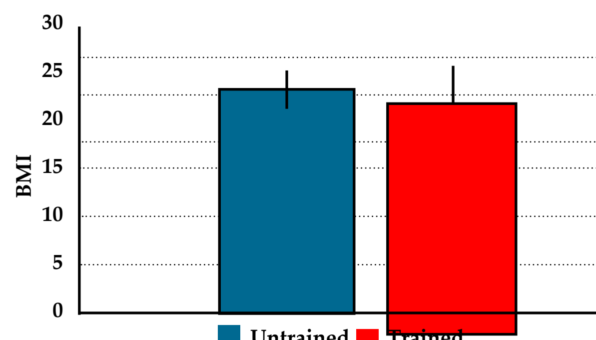

Fig. 3a

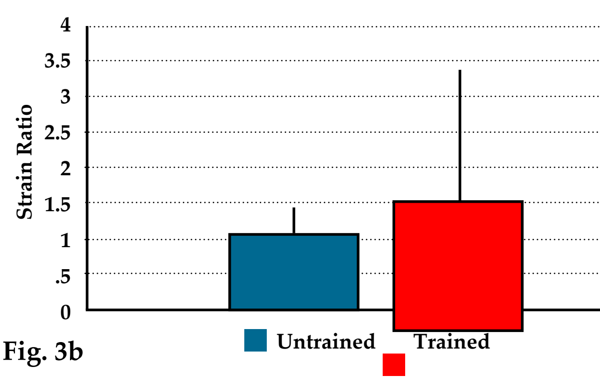

Fig. 3b

Fig 3. (A) BMI of untrained and trained volunteers and **(B)** Average strain ratio for distal biceps tendon among untrained and trained volunteers.

RESULTS

A total of 20 subjects volunteered for the study. All were healthy males in their early or mid-twenties. Two subjects were left hand dominant in the trained group while untrained group had none. There was no significant difference for the untrained and trained group in their BMI (Fig 3A). Average BMI for untrained and trained subjects was calculated to be in the healthy range. Untrained and trained groups had a mix of all; underweight, healthy and overweight individuals.

There was no obese subject in either group. BMI for trained subjects on average was insignificantly higher when compared to untrained subjects.

Furthermore, elastographic strain ratios were recorded and the statistics reveal that strain ratios for distal biceps tendon for untrained and trained subjects were insignificnt ($p = 0.23$), though, strain ratios for trained individuals were higher (Fig 3B).

Another factor that was measured was the thickness of the distal biceps tendon. The results demonstrated that thickness of distal biceps tendon among untrained and trained subjects significantly ($p = 0.03$) varied. Subjects who undergo regular training for their biceps demonstrated an increased thickness (Fig 4A and 4B). No correlation was observed among thickness and BMI values in either of the study groups.

Fig. 4a

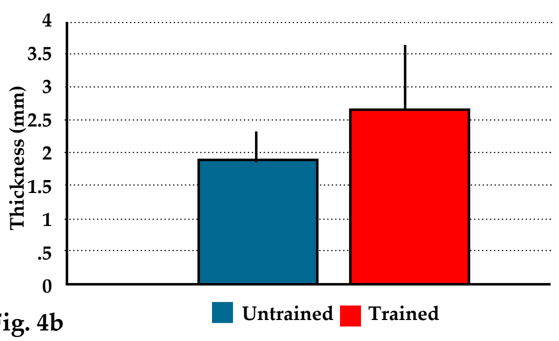

Fig. 4b

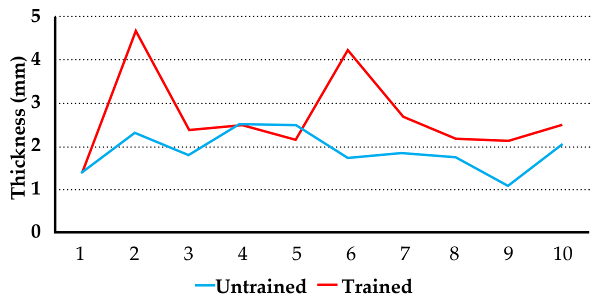

Fig 4. Thickness of distal bicep tendon among trained and untrained participants. **(A)** average thickness and **(B)** thickness of distal biceps tendon for each individual participant.

DISCUSSION

The current study is a pilot study where the stiffness of distal biceps tendon was evaluated using strain elastography technique among individuals who train their biceps muscle regularly with those who have a sedentary lifestyle.

Results of the present study reveal stiffer distal biceps brachii tendon among the individuals who perform weight training of their biceps on a routine basis than those who have a sedentary lifestyle. Although there is no data available specifically on the effect of exercise over stiffness of distal biceps tendon, a recent study suggested that tendon stifness is increased due to exercise[14]. In a separate research by S. Bohm and co-workers, they reported that tendon adapts to long-term exercise in a more efficient way than in a short-term period[17]. Moreover, it has also been reported that tendon stiffness is proportional to the time spent in training[18]. Biceps tendon injuries are usually seen with individuals lifting weights more than 68 kg[19]. Furthermore, the incidence occurs commonly within the groove and for a population who are in their 60s or 70s, the reason behind it being the weakening in tendon as a result of degenerative changes over time[20].

In the present study, an increased stiffness in tendon can also be associated to upturn in the type I collagen content in the tendon[21], as prolonged exercise plays an important role in synthesis of type I collagen[22]. The current study is based on an all-male population. However, it is essential to study tendon stiffness among women as well because the collagen in tendon develops differently among women than in men[23].

In the present study, it was observed that distal biceps tendon of trained individuals appeared clearer and demonstrated intense fibrillar pattern (Fig 5) than their untrained counterparts. Analogous results were presented by Vilarta and Vidal in their studies for Achilles tendon[24]. They reported stiffness of Achilles tendon among rats increased after exercise and the collagen fibers were better alligned.

Although ultrasound elastography studies on biceps muscle suggests that muscle hardness is associated with exercise, there is no data available if stiffness of distal biceps tendon is associated with exercise. Further studies are essential in order to establish a relationship between distal biceps tendon and exercise. The present research aimed to find the stiffness of distal biceps tendon among untrained and trained subjects using strain elastogrpahy.

This research provides first-hand information about the role of exercise on distal biceps tendon stiffness. The insignificant differences in strain ratios of distal biceps tendon may be due to the small number of participants. Moreover, the high standard deviation in strain ratios of trained subjects is likely due to the variation in exercise type that an individual performs to train their biceps. Findings here can be related to an earlier study where Arampatzis and co -workers found that stiffness in tendon increases due to exercise with a high strain magnitude only[25]. In the present study, the type of exercise that an individual performed was not recorded. Future studies must be directed towards the type of exercise and its effect on distal biceps tendon. Moreover, the sample size in future studies should be enhanced significantly

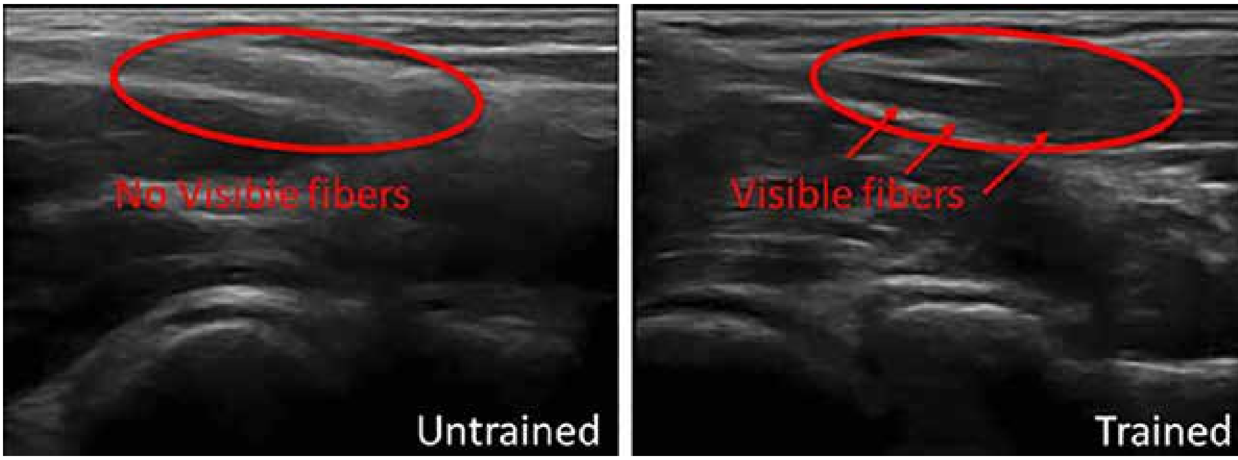

Fig 5. B-mode image of distal biceps tendon for untrained and traind individual. Visible fiber are shown with arrows and the red ellipse highlights the tendon.

and a measure of repeatability and reproducibility should also be taken into account. The current study classified individuals with respect to their activity in the past year. Previous physical activity must also be taken into account in future.

CONCLUSION

The pilot study reveals that distal biceps tendon stiffness increases due to training and the thickness of distal biceps tendon is also dependent upon exercise. However, none of them are dependent upon the BMI. Individuals who regularly exercise their biceps are less prone to sudden injury in their biceps as their tendons are stiffer than their counterparts. More specifically, sports personnels and scientists should be aware of the difference in physical attributes of trained and untrained individuals.

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