ORIGINAL ARTICLE

Ultrasound Imaging of Acute Biceps Tendon Changes After Wheelchair Sports

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ABSTRACT. van Drongelen S, Boninger ML, Impink BG, Khalaf T. Ultrasound imaging of acute biceps tendon changes after wheelchair sports. Arch Phys Med Rehabil 2007;88: 381-5.

Objectives: To investigate acute changes in the biceps tendon after a high-intensity wheelchair propulsion activity and to determine whether these changes are related to subject characteristics.

Design: The biceps tendon was imaged with ultrasound before and after wheelchair basketball or quad rugby. The average diameter of the tendon was calculated as well as the echogenicity ratio (the pixel intensity ratio of the biceps tendon to a reference just superficial to the tendon sheath).

Setting: National Veterans Wheelchair Games in 2004 and 2005.

Participants: Forty-two subjects who participated in wheelchair basketball or quad rugby at the Veterans Games.

Interventions: Not applicable.

Main Outcome Measures: Biceps tendon diameter and biceps echogenicity.

Results: The echogenicity ratio of the tendon significantly decreased from 1.97 to 1.73 after the event (P=.038). The diameter of the biceps tendon increased from 4.60 to 4.82mm (P=.178). Also, it was found that the change in tendon diameter positively correlated with the time of play (P=.004).

Conclusions: Acute changes in biceps tendon properties after exercise were found and likely represent edema, a first sign of overuse injury. The significance of continuous activity was shown by the fact that subjects who had more playing time showed a larger increase in tendon diameter.

Key Words: Rehabilitation; Shoulder; Tendon injuries; Ultrasonography; Wheelchairs.

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AMONG PEOPLE WITH a spinal cord injury (SCI), shoulder pain is a common complaint with a prevalence of between 30% and 73%.[1-4] Injuries to the shoulder can be the result of an acute overload, multiple-repetition load (chronic overuse), or single-event trauma to tissue made vulnerable by overuse (acute on chronic). Persons who depend on a manual wheelchair for their main means of mobility experience these high overloads and repetitive overuse loads on their upper extremities in locomotion and in performing daily tasks.

To diagnose shoulder pathology, different imaging methods have been used including magnetic resonance imaging, magnetic resonance arthrography, and computed tomography. Musculoskeletal ultrasound has the advantages over these systems of being easy to perform in an office setting and allowing dynamic examination of joints during motion. Ultrasound has been performed for approximately 25 years,[5] and the technique has been refined and is widely accepted as an important tool with high precision and accuracy in diagnosis.[6,7] A study by Allen and Wilson[8] has shown ultrasound to be a very powerful and accurate method for examining the biceps mechanism, rotator cuff, and synovium.

Read and Perko[9] and Thain and Adler[10] have shown that ultrasound is an excellent clinical tool to diagnose chronic tendon injuries. Acute tendon injuries have not been investigated. These acute changes to tendons of the shoulder, which might occur after sport participation, can be part of the pathologic process that leads to chronic pathology and pain. Acute overuse injuries to tendons normally begin with inflammation of the tissue surrounding the tendon, after which fluid is secreted into the tendon sheath.[11] Isolated biceps tendinitis is uncommon.[12] Biceps tendinitis is often secondary to impingement or rotator cuff tears[7,13] because the biceps tendon sheath is in direct communication with the glenohumeral joint. Insight into the acute changes in the biceps tendon after activity could contribute to a better understanding of the etiology of chronic pathology.

When using ultrasound, structures containing more fluid appear darker or are less echogenic. Abnormal or nonuniform echogenicity on ultrasound is more often indicative of tendinosis, tendinopathy, or mucoid degeneration.

There is already evidence that links the load of daily wheelchair propulsion to chronic overuse symptoms.[14] During sport participation, the load on the upper extremities is more pronounced because the forces to propel the wheelchair and the frequency of these forces are much higher.[15,16] Next to the frequency and the magnitude of the forces, the time of play and the number of rest periods are relevant factors to the development of musculoskeletal disorders.[17] Not only are the task requirements risk factors for shoulder damage but personal characteristics, like body mass index, are risk factors as well.[18] The rolling resistance, and thus the work needed to propel a wheelchair, is directly related to weight.[19] Besides, in wheelchair basketball and quad rugby, there is a lot of starting and stopping, resulting in an increased frequency of accelerating. When accelerating, body mass is a critical component for the necessary force.

Table 1: Subject Characteristics

Subjects	Age (y)	Height (m)	Body Mass (kg)	Injury Level (range)	Time Since Injury (y)
Subjects with tetraplegia (n=11)	45.8±9.1	1.81±0.09	76.7±10.3	C1 incomplete to C7 complete	20.2±9.6
Subjects with paraplegia (n=21)	40.3±9.4	1.79±0.08	73.9±13.2*	T1 incomplete to L5 complete	12.1±9.7
Non-SCI subjects (n=2)	37.1±14.7	1.88±0.07	99.8±25.7*	NA	8.5±6.6
Mean (n=34)	41.9±9.6	1.80±0.08	76.4±14.0	NA	14.5±10.2

NOTE. Values are mean ± SD.
Abbreviation: NA, not applicable.
*Significantly different between non-SCI and subjects with paraplegia (P=.038).

In this study, we used ultrasound to investigate acute changes in the biceps tendon after a high-intensity wheelchair propulsion activity. We hypothesized that because of increased edema, the biceps tendon would become less echogenic and increase in size after participation in an intense physical activity. Furthermore, we expected that subjects with a higher body mass would show larger changes in the biceps tendon characteristics and that the duration of wheelchair activity is positively correlated to these changes.

METHODS

Participants

Persons who participated in wheelchair basketball or quad rugby at the National Veterans Wheelchair Games of 2004 and 2005 were recruited for this study. A convenience sample of 42 subjects participated in this study after giving written informed consent.

Subjects were eligible to participate if they used a wheelchair as their main means of mobility and were between 18 and 65 years old. The exclusion criterion was a history of trauma or surgery to both arms. The protocol of this study received approval by the institutional review board of the Veterans Affairs, Pittsburgh Healthcare System.

Procedure

All participants completed a general information form that provided date of birth, date of injury, injury level, sex, height, and weight (table 1), and answered a questionnaire related to their shoulder and arm pain. Subjects then underwent a baseline ultrasound of the nondominant arm before the event and an ultrasound within 30 minutes after the event. The nondominant side was measured to limit the influence of daily tasks, which are more likely performed by the dominant arm.

All shoulders were examined by 1 of 2 examiners who had prior training and experience with musculoskeletal ultrasound. Ultrasound was performed with a Diasus Ultrasound Scanning Systems[a] using a 5- to 10-MHz linear array transducer.

The protocol used to examine the structures of the shoulder was based on previously described techniques.[20-23] The transverse image of the biceps tendon was obtained when the subject's arm was resting in his/her lap. Supination of the hand with external rotation of the shoulder improved the visualization of the bicipital groove. The transducer was then turned 90° to obtain the longitudinal image of the biceps tendon.

At the postgame ultrasound, participants reported their actual time of play in the event. In addition, time from the end of the event until the postgame ultrasound was noted.

Data Analysis

Before analyzing the images, the images were screened for usability by 2 reviewers. Base criteria were good definition of the boundaries of the biceps tendon and identification of the same part of the tendon in both images. In case of doubt, a third reviewer was consulted. To prevent erroneous values being included in the results, the calculated values were checked for normal distribution by probability plots. Values deviating more than 4 standard deviations (SDs) were considered outliers and were removed from the analyses.

The biceps tendon characteristics (tendon diameter, echogenicity) were analyzed with a Matlab[b] program, which was written by the investigators. The images were displayed in a random order, providing for blinding of the pre- and postgame images.

In the longitudinal images of the tendon, a length of 2cm was selected by the investigator (fig 1), and the tendon was outlined over this length. This selection included the narrowest part of the tendon. The average diameter of this selection was calculated.

To investigate changes in the fluid content of the tendon, the echogenicity of the tendon was determined by calculating the average pixel intensity value (a pixel intensity value of 0 corresponded to black and 255 to white) throughout the selected area. It was possible that we observed a decrease in tendon echogenicity when comparing the 2 images, but this could be inaccurate without considering all information in the entire image. If the overall brightness (controlled by machine settings) of the first image was greater than that of the second image, we would see a decrease in echogenicity not related to a change in the tendon. To resolve this issue, we used the tendon to reference echogenicity ratio. By using the average pixel intensity of a reference area just superficial to the tendon (one tenth of the total space above the tendon) (see fig 1), we controlled for differences in the overall brightness as well as differences caused by probe orientation or signal variation with depth. The echogenicity ratio was calculated as the pixel intensity ratio of the biceps tendon to a reference just superficial to the tendon sheath. A lower echogenicity ratio means that the tendon is darker with respect to the reference and, therefore, contains more fluid/water than the reference. If this ratio decreases, then there are 3 possible explanations: (1) the tendon became darker (ie, more fluid in the tendon); (2) the reference became lighter (ie, less fluid in the reference); or (3) both 1 and 2 (ie, the tendon became darker and the reference became lighter). The opposite would be true if the ratio increased.

Statistical Analysis

Paired sample t tests were performed to find differences between the biceps tendon diameter and the tendon echogenicity ratio of the pre- and postgame ultrasound images. A 1-way analysis of variance (ANOVA) was performed to find differences between the images of the persons with tetraplegia, those with paraplegia, and those without an SCI (independent variable: disability with 3 levels: tetraplegia, paraplegia, non-SCI; dependent variables: biceps tendon properties, subject charac-

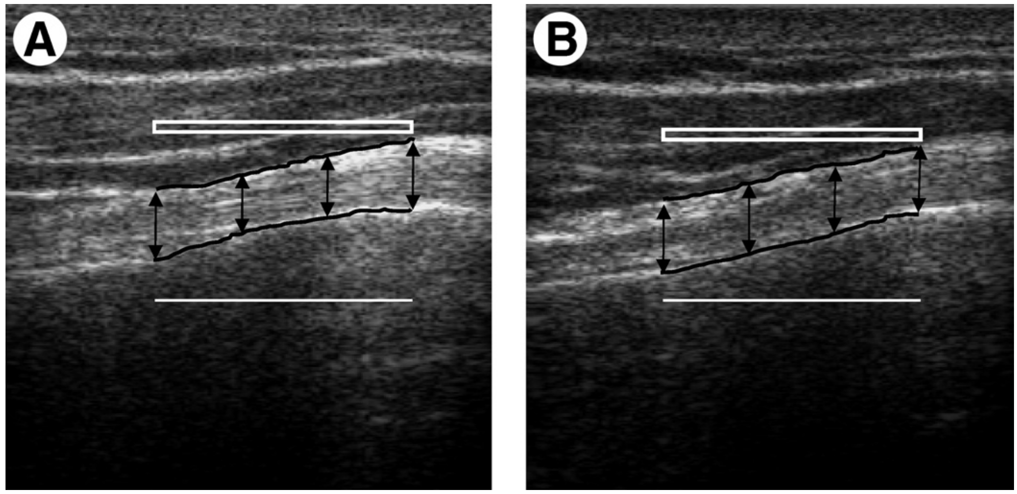

Fig 1. Typical example of a (A) pregame and (B) postgame image of the biceps tendon. The arrows indicate the diameter of the biceps tendon, the line the 2cm selected area, and the bar the 2-cm reference area. The tendons have been outlined by the black lines.

teristics). A Levene test of homogeneity of variance was performed to validate the application of ANOVA.

An independent *t* test was performed to find differences in the biceps tendon properties between subjects reporting pain or no pain in the measured shoulder during the previous month. Correlations between biceps tendon properties, subject characteristics, and play time were evaluated by using a Spearman ρ.

Significance was set at *P* less than .05 and a trend was reported with a *P* less than .10.[24]

RESULTS

Participants

Of the 42 subjects who entered the study, data of 34 subjects (33 men, 1 woman) were used for the data analysis (see table 1). The images of 5 subjects were unsatisfactory to clearly identify and measure the biceps tendon. One subject did not participate in his sporting event; therefore, no postgame ultrasound could be performed. The biceps characteristics of 2 subjects were more than 4 SDs from the mean; therefore, these subjects were considered outliers and were omitted as well. We compared excluded subjects to those included and found no difference with respect to age, years of injury, or height. However, the excluded subjects had a significantly higher body mass.

The Levene test of homogeneity of variance showed that it was justified to compare the groups with an ANOVA. The subjects without an SCI had a significantly higher body mass compared with the subjects with paraplegia ($F=3.625$, $P=.038$). Subjects with tetraplegia trended toward more years since injury compared with non-SCI subjects ($F=2.973$, $P=.066$).

The average time from the end of the event to undergoing the postgame ultrasound was 10.1±6.9 minutes. The average time the subjects reported participating in their sporting event was 28.7±16.6 minutes.

Biceps Tendon Characteristics

The echogenicity of the tendon in relation to the reference superficial to the tendon sheath significantly decreased from 1.97 to 1.73 after the event ($t=2.160$, $P=.038$). The diameter of the biceps tendon increased from 4.60 to 4.82mm, but this change was not significant ($t=-1.377$, $P=.178$).

Also, for the biceps tendon characteristics, the Levene test of homogeneity of variance showed that it was justified to use an ANOVA. No differences were found for the echogenicity ratio and the tendon diameter before and after the event among the 3 subject groups (table 2).

Four subjects with tetraplegia and 9 subjects with paraplegia reported pain during the last month in the measured arm. Subjects who reported pain showed a lower echogenicity ratio before ($t=2.480$, $P=.019$) as well as after the event ($t=2.056$, $P=.048$) compared with subjects who did not report pain.

Correlations

A Kolmogorov-Smirnov test showed that play time and time after play were nonuniformly distributed so a nonparametric correlation test was used. The only correlation found between the biceps tendon properties and the subject characteristics was that the echogenicity (tendon/reference) ratio of the pregame images was negatively correlated with weight ($\rho=-.363$, $P=.035$). The biceps diameter trended toward being larger in subjects with a higher body mass ($\rho=.298$, $P=.087$).

Playing time trended toward being related to change in diameter ($\rho=-.303$, $P=.082$), with greater playing time positively related to change in biceps diameter. On inspection of the data, it was noted that all subjects who reported participat-

Table 2: Biceps Tendon Characteristics Before and After the Event

Subjects	Diameter Before	Diameter After	Echogenicity Before	Echogenicity After
Subjects with tetraplegia (n=11)	4.19±0.61	4.42±0.79	2.01±0.68	1.80±0.56
Subjects with paraplegia (n=21)	4.77±0.99	4.98±0.93	1.95±0.82	1.66±0.56
Non-SCI subjects (n=2)	4.97±1.32	5.27±0.75	1.96±0.16	2.02±0.69
Mean (n=34)	4.60±0.92	4.82±0.90	1.97±0.74	1.73±0.56

NOTE. Values are mean ± SD.

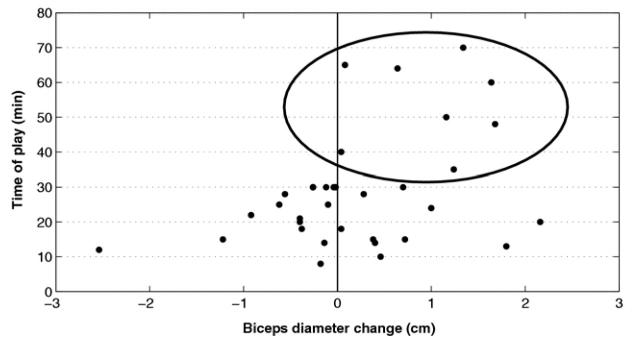

Fig 2. Relation between diameter change of the biceps tendon and the amount of play time. Positive change indicates an increase in the tendon diameter; negative change indicates a decrease.

ing for over 30 minutes (n=8) had an increase in tendon diameter. This was further evaluated with a Kruskall-Wallis test comparing the over 30-minute group to the group that played 30 or less minutes, and a significant difference was found (P=.004) (fig 2).

DISCUSSION

In this study, we found that after exercise the tendon to reference echogenicity ratio decreased. The decrease in echogenicity likely represents an increase in fluid in the tendon. Increased fluid in the tendon can be representative of edema, and one might expect it to be the cause of an increase in tendon diameter. However, the increase in biceps tendon diameter we found (from 4.60 to 4.82mm after the game) was not significant.

In the acute phase of tendon pathology, increased fluid content leads to swelling of the tendon.[25] In the chronic phase, small amounts of fluid within the biceps tendon sheath are abnormal but are considered nonspecific. Because the tendon of the long head of the biceps is intra-articular and in direct contact with the glenohumeral joint, larger amounts of fluid can be an indication for abnormalities elsewhere in the glenohumeral joint.[20,26] In our subject population, we found that subjects who reported pain showed a lower echogenicity ratio of the biceps tendon, which might indicate that pathology in the shoulder is present.[27-29]

The echogenicity ratio of the tendon showed a negative correlation with body mass in the pregame images. Surprisingly, the relation between the echogenicity ratio and body mass was not found in the postgame images. Also, we did not find a relation between the biceps diameter and body mass. Bigger changes in the postgame images were expected for subjects with a higher body mass because the amount of work needed to propel a wheelchair is directly related to weight.[18]

With respect to the subject's participation in the event, we found that the change in tendon diameter positively correlated with the time of play. Thus, in subjects who played longer, the tendon diameter change was larger (ie, the tendon became wider); indicating that duration is a risk factor for developing overuse injuries.

It has already been stated from the beginning of wheelchair studies that this task is responsible for the large amount of overuse injuries in the shoulder.[3,15,30,31] However, hard evidence of linking wheelchair propulsion to physical evidence has always been a limitation. In this study, we found not only that the changes in the biceps tendon characteristics are directly related to wheelchair propulsion but also that the amount of change was related to the duration of propulsion. Although the sports activities (quad rugby or wheelchair basketball) might be considered too extreme compared with daily activities, they are probably not when the obstacles and barriers encountered daily in the community (eg, constant acceleration and braking, curbs, slopes) are taken into account.

This study does not show that a short bout of exercise is related to chronic pathology. A recent study by Mercer et al[14] reported that long-term wheelchair use leads to damage. They found that specific joint forces and moments during wheelchair propulsion are directly related to shoulder pathology. Reducing subjects' wheelchair activities is not preferable because exercise can reduce the risk on coronary heart diseases.[32] So instead of limiting subjects' participation, the need is to reduce the overall force to propel the wheelchair. This could be accomplished by an alternative wheelchair setup, propulsion training, and weight control.

This study measured wheelchair users at an athletic event, which made it hard to control everything during the pretest and posttest measurements. Therefore, we were extra careful to exclude possible errors in the analyses. First, the images were screened by 2 examiners to identify the boundaries and the same part of the tendon in both images. After the initial analyses, unrealistic values deviating more than 4 SDs were excluded. Excluding these subjects did not lead to more significant results. However, the fact that the excluded subjects had a higher body mass could have biased the result. The signal properties of ultrasound vary with the type of tissue through which the signal is traveling, and the signal quality decreases when traveling through more soft tissue. The difference found in body mass between the excluded subjects and the subjects with a spinal cord injury likely reflect difficulty imaging subjects with a higher body mass.

Study Limitations

A limitation of this study was the variability in the personal characteristics of the included subjects. Subject characteristics could not be controlled because the measurements took place at an athletic event. Our main outcome measure was the difference in tendon characteristics before and after the event. This repeated-measure design should control for subject variability. The fact that we had a heterogeneous group adds to the generalizability of our findings.

Another limitation of this study was that not all subjects were measured at the same time after the exercise. The ultrasound was taken as soon as possible after the games. However, several subjects had to be measured and subjects had to come to the provisional laboratory, so the time until they were measured was as long as 30 minutes. Because time after competition did not correlate to the measured ultrasound variables, we believe it is safe to say that measuring within 30 minutes after the game did not influence the results; however, measurements at fixed time intervals after the participation in the sporting event would be recommended for future studies.

To standardize the protocol used even more, it would be ideal to measure subjects in a laboratory not only immediately after the exercise but also to follow subjects during the subsequent hours as well. Because ultrasound is sensitive to the orientation of the probe in relation to the anatomic structure of interest (anisotropy), procedures to guarantee the same orientation of the probe before and after the exercise bout will improve the results.

CONCLUSIONS

Acute changes in biceps tendon properties after exercise were found. A decrease in tendon echogenicity likely represents edema, a first sign of overuse injury. Subjects who had more playing time showed a larger increase in the tendon diameter, showing the significance of continuous activity. The fact that subjects with pain had a lower tendon echogenicity might indicate additional pathology. Further research will be necessary to improve the understanding of the effect of acute changes on chronic shoulder pathology.

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Suppliers

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b. The MathWorks Inc, 3 Apple Hill Dr, Natick, MA 01760-2098.