ULTRASOUND CHANGES, PAIN, AND PATHOLOGY IN SHOULDER TENDONS AFTER REPEATED WHEELCHAIR TRANSFERS

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ABSTRACT

Twenty-six wheelchair users with spinal cord injury (SCI) were recruited for this cross-sectional, repeated-measures study. Goals were to evaluate biceps and supraspinatus tendon thickness, variance, echogenicity, and contrast before and after repeated transfers, and relate those changes to measures of pain and pathology. Significant decreases occurred in biceps tendon variance, echogenicity, and contrast. Quantitative ultrasound variables correlated with scores from both the Ultrasound Shoulder Pathology Rating Scale and Wheelchair Users Shoulder Pain Index. Results indicate that transfers change the structure of tendons, which could in turn alter their function and increase risk of injury; these changes were related to severity of shoulder pain and pathology. While further investigation into specific risk factors is warranted, this information could translate into improved methods of prevention and rehabilitation of rotator cuff pathology in individuals with SCI.

INTRODUCTION

There are approximately 256,000 individuals with spinal cord injury (SCI) in the United States (NSCISC, 2012) and a majority of these individuals use a wheelchair for their mobility. A large percentage of wheelchair users with SCI experience shoulder pain and injury. While the direct cause is not fully understood, it has been hypothesized that overuse of the upper limb experienced by this population is a major contributor (Nawoczenski, Clobes, Gore, et al., 2003). People with SCI rely on their upper limbs for the performance of most activities of daily living. Repeated performance of activities that place a high load on the shoulders, such as wheelchair propulsion or transfers, can alter shoulder tendon microstructure and lead to tendon injury or pathology (Collinger, Impink, Ozawa, Boninger, 2010)..

Ultrasound provides investigators with a non-invasive, real-time method to measure changes in soft tissue architecture. A recent study used quantitative ultrasound (QUS) methods to investigate acute changes in biceps and supraspinatus tendons after intense wheelchair propulsion (Collinger, Impink, Ozawa, Boninger, 2010). QUS has been shown to be a valid measure of shoulder tendon pathology (Collinger, Fullerton, Impink, Koontz, Boninger, 2010). Using this method to study acute changes in shoulder tendons after transfers would provide valuable information that could translate into improved methods of prevention and rehabilitation of rotator cuff (RTC) pathology in individuals with SCI.

QUS outcome variables of interest include tendon thickness, variance, echogenicity, and contrast. We hypothesized there would be an increase in thickness and decrease in variance, echogenicity, and contrast of the biceps and supraspinatus tendons after repeated transfers; changes in QUS variables will positively correlate with biceps and supraspinatus tendinopathy scores of the Ultrasound Shoulder Pathology Rating Scale (USPRS) and Wheelchair Users Shoulder Pain Index (WUSPI); and subjects with greater baseline pathology will experience greater changes in QUS variables. These hypotheses were determined based on previous data reporting QUS changes in biceps and supraspinatus tendons after propulsion (Collinger, Impink, Ozawa, Boninger, 2010).

METHODS

Subjects

Participants were recruited from the 2012 National Veterans Wheelchair Games. Participants were included in the study if they were greater than 18 years old, had a non-progressive SCI that occurred over one year prior to the start of the study, used a wheelchair for over 40 hours/week, and were able to independently transfer to and from a surface in 30 seconds. They were excluded if they had any arm pain that limited their ability to transfer, actively used their leg muscles when transferring, or had a current or recent history of pressure sores or cardiopulmonary issues.

Baseline Questionnaires and Examinations

Institutional Review Board approval was obtained prior to implementation of study procedures. After participants provided written informed consent, they provided demographic information and completed the WUSPI (Curtis, Roach, Brooks Applegate, et al., 1995) to assess baseline levels of shoulder pain. Each participant underwent a physical exam evaluating upper and lower extremity motor scores according to the International Standards for Neurological Classification of SCI (Marino, Barros, Biering-Sorensen, et al., 2003), and were evaluated for shoulder tendon pathology using the USPRS (Brose, Boninger, Fullerton, et al., 2008). The same investigator performed the physical examination and USPRS on all participants.

Quantitative Ultrasound Examination

Participants underwent a QUS exam of the biceps and supraspinatus tendons. To image the biceps tendon, participants sat in their wheelchair with their non-dominant arm bent at 90̊, forearm supinated, and wrist resting on the ipsilateral thigh. The widest part of the tendon was imaged in the longitudinal view, with the apex of the humeral lesser tuberosity at the edge of the image. A hyperechoic A-shaped steel reference marker was taped to the participants' skin at the distal end of the transducer. The cross-bar of the marker created a distinct interference pattern at the top of the image, which was used to define the region of interest (ROI) upon which the analyses were performed. To image the supraspinatus tendon, the participant placed their hand on their lower back with elbow facing posteriorly as if reaching into their back pocket. The widest part of the tendon was imaged in transverse view. The marker was taped to the skin at the proximal end of the transducer.

Biceps and supraspinatus images were collected at baseline and post-transfers (PT) timepoints. Both markers remained on the skin in the same locations while transferring. Further details of the QUS protocol have been described previously (Collinger, Gagnon, Jacobson, Impink, Boninger, 2009).

Transfer Protocol

All transfers were performed using the participants' own wheelchairs. Eighteen total transfers were performed to and from a mat table of varying heights; this number is the estimated number of transfers performed per day by individuals with SCI (Samuelsson, Tropp, Gerdle, 2004). The first and last set of six were level transfers, while the middle set of six was two inches higher than their wheelchair seat. A 60-second break was given between each set. A speed of one transfer per fifteen seconds was chosen and controlled with a metronome. At the end of the transfer protocol, participants rated their perceived level of exertion using a Borg scale.

Image Analysis

A MATLAB computer program was used to analyze all images. Tendon thickness was calculated by tracing the upper and lower boundaries of the tendon within the ROI. A histogram representing greyscale values of each pixel within the tendon was calculated. Echogenicity is a measure of tendon brightness, and was determined as the average greyscale value of all pixels in the image. Variance describes the heterogeneity of pixels in the image and was derived directly from the histogram. A co-occurrence matrix was calculated to determine contrast of the tendon. The co-occurrence matrix describes the probability that two neighboring pixels will have a given greyscale value (0 – 255). Contrast represents differences in intensity between neighboring pixels over the entire image and quantifies fiber alignment. In an ultrasound image, a healthier tendon would appear brighter and more hyperechoic with alternating light and dark bands perpendicular to the probe; thus, it would have greater variance, echogenicity, and contrast (Collinger, Gagnon, Jacobson, Impink, Boninger, 2009).

Statistical Analyses

Significance was set to $p<0.05$; significant trends were reported as $p<0.10$. Differences between baseline and PT data were calculated to yield the magnitude of change (MC) of each variable. Descriptive values were determined for demographics, baseline QUS, and MC of QUS variables. Normality was tested using the Kolmogorov-Smirnov test. Partial correlations were determined between baseline and MC of QUS variables and WUSPI and USPRS scores. A repeated-measures ANCOVA was used to determined significant differences between baseline and PT values. Years since injury, weight of participants, and upper limb motor scores were covariates in partial correlation and ANCOVA analyses. Small deviations in probe position or angle could induce variability in QUS measurements; to reduce error, outliers greater than 3 standard deviations above or below the mean were not included in the analysis.

RESULTS

Subjects

A convenience sample of 28 participants completed the study. Data from two of the participants were not included because the images of their tendons were unable to be analyzed. One participant did not have the arm strength to perform elevated transfers, so instead completed three sets of level transfers. A summary of subject demographics is presented in Table 1. Median upper and lower extremity motor scores were 50 and 7.5, respectively. Median biceps and supraspinatus pathology grades were both 1, indicating mild tendinosis. The median BORG scale rating was 9. The mean WUSPI score was 22.1. No demographic variables correlated with MC of QUS variables.

Table 1: Subject demographics (mean ± standard deviation, frequencies).

Age (years)	51.23 ± 11.98
Years Since Injury	16.25 ± 11.53
Weight (kg)	80.21 ± 18.03
Gender	20 males, 6 females
Ethnicity	10 white, 16 non-white
Injury Level	17 paraplegia, 9 tetraplegia

Within-Subjects and Correlational Analyses

ANCOVA results for both tendons are presented in Tables 2 and 3 with corresponding means and standard deviations. Supraspinatus variance MC (r = .673, p = .001) and biceps contrast MC (r = .486, p = .019) significantly correlated with WUSPI scores. Biceps echogenicity MC significantly correlated with USPRS biceps grade (r = .595, p = .003), with a significant trend in biceps variance MC and USPRS biceps grade (r = .401, p = .058).

Table 2: Repeated-measures ANCOVA results for biceps tendon QUS variables. Baseline and PT values are expressed as means with standard deviations in parentheses.

	Baseline	PT	*F*	*df*	*p*
Width	5.33 (1.79)	5.51 (2.07)	1.311	1	.265
Variance	2195.27 (719.76)	2170.24 (1031.45)	5.652	1	.027
Echogenicity	114.95 (32.78)	112.35 (33.12)	9.672	1	.005
Contrast	5.88 (2.58)	5.77 (2.55)	4.543	1	.044

Table 3: Repeated-measures ANCOVA results for supraspinatus tendon QUS variables. Baseline and PT values are expressed as means with standard deviations in parentheses.

	Baseline	PT	*F*	*df*	*p*
Width	6.90 (1.05)	6.80 (1.08)	0.604	1	.445
Variance	1874.90 (719.49)	2042.86 (791.19)	3.076	1	.093
Echogenicity	94.81 (24.81)	99.54 (22.64)	3.779	1	.065
Contrast	4.23 (1.71)	4.77 (1.68)	2.564	1	.122

DISCUSSION

Biceps tendons of participants in the current study experienced acute changes in structure and texture as a result of repeated transfers. Tendons appeared darker with greater fiber misalignment, indicating transfers are causing damage. Results from this study are similar to those related to intense wheelchair propulsion (Collinger, Impink, Ozawa, Boninger, 2010). Acute damage to tendons as a result of transfers and other activities of daily living may accumulate over time and contribute to the development of shoulder pain and/or pathology.

Changes in QUS markers of tendon damage correlated with baseline shoulder pain and pathology measures. Significant and trending correlations had medium to large effect sizes, indicating a strong relationship between transfers, pain, and pathology. Due to the correlational nature of the data, it cannot be concluded that changes occurring in shoulder tendons during transfers directly cause pain and pathology. Further investigation into biomechanical risk factors is necessary to develop a cause-and-effect relationship.

Study Limitations

Thirteen subjects had lower extremity motor scores greater than 0 indicating they had strength in their leg muscles that could have aided in transfers. While exclusion criteria attempted to control for this, it is possible participants unknowingly used their leg muscles when transferring. This would reduce load on the shoulder and skew results.

CONCLUSIONS

Repeated transfers produced measurable changes in shoulder tendon structure and texture in a sample of individuals with SCI. Degenerative changes were related to presence and severity of tendon pain and pathology. This change with transfers is further evidence that transfers likely lead to pathology. Further investigation into the relationship between transfer biomechanics and QUS changes is needed to determine risk factors when transferring. This information can aid in prevention of rotator cuff tendon pathology and shoulder pain.

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