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Ultrasound assessment of extensor pollicis brevis tendon excursion in different wrist positions in healthy people

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ABSTRACT

Study Design: Cross-sectional, observational study.
Introduction: There is little reported on the in vivo mechanics and behavior of extensor pollicis brevis (EPB) in relation to wrist position. Wrist position is known to significantly influence tendon excursion and therefore function of the digits. Ultrasound imaging (USI) can be used to assess in vivo tendon behavior and excursion. An improved knowledge of the excursion of the EPB tendon is important in understanding normal tendon mechanics and potentially pathological tendon disorders such as de Quervains tenosynovitis.
Purpose of the Study: To assess the reliability of using USI to measure EPB tendon excursion and to quantify EPB tendon excursion in 3 wrist positions.
Methods: USI with speckle-tracking analysis were utilized to assess 49 normal EPB tendons (25 subjects). Tendon excursion was measured in wrist flexion (45°), wrist neutral and wrist extension (45°) on 2 different occasions.
Results: The within- and between-session reliability of using USI to quantify EPB tendon excursion was "excellent" and "high," respectively. Wrist position had a significant influence on EPB tendon excursion ($P \leq .05$). EPB excursion in the neutral wrist position was statistically greater than the other 2 positions ($P < .05$).
Discussion: EPB tendon excursion has been shown to be dependent on the wrist positions of flexion and extension. The measures are notably lower than those found in cadaver studies; however, they follow a similar pattern with greatest excursion occurring in the neutral wrist position and least in flexion. This information is useful for EPB tendon rehabilitation and in consideration of biomechanics and pathogenesis of disorders that affect EPB tendon.
Conclusion: In vivo EPB tendon excursion measures have been quantified, and wrist position has been found to have an influence on excursion. USI with speckle-tracking analysis are considered to be reliable methods for measuring EPB tendon excursion.

Introduction

There is little reported on the in vivo mechanics and behavior of extensor pollicis brevis (EPB), a tendon that passes from the distal part of the forearm, across the wrist and thumb, and serves to extend the thumb at the metacarpophalangeal joint.[1] The earliest recorded quantification of EPB tendon excursion was a cadaveric study conducted by Boyes[2] where he reported 30 mm of excursion from full composite wrist and thumb extension, through to full composite wrist and finger flexion.

The position of the wrist can significantly influence the movement and function of many long-finger tendons.[2] From their cadaver study, Kutsumi et al[3] identified that EPB tendon excursion was significantly greater than abductor pollicis longus (APL) tendon excursion, during thumb extension to flexion, in the well-known pathognomonic position of Finkelstein's test, which exploits wrist ulnar deviation to load these tendons. Although this study did not examine tendon excursion during movements of the wrist, Kutsumi et al[3] identified that static wrist positions of flexion and extension

Conflicts of interest: All named authors hereby declare that they have no conflicts of interest to disclose.

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significantly influenced EPB tendon excursion during thumb extension to flexion.

Kutsumi et al[3] found that the greatest EPB excursion occurred in a neutral wrist position and that the least excursion occurred in 60° of wrist flexion.[3] They also found that the position of least tendon excursion (wrist flexion) was associated with greater tendon gliding resistance and suggested that EPB and/or APL tendons moving against the extensor retinaculum in wrist flexion may be the primary aggravating factor in de Quervains tenosynovitis.[3] As movement of the thumb is such a critical component of many functional activities, the notion of wrist flexion and extension significantly affecting EPB tendon excursion warrants further investigation.

Cadaver studies, although important, do not provide information about tendon behavior during normal functional movement, and the literature has identified the need for further examination of in vivo tendon behavior.[4-7] Advancement in ultrasound imaging (USI) technology has enabled greater access to examine in vivo behavior of a number of different tissues including the long finger tendons.[8-11] A method utilizing speckle tracking of B-mode grayscale ultrasound features, analyzed with a cross-correlation algorithm to assess tissue motion,[12] has been shown to be reliable for the assessment of peripheral nerve excursion, for example, for the assessment of median,[13,14] ulnar,[15] and radial[16] nerves. Furthermore, this same method was employed by Chen et al[9] who investigated in vivo tendon excursion of extensor pollicis longus (EPL) tendon across the thumb metacarpal and was found to be significantly less than in vitro measures published by Boyes.[2] To date, much of the work that has utilized USI to assess long-finger tendon movement has focused on the flexor tendons. There is a paucity of research that has assessed in vivo mechanics of the extensor tendons using USI.

Purpose of the study

The primary aims of this study were to determine quantitative in vivo data on longitudinal EPB tendon excursion in different wrist positions and to determine reliability of the USI and cross-correlation methods utilized. The secondary aims were to measure whether tendon excursion was correlated to total active range of motion (TAROM) of the thumb, age, gender, and hand dominance. The present study deliberately targeted a healthy population to assess the reliability of the methods and techniques used. Future research will look at the same EPB excursion measures in people with de Quervains tenosynovitis. On the basis that de Quervains tenosynovitis is more predominant in women particularly toward the third to fifth decades,[17,18] these secondary aims were justified with a view toward future research in people with de Quervains tenosynovitis.

The findings from this research may be useful in the rehabilitation of EPB tendon following injury, surgery, and disease as well as in further study of clinical populations, for example, de Quervains tenosynovitis, where tendon excursion may be compromised. Methods used may be utilized for further study of tendon excursion in general.

Methods

Study design

A controlled laboratory cross-sectional study using a single-group, within-participant comparison was utilized for this research.

Participant recruitment

Participant recruitment was via response to advertisements placed around the university campus where the research was held. Following application of the inclusion and exclusion criteria, 25 participants were recruited into the study. The participants met the inclusion criteria of this study, if they had no known current or previous conditions that affected their wrists, were aged between 18 and 65 years and spoken conversational English. Informed consent was obtained from all participants before entering into the study. Participants were excluded if they had current pain in either wrist or thumb, autoimmune disorders (eg, rheumatoid arthritis), endocrinological disorders (eg, diabetes), neurological conditions (eg, Parkinson's disease), previous history of fractures to either wrist or hand, and a current or previous history of de Quervains tenosynovitis. One participant reported a previous injury to her right wrist which was excluded allowing for 49 wrists to be examined. There were 24 right wrists and 25 left wrists examined.

Based on data from the first 15 participants, a power calculation and sample size analysis was possible. This involved using EPB tendon excursion as the dependent variable where the calculations were based upon a 30% difference in tendon excursion being observed between the different wrist positions. With power set at 0.8 and an alpha level of 0.05, this calculation resulted in 25 participants being required.

Demographic data were collected including age, gender hand dominance, and thumb composite active range of motion (TAROM) from all participants. Before the initial assessment, thumb TAROM was measured using a goniometer. With the forearm in neutral rotation and the ulnar border supported on a table, the goniometer was placed on the dorsal aspect of all joints of the thumb and for the carpometacarpal joint, flexion was taken at 0°. TAROM was calculated using the American Society of Hand Therapists recommended formula for digital joint motion (TAROM = sum of flexion − sum of extension, which reflects composite movement measures for flexion and extension for all relevant joints including the carpometacarpal, metacarpophalangeal, and interphalangeal joints).[19] Each participant attended 2 separate occasions for imaging of the EPB tendon. Ethics approval was obtained by the Auckland University of Technology Ethics Committee.

Participant position and wrist angles

A 2.4 mm thermoplastic hinged wrist orthosis was constructed and mounted on a wooden block, and secured on a base (Fig. 1). The hand component could slide proximally or distally to fit different arm sizes. Straps were used to secure the forearm in the gutter component and the hand in the hand component. Wrist positions of 45° flexion and extension along with wrist neutral were chosen to examine EPB tendon movement. The angles were selected as were considered a more moderate position rather that the 30° and 60° used by Kutsumi et al.[3]

A protractor was secured to the board at the base of the wooden mount with the central point aligned directly beneath the hinge of the orthosis. Manual markings were made along the lines of the protractor angles at 45° on either side from the center point beneath the hinge.

Each participant was seated in a stationary chair with their spine supported by resting against the back of the chair with their feet flat on the ground. The participants' arm was supported on an adjustable table so that the humerus was in a relaxed, abducted, and stable position. The elbow was flexed at 90° and the forearm in a neutral rotated position. The hand and forearm were placed within the orthosis so that the wrist axis was directly over the hinge of the orthosis (Fig. 1).

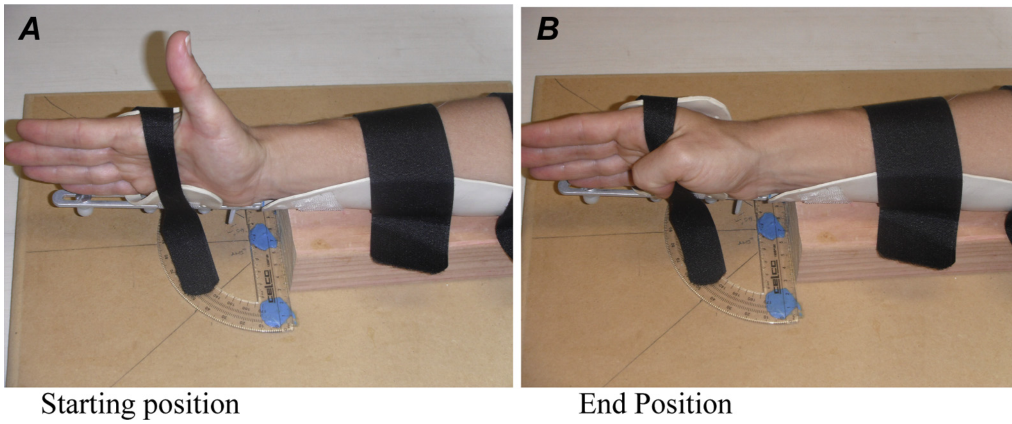

Fig. 1. Participant set up. (**A**) Starting position; (**B**) end position.

USI protocol

Transducer

B-mode USI was performed using a Phillips iU22 (Philips Medical Systems Co, Eindhoven, the Netherlands) ultrasound machine with a L5-7io (15-7 MHz) linear array transducer. The depth of tendon imaging was taken at 2 cm and chosen because of the superficial aspects of the tendons between the distal radius, and the skin and subcutaneous tissue. All structures including the bone, tendons, vessels, and subcutaneous tissue, were easily identifiable at this depth in both longitudinal and transverse planes. A small amount of ultrasound gel was placed between the transducer and the skin, acting as a coupling medium. The level of pressure from the probe was maintained so that minimal pressure was applied while maintaining a full image that was uninterrupted by side artifacts (ie, shadowing). This pressure enabled the transducer to be maintained in a static position which was held during thumb movements.

Location of EPB tendon and transducer placement

Anatomically, the EPB tendon lies dorsal and ulnar to the APL tendon within the same compartment. EPB was located using the method outlined by Hazani et al[20] who described the location of APL by intersecting a line between Lister's tubercle, the radial styloid, and the scaphoid. Once APL was identified, The EPB tendon was confirmed, with USI, to the ulnar side of APL. There are known anomalies of the EPB and APL tendons within the first dorsal compartment (eg, septation, multiple tendon slips),[20] however, these anomalies were not identifiable by the primary investigator as seen with USI.

The transducer was placed transversely, to allow initial identification of the EPB tendon, and then longitudinally (Fig. 2), following the tendon proximally toward its muscle origin. The tendon of EPB was easily differentiated from the tendon of EPL, which is distinct and more dorsal than EPB, and visible as it traverses around Lister's tubercle.[21]

The EPB tendon was identified in the longitudinal view (Fig. 3) over the distal radius on the radial side by differentiating it from the APL tendon. A minimum number of 5 recordings were taken during thumb motion from full composite extension to full composite flexion, in each of the 3 wrist positions. Three optimal trials were necessary for analysis. An optimal trial required good visualization of the EPB tendon throughout the whole video sequence. Where more than 2 trials were optimal and therefore available for analysis, 3 trials were randomly selected for analysis of EPB tendon excursion. The same procedure was repeated for each subject within 4 weeks of initial recordings. A single assessor, a certified hand therapist (American Society of Hand Therapists), with 15 years of hand therapy experience including USI (E.K.) who conducted all of the USI measures was blind to previous measures taken. USI analyses were not performed until completion of both data collection sessions.

USI and analysis

Individual ultrasound digital recordings (cineloops) of EPB tendon movement were captured at a frame rate of 10 images per second (10 Hz). The transducer frequency was set at 15 MHz to allow the clearest resolution of the underlying tendon. The gain settings were adjusted to provide the best visual clarity for each image. All images taken forward for analysis were converted to digital frames (bitmaps) using the AVI4BMP (version 2.4, Bottomap Software) digital conversion software. These sequences of digital frames were then analyzed offline using software developed in Matlab (Mathworks). The software employs a frame-by-frame cross-correlation algorithm to measure the motion (pixel shifts) of fine speckle features in selected regions of interest (ROIs) between adjacent frames of the image sequence.[12] The tendon ROIs were digitally outlined within the tendon itself along its length (as seen within the field of view). In order to eliminate any movement that may have occurred from movement of the transducer against the skin, another set of ROIs (background ROIs) were outlined within structures, within the same image, that were stationary (ie, radius). The pixel shift measurements of the background ROIs were then subtracted from pixel shift measurements recorded from the

Fig. 2. Transducer placement longitudinally over EPB. EPB = extensor pollicis brevis.

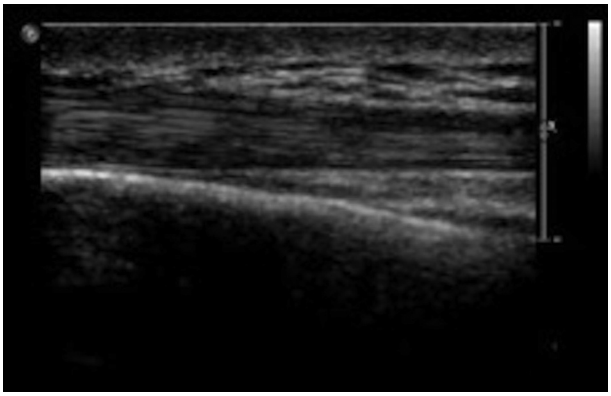

Fig. 3. Longitudinal USI image of the EPB tendon. USI = ultrasound imaging; EPB = extensor pollicis brevis.

tendon ROIs. This method of ultrasound analysis of soft tissue movement has been previously reported for assessment of excursion of the EPL tendon,[9] radial nerve,[16] and median nerve.[14]

Statistical analyses

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software (Chicago, IL). Descriptive analyses (means and standard deviations [SDs]) were performed for the demographic variables of the cohort.

As has been recommended for reliability studies conducted using USI measures,[22,23] the following statistical methods were used to examine repeated-measures (test-retest) reliability: intraclass correlation coefficients (ICCs) (with 95% confidence intervals [CIs] determined), standard error of measurement, minimal detectable change along with Bland-Altman plots. These reliability analyses were conducted for each of the 3 wrist positions (wrist flexion, neutral, and extension) along with pooled data for all the wrist positions combined. The interpretation of the ICC results were deemed "very high" with an ICC between 0.90 and 1.00, "high" 0.70–0.89, "moderate" 0.50–0.69, "low" 0.30–0.49, and "very low" 0–0.29.[24]

Statistical comparisons for EPB tendon excursion across the different wrist positions used were conducted using a 1-way analysis of variance with the alpha level set at $P \leq .05$. Furthermore, correlations between EPB tendon excursion and TAROM and against key demographic variables (age, gender, and hand dominance) were analyzed for the pooled data (combining the data for all 3 wrist positions) using Pearson's correlation coefficient.

Results

Twenty-five participants (15 females and 10 males) consented to participate in this study. There were 21 European, 2 Maori, and 2 Asian participants. The mean age of the participants was 39.8 years (12.9 SD). In regard to hand dominance, 23 reported being right-handed while 2 were left handed. The mean and SDs for each individual thumb joint and TAROM is presented in Table 1.

Table 1
Thumb joints active range of motion (degrees)

Thumb joint	Mean range of motion (degrees)	Standard deviation (SD)
CMCJ	46.6	7.0
MCPJ	49.7	14.3
IPJ	74.1	24.1
TAROM	170.4	26.3

CMCJ = carpometacarpal joint; IPJ = interphalangeal joint; MCPJ = metacarpalphalangeal joint; TAROM = total active range of motion.

The reliability (presented as ICC; 95% CI) for assessing EPB tendon excursion using USI, for pooled data combining the different wrist positions, within-session 1 (0.88; 0.84–0.91) and within-session 2 (0.87; 0.92–0.90) were both "high." The neutral wrist position demonstrated "excellent" reliability for within-session 1 (0.93; 0.88–0.96) and within-session 2 (0.91; 0.84–0.95). Between-session analyses were found to be "acceptable" for all data (0.76; 0.66–0.83) and "high" for the neutral wrist position (0.80; 0.64–0.89). From pooled data across the testing sessions, the standard error of measurement and minimal detectable change for each wrist position were: wrist extension 0.181 mm and 0.509 mm, wrist neutral 0.179 mm and 0.587 mm, and wrist flexion 0.179 mm and 0.587 mm. A Bland-Altman plot which represent these findings, from the pooled data across the sessions, compares the difference between the excursion scores plotted against the average scores (Fig. 4).

Results showed that there was a statistically significant difference for EPB tendon excursion between the 3 wrist positions ($P < .05$). EPB excursion in the neutral wrist position was statistically greater from the other 2 positions ($P < .05$). EPB tendon excursion for each position was mean (±SD): neutral 2.78 mm (±1.89 mm), extension 1.67 mm (±1.15 mm), and flexion 1.62 (±1.4 mm) (Fig. 5). No statistically significant difference ($P > .05$) in EPB tendon excursion was seen between either gender. No statistically significant difference ($P > .05$) was found for EPB tendon excursion between the wrists being in flexion compared to extension.

Tendon excursion was found to decrease with age and although the influence was small, it was found to be statistically significant ($P < .05$). A low correlation between EPB tendon excursion and TAROM when all measures in all wrist positions were analyzed indicated that TAROM also reduced with age. Hand dominance did not influence tendon excursion ($P > .05$).

Discussion

The main findings of this study are that tendon excursion of EPB at the wrist during full active thumb extension to flexion is dependent on wrist position and that EPB has a greater amount of excursion when the wrist is in the neutral position compared with the other positions of wrist flexion and extension. EPB excursion is least in wrist flexion.

The measurements were less than expected compared with previous cadaver research.[2,3] When the wrist was in neutral

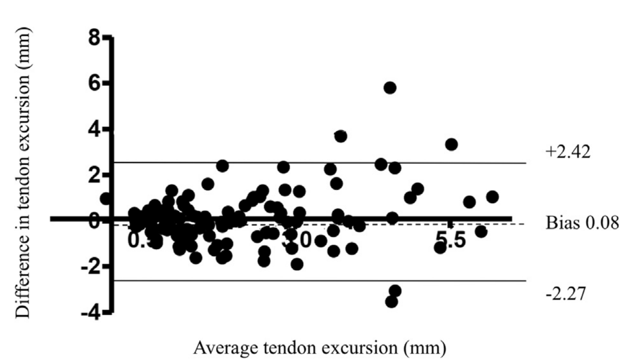

Fig. 4. A Bland-Altman graph (difference vs average) for EPB tendon excursion measurements between-session 1 and 2 analyses. *Solid line* indicates 95% limits of agreement. EPB = extensor pollicis brevis.

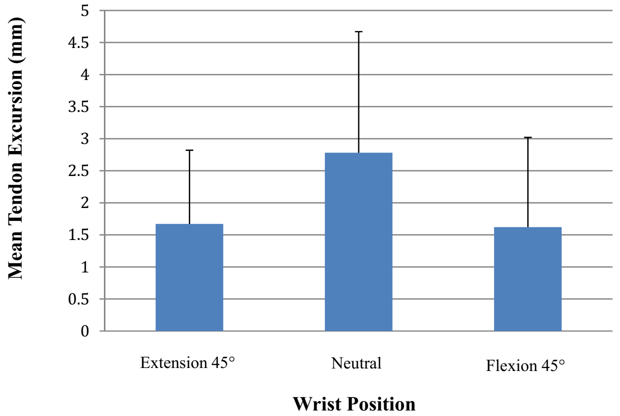

Fig. 5. Mean EPB tendon excursion for each wrist position. EPB = extensor pollicis brevis.

position, there was greater tendon excursion than when the wrist was flexed and extended at 45°. The amount of excursion in the neutral wrist position (2.78 ± 1.89 mm) during thumb motion, through full extension-flexion range, is considerably less than in vitro results found by Kutsumi et al[3] (14 mm) and Boyes[2] (15 mm).

The pattern of difference of EPB tendon excursion found between wrist positions is consistent with the cadaver measures and the large in vivo vs in vitro differences in excursion measures can be likened to those found by Chen et al[9] in their study of EPL excursion using the same methodology. These differences could be accounted for by a number of factors such as the difference in in vivo and in vitro tissue properties, the loss of viscoelastic properties in cadavers, the level of tissue dissection to reveal tendons, differences in age of participants (mean 39.8 years in the present study) and aged cadavers, the restriction of wrist ulnar deviation during testing, agonist and antagonistic muscle tensions, eccentric EPB muscle action, conscious execution of new or altered motor pattern required for the testing and finally, tendon strain. It is recognized that different tissues possess different viscoelastic properties such as force-relaxation, hysteresis and creep. The point of tissue failure, or deformation of tendons, as well as being time dependent, differs in live and cadaver tissues.[25]

Measurement of EPB tendon excursion utilizing USI and a cross-correlation algorithm was found to be a highly reliable method of in vivo tendon analysis. The ICC results ranged from 0.63 (with wider CI intervals for wrist flexion positions) to 0.93 (with narrower CI intervals for the neutral position). Within-session intrarater reliability was found to be higher than between-session intrarater reliability.

The methods described have previously been shown to be reliable in measurement of EPL[10] and in longitudinal nerve excursion analyses.[14,15,17,25] The same methods could be useful in further research and in clinical evaluation in measuring tendon excursion. USI equipment is relatively inexpensive and easily accessible, compared to other imaging technologies. A high level of anatomical knowledge of the area under examination, together with examiner experience and practice, could further improve reliability.

Limitations

The investigation was limited to a normal population and cannot be extrapolated to a pathological group. It is recognized that wrist ulnar deviation was not included in this study and that it would be an important motion to investigate in future studies given the potential mechanical influence this movement may have upon the APL and EPB tendons. In addition, it would be useful to further examine EPB and APL excursion in composite motions of thumb and wrist flexion and extension.

Clinical implications

The quantitative information gained about EPB tendon excursion is important in the consideration of optimal orthotic positioning in the management of conditions such as de Quervains tenosynovitis as well as for rehabilitative tendon gliding exercises which may be utilized posttendon repair. It is recommended that further studies be undertaken, using similar methods that explore tendon excursion in people with de Quervains tenosynovitis. These methods could also be utilized to examine tendon strain and/or gliding resistance in different wrist and/or thumb positions as well as the behavior of other tendons over other joints.

Knowledge of how wrist flexion and extension influence EPB excursion could also be useful in understanding the pathogenesis of disorders such as de Quervains tenosynovitis. The information could be applicable in the education of patients with EPB tendon pathology with respect to activity modification. It could also be useful to hand surgeons in regard to postoperative positioning of the thumb following surgery involving EPB and possibly for consideration in tendon transfer surgeries.

Conclusion

This study has provided reliable, quantitative data on EPB tendon excursion in vivo in healthy participants. It is the first study known to analyze EPB tendon excursion in vivo, and the second study to utilize the cross-correlation algorithm for tendon analyses. The results are for a normal nonpathological adult population but provide valuable information for further comparative studies involving EPB, both in normal and diseased states. USI and cross-correlation methods are a reliable tool for measuring tendon excursion in vivo.

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1. At its core this article is a _______________ study
  a. clinical
  b. reliability
  c. rehabilitation
  d. validity

2. The study investigates how wrist position affects _______________ excursion
  a. ECRB
  b. ECRL
  c. EPL
  d. EPB

3. The USI technique utilized
  a. computerized tomography
  b. integrated spectral videography
  c. speckle-training analysis
  d. spiral-training analysis

4. The greatest excursion was found with the wrist
  a. in extension
  b. in neutral
  c. in radial deviation
  d. in flexion

5. The data show the technique to be satisfactorily reliable
  a. true
  b. false

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