Sonographic Measurement of Middle Finger Flexor Tendons: Normal Measurements and Reproducibility of Data

HALA REAICHE, MS*

MARIE WILLIAMS, PHD†

MAUREEN MCEVOY, MS†

Various sonography studies have evaluated the normal flexor tendons of the fingers by reporting the echogenicity of these structures. Due to the descriptive nature of these studies, little information is available concerning the reproducibility of sonographic measures of the finger flexor tendons. The aim of this study was to determine whether sonography measurement of finger flexor tendons can provide reproducible information. The study used a test-retest, same-subject experimental design. Individuals who had no history of injury or surgery to the fingers had the right and left middle fingers of both hands assessed on two different occasions (test 1 and test 2) separated by at least 4 hours. The flexor tendons were assessed for continuity and measured for thickness at three points along the finger: the heads of the metacarpal, proximal phalanx, and middle phalanx. Reliability was assessed using Pearson's Correlation Coefficient (r), t test (paired two-tail), and the intraclass correlation coefficient ($ICC_{1,1}$). The majority of measures had an excellent linear correlation ($r > 0.75$). The t tests indicated that there were no significant differences between the two tests ($P \leq .05$). High $ICC_{1,1}$ values suggested that there were excellent relationships between the measures on the two occasions of testing. No significant differences were found between measures of the left and right hands. The synovial sheath-pulley systems were evident as an echogenic specular reflection situated anteriorly to the flexor tendons in all individuals. Using this measurement protocol, sonography was found to be a reliable method of measuring and assessing the flexor tendons of the fingers.

Key words: musculoskeletal sonography, finger flexor tendons, synovial sheath-pulley system

From the *School of Medical Radiation and the †School of Physiotherapy, University of South Australia.

Reprint requests: Hala Reaiche, School of Medical Radiation, Division of Health Sciences, University of South Australia, City East Campus, North Terrace, Adelaide, South Australia 5000. E-mail: hala.reaiche@unisa.edu.au.

High-resolution ultrasound is a noninvasive, nonhazardous, and widely available diagnostic tool. It is relatively inexpensive compared with other modalities such as computed tomography and

magnetic resonance imaging.[1,2] Sonography is capable of delineating normal soft tissue structures and detecting changes in the tendons and surrounding structures. It is a useful diagnostic tool in evaluating tendinous abnormalities.[3,4]

The current literature relating to sonography assessment of the finger flexor tendons is predominantly descriptive in nature, focusing on the normal and pathological sonographic appearance. To our knowledge, no prospective experimental study has considered the reproducibility of sonographic measures of the finger flexor tendons. While the clinical applications of this knowledge may not alter day-to-day practice for clinical sonographers, it is essential for experimental research in which sonography evaluation is planned as an outcome measure. This study presents a preliminary measurement procedure for finger flexor tendons, investigates the intrarater reliability of these measures, and compares left and right measures.

Materials

A test-retest, same-subject design was used. Ethical approval was granted by the University of South Australia. Individuals were invited to participate in this study if they were between 18 and 45 years of age. Individuals were excluded if they had current finger/hand/wrist injuries; had previous surgery/trauma to either arm, wrist, hand, or fingers; were unable to give informed consent; were unable to assume the test position needed to conduct the examination; or were unable to return for retesting.

The ultrasound system used was the ATL HDI 5000 (Advanced Technology Laboratories, Bothell, WA). The transducer used was a high-frequency linear array transducer 12-5 MHz (L12-5) with a 38-mm footprint. A qualified sonographer was the sole operator throughout the study. The participant was seated on a chair across from and facing the sonographer. The participant's upper arm was parallel to the body and in contact with his or her side. The supinated forearm rested on the table with the elbow bent to 90 degrees. This ensured that the wrist and middle finger were in the neutral position and were flat on the table. The middle finger was defined as the finger between the index and ring fingers. The fingers were extended, but care was taken to ensure that they were not hyperextended. All measurements of anatomical structures were taken using electronic calipers of the ultrasound unit. These results were displayed on the screen and were recorded by the sonographer.

Method

TRANSVERSE SCAN

Once the participant was in the correct position, sufficient aqueous gel was placed on the middle finger. Using the L12-5, the flexor tendons were scanned in the transverse plane with view of the metacarpal phalangeal joint (MCPJ). The two tendons, flexor digitorum profundus (FDP) tendon and flexor digitorum superficialis (FDS) tendon, were scanned distally in the transverse plane to the proximal interphalangeal joint (PIPJ). Further scanning took place in the transverse plane to the distal interphalangeal joint (DIPJ). The FDS tendon division took place over the proximal phalanx, with the two halves separating and coming in under the FDP tendon to reach the shafts of the middle phalanx where they attached. The FDP tendon was assessed transversely to its insertion point at the base of the distal phalanx. The maximum width and thickness of the tendons were assessed in the transverse plane (Fig. 1).

LONGITUDINAL SCAN

Once the tendons were localized in the transverse plane, the transducer was rotated to scan in the longitudinal plane at the MCPJ. At this point, the FDP and FDS tendons were viewed. The interface between the two tendons was identified as a continuous

FIG. 1. Transverse image of finger flexors.

FIG. 2. Longitudinal measurement of the flexor digitorum profundus (FDP) tendon and the flexor digitorum superficialis (FDS) tendon at the head of the metacarpal (MCPJ = metacarpal phalangeal joint).

FIG. 3. Longitudinal measurement of the digitorum superficialis tendon (FSPT) + flexor digitorum profundus tendon (FDPT) at the head of the proximal phalanx (PIPJ = proximal interphalangeal joint).

echogenic line. Scanning longitudinally allowed the tendons to be distinguished and separated from other surrounding anatomy. Measurements were made immediately superior to the anterior part of the head of the metacarpal to determine thickness (cm) of the FDP tendon and the FDS tendon (Fig. 2). The FDP tendon lay anteriorly to the metacarpal, with the FDS tendon lying anteriorly to the FDP tendon. The tendon thickness could be separated and measured individually.

The tendons were scanned distally to the PIPJ. A measurement of thickness of the tendons was made at the level of the highest point of the head of the proximal phalanx (Fig. 3). At this point, the two tendons were no longer distinguishable from each other. Further scanning of the tendons toward the DIPJ was completed to determine continuity of the tendons. Scanning either side of the FDP tendon identified the insertion points of the FDS tendon. The insertion points were seen approximately at the base of the middle phalanx.

Scanning distally along the middle phalanx was performed to assess the FDP tendon. At the level of the highest point of the head of the middle phalanx, a measurement of thickness of the tendon was made (Fig. 4). The FDP tendon was scanned to the DIPJ and further distally to its insertion point at the base of the distal phalanx. The same procedure was performed on the contralateral hand. The scans were repeated after 4 hours or on the following day.

Scanning in the longitudinal plane assessed the synovial sheath-pulley system. The synovial sheath-pulley system was identified as an echogenic specular reflection anterior to the flexor tendons (Fig. 5). An echogenic reflection from the synovial sheath will only be apparent when the structure's surface is oriented perpendicular to the ultrasound beam.

DATA ANALYSIS

Data were analyzed for relationships between the two occasions of testing using parametric statistics. Pearson's Correlation Coefficient (r) was used to determine the strength of the linear correlation

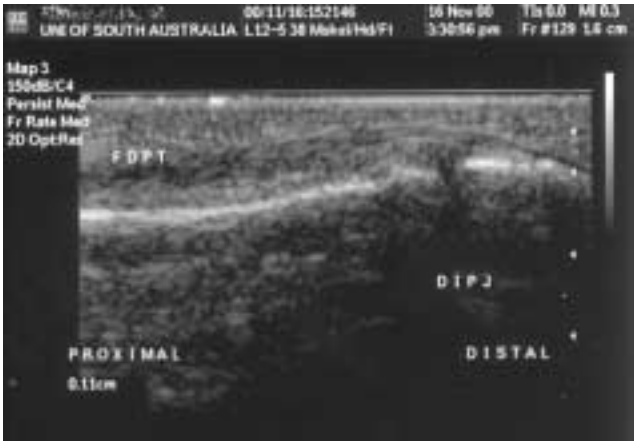

FIG. 4. Longitudinal measurement of the flexor digitorum profundus tendon (FDPT) at the head of the middle phalanx (DIPJ = distal interphalangeal joint).

FIG. 5. Fibrous synovial sheath-pulley system (arrows).

between the measures from test 1 to test 2. Levels of agreement were defined by Dawson-Saunders and Trapp[5] as $r > 0.75$ representing a very good to excellent result, $r = 0.5$ to 0.75 representing a moderate to good result, $r = 0.25$ to 0.5 representing a fair result, and $r =$ 0 to 0.25 representing a poor result. The paired t test compared the mean scores between test 1 and test 2. A value of $P \leq .05$ was regarded as a significant difference.[6] The intraclass correlation coefficient ($ICC_{1,1}$) was calculated from a one-way analysis of variance and indicated that the variation between the participants was greater than the variation within the participants, where values fell between 0.8 and 1.0.[6]

Results

Twenty-seven individuals aged 18 to 45 years participated in this study (11 male, 16 female). Seven participants were excluded because they did not return for the follow-up scan, leaving a total of 20 participants. The middle fingers of the right and left hands of each individual were scanned (n = 40 fingers). Descriptive data for flexor tendon thickness are presented in Table 1.

Results for all analyses are presented in Table 2. Pearson's Correlation Coefficient indicated that there was a very good to excellent linear correlation between the variables FDP right test 1/right test 2 (R1/R2) at metacarpal head (MCH), head of proximal phalanx (HPP) R1/R2, and HPP left test 1/left test 2 (L1/L2) (0.77, 0.85, and 0.86, respectively). All the other variables were greater than 0.5 and below 0.75, indicating a moderate to good result. The t test indicated that there were no significant differences between the two tests. The high ICC (ICC > 0.8) indicated little variation between the two tests for all but three measures. The correlations for the FDS L1/L2 at MCH, FDP L1/L2 at MCH, and FDP head of middle phalanx L1/L2 were 0.76, 0.78, and 0.76, respectively, which is just below the recommended ICC > 0.8.

Statistical analysis was conducted to determine the level of relationship between the right and left fingers. When measures for the right and left hands were compared, there was a good to excellent relationship determined by Pearson's Correlation Coefficient for all variables with the exception of HPP R/L, which showed a slightly diminished correlation of 0.64. The t tests indicated no significant differences for any measure between the right and left fingers. $ICC_{1,1}$

TABLE 1
Tendon Thickness Range

Measurement Point	Minimum Thickness	Maximum Thickness	Mean	*SD*
FDP MCH	0.12	0.25	0.178	0.025
FDS MCH	0.13	0.21	0.174	0.019
FDS/FDP HPP	0.12	0.28	0.224	0.026
FDP HMP	0.08	0.15	0.118	0.015

Data were obtained by pooling data from test 1 and test 2, right and left fingers. FDP = flexor digitorum profundus, FDS = flexor digitorum superficialis, MCH = metacarpal head, HPP = head of proximal phalanx, HMP = head of middle phalanx.

TABLE 2
Statistical Outcomes for Analysis of Relationships Between the Two Occasions of Testing

	Pearson's Correlation Coefficient (r)	t Test (P, two-tailed)	Intraclass Correlation Coefficient
FDS R1/R2 at MCH	0.70	.33	0.99
FDS L1/L2 at MCH	0.63	.13	0.76
FDP R1/R2 at MCH	0.77	.27	0.86
FDP L1/L2 at MCH	0.63	.59	0.78
PPH R1/R2	0.85	.87	0.92
PPH L1/L2	0.86	.36	0.92
FDP HMP R1/R2	0.72	.86	0.84
FDP HMP L1/L2	0.60	.51	0.76
Acceptable level	> 0.75	≤ .05	> 0.80

R1 = right test 1, R2 = right test 2, L1 = left test 1, L2 = left test 2, FDS = flexor digitorum superficialis, FDP = flexor digitorum profundus, MCH = metacarpal head, PPH = head of proximal phalanx, HMP = head of middle phalanx.

TABLE 3
Right Middle Finger Compared With Left Middle Finger ($n = 40$)

	Pearson's Correlation Coefficient (r)	t Test (P, two-tailed)	Intraclass Correlation Coefficient
FDS R/L at MCH	0.84	.42	0.91
FDP R/L at MCH	0.79	.51	0.88
HPP R/L	0.64	.80	0.78
FDP HMP R/L	0.72	.11	0.83
Acceptable level	> 0.75	≤ .05	> 0.80

R = right middle finger, L = left middle finger, FDS = flexor digitorum superficialis, FDP = flexor digitorum profundus, MCH = metacarpal head, HPP = head of proximal phalanx, HMP = head of middle phalanx.

indicated excellent relationships for all but one measure with HPP R/L of 0.78. This is just below the recommended ICC > 0.8 (Table 3).

The synovial sheath-pulley system was identified as an echogenic specular reflection on all 27 participants (54 fingers including 7 that were excluded due to nonattendance on the second test were scanned). There was 100% agreement that the synovial sheath-pulley system was identified on both occasions.

Discussion

While this study examined the middle finger of the left and right hands, it is likely that the anatomy and the ultrasound appearance of the index, ring, and little fingers are comparable to the middle finger.[7,8] The measurement procedure was shown to be highly reproducible for the majority of measures. Weaker relationships between some of the measures may be due to a number of factors. Minor alterations in finger position from the first scan to the second could have influenced the results. Positioning of the finger is important because the transducer may not be able to make contact appropriately with the skin surface, or the obliquity of the finger will cause the tendons to be scanned in a slightly different plane compared with the first test. This would cause a disparity in the thickness of the tendons. Operator error in transducer skills, such as transducer positioning, system settings, or instructions to the participant, may result in less than optimal images.

Transducer manipulation is essential for competent scanning. Transducer positioning involves orientation and positioning elements, as movements of tilting, angling, and rotation are necessary in producing optimum images.[9] Any changes of the transducer manipulation, even if slight, will have an effect on reproducing images. Movement of the transducer is an essential skill required by sonographers, and this skill is known to have a substantial effect on the image quality, even if it is only by a few millimeters.[9] It should also be noted that the lack of an independent assessor may have introduced a positive bias into the results.

No significant differences between the right and left middle fingers were found. This finding suggests that dominance in one hand does not significantly alter the morphology of tendons. Normal clinical practice requires that sonographers compare the contralateral side to determine differences between the affected and unaffected side. But we have found no proof in the literature that the contralateral side can be used as a comparison to the affected side. The results of this study support current clinical practice. Sonographers may be confident that any changes to the flexor tendons of an injured hand can be compared with the contralateral uninjured side with the assumption that any changes are noteworthy.

The echotexture of the tendon is best shown when the ultrasound beam is strictly perpendicular to the tendon.[10] If it is not perpendicular, scattering the oblique beam results in an artifactually hypoechoic tendon, a phenomenon called anisotropy. The curve of the flexor tendons, the tendons' relationship to the skin surface, or the placement of the transducer can produce the effect of anisotropy. Due to anisotropy, the reproducibility of measurements of the tendons can be affected, resulting in moderate linear relationships.

Serafini et al.[4] stated that the fibrous annular pulleys surrounding the tendons at the head of the metacarpals could not be seen on ultrasound. Prior to commencing this study, a cadavic finger was sequentially dissected and scanned by the principal investigator.[11] The pulley system was identified as localized thickenings of the tendon sheath rather than a separate entity from the tendon sheaths. The synovial sheath-pulley system was identified as an echogenic specular reflection anterior to the flexor tendons in the cadavic finger. This only appeared when the synovial sheath-pulley system was perpendicular to the ultrasound beam. In this study, the synovial sheath-pulley system could be identified on all 27 individuals (54 fingers). Identification of the synovial sheath pulley system in

the current study compared with the findings of Serafini et al. may result from improvements in ultrasound technology, specifically in spatial resolution.

This study presents a range of tendon thicknesses at three different points along the flexor tendons for the right and left middle fingers. Serafini et al.[4] described the combined thicknesses of the superficial and deep flexor tendons of the fingers at the meta-carpophalangeal junction and reported these to range between 0.29 and 0.44 cm. These figures are comparable with the combined thickness range of 0.25 to 0.46 for the FDP and FDS tendons as found in the current study.

Conclusion

Using a specific measurement protocol designed for flexor tendons of the fingers, a reproducible technique was established. By determining that sonography is a reproducible method of measuring and assessing flexor tendons of the fingers, this study has demonstrated that sonography is a useful means of measuring flexor tendons in quantitative terms (interval data) rather than purely describing the appearances of the structures (qualitative). Such protocols are essential for prospective studies in clinical groups.

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