Reproducibility of ultrasonographic thickness measurements of the common lateral extensors of the elbow

Masterthesis

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Abstract

Background: In individuals with clinical appearances of lateral elbow tendinopathy, the thickness of the common lateral extensors tendon is commonly evaluated by musculoskeletal ultrasonography. To date, the inter- and intra-rater reliability and intra-rater agreement of objective thickness measurements, in longitudinal as well as in transversal plane, are unknown. The reproducibility of these thickness measurement, by a standardized measurement protocol, should be established before it can be integrated into daily practice and study protocols.

Objective: To determine the inter- and intra-rater reliability and intra-rater agreement of musculoskeletal ultrasound thickness measurements of the common lateral extensors tendon of the elbow in the longitudinal and transversal plane in healthy adults.

Study design: A test-retest design.

Methods: The thickness of the common lateral extensors tendon was measured by ultrasonography in the longitudinal and transversal plane. Each participant was measured two times by rater 1 and rater 2, using a standardized protocol. Reproducibility was assessed by the intraclass correlation coefficient (ICC) and the smallest detectable change (SDC).

Results: Seventy-three healthy individuals participated in the study (44% females) with a mean ± SD age of 35.7 ± 14.9 years. Inter-rater reliability for both the longitudinal and transversal plane were fair to good (ICC of 0.67 and 0.49 respectively). ICC values for intra-rater reliability varied between fair to good and excellent (ICC of 0.73-0.92). P-values were < 0.05 in all cases. The SDC for both raters, as well as for the longitudinal and transversal plane, ranged from 0.50 to 0.78 mm and comprised 9.8-16.3% of the mean thickness.

Conclusion: Objective musculoskeletal ultrasonographic thickness measurement of the common lateral extensors tendon of the elbow has fair to excellent intra- and inter-rater reliability. In addition, agreement is acceptable, which makes musculoskeletal ultrasound a valuable tool for the evaluation of treatment effects on tendon thickness over time.

Keywords: Ultrasonography, lateral elbow tendinopathy, tennis elbow, reliability, agreement.

Samenvatting

Achtergrond: Bij personen met klinische verschijnselen van laterale extensoren tendinopathie wordt frequent de dikte van de gezamenlijke laterale extensoren pees beoordeeld door middel van musculoskeletale echografie. Tot op heden is de inter- en intra-beoordelaarsbetrouwbaarheid en de intra-beoordelaarsovereenstemming van deze objectieve diktemetingen, in het longitudinale en transversale vlak, nog onbekend. De reproduceerbaarheid van deze diktemetingen, middels een gestandaardiseerd protocol, dient te worden vastgesteld voordat deze consequent kunnen worden geïntegreerd in de dagelijkse praktijk en studieprotocollen.

Doelstelling: Het bepalen van de inter- en intra-beoordelaarsbetrouwbaarheid en intra-beoordelaarsovereenstemming van musculoskeletale echografie diktemetingen van de gezamenlijke extensoren pees van de elleboog in het longitudinale en transversale vlak bij gezonde volwassenen.

Studiedesign: Een test-hertest design.

Methode: De dikte van de gezamenlijke laterale extensoren pees werd gemetenmiddels echografie in het longitudinale en transversale vlak. Elke participant werd twee keer gemeten door meter 1 en meter 2, met gebruik van een gestandaardiseerd protocol. De reproduceerbaarheid werd bepaald door middel van de intraclass correlatie coëfficiënt (ICC) en de minimaal detecteerbare verandering (MDV).

Resultaten: Drieënzeventig gezonde personen namen deel aan de studie (44% vrouwen) met een gemiddelde ± SD leeftijd van 35,7± 14.9 jaren. Inter-beoordelaarsbetrouwbaarheid voor zowel het longitudinale als voor het transversale vlak waren redelijk tot goed (ICC van respectievelijk 0,67 en 0,49). ICC waarden voor intra-beoordelaarsbetrouwbaarheid varieerden van redelijk en goed tot uitstekend (ICC van 0,73-0,92). De P-waarden waren in alle gevallen< 0,001. De MDV voor beide meters alsook voor het longitudinale en transversale vlak, vielen binnen het bereik van 0,50 tot 0,78 mm en behelsden 9,8-16,3% van de gemiddelde dikte.

Conclusie: Objectieve musculoskeletale echografische diktemetingen van de gezamenlijke laterale extensoren pees van de elleboog hebben een redelijke tot uitstekende inter- en intra-beoordelaarsbetrouwbaarheid. Daarnaast is de overeenstemming acceptabel, waardoor musculoskeletale echografie een waardevol middel is voor de evaluatie van behandeleffecten op peesdikte in de tijd.

Introduction

Lateral elbow tendinopathy (LET) is a disorder concerning histopathological changes of the common lateral extensors tendon (CET) of the elbow, resulting in pain and loss of function of the affected tendon. LET occurs more often in the dominant arm and typically between the ages of 30 and 50 years (1). It frequently leads to the inability to work, resulting in a high economic burden (2,3). LET is a disorder with an incidence of 4-7 of 1000 adults per year and a prevalence of 1.1-1.3% in Western countries (3-5).

Musculoskeletal ultrasonography (MSU) is a non-invasive, low-cost and frequently used diagnostic technique in physical therapeutic practice to identify histopathological changes of elbow structures (6-10). Important histopathological tissue changes associated with clinical symptoms of LET, such as tendon thickening or thinning, calcifications, hypoechogenicity and ruptures, can be identified by MSU (11-14). Alterations in the fibrillar pattern of the tendon, including thickening, can be understood as a result of the histopathological changes at the boundaries between the endotendineum septa and collagen, attributable to lesions of these structures (15). Consequently, insight in tendon thickness in patients with LET is important for the quantification of the extent of tendon injury and for the evaluation of treatment effects over time.

Research focusing on the reproducibility of MSU measurement of CET is limited. Lee et al. (16) evaluated the inter-rater reliability of transversal MSU measurements of the CET thickness in healthy individuals and in patients with clinical diagnosis of LET. Intraclass correlation coefficients (ICC) were excellent (ICC of 0.86 and 0.73 respectively). This study did not evaluate the longitudinal thickness measurement, as recommended by the European Society of Musculoskeletal Radiology (12,13,15,17,18). Furthermore, the intra-rater reliability as well as the smallest detectable change (SDC), which is part of reproducibility and essential for evaluative purposes to represent a real change for repetitive measurements, were not determined in this study (31).

Miller *et al.* (19) investigated the intra-rater reliability of MSU measurements in individuals with the clinical diagnosis of LET. The Kappa value was fair for tendon thickening (Kappa of 0.53). Poltawski *et al.* (20) determined inter-rater reliability for

the assessment of features of LET in individuals with the clinical diagnosis of LET. Reliability was poor for tendon thickening (ICC of 0.46, 95% CI of 0.16-0.68). One possible explanation for this fair and poor reproducibility reported in earlier research, is that raters used different interpretations of the LET features under measurement and indistinct definition of tendon boundaries between raters. These studies focused on the diagnosis of LET by subjective dichotomous or ordinal scales, and did not perform an objective quantitative thickness measurement of the CET. Consequently, more insight in the reproducibility of MSU thickness measurement of the CET, using objective quantitative measurements, is needed.

Earlier research on the reliability of MSU in other structures has shown that MSU seems to be a rater-dependent diagnostic technique (21,22). This variation seems to be specifically dependent of the level of experience and standardization of techniques (21,22). Despite this, only a few studies have been performed on reproducibility of the CET measurements using various protocols (11,16,19). A standardized detailed protocol for measurement of the CET is lacking, resulting in the need for a reproducible protocol. Reproducibility of thickness measurement of the CET, using a standardized measurement protocol, should be established before MSU assessment can be integrated into daily practice and study protocols.

Therefore, the purpose of the current study is to determine intra- and inter-rater reliability and intra-rater agreement of MSU measurements of the longitudinal and transversal thickness of the common lateral extensor tendons of the elbow in healthy adult subjects, using a standardized measurement protocol.

Methods

Study design

To determine inter- and intra-rater reliability, as well as intra-rater agreement, a test-retest design was used.

Participants

Between March 2013 and April 2013, a convenience sample of healthy adult subjects was recruited at Fontys University of Applied Sciences in Eindhoven, the Netherlands. The sample size was determined at n = 39 according to Walter *et al.*

(23). Subjects with a previous history of injury of the upper extremity, any upper extremity surgery in their medical history, current elbow pain or limited range of motion of the elbow, were excluded from the study. The study was approved by the Research Ethics Committee of the University Medical Center Utrecht and each participant gave written informed consent before participating.

MSU measurements

Imaging was conducted by two physical therapists, with three (M.T.) and seven (M.S.) years of clinical MSU experience. Each rater was trained for one hour on four healthy volunteers to become familiar with the measurement protocol. The raters measured the thickness of the CET of the dominant arm of all participants in transversal and longitudinal plane in mm. Each thickness measurement was performed two times consecutively of which the average thickness was used for statistical analysis. Greyscale MSU was performed using two MylabOne (Esaote Benelux BV, Maastricht, the Netherlands) ultrasound scanners with a 13 MHz linear array transducer and a standardized superficial musculoskeletal preset.

Measurements were performed as described by the European Society of Musculoskeletal Radiology in the Musculoskeletal Ultrasound Technical Guidelines II, Elbow (17). Specified posture and measurement definitions were added in order to make the examination reproducible. The following specifications were added, the elbow was imaged with the participant seated with the arm to be measured at the examination table in front of the participant. The shoulder was placed in approximately 70° anteflexion, 90° elbow flexion, with the forearm in neutral position between supination and pronation, and with the thumb directed towards the ceiling. The raters applied the transducer with light pressure. Longitudinal tendon thickness was measured by placing one marker on the tendon surface, and another marker on the cortical bony interface of the lateral epicondyle. The measurements were performed approximately five mm from the joint midpoint. The transducer was placed in approximately 80° from the transversal plane in order to reach optimal image quality. Transversal tendon thickness was measured at the point where the humeral bone first appeared moving the transducer in proximal direction adjacent to the humeral-radial joint. According to daily practice, the thickness measurements were

performed instantly when the image was fixed, and the images were saved on a computer.

Measurement procedure

Baseline characteristics included gender, age (years), height (meters), weight (kilograms), body mass index (BMI in kilograms per meter squared), and the dominant arm. The measurement procedures are shown in figure 1. Each participant was independently measured two times by both raters. First, participant 1 was measured by rater 1 and participant 2 by rater 2. These measurements included a total of four measurements, two longitudinal and two transversal images per participant. After each measurement, participants changed rater, and the same procedure was repeated. The time between two measurements of one participant by one rater was approximately ten minutes and the raters were blinded for each other's and their own previous measurements through documentation of the outcomes by an assistant. To assess inter-rater reliability, the first measurements of both raters were used in the statistical analysis.

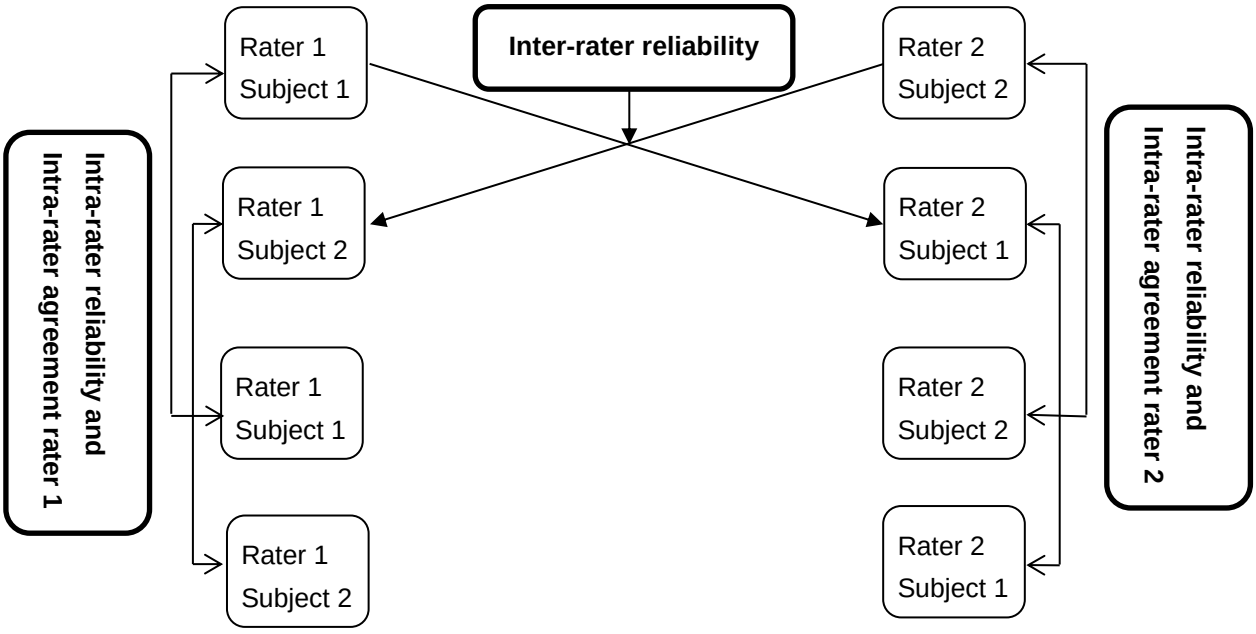

Figure 1. Flowchart of the study procedure.

Statistical analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (IBM SPSS) version 19.0 (SPSS Corp, Chicago, Ill, MSUA). The outcome measure was thickness measurement of the CET in mm. Baseline characteristics and mean CET thickness were presented as mean ± SD or percentages. All data were checked for normal distribution.

Reliability

For both inter- and intra-rater reliability, the $ICC_{agreement}$ (model 2,2) with a 95% CI was calculated (24,25). The ICC for intra-rater reliability of MSU measurement was computed for the longitudinal and transversal plane measurements for the two raters separately. The ICC for inter-rater reliability of MSU measurements was computed for longitudinal and transversal plane measurements. The ICC values were evaluated according to the rating criteria excellent > 0.75, fair to good 0.40–0.74 and poor < 0.40, as suggested by Shrout *et al.* (24).

Agreement

For intra-rater agreement of MSU measurement, the SDC was computed for the two raters, and for the longitudinal en transversal plane separately in mm, and as a percentage of the mean thickness. The SDC was based on the standard error of measurement (SEM), and was calculated using the formula $SDC = SEM_{agreement} \times \sqrt{2} \times 1.96$ (26). The $SEM_{agreement}$ was calculated using the formula $\sqrt{\sigma^2_{error}} = \sqrt{(\sigma^2_{measurement} + \sigma^2_{residual})}$ (25).

Results

Seventy-three healthy individuals participated in the study (44% females) with a mean (± SD) age of 35.7 (14.9) years and a mean (± SD) BMI of 23.9 (3.6) kg/m^2. Sixty-four participants were right hand dominant. A summary of the descriptive data for longitudinal and transversal thickness of the CET, for both raters separately, is presented in Table 1. There were no missing values and all data were normally distributed.

Table 1. The mean common lateral extensors tendon thickness ± SD and 95% CI for ultrasonographic measurements recorded by two raters (n=73).

	Mean ± SD in mm	95% CI
Set 1		
Lateral extensors longitudinal		
Rater 1 (M.T.)	5.11 ± 0.66	4.96-5.26
Rater 2 (M.S.)	5.34 ± 0.68	5.18-5.49
Lateral extensors transversal		
Rater 1 (M.T.)	4.65 ± 0.61	4.51-4.80
Rater 2 (M.S.)	4.76 ± 0.54	4.63-4.88
Set 2		
Lateral extensors longitudinal		
Rater 1 (M.T.)	5.10 ± 0.63	4.96-5.25
Rater 2 (M.S.)	5.33 ± 0.64	5.18-5.48
Lateral extensors transversal		
Rater 1 (M.T.)	4.70 ± 0.58	4.57-4.84
Rater 2 (M.S.)	4.80 ± 0.52	4.68-4.92

SD: standard deviation; CI: confidence interval

Inter-rater reliability for both the longitudinal and transversal plane were fair to good (ICC of 0.67 and 0.49 respectively). ICC values for intra-rater reliability for both raters as well as for longitudinal and transversal plane were excellent (ICC of 0.85-0.92), with the exception of the ICC for rater two in transversal plane, which was fair to good (ICC of 0.73). All ICC values were statistically significant with P-values < 0.001. The SDC for both raters, as well as for longitudinal and transversal plane, ranged from 0.50 to 0.78 mm and comprised 9.8-16.3% of the mean thickness. The ICC values for inter- and intra-rater reliability, and the SDC values for intra-rater agreement are shown in table 2.

Table 2. Inter- and intra-rater reliability and intra-rater agreement for ultrasonographic measurements of the common lateral extensors tendon thickness recorded by two raters (n=73).

	ICC (95% CI)	SDC in mm (percentage of the mean thickness)
Inter-rater reliability	0.67 (0.48-0.79)	-
Lateral extensors longitudinal		
Inter-rater reliability	0.49(0.30-0.65)	-
Lateral extensors transversal		
Intra-rater reliability		
Lateral extensors longitudinal		
Rater 1 (M.T.)	0.92 (0.88-0.95)	0.50 (9.8)
Rater 2 (M.S.)	0.86 (0.79-0.91)	0.67 (12.6)
Intra-rater reliability		
Lateral extensors transversal		
Rater 1 (M.T.)	0.85 (0.77-0.90)	0.64 (13.7)
Rater 2 (M.S.)	0.73 (0.60-0.82)	0.78 (16.3)

ICC: intraclass correlation coefficient; CI: confidence interval; SDC: smallest detectable change; P-values were <0.001 in all cases

Discussion

The aim of this study was to determine inter- and intra-rater reliability and intra-rater agreement of quantitative MSU measurements of the CET of the elbow. The results show that this method seems to be reproducible for measuring CET thickness. This study demonstrates good to excellent intra-rater reliability (ICC of 0.73-0.92), and fair to good inter-rater reliability (ICC of 0.49-0.67) of MSU thickness measurement of the CET for both longitudinal and transversal plane. Additionally, this study provides SDC values to reflect a real change for evaluative purposes in daily practice, and as a reference for future studies. The SDC values for both raters seem small with values between 0.50 and 0.78 mm, comprising 9.8-16.3% of the mean CET thickness. The results of the current study demonstrate that a thickness change of more than 0.50-0.64 mm for longitudinal measurement and 0.64-0.78 mm for transversal measurements represents a real change in follow-up measurements. Based on the results, longitudinal measurement of CET thickness seems to be the best measurement procedure for the use in daily practice.

This is the first study that investigated all components of reproducibility of the MSU thickness measurements of CET. To date, only one study determined the inter-rater reliability of objective MSU thickness measurement of the CET in transversal plane solely (16). Lee *et al.* (16) demonstrate excellent inter-rater reliability for MSU measurements in healthy individuals and patients with a clinical diagnosis of LET (ICC of 0.86 and 0.75 respectively). The ICC value for the transversal thickness measurement from the current study was lower (ICC of 0.49). The ICC values in the current study are based on a standardized protocol, the thickness measurement in longitudinal plane was better specified by means of the exact points of measurements, instead of the less exact location for measurement in transversal plane. This could explain the lower ICC value for the inter-rater reliability for the transversal measurements compared to the results of Lee *et al.* (16) and to the ICC values of the longitudinal measurements in the current study. Another explanation could be that the raters had less experience in measuring the CET thickness in transversal plane because they use the longitudinal measurement more frequently in daily practice. Even though both measurements demonstrated sufficient levels of reliability, it is recommended to apply the longitudinal thickness measurement rather than the transversal in daily practice.

Several studies investigated the reproducibility of quantitative MSU measurements in other tendons, such as the Achilles and the patellar tendon (27-29). Our findings are in agreement with these studies. Cassel *et al.* (27) reported a fair to good and excellent intra-rater reliability (ICC of 0.60 and 0.84 respectively) for the Achilles and patellar tendon thickness measurement in healthy subjects. Ying *et al.* (28) studied inter-rater reliability for measurements of the Achilles tendon thickness in healthy subjects. A fair to good level of inter-rater reliability was observed (ICC of 0.68). Leong *et al.* (29) showed an excellent intra-rater reliability (ICC of 0.92) for the MSU measurement of supraspinatus tendon thickness.

To our knowledge, this is the first study in which the SDC has been determined for MSU measurement of the CET thickness. The interpretation of the SDC should be considered in contrast with reference values of tendon thickness in individuals with clinical appearances of LET. A few studies determined reference values for healthy individuals as well as for individuals with clinical symptoms of LET (16,30). Lee *et al.* (16) found significantly different means for transversal CET thickness between symptomatic patients and healthy individuals of 4.8 mm and 3.0 mm respectively. They stated that a thickness greater than 4.2 mm was highly predictive for LET. This indicates that a tendon thickness increase of approximately 40% could be assessed in the CET of symptomatic individuals compared to tendon thickness of healthy subjects. The SDC in our study comprise 9.8-16.3% of the mean thickness. Consequently, it is to be expected that a thickened tendon will exceed the SDC values found in this study, which suggests a clinical applicable SDC. In the study of Lee *et al.* (16), the measurements were performed closer to the lateral epicondyle, leading to smaller means than the means in the current study. Leong *et al.*(29) found a SDC of approximately 9% of the mean for supraspinatus thickness in healthy individuals, which is slightly lower than the SDC proportion of the mean found in our study. This lower SDC could be a result of measuring a small amount of 22 shoulders in 11 individuals resulting in less variation in the study of Leong *et al.* (29).
Jaen-Diaz et al. (30), Toprak *et al.* (31), and Unturun *et al.* (32) determined reference values of 4.02 - 5.30 mm, 4.57 mm (SD ± 0.63), and 4.60 mm (SD ± 0.65) respectively, for CET thickness of the dominant arm in healthy people, which are comparable to our findings.

When applying the SDC it should be taken into account that the lateral collateral ligament cannot be distinguished from the covering CET, caused by a similar fibrillar echotexture (33,17).

The results of the current study cannot confirm the conclusions of previous research on the reliability of MSU measurements of other structures, which indicate that MSU seems to be a rater-dependent diagnostic technique (21,22). Since the less experienced rater shows higher ICC values for intra-rater reliability, the rater experience does not appear to have influence on reproducibility in the current study. Besides the rater experience, standardization of measurements is another factor that influences variation in measurements (21,22). The extended and structured measurement protocol, especially for the longitudinal measurements, used in this study could explain the fact that the ICC values of both raters are only slightly different. Another explanation could be that the less experienced rater still had three years of clinical MSU experience. Future research should focus on the influence of rater experience on reproducibility of MSU measurement, including more raters with various levels of experience.

The current study provides evidence on the clinical valuableness of objective MSU thickness measurements of the CET that could contribute to the diagnoses of LET and the evaluation of treatment effects on tissue level. Up till now, most studies on reproducibility of the CET thickness measurements used subjective dichotomous or ordinal scales as a classification, which makes it difficult to determine the exact boundaries between thickening, thinning or normal appearances of the tendons as well as to determine real thickness changes over time (10,19,20). The results of the current study show that reproducibility is higher for objective CET thickness measurements compared to the thickness measurements through a dichotomous or ordinal scale. Miller *et al.* (19) found a Kappa value of 0.53 for intra-rater reliability and Poltawski *et al.* (20) found an ICC value of 0.46 for inter-rater reliability for subjective MSU measurements of CET thickness. These reliability values are lower compared to the values found in the current study of 0.73-0.92 and 0.49-0.67 respectively. Consequently, the current study provides a reproducible MSU protocol for execution of quantitative thickness measurements of the CET for the use in daily practice.

The current study has some limitations. First of all, measurements of a single participant were repeated on the same day for practical reasons and because it was expected that subjects would remain stable between assessments. A short period between the assessments increases the risk that the raters remember the outcome of the former measurement. It is, however, unlikely that the raters remembered the quantity of the former measurements, because the subjects alternated between raters during one measurement session and the outcome was documented by a research assistant. Secondly, only healthy subjects were evaluated in the current study, rather than patients with clinical diagnosis of LET, which makes the results not generalizable to patients with LET. Future research should determine reproducibility of MSU thickness measurement of the CET, following this protocol, in subjects diagnosed with LET.

Conclusion

Objective musculoskeletal ultrasonographic thickness measurement of the common lateral extensor tendons of the elbow has fair to excellent intra- and inter-rater reliability. In addition, agreement is acceptable, which makes musculoskeletal ultrasound a valuable tool for the evaluation of treatment effects on tendon thickness over time.

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