



HAL
open science

Intra- and Interobserver Reliability of Ultrasound Measurement of the Plantar Fascia.

Michael Skovdal Rathleff, Carsten Møller Mølgaard, Jens Lykkegaard Olesen

► **To cite this version:**

Michael Skovdal Rathleff, Carsten Møller Mølgaard, Jens Lykkegaard Olesen. Intra- and Interobserver Reliability of Ultrasound Measurement of the Plantar Fascia.. *Journal of Clinical Ultrasound*, 2011, 39 (3), pp.128. <10.1002/jcu.20787>. <hal-00613769>

HAL Id: hal-00613769

<https://hal.science/hal-00613769v1>

Submitted on 6 Aug 2011

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization



**Intra- and Interobserver Reliability of Ultrasound
Measurement of the Plantar Fascia.**

Journal:	<i>Journal of Clinical Ultrasound</i>
Manuscript ID:	JCU-10-091.R1
Wiley - Manuscript type:	Research Article
Keywords:	foot, musculoskeletal, plantar fascia, Plantar fasciitis, sonography

SCHOLARONE™
Manuscripts

Review

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Ultrasound Measurement of the plantar fascia

Intra- and Interobserver Reliability of Ultrasound Measurement of the Plantar Fascia.

For Peer Review

1 Ultrasound Measurement of the plantar fascia
2
3
4
5

6 **ABSTRACT**

7 **Purpose**

8
9
10 To determine intra- and interobserver reliability and measurements precision of Ultrasound Imaging
11 (US) assessment of plantar fascia thickness when using one, the mean of two or three
12 measurements..
13
14
15
16
17

18 **Methods**

19
20 Two experienced observers scanned 20 healthy subjects twice with 60 minutes between test and
21 retest. A GE LOGIQe ultrasound scanner was used in the study. The built-in software in the scanner
22 was used to measure the thickness of the plantar fascia (PF). Reliability was calculated using
23 intraclass correlation coefficient (ICC) and limits of agreement (LOA).
24
25
26
27
28
29

30 **Results**

31
32 Intraobserver reliability using one sonogram was ICC 0.50 and 0.52, and using the mean of three
33 sonograms intraobserver reliability increased up to 0.77. Interobserver reliability when measuring
34 one sonogram was ICC 0.62 and increased to 0.82 when using the average of three sonograms.
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
LOA showed that when using the average of 3 sonograms, LOA decreased to 0.6 mm,
corresponding to 17.5% of the mean thickness of the PF.

56 **Conclusions**

57
58
59
60
The results showed that reliability increases when using the mean of three sonograms compared to
one. Limits of agreement based on intratester reliability shows that changes in thickness that are
larger than 0.6 mm can be considered actual changes in thickness and not a result of measurement
error.

Keywords: foot; musculoskeletal; plantar fascia; plantar fasciitis; reliability;sonography

1 Ultrasound Measurement of the plantar fascia
2
3

4 **Introduction**

5
6
7 Ultrasound imaging (US) is a well-established, non-invasive method for examining soft tissue
8
9 structures of the foot, including the plantar fascia (PF).^{1,2} It is a valuable tool in clinical practice to
10
11 evaluate the integrity of musculoskeletal structures qualitatively^{3,4}. Healthy tendons are known to
12
13 have a well-organized, uniform, hyperechoic pattern of collagen.⁵ Conversely, tendons with
14
15 pathology is often thicker and have a more disorganized, diffuse or hypoechoic appearance on US.
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

^{1,4} In essence, tendon health can be clinically evaluated by recording a grayscale sonogram of the tendon.

Diagnosis of plantar fasciitis is often made due to a combination of patient complaints, localization of pain and measurable thickening of the PF. This has been reported in case control studies where patients with plantar fasciitis was compared to healthy subjects.^{2,7} Interestingly a correlation has been seen between a reduction in the thickness of the PF and a reduction in pain.⁸

Ultrasonography is often used to support the diagnosis of plantar fasciitis by measuring a thickening of the PF. During rehabilitation US may also be used to secure that rehabilitation is proceeding as expected. The goal during rehabilitation is to observe a reduction in the thickness of the PF as well as a reduction in pain. The main problem with US is that it is a real-time and operator-dependent technique, and factors such as transducer-handling and machine-settings might influence size and appearance of the PF. If patients are examined several times by different examiners, it is essential to know intraobserver and interobserver reliability and precision of the method. This will allow the examiner to know if the changes observed are actual changes in thickness or a result of measurement error. To our knowledge, inter- and intraobserver reliability of US assessment of PF thickness and intra-day variation in the thickness of the PF are not yet known.

1 Ultrasound Measurement of the plantar fascia

2
3
4 The purpose of the study is to determine intra- and interobserver reliability and measurement
5
6 precision of US assessment of PF thickness when using one or the average of multiple scans. We
7
8 expected that intraobserver reliability would be higher than interobserver reliability and that both
9
10 inter- and intraobserver reliability would increase if the mean of three measurements was used.
11
12 Overall we expected that through a standardized protocol in which one examiner records and
13
14 measures three sonograms, US will be reliable ($ICC > 0.75$) and precise (Limits of agreement
15
16 $< 20\%$).
17
18
19

20 21 22 23 **Methods**

24 25 **Participants**

26
27 Twenty healthy volunteers, aged 20 to 31 years, without lower extremity symptoms, were recruited
28
29 for this study. Exclusion criteria were prior history of surgery to the foot and current or prior pain in
30
31 PF. Participants provided consent on forms approved by the local Ethics Committee in Denmark
32
33 (N-2009-0050).
34
35
36
37
38

39 40 **Examiners**

41
42 Two experienced observers were recruited for the study. Both had used musculoskeletal US as part
43
44 of daily examinations for 2-5 years. In order to minimize learning effect from customization to the
45
46 specific US machine used in the study, both examiners were allowed a recommendation period of 4
47
48 sessions with the US machine.
49
50

51 52 **Test**

53
54 Measurements were carried out using the set of recommendations from the ESSR (European
55
56 Society of Musculoskeletal Radiology), figure 1.⁹ Subjects were positioned in a prone position. The
57
58 toes were dorsally flexed, and the talo-crural joint was positioned in 0 degrees. As the PF is
59
60

1 Ultrasound Measurement of the plantar fascia

2
3
4 attached at the plantar surface at the toes, dorsal flexion of the toes creates tension in the PF and
5
6 makes the borders of the fascia more clearly defined. The transducer was placed over the plantar
7
8 aspect of the hindfoot to examine the PF at the insertion onto the calcaneus. Long-axis sonograms
9
10 were obtained approximately 0.5cm medial to the midline of the plantar surface of the foot, figure
11
12 2. Sonograms of both the right and the left foot were used in the study. The scanner was from
13
14 General Electric Healthcare (3135 Easton Tpke, Fairfield, CT, USA), model LOGIQ e. The
15
16 transducer that was used was a 12L RS, 13 MHz linear transducer. Scan depth was set to 2 cm.
17
18

19
20 Three successive scans were made of each foot to resemble a feasible clinical setting. Between each
21
22 scan the transducer was moved away from the foot and then repositioned. It was decided at random
23
24 whether observer 1 or 2 did the first scan and whether the scans were initiated on the left or the right
25
26 foot. To investigate whether the two examiners would increase reliability during the day of testing,
27
28 all subjects received a consecutive identification number. This allowed us to ensure that no learning
29
30 effect would influence the results.
31
32
33

34
35
36
37 Figure 1 about here.

38
39
40
41
42 Figure 2 about here.

43
44 Retest

45
46 After a period of approximately 60 minutes, the subjects underwent a second ultrasound
47
48 examination. During the retest, three additional sonograms of the PF were recorded. Care was taken
49
50 to maintain the same standardized foot position, to keep the ultrasound machine settings constant,
51
52 and to replicate the exact measurement. As physical activity and time-of-day might influence on the
53
54 actual thickness of the PF, we chose a period of 60 minutes between test and retest.^{9,10} All subjects
55
56 were instructed to rest between test and retest.
57
58
59
60

1 Ultrasound Measurement of the plantar fascia
2
3
4
5

6 Sonogram Analysis 7

8 All sonograms were measured using the built-in software in the scanner. PF thickness
9 measurements were made at the insertion onto the calcaneus. A third person randomly loaded
10 sonograms onto the screen for examiner 1 and 2 to measure, thereby blinding the observers to
11 which subject they were measuring.
12
13
14
15
16
17

18 Data Analysis 19

20 Statistical analysis was performed using SPSS version 15.0. The dependant measure of PF thickness
21 was calculated using the built-in software in the scanner. Each sequential measurement was
22 arranged in SPSS as a separate variable, and intraexaminer reliability with 95% confidence intervals
23 (CI) was estimated using two-way mixed-model, consistency-type intraclass correlation coefficients
24 (ICC).
25
26
27
28
29
30
31
32
33

34 Both examiners were blinded during measurement of the current and previous thickness values. The
35 reliability when using a single measurement was estimated using the first 2 measurement variables
36 and the “single measures” output from SPSS. The reliability when using a mean of 2 measurements
37 was estimated using the first 2 measurement variables and the “average measures” output from
38 SPSS. The reliability when using a mean of 3 measurements was similarly estimated using the first
39 3 measurement variables and the “average measures” output from SPSS. To determine
40 interobserver reliability, a parallel model (two-way random effect, total agreement) with single
41 measurement and mean values of 2 and 3 measurements was calculated.
42
43
44
45
46
47
48
49
50
51
52

53 Measurement precision was assessed by limits of agreement (LOA) and LOA as a percentage of the
54 mean value (LOA%).
55
56
57
58
59
60

1 Ultrasound Measurement of the plantar fascia
2
3

4 **Results** 5

6 The sample included in the study consisted of 4 men and 16 women. Mean age was 24.1 (SD 2.6).
7

8 Mean body mass index (BMI) was 22.2 (SD 2.1).
9

10 Paired t-test shows no significant difference between the right and left PF, ($p>0.05$), table 1. Paired
11

12 t-test shows no systematic difference in thickness between test and retest for observer 1 or observer
13

14 2 ($p>0.05$). ICC values show no significant difference in reliability between right and left PF which
15

16 is the reason why the right and left plantar fascias are pooled in the reliability analysis.
17
18
19
20
21
22

23 Table 1
24
25
26
27

28 **Intraobserver** 29

30 Intraobserver reliability measured by ICC for observer 1 using one sonogram was 0.50 (CI 0.23-
31

32 0.70) and increased to 0.77 (CI 0.56-0.87) when using the average of three sonograms.
33

34 Intraobserver reliability for observer 2 using one sonogram was 0.52 (CI 0.09-0.75) and increased
35

36 to 0.67 (CI 0.39-0.82) when using the average of three sonograms. When using one sonogram, LOA
37

38 was 0.8mm for observer 1 and 0.9 for observer 2. LOA decreased to 0.6mm (LOA% of 17.5%) and
39

40 0.8mm (LOA% 20.8) when using the mean of three sonograms, table 2.
41
42
43

44 Table 2
45
46

47 **Interobserver** 48

49 Interobserver reliability when measuring different sonograms measured by ICC was 0.62 (CI 0.37-
50

51 0.78) and increased to 0.82 (CI 0.65-0.91) when using the mean of three sonograms, table 3. When
52

53 the observers measured the same set of sonograms, reliability measured by ICC was 0.71 (CI 0.50-
54

55 0.84) and 0.73 (CI 0.55-0.85) and increased to 0.89 (CI 0.78-0.95) and 0.91 (CI 0.82-0.95)
56
57
58

59 Table 3
60

1 Ultrasound Measurement of the plantar fascia
2
3
4
5
6

7 Doing a visual inspection of the consecutive ID number plotted against the difference between test
8 and retest, there are no sign of learning effect with decreased difference with increasing ID number.
9
10 Furthermore a Bland-Altman plot with the difference between test and retest plotted against the
11 thickness of the PF shows no sign of increased error with increased thickness of the PF.
12
13
14
15
16
17

18 Discussion

19
20 The purpose of this study was to determine the intra- and interobserver reliability of US assessment
21 of PF thickness and to investigate improvements in measurement precision when using the mean
22 value of three measurements compared to one. Intraobserver reliability using one sonogram was
23 0.50 and 0.52 and using the mean of three sonograms intraobserver reliability increased to 0.67 and
24 0.77. Interobserver reliability when using one sonogram was 0.62 and increased to 0.82 when using
25 the average of three sonograms. LOA based on intratester reliability shows that changes in
26 thickness that are larger than 0.8mm can be considered actual changes in thickness and not a result
27 of measurement error.
28
29
30
31
32
33
34
35
36
37
38

39 A study by Liang et al¹² examined the intraobserver reliability of US to assess the thickness of
40 fascia plantaris in 14 patients diagnosed with plantar fasciitis. They showed ICC values of 0.90 (CI
41 0.70-0.97). Craig et al¹³ did a similar study on an unknown number of patients with diabetes and
42 found ICC of 0.89. Neither Liang et al¹² or Craig et al¹³ reported whether the measurements were
43 done by a blinded observer, how long time there was between test and retest or which ICC model
44 was used. This makes a direct comparison difficult.
45
46
47
48
49
50
51
52
53
54
55

56 Intraobserver reliability

57
58
59
60

1 Ultrasound Measurement of the plantar fascia

2
3
4 Koppenhaver¹⁴ examined the intraobserver reliability US to assess the thickness of transverses
5 abdominis (TrA) and multifidi (MU) with a study design similar to this. They found ICC values of
6
7 0.83 (CI 0.67-0.91) and 0.79 (CI 0.61-0.81), corresponding to 15.1% and 19.1% Standard Error of
8
9 the Estimate (SEM), which approximately corresponds to LOA of 0.7 mm and 0.9 mm. SEM and
10
11 LOA are comparable if study designs are similar.¹⁵ Springer et al¹⁶ did a similar study where they
12
13 found a intraobserver SEM of 17% when measuring the thickness of TrA, corresponding to
14
15 measurements precision of 1.3 mm. Bjordal¹⁷ examined intraobserver reliability when measuring
16
17 the thickness of the tendon from m supraspinatus. They found LOA of 0.4 mm and a mean value of
18
19 tendon thickness of 6.6 mm.
20
21
22
23
24
25
26
27

28 **Interobserver reliability**

29
30 O'Connor¹⁸ did an interobserver study of US measurement of Achilles tendon thickness. They
31
32 found a LOA% of 29%. Ying¹⁹ did a similar study and found interobserver measurement error
33
34 between 5 observers of 0.9-1.1 mm, which corresponds to a LOA% of approximately 20%.
35
36
37
38
39

40 It appears that intraobserver reliability of US assessments of human tendon and muscle thickness
41
42 are between 0.4 mm and 1.3 mm when measuring healthy tendons. LOA% is between 15 and 19%.

43
44 Interobserver reliability is slightly lower with LOA% of approximately 20%. We found
45
46 intraobserver reliability of ICC 0.77 and 0.67 and LOA 0.6 mm and 0.8 mm, corresponding to
47
48 17.5% and 20.8%. Interobserver reliability was ICC 0.82, LOA 0.57, corresponding to 15.8%. Both
49
50 intra- and interobserver reliability found in the literature correspond to the findings in this study.
51
52
53
54
55

56 **Clinical Relevance**

1 Ultrasound Measurement of the plantar fascia

2
3
4 Genc et al²⁶ showed a significant correlation between a decrease in thickness of the PF and
5
6
7 reduction in pain. This was present at both 1 and 6 months after treatment. They found that PF
8
9
10 thickness decreased 1.7 mm from initial treatment until follow-up at 1 month. At the next follow-up
11
12 after 6 months, the PF thickness had decreased another 0.6mm. Put into context of the current study,
13
14 the change in PF thickness that they observed in the first month of treatment reflects actual changes
15
16 in the thickness. However the change in thickness between 1 and 6 months of follow-up might be
17
18 caused by measurement error as they only recorded one sonogram. The results of this study showed
19
20 that if only one sonogram is measured, then the minimal detectable change in PF thickness is
21
22
23 0.8mm while it decreases to 0.6mm if three sonograms are used.
24
25
26
27

28 **Limitations of ICC**

29
30 In order to analyze intra- and interobserver reliability, we used ICC and LOA. ICC is a very
31
32 common method for describing reliability in different settings. However ICC has some limitations.
33
34 The size of ICC depends on the ratio of the variability between subjects to the total variability.¹⁸
35
36 This means that the size of ICC may be affected by factors related to the study sample itself.¹⁸ If
37
38 two separate test-retest studies are performed on two study samples where one study sample
39
40 consists of a homogenous group and the other consists of a very heterogeneous groups, the results
41
42 will be different. This is not because the methods being used have different reliability in the two
43
44 groups, but because ICC is dependent on the ratio of the variability between subjects to the total
45
46 variability.¹⁸ The higher ICC in a heterogeneous group is due to the calculations that ICC is based
47
48 on and not due to the fact that the methods in the two study samples disagree. The consequence is
49
50 that it is easier to disguise measurement error in a heterogeneous population. Liang et al¹² and Craig
51
52 et al¹³ both examined pathological groups that may consist of a more heterogeneous sample. This
53
54
55
56
57
58
59
60

1 Ultrasound Measurement of the plantar fascia

2
3
4 may explain why the LOA found in the current study corresponds to other studies, but ICC in the
5
6 current study is lower than what was reported by Liang et al¹² and Craig et al.¹³
7
8
9

10 11 **Comparison of mean thickness of the PF**

12 The earliest study where the thickness of the Pf was quantified by US was published in 1993.²¹

13
14
15 Studies that examine healthy subjects find mean values of the thickness between 2.6 and 3.9 mm.^{7,}

16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

21-27 The two largest studies, which included 154 and 110 subjects, found mean thickness of the PF of 3.2 mm (women and men combined) and 3.3 mm(± 0.3 mm) for women and 3.9 mm (± 0.5 mm) for men. The average values in these studies are very similar to the ones found in the present study.

Discrepancy in the positioning of subjects, different reference point of measurement and body mass index may to some extent explain the variation from 2.6 to 3.9 mm.

33 **Largest measurement error from scan or measurement**

34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

The results in table 2 and 3 show that the interobserver reliability when both observers measure the same scans is higher than when they measure separate scans. This indicates that scan is a source of error rather than measurement of the scan. The thickness of the PF is not identical across the entire insertion onto the calcaneus.²⁸ This means that movement of the transducer might affect the recorded thickness. Furthermore it indicates that some of the variance across the different scan is not only due to measurement error, but reflects actual changes in thickness.

52 **Conclusion**

53
54
55
56
57
58
59
60

Measurement of PF thickness by US is a reliable method. If the same observer measures the same person twice, the difference will be maximum 0.6 - 0.8 mm (ICC 0.67 – 0.77) in 95 % of the examinations when using the mean of three sonograms. If two different observers examine the same

1 Ultrasound Measurement of the plantar fascia
2
3

4 subject twice, the measurement error will be maximum 0.6 mm (ICC 0.82) in 95 % of the
5
6 examinations.
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For Peer Review

1 Ultrasound Measurement of the plantar fascia
2
3
4
5
6

7 Reference List
8

- 9 1. Fornage BD, Rifkin MD Ultrasound examination of the hand and foot. Radiol Clin North Am
10 1988; 26: 109-129
11
12
13
14
15 2. Cardinal E, Chhem RK, Beauregard CG, et al. Plantar fasciitis: sonographic evaluation.
16
17 Radiology 1996; 201: 257-259
18
19
20 3. Kannus P, Jozsa L Histopathological changes preceding spontaneous rupture of a tendon. A
21 controlled study of 891 patients. J Bone Joint Surg Am 1991; 73: 1507-1525
22
23
24
25
26 4. Martinoli C, Bianchi S, Derchi LE Tendon and nerve sonography. Radiol Clin North Am
27
28 1999; 37: 691-711, viii
29
30
31
32 5. Fornage BD, Rifkin MD Ultrasound examination of tendons. Radiol Clin North Am 1988; 26:
33 87-107
34
35
36
37
38 6. McPoil TG, Martin RL, Cornwall MW, et al. Heel pain--plantar fasciitis: clinical practice
39 guidelines linked to the international classification of function, disability, and health
40 from the orthopaedic section of the American Physical Therapy Association. J
41
42 Orthop Sports Phys Ther 2008; 38: A1-A18
43
44
45
46
47
48 7. Wearing SC, Smeathers JE, Sullivan PM, et al. Plantar fasciitis: are pain and fascial
49 thickness associated with arch shape and loading? Phys Ther 2007; 87: 1002-1008
50
51
52
53
54 8. Hammer DS, Adam F, Kreutz A, et al. Ultrasonographic evaluation at 6-month follow-up of
55 plantar fasciitis after extracorporeal shock wave therapy. Arch Orthop Trauma Surg
56
57 2005; 125: 6-9
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Ultrasound Measurement of the plantar fascia

9. Beggs, I, Bianchi, S, Bueno, A, and et al. Musculoskeletal Ultrasound Technical Guidelines: VI. Ankle. [First edition]. 2010. European Society of Musculoskeletal Radiology. Accessed 19-8-2010 on www.essr.org/html/img/pool/ankle.pdf
10. Grigg NL, Stevenson NJ, Wearing SC, Smeathers JE Incidental walking activity is sufficient to induce time-dependent conditioning of the Achilles tendon. *Gait Posture* 2009 2010; 31(1):64-7.
- 11 Grigg NL, Wearing SC, Smeathers JE Eccentric calf muscle exercise produces a greater acute reduction in Achilles tendon thickness than concentric exercise. *Br J Sports Med* 2009; 43: 280-283
12. Liang HW, Wang TG, Chen WS, et al. Thinner plantar fascia predicts decreased pain after extracorporeal shock wave therapy. *Clin Orthop Relat Res* 2007; 460: 219-225
13. Craig ME, Duffin AC, Gallego PH, et al. Plantar fascia thickness, a measure of tissue glycation, predicts the development of complications in adolescents with type 1 diabetes. *Diabetes Care* 2008; 31: 1201-1206
14. Koppenhaver SL, Parent EC, Teyhen DS, et al. The effect of averaging multiple trials on measurement error during ultrasound imaging of transversus abdominis and lumbar multifidus muscles in individuals with low back pain. *J Orthop Sports Phys Ther* 2009; 39: 604-611
15. Atkinson G, Nevill A Typical error versus limits of agreement. *Sports Med* 2000; 30: 375-381

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Ultrasound Measurement of the plantar fascia

16. Springer BA, Mielcarek BJ, Nesfield TK, et al. Relationships among lateral abdominal muscles, gender, body mass index, and hand dominance. *J Orthop Sports Phys Ther* 2006; 36: 289-297
17. Bjordal, JM, Demmink, JH, and Ljunggren AE. Tendon Thickness and Depth from Skin for Supraspinatus, Common Wrist and Finger Extensors, Patellar and Achilles Tendons: Ultrasonography study of healthy subjects. *Phys.Ther.* 89[6], 375-383. 2005.
18. O'Connor PJ, Grainger AJ, Morgan SR, et al. Ultrasound assessment of tendons in asymptomatic volunteers: a study of reproducibility. *Eur Radiol* 2004; 14: 1968-1973
19. Ying M, Yeung E, Li B, et al. Sonographic evaluation of the size of Achilles tendon: the effect of exercise and dominance of the ankle. *Ultrasound Med Biol* 2003; 29: 637-642
20. Norman G The pruning of Doctor McDonough and the "humanizing" of statistics. *Fertil Steril* 1997; 68: 570-573
21. Wall JR, Harkness MA, Crawford A Ultrasound diagnosis of plantar fasciitis. *Foot Ankle* 1993; 14: 465-470
22. Vohra PK, Kincaid BR, Japour CJ, et al. Ultrasonographic evaluation of plantar fascia bands. A retrospective study of 211 symptomatic feet. *J Am Podiatr Med Assoc* 2002; 92: 444-449

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Ultrasound Measurement of the plantar fascia

23. Pascual HJ, Garcia JM, Matamoros EC, et al. Relationship of body mass index, ankle dorsiflexion, and foot pronation on plantar fascia thickness in healthy, asymptomatic subjects. *J Am Podiatr Med Assoc* 2008; 98: 379-385
24. Akfirat M, Sen C, Gunes T Ultrasonographic appearance of the plantar fasciitis. *Clin Imaging* 2003; 27: 353-357
25. Ozdemir H, Yilmaz E, Murat A, et al. Sonographic evaluation of plantar fasciitis and relation to body mass index. *Eur J Radiol* 2005; 54: 443-447
26. Genc H, Saracoglu M, Nacir B, et al. Long-term ultrasonographic follow-up of plantar fasciitis patients treated with steroid injection. *Joint Bone Spine* 2005; 72: 61-65
27. Sabir N, Demirlenk S, Yagci B, et al. Clinical utility of sonography in diagnosing plantar fasciitis. *J Ultrasound Med* 2005; 24: 1041-1048
28. Moraes do Carmo CC, Fonseca de Almeida Melao LI, et al. Anatomical features of plantar aponeurosis: cadaveric study using ultrasonography and magnetic resonance imaging. *Skeletal Radiol* 2008; 37: 929-935

Ultrasound Measurement of the plantar fascia

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Intra- and Interobserver Reliability of Ultrasound Measurement of the Plantar Fascia.

Deleted: Quantitative

Deleted: Human

For Peer Review

1 Ultrasound Measurement of the plantar fascia

2
3
4
5 **ABSTRACT**

6
7 **Purpose**

8 To determine intra- and interobserver reliability and measurements precision of [Ultrasound Imaging](#)
9 [\(US\)](#) assessment of plantar fascia thickness when using one, the mean of two or three
10 [measurements](#).
11
12
13

Deleted: UI

Deleted: image

Deleted: s

14
15 **Methods**

16 Two experienced observers scanned 20 healthy subjects twice with 60 minutes between test and
17 retest. A GE LOGIQe ultrasound scanner was used in the study. The [built-in](#) software in the scanner
18 was used to measure the [thickness](#) of the [plantar fascia \(PF\)](#). Reliability was calculated using
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
intraclass correlation coefficient (ICC) and limits of agreement (LOA).

Deleted: inbuilt

Deleted: diameter

Deleted: PF

36
37 **Results**

38 Intraobserver reliability using one [sonogram](#) was ICC 0.50 and 0.52, and using the mean of three
39 [sonograms](#) intraobserver reliability increased up to 0.77. Interobserver reliability when measuring
40 one [sonogram](#) was ICC 0.62 and increased to 0.82 when using the average of three [sonograms](#).
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
LOA showed that when using the average of 3 [sonograms](#), LOA decreased to 0.6 mm,
corresponding to 17.5% of the mean [thickness](#) of the [PF](#).

Deleted: image

Deleted: image

Deleted: image

Deleted: image

Deleted: image

Deleted: 3

Deleted: diameter

Deleted: plantar fascia

36
37 **Conclusions**

38 The results showed that reliability increases when using the mean of three [sonograms](#) compared to
39 one. Limits of agreement based on intratester reliability shows that changes in [thickness](#) that are
40 larger than 0.6 mm can be considered actual changes in [thickness](#) and not a result of measurement
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
error.

Deleted: image

Deleted: diameter

Deleted: 3

Deleted: diameter

46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Keywords: [foot](#); [musculoskeletal](#); [plantar fascia](#); [plantar fasciitis](#); [reliability](#); [sonography](#)

Deleted: ; foot

Deleted: plantar fasciitis

Ultrasound Measurement of the plantar fascia

Introduction

Ultrasound imaging (US) is a well-established, non-invasive method for examining soft tissue structures of the foot, including the plantar fascia (PF).^{1,2} It is a valuable tool in clinical practice to evaluate the integrity of musculoskeletal structures qualitatively^{3,4}. Healthy tendons are known to have a well-organized, uniform, hyperechoic pattern of collagen.⁵ Conversely, tendons with pathology is often thicker and have a more disorganized, diffuse or hypoechoic appearance on US.^{1,4} In essence, tendon health can be clinically evaluated by recording a grayscale sonogram of the tendon.

Deleted: UI

Deleted: qualitatively

Deleted: ,

Deleted: UI

Deleted: image

Deleted: texture

Diagnosis of plantar fasciitis is often made due to a combination of patient complaints, localization of pain and measurable thickening of the PF. This has been reported in case control studies where patients with plantar fasciitis was compared to healthy subjects.^{2,7} Interestingly a correlation has been seen between a reduction in the thickness of the PF and a reduction in pain.⁸

Deleted: as

Deleted: between

Deleted: plantar fascia

Deleted: PF

Deleted: are

Deleted: diameter

Deleted: plantar fascia

Ultrasonography is often used to support the diagnosis of plantar fasciitis by measuring a thickening of the PF. During rehabilitation US may also be used to secure that rehabilitation is proceeding as expected. The goal during rehabilitation is to observe a reduction in the thickness of the PF as well as a reduction in pain. The main problem with US is that it is a real-time and operator-dependent technique, and factors such as transducer-handling and machine-settings might influence size and appearance of the PF. If patients are examined several times by different examiners, it is essential to know intraobserver and interobserver reliability and precision of the method. This will allow the examiner to know if the changes observed are actual changes in thickness or a result of measurement error. To our knowledge, inter- and intraobserver reliability of US assessment of PF thickness and intra-day variation in the thickness of the PF are not yet known.

Deleted: plantar fascia

Deleted: As UI is an integrated part of the diagnosis and evaluation of treatment success, patients are often examined several times to control if rehabilitation is proceeding as expected.

Deleted: diameter

Deleted: plantar fascia

Deleted: UI

Deleted: can

Deleted: plantar fascia

Deleted: diameter

Deleted: UI

Deleted: plantar fascia

Deleted: diameter

Deleted: plantar fascia

Deleted: is

1 Ultrasound Measurement of the plantar fascia

2
3 The purpose of the study is to determine intra- and interobserver reliability and measurement
4 precision of US assessment of PF thickness when using one or the average of multiple scans. We
5 expected that intraobserver reliability would be higher than interobserver reliability and that both
6 inter- and intraobserver reliability would increase if the mean of three measurements was used.

Deleted: s

Deleted: UI

Deleted: plantar fascia

Deleted: will

7
8 Overall we expected that through a standardized protocol in which one examiner records and
9 measures three sonograms, US will be reliable (ICC>0.75) and precise (Limits of agreement
10 $\leq 20\%$).

Deleted: image

Deleted: UI

Deleted:

Deleted:

11 **Methods**

12 **Participants**

13
14 Twenty healthy volunteers, aged 20 to 31 years, without lower extremity symptoms, were recruited
15 for this study. Exclusion criteria were prior history of surgery to the foot and current or prior pain in
16 PF. Participants provided consent on forms approved by the local Ethics Committee in Denmark
17 (N-2009-0050).

Deleted: ,

Deleted: the plantar fascia

Deleted: National

18 **Examiners**

19
20 Two experienced observers were recruited for the study. Both had used musculoskeletal US as part
21 of daily examinations for 2-5 years. In order to minimize learning effect from customization to the
22 specific US machine used in the study, both examiners were allowed a recommendation period of 4
23 sessions with the US machine.

Deleted: have

Deleted: been using

Deleted: UI

Deleted:

Deleted: between

Deleted: and

Deleted: Prior to testing

Deleted: were instructed in the use of the specific UI machine and

Deleted: UI

Deleted: used in the study.

24 **Test**

25
26 Measurements were carried out using the set of recommendations from the ESSR (European
27 Society of Musculoskeletal Radiology), figure 1.⁹ Subjects were positioned in a prone position. The
28 toes were dorsally flexed, and the talo-crural joint was positioned in 0 degrees. As the PF is

Deleted: plantar fascia

Ultrasound Measurement of the plantar fascia

attached at the plantar surface at the toes, dorsal flexion of the toes creates tension in the PF and makes the borders of the fascia more clearly defined. The transducer was placed over the plantar aspect of the hindfoot to examine the PF at the insertion onto the calcaneus. Long-axis sonograms were obtained approximately 0.5cm medial to the midline of the plantar surface of the foot, figure 2. Sonograms of both the right and the left foot were used in the study. The scanner was from

Deleted: s

Deleted: plantar fascia

Deleted: to use the windlass mechanism to stretch the plantar fascia

Deleted:

Deleted: plantar fascia

Deleted: scans

Deleted: just

Deleted: Image

Deleted: from

General Electric Healthcare (3135 Easton Tpk, Fairfield, CT, USA), model LOGIQ e. The

transducer that was used was a 12L RS, 13 MHz linear transducer. Scan depth was set to 2 cm.

Three successive scans were made of each foot to resemble a feasible clinical setting. Between each scan the transducer was moved away from the foot and then repositioned. It was decided at random whether observer 1 or 2 did the first scan and whether the scans were initiated on the left or the right foot. To investigate whether the two examiners would increase reliability during the day of testing,

Deleted: randomly chosen

Deleted: if

Deleted: randomly chosen if

Deleted: if

all subjects received a consecutive identification number. This allowed us to ensure that no learning effect would influence the results.

[Figure 1 about here.](#)

[Figure 2 about here.](#)

Retest

After a period of approximately 60 minutes, the subjects underwent a second ultrasound examination. During the retest, three additional sonograms of the PF were recorded. Care was taken to maintain the same standardized foot position, to keep the ultrasound machine settings constant, and to replicate the exact measurement. As physical activity and time-of-day might influence on the actual thickness of the PF, we chose a period of 60 minutes between test and retest.^{9,10} All subjects where instructed to rest between test and retest.

Deleted: image

Deleted: plantar fascia

Deleted: could

Deleted: plantar fascia

Deleted: o

Deleted: No significant change in the quantitative ultrasound outcomes were expected during the initial and final tests, because subjects were instructed to rest between these tests.

Ultrasound Measurement of the plantar fascia

Sonogram Analysis

All sonograms were measured using the built-in software in the scanner. PF thickness measurements were made at the insertion onto the calcaneus. A third person randomly loaded sonograms onto the screen for examiner 1 and 2 to measure, thereby blinding the observers to which subject they were measuring.

Deleted: Image

Deleted: image

Deleted: inbuilt

Deleted: Plantar fascia

Deleted: image

Deleted: and

Data Analysis

Statistical analysis was performed using SPSS version 15.0. The dependant measure of PF thickness was calculated using the built-in software in the scanner. Each sequential measurement was arranged in SPSS as a separate variable, and intraexaminer reliability with 95% confidence intervals (CI) was estimated using two-way mixed-model, consistency-type intraclass correlation coefficients (ICC).

Deleted: plantar fascia

Deleted: inbuilt

Deleted:

Deleted: 2

Both examiners were blinded during measurement of the current and previous thickness values. The reliability when using a single measurement was estimated using the first 2 measurement variables and the “single measures” output from SPSS. The reliability when using a mean of 2 measurements was estimated using the first 2 measurement variables and the “average measures” output from SPSS. The reliability when using a mean of 3 measurements, was similarly estimated using the first 3 measurement variables and the “average measures” output from SPSS. To determine interobserver reliability, a parallel model (two-way random effect, total agreement) with single measurement and mean values of 2 and 3 measurements was calculated.

Deleted: to

Deleted: (model 3,1)

Deleted: (model 3,2)

Deleted: ,

Deleted: ,

Deleted: (model 3,k)

Deleted: ICC 2.1 was calculated using

Measurement precision was assessed by limits of agreement (LOA) and LOA as a percentage of the mean value (LOA%).

Deleted: To asses m

Deleted: e used

1 Ultrasound Measurement of the plantar fascia

2
3 **Results**

4 The sample included in the study consisted of 4 men and 16 women. Mean age was 24.1 (SD 2.6).

5 Mean body mass index (BMI) was 22.2 (SD 2.1).

6 Paired t-test shows no significant difference between the right and left PF, (p>0.05), table 1. Paired
7 t-test shows no systematic difference in thickness between test and retest for observer 1 or observer
8 2 (p>0.05). ICC values show no significant difference in reliability between right and left PF which
9 is the reason why the right and left plantar fascias are pooled in the reliability analysis.

- Deleted: PF
- Deleted: plantar fascia
- Deleted: diameter
- Deleted: re-test
- Deleted: PF
- Deleted: plantar fascia

10
11
12
13
14
15
16
17
18 Table 1

19
20
21
22 **Intraobserver**

23 Intraobserver reliability measured by ICC for observer 1 using one sonogram was 0.50 (CI 0.23-
24 0.70) and increased to 0.77 (CI 0.56-0.87) when using the average of three sonograms.

25 Intraobserver reliability for observer 2 using one sonogram was 0.52 (CI 0.09-0.75) and increased
26 to 0.67 (CI 0.39-0.82) when using the average of three sonograms. When using one sonogram, LOA
27 was 0.8mm for observer 1 and 0.9 for observer 2. LOA decreased to 0.6mm (LOA% of 17.5%) and
28 0.8mm (LOA% 20.8) when using the mean of three sonograms, table 2.

29
30
31
32
33
34
35
36 [Table 2](#)

37
38 **Interobserver**

39 Interobserver reliability when measuring different sonograms measured by ICC was 0.62 (CI 0.37-
40 0.78) and increased to 0.82 (CI 0.65-0.91) when using the mean of three sonograms, table 3. When
41 the observers measured the same set of sonograms, reliability measured by ICC was 0.71 (CI 0.50-
42 0.84) and 0.73 (CI 0.55-0.85) and increased to 0.89 (CI 0.78-0.95) and 0.91 (CI 0.82-0.95)

43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Table 3

- Deleted: image
- Deleted: image
- Deleted: image
- Deleted: image
- Deleted: U
- Deleted: image
- Deleted: 76
- Deleted: one
- Deleted: 1
- Deleted: two
- Deleted: 3
- Deleted: 75
- Deleted: image
- Deleted: 3
- Deleted: image
- Deleted: image
- Deleted: 2
- Deleted: image
- Deleted: 2

Ultrasound Measurement of the plantar fascia

Doing a visual inspection of the consecutive ID number plotted against the difference between test and retest, there are no sign of learning effect with decreased difference with increasing ID number.

Deleted: re-test

Furthermore a Bland-Altman plot with the difference between test and retest plotted against the

thickness of the PF shows no sign of increased error with increased thickness of the PF.

Deleted: diameter

Deleted: plantar fascia

Deleted: PF

Deleted:

Deleted: diameter

Deleted: diameter

Deleted: plantar fascia

Deleted: PF

Deleted: UI

Deleted: plantar fascia

Deleted: secondly

Deleted: image

Deleted: image

Deleted: image

Deleted: image

Discussion

The purpose of this study was to determine the intra- and interobserver reliability of US assessment of PF thickness and to investigate improvements in measurement precision when using the mean value of three measurements compared to one. Intraobserver reliability using one sonogram was 0.50 and 0.52 and using the mean of three sonograms intraobserver reliability increased to 0.67 and 0.77. Interobserver reliability when using one sonogram was 0.62 and increased to 0.82 when using the average of three sonograms. LOA based on intratester reliability shows that changes in thickness that are larger than 0.8mm can be considered actual changes in thickness and not a result of measurement error.

Deleted: diameter

Deleted: 75

Deleted: diameter

Deleted: UI

Deleted: diameter

A study by Liang et al¹² examined the intraobserver reliability of US to assess the thickness of fascia plantaris in 14 patients diagnosed with plantar fasciitis. They showed ICC values of 0.90 (CI 0.70-0.97). Craig et al¹³ did a similar study on an unknown number of patients with diabetes and found ICC of 0.89. Neither Liang et al¹² or Craig et al¹³ reported whether the measurements were done by a blinded observer, how long time there was between test and retest or which ICC model was used. This makes a direct comparison difficult.

Deleted: if

Deleted: or

Deleted: re-test

Deleted: ,

Intraobserver reliability

Ultrasound Measurement of the plantar fascia

Koppenhaver¹⁴ examined the intraobserver reliability US to assess the thickness of transverses abdominis (TrA) and multifidi (MU) with a study design similar to this. They found ICC values of 0.83 (CI 0.67-0.91) and 0.79 (CI 0.61-0.81), corresponding to 15.1% and 19.1% Standard Error of the Estimate (SEM), which approximately corresponds to LOA of 0.7 mm and 0.9 mm. SEM and LOA are comparable if study designs are similar.¹⁵ Springer et al¹⁶ did a similar study where they found a intraobserver SEM of 17% when measuring the thickness of TrA, corresponding to measurements precision of 1.3 mm. Bjordal¹⁷ examined intraobserver reliability when measuring the thickness of the tendon from m supraspinatus. They found LOA of 0.4 mm and a mean value of tendon thickness of 6.6 mm.

- Deleted: UI
- Deleted: diameter
- Deleted:
- Deleted:
- Deleted: approximately
- Deleted: 68
- Deleted: 89
- Deleted:
- Deleted: diameter
- Deleted: 35

Interobserver reliability

O'Connor¹⁸ did an interobserver study of US measurement of Achilles tendon thickness. They found a LOA% of 29%. Ying¹⁹ did a similar study and found interobserver measurement error between 5 observers of 0.9-1.1 mm, which corresponds to a LOA% of approximately 20%.

- Deleted: UI
- Deleted: diameter
- Deleted:
- Deleted: 4
- Deleted: 07

It appears that intraobserver reliability of US assessments of human tendon and muscle thickness are between 0.4 mm and 1.3 mm when measuring healthy tendons. LOA% is between 15 and 19%. Interobserver reliability is slightly lower with LOA% of approximately 20%. We found intraobserver reliability of ICC 0.77 and 0.67 and LOA 0.6 mm and 0.8 mm, corresponding to 17.5% and 20.8%. Interobserver reliability was ICC 0.82, LOA 0.57, corresponding to 15.8%. Both intra- and interobserver reliability found in the literature correspond to the findings in this study.

- Deleted: UI
- Deleted: diameter
- Deleted: 35
- Deleted:
- Deleted:
- Deleted: 3
- Deleted: 75
- Deleted:
- Deleted:
- Deleted: s

Clinical Relevance

Ultrasound Measurement of the plantar fascia

Genc et al²⁶ showed a significant correlation between a decrease in thickness of the PF and reduction in pain. This was present at both 1 and 6 months after treatment. They found that PF thickness decreased 1.7 mm from initial treatment until follow-up at 1 month. At the next follow-up after 6 months, the PF thickness had decreased another 0.6mm. Put into context of the current study, the change in PF thickness that they observed in the first month of treatment reflects actual changes in the thickness. However the change in thickness between 1 and 6 months of follow-up might be caused by measurement error as they only recorded one sonogram. The results of this study showed that if only one sonogram is measured, then the minimal detectable change in PF thickness is 0.8mm while it decreases to 0.6mm if three sonograms are used.

Formatted: Superscript

Deleted: plantar fascia

Deleted: plantar fascia

Deleted: six

Deleted: plantar fascia

Deleted: plantar fascia

Deleted: could

Deleted: from

Deleted: plantar fascia

Limitations of ICC

In order to analyze intra- and interobserver reliability, we used ICC and LOA. ICC is a very common method for describing reliability in different settings. However ICC has some limitations. The size of ICC depends on the ratio of the variability between subjects to the total variability.¹⁸ This means that the size of ICC may be affected by factors related to the study sample itself.¹⁸ If two separate test-retest studies are performed on two study samples where one study sample consists of a homogenous group and the other consists of a very heterogeneous groups, the results will be different. This is not because the methods being used have different reliability in the two groups, but because ICC is dependent on the ratio of the variability between subjects to the total variability.¹⁸ The higher ICC in a heterogeneous group is due to the calculations that ICC is based on and not due to the fact that the methods in the two study samples disagree. The consequence is that it is easier to disguise measurement error in a heterogeneous population. Liang et al¹² and Craig et al¹³ both examined pathological groups that may consist of a more heterogeneous sample. This

Deleted: ¶

Deleted: T

Deleted: re-test

Deleted: ,

Deleted: group is

Deleted: study sample

Deleted: an artefact of

Deleted: ,

Deleted: because

1 Ultrasound Measurement of the plantar fascia

2
3 may explain why the LOA found in the current study corresponds to other studies, but ICC in the
4
5 current study is lower than what was reported by Liang et al.¹² and Craig et al.¹³

9 Comparison of mean thickness of the PF

10 The earliest study where the thickness of the PF was quantified by US was published in 1993.²¹

11 Studies that examine healthy subjects find mean values of the thickness between 2.6 and 3.9 mm.⁷

12
13 ²¹⁻²⁷ The two largest studies, which included 154 and 110 subjects, found mean thickness of the PF
14 of 3.2 mm (women and men combined) and 3.3 mm (± 0.3 mm) for women and 3.9 mm (± 0.5 mm)

15
16 for men. The average values in these studies are very similar to the ones found in the present study.

17
18 Discrepancy in the positioning of subjects, different reference point of measurement and body mass
19
20 index may to some extent explain the variation from 2.6 to 3.9 mm.

Deleted: The external validity

Deleted: plantar fascia

Deleted: of mean values of the
plantar fascia

Deleted: .

Deleted: diameter

Deleted: plantar fascia

Deleted: UI

Deleted: s

Deleted: diameter

Deleted: that

Deleted: diameter

Deleted: plantar fascia

Deleted: PF

Deleted: .

26 **Largest measurement error from scan or measurement**

27
28 The results in table 2 and 3 show that the interobserver reliability when both observers measure the
29
30 same scans is higher than when they measure separate scans. This indicates that scan is a source of

31 error rather than measurement of the scan. The thickness of the PF is not identical across the entire
32
33 insertion onto the calcaneus.²⁸ This means that movement of the transducer might affect the

34 recorded thickness. Furthermore it indicates that some of the variance across the different scan is
35
36 not only due to measurement error, but reflects actual changes in thickness.

Deleted: diameter

Deleted: plantar fascia

Deleted: diameter

Deleted: are

Deleted: s

Deleted: diameter

42 **Conclusion**

43 Measurement of PF thickness by US is a reliable method. If the same observer measures the same
44
45 person twice, the difference will be maximum 0.6 - 0.8 mm (ICC 0.67 – 0.77) in 95 % of the

46
47 examinations when using the mean of three sonograms. If two different observers examine the same
48
49

Deleted: PF

Deleted: plantar fascia

Deleted: UI

Deleted: two times

Deleted: in 95 % of the times

Deleted: 3

Deleted: 75

Deleted: image

Ultrasound Measurement of the plantar fascia

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

subject twice, the measurement error will be maximum 0.6 mm (ICC 0.82) in 95 % of the examinations.

Deleted: then in 95 % of the examinations

Deleted: imally

Deleted: 57

Deleted: .

Deleted: Clinical Relevance¶
The results showed that reliability increases when using the mean of three images compared to one. Limits of agreement based on intratester reliability shows that changes in diameter that are larger than 0.63 mm can be considered actual changes in diameter and not a result of measurement error. ¶

For Peer Review

1 Ultrasound Measurement of the plantar fascia
2
3
4

5 Reference List
6

- 7 1. Fornage BD, Rifkin MD Ultrasound examination of the hand and foot. Radiol Clin North Am
8 1988; 26: 109-129
9
10
11 2. Cardinal E, Chhem RK, Beauregard CG, et al. Plantar fasciitis: sonographic evaluation.
12 Radiology 1996; 201: 257-259
13
14
15 3. Kannus P, Jozsa L Histopathological changes preceding spontaneous rupture of a tendon. A
16 controlled study of 891 patients. J Bone Joint Surg Am 1991; 73: 1507-1525
17
18
19 4. Martinoli C, Bianchi S, Derchi LE Tendon and nerve sonography. Radiol Clin North Am
20 1999; 37: 691-711, viii
21
22
23 5. Fornage BD, Rifkin MD Ultrasound examination of tendons. Radiol Clin North Am 1988; 26:
24 87-107
25
26
27 6. McPoil TG, Martin RL, Cornwall MW, et al. Heel pain--plantar fasciitis: clinical practice
28 guidelines linked to the international classification of function, disability, and health
29 from the orthopaedic section of the American Physical Therapy Association. J
30 Orthop Sports Phys Ther 2008; 38: A1-A18
31
32
33 7. Wearing SC, Smeathers JE, Sullivan PM, et al. Plantar fasciitis: are pain and fascial
34 thickness associated with arch shape and loading? Phys Ther 2007; 87: 1002-1008
35
36
37 8. Hammer DS, Adam F, Kreutz A, et al. Ultrasonographic evaluation at 6-month follow-up of
38 plantar fasciitis after extracorporeal shock wave therapy. Arch Orthop Trauma Surg
39 2005; 125: 6-9
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Ultrasound Measurement of the plantar fascia

- 1
2
3 9. Beggs, I, Bianchi, S, Bueno, A, and et al. Musculoskeletal Ultrasound Technical Guidelines:
4
5 VI. Ankle. [First edition]. 2010. European Society of Musculoskeletal Radiology.
6
7 Accessed 19-8-2010 on www.essr.org/html/img/pool/ankle.pdf
8
9
- 10
11 10. Grigg NL, Stevenson NJ, Wearing SC, Smeathers JE Incidental walking activity is sufficient
12
13 to induce time-dependent conditioning of the Achilles tendon. *Gait Posture* 2009
14
15 2010; 31(1):64-7.
16
17
- 18 11 Grigg NL, Wearing SC, Smeathers JE Eccentric calf muscle exercise produces a greater
19
20 acute reduction in Achilles tendon thickness than concentric exercise. *Br J Sports*
21
22 *Med* 2009; 43: 280-283
23
24
- 25 12. Liang HW, Wang TG, Chen WS, et al. Thinner plantar fascia predicts decreased pain after
26
27 extracorporeal shock wave therapy. *Clin Orthop Relat Res* 2007; 460: 219-225
28
29
- 30 13. Craig ME, Duffin AC, Gallego PH, et al. Plantar fascia thickness, a measure of tissue
31
32 glycation, predicts the development of complications in adolescents with type 1
33
34 diabetes. *Diabetes Care* 2008; 31: 1201-1206
35
- 36 14. Koppenhaver SL, Parent EC, Teyhen DS, et al. The effect of averaging multiple trials on
37
38 measurement error during ultrasound imaging of transversus abdominis and lumbar
39
40 multifidus muscles in individuals with low back pain. *J Orthop Sports Phys Ther*
41
42 2009; 39: 604-611
43
44
- 45 15. Atkinson G, Nevill A Typical error versus limits of agreement. *Sports Med* 2000; 30: 375-
46
47 381
48
49
50
51
52
53
54
55
56
57
58
59
60

Ultrasound Measurement of the plantar fascia

16. Springer BA, Mielcarek BJ, Nesfield TK, et al. Relationships among lateral abdominal muscles, gender, body mass index, and hand dominance. *J Orthop Sports Phys Ther* 2006; 36: 289-297
17. Bjordal, JM, Demmink, JH, and Ljunggren AE. Tendon Thickness and Depth from Skin for Supraspinatus, Common Wrist and Finger Extensors, Patellar and Achilles Tendons: Ultrasonography study of healthy subjects. *Phys.Ther.* 89[6], 375-383. 2005.
18. O'Connor PJ, Grainger AJ, Morgan SR, et al. Ultrasound assessment of tendons in asymptomatic volunteers: a study of reproducibility. *Eur Radiol* 2004; 14: 1968-1973
19. Ying M, Yeung E, Li B, et al. Sonographic evaluation of the size of Achilles tendon: the effect of exercise and dominance of the ankle. *Ultrasound Med Biol* 2003; 29: 637-642
20. Norman G The pruning of Doctor McDonough and the "humanizing" of statistics. *Fertil Steril* 1997; 68: 570-573
21. Wall JR, Harkness MA, Crawford A Ultrasound diagnosis of plantar fasciitis. *Foot Ankle* 1993; 14: 465-470
22. Vohra PK, Kincaid BR, Japour CJ, et al. Ultrasonographic evaluation of plantar fascia bands. A retrospective study of 211 symptomatic feet. *J Am Podiatr Med Assoc* 2002; 92: 444-449

Ultrasound Measurement of the plantar fascia

- 1
2
3 23. Pascual HJ, Garcia JM, Matamoros EC, et al. Relationship of body mass index, ankle
4 dorsiflexion, and foot pronation on plantar fascia thickness in healthy, asymptomatic
5 subjects. *J Am Podiatr Med Assoc* 2008; 98: 379-385
6
7
8
9
10 24. Akfirat M, Sen C, Gunes T Ultrasonographic appearance of the plantar fasciitis. *Clin*
11 *Imaging* 2003; 27: 353-357
12
13
14 25. Ozdemir H, Yilmaz E, Murat A, et al. Sonographic evaluation of plantar fasciitis and
15 relation to body mass index. *Eur J Radiol* 2005; 54: 443-447
16
17
18
19 26. Genc H, Saracoglu M, Nacir B, et al. Long-term ultrasonographic follow-up of plantar
20 fasciitis patients treated with steroid injection. *Joint Bone Spine* 2005; 72: 61-65
21
22
23 27. Sabir N, Demirlenk S, Yagci B, et al. Clinical utility of sonography in diagnosing plantar
24 fasciitis. *J Ultrasound Med* 2005; 24: 1041-1048
25
26
27
28 28. Moraes do Carmo CC, Fonseca de Almeida Melao LI, et al. Anatomical features of plantar
29 aponeurosis: cadaveric study using ultrasonography and magnetic resonance
30 imaging. *Skeletal Radiol* 2008; 37: 929-935
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60**Table 1**

Diameter of fascia plantaris [mm]	Men		Women		All	
	Mean (SD)		Mean (SD)		Mean (SD)	
	Right	Left	Right	Left	Right	Left
Diameter observer 1	3.93 (0.14)	3.82 (0.16)	3.44 (0.36)	3.45 (0.41)	3.55 (0.37)	3.49 (0.31)
Diameter observer 2	4.03 (0.39)	3.93 (0.39)	3.54 (0.37)	3.58 (0.40)	3.63 (0.38)	3.67 (0.29)

For Peer Review

Table 2

Limits of agreement (LOA)	1 image	% of observers average	Mean of 2 images.	% of observers average	Mean of 3 images.	% of observers average
Observer 1 [mm]	0.76	21.1 %	0.67	18.6 %	0.63	17.5 %
Observer 2 [mm]	0.91	25.3 %	0.82	22.8 %	0.75	20.8 %
Interobserver [mm]	0.67	18.6 %	0.62	17.2 %	0.57	15.8 %
Interobserver, both observers measure observer 1's scans. [mm]	0.59	16.3 %	0.52	14.4 %	0.47	13.0 %
Interobserver, both observers measure observer 2's scans. [mm]	0.55	15.6 %	0.49	13.9 %	0.43	12.2 %

Table 3

Intraclass correlation coefficient.	1 image	Mean of 2 images	Mean of 3 images.
Intraobserver, observer 1 [ICC 95 % CI]	0.50 (0.23-0.70),	0.73 (0.48-0.85)	0.77 (0.56-0.87)
Intraobserver, observer 2 [ICC 95 % CI]	0.52 (0.09-0.75)	0.64 (0.32-0.81)	0.67 (0.39-0.82)
Interobserver [ICC 95 % CI]	0.62 (0.37-0.78)	0.80 (0.60-0.90)	0.82 (0.65-0.91)
Interobserver [ICC 95 % CI]. Both observers measure observer one's scans.	0.71 (0.50-0.84)	0.86 (0.71-0.93)	0.89 (0.78-0.95)
Interobserver [ICC 95 % CI]. Both observers measure observer two's scans.	0.73 (0.55-0.85)	0.89 (0.79-0.94)	0.91 (0.82-0.95)

1
2
3
4 Table legends
5
6
7
8

9 Table 1: Diameter of the plantar fascia sub grouped by gender as well as combined, shown for
10 observer 1 and 2.
11
12

13
14
15 Table 2: Intra- and interobserver reliability presented as Limits of Agreement (LOA), and LOA as
16 percentage of observers' average diameter based on all measurements.
17
18
19

20
21
22
23 Table 3: Intra- and interobserver reliability. Values are presented as ICC with 95 % confidence
24 interval.
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

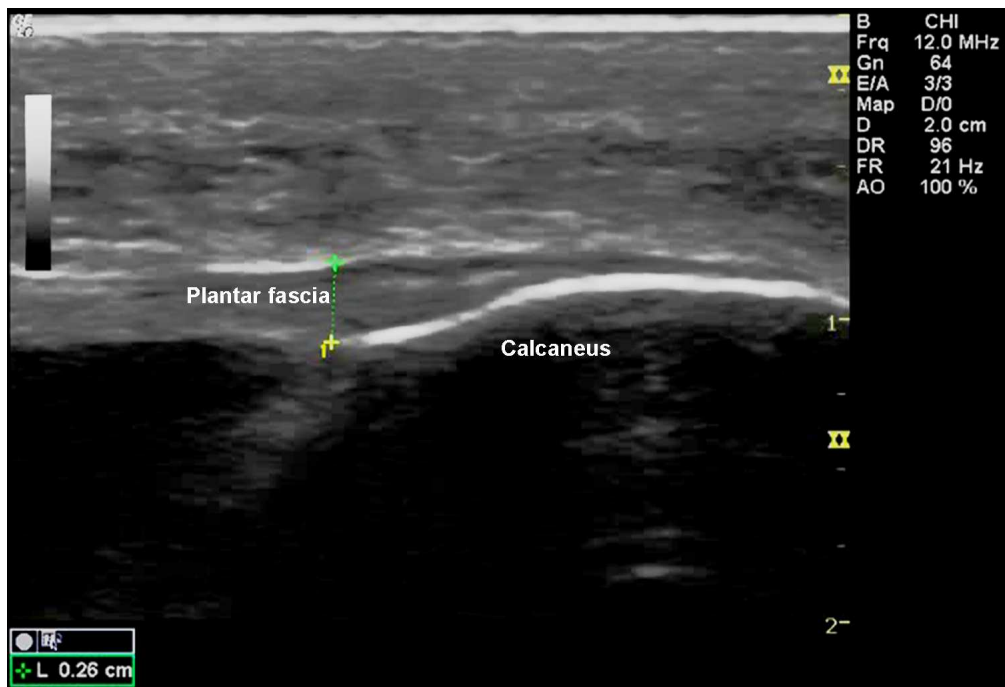


Figure 1 Long-axis sonograms of the plantar fascia at the insertion onto the calcaneus. 254x172mm (150 x 150 DPI)

Review



Figure 2 The blue bar on the image indicates placement of the probe on the plantar aspect of the hindfoot.
96x155mm (150 x 150 DPI)