Reliability of measuring Abductor hallucis muscle parameters using two different diagnostic ultrasound machines

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ABSTRACT

Background: Diagnostic ultrasound provides a method of analysing soft tissue structures of the musculoskeletal system effectively and reliably. The aim of this study was to evaluate within and between session reliability of measuring muscle dorso-plantar thickness, medio-lateral length and cross-sectional area, of the Abductor hallucis (AbdH) muscle using two different ultrasound machines, a higher end Philips HD11 Ultrasound machine and clinically orientated Chison 8300 Deluxe Digital Portable Ultrasound System.

Methods: The AbdH muscle of both the left and right feet of thirty asymptomatic subjects was imaged and then measured using both ultrasound machines. Interclass correlation coefficients (ICC) with 95% confidence intervals (CI) were used to calculate both within and between session intra-tester reliability. Standard error of the measurement (SEM) calculations were undertaken to assess difference between the actual measured score across trials and the smallest real difference (SRD) was calculated from the SEM to indicate the degree of change that would exceed the expected trail to trail variability.

Results: The ICCs, SEM and SRD for dorso-plantar thickness and medial-lateral length were shown to have excellent to high within and between-session reliability for both ultrasound machines. The between-session reliability indices for cross-sectional area were acceptable for both ultrasound machines.

Conclusions: The results of the current study suggest that regardless of the type ultrasound machine, intra-tester reliability for the measurement the abductor hallucis muscle parameters is very high.

INTRODUCTION

The widespread interest in musculoskeletal ultrasound (US) over the last decade has lead to improvements in technology and the development of subsequent smaller less expensive machines with better resolution [1]. US has also been reported to be most cost-effective and feasible method among the imaging modalities, to measure, muscle dorso-plantar thickness, medio-lateral width and cross-sectional area of muscles [2,3].

With the availability of US equipment there has been an increase in research evaluating intrinsic muscle parameters of the foot such as abductor hallucis, extensor digitorum brevis, the first intraosseous dorsalis muscle, adductor hallucis and the first lumbrical muscle [4,5]. With the advent of small transducers and machines that are portable accessibility to evaluate smaller joints and muscles has made US more user-friendly in the routine clinical care setting [1]. With the introduction of new technology there is a need to identify the reliability of measuring muscle parameters such as thickness and cross-sectional area. Another important issue in the musculoskeletal arena is the assessment of inter-scanner variability [1]. A previous study undertaken by the authors reported on the excellent intra-tester reliability of using one US machine to assess AbdH muscle parameters [4]. However, clinicians should be aware of measurement errors involved when using different US machines. This is of particular importance when there is inter-changeability of US machines in large clinical settings. Therefore, the aim of the study was to evaluate within and between session reliability of measuring muscle dorso-plantar thickness, medio-lateral length and cross-sectional area, of AbdH muscle using two different ultrasound machines commonly used in different scopes of clinical practice.

METHOD

Subjects

Thirty subjects (twenty female, ten male) were recruited and completed the study with a mean age of 28.24 ±10.2 years, mean weight of 68.8 ±12.35Kg, and a mean height of 1.71 ± 0.97m. Informed consent to participate in this study was given by all subjects. Subjects met the inclusion criteria if they were healthy individuals between the ages 18-60 and did not have a history of inflammatory arthritis, previous foot or ankle surgery, diabetes, lower limb amputation, or severe hallux valgus as defined by the Manchester Scale [6]. The procedures used in this study were approved by the Universities Ethics Committee.

Equipment

A ‘higher end’ Philips HD11 Ultrasound machine, with linear probe (12-5 MHz), and a Chison 8300 Deluxe Digital ‘portable’ Ultrasound System, with linear probe (7.5MHz) were used to scan images of the AbdH muscle. An Aquaflex® Ultrasound Gel Pad (Fairfield, USA) was applied directly onto the subject’s skin, superficial to the AbdH muscle, ensuring optimal transducer contact and signal penetration. Philips Q-lab Software (Release 5.0) was employed for data quantification from the images taken from the Philips HD11, and the Chison 8300 inbuilt software was used for the images captured on that machine.

Experimental Procedure

The AbdH muscle of both the left and right foot, for each of the thirty subjects were imaged, for digital investigation, and three separate measures of each foot were recorded. This experimental procedure was undertaken with the same subject on both the Philips HD11 and Chison 8300 for between machine reliability. This entire process was then repeated at least three days post (mean = 8.7days) to obtain between day test results. Ultrasound imaging and measurements were performed by one sonographer of 2 years experience.

Each subject was positioned in supine lying. The heel and plantar aspect, excluding the first metatarsal, of the involved foot rested against a stable platform designed to fix the ankle in a zero degree neutral position. The posterior aspect of the knee was supported in approximately 15-degrees flexion. The uninvolved leg was also supported. The sonographer manually palpated relevant bony anatomical landmarks and marked them for orientation. These included a reference line for scanning directly inferior from the most anterior aspect of the medial malleolus. The ultrasound gel pad was applied onto the AbdH muscle belly, inferior to the medial malleolus. The AbdH muscle was imaged with the transducer applied at a perpendicular angle to the long axis of the foot on the proximal aspect of the reference line. Minimal pressure was applied with the transducer to reduce any possible alterations to the muscle fibres and architecture. An image of the AbdH muscle was captured using both machines (Figure 1 & 2) and stored on the hard drive for later analysis. Measurement and analysis were undertaken independent of one another to ensure blinding of the results.

The Philips HD11 images were analysed using onscreen digital callipers, where as the Chison 8300 measurements were calculated using manual measurement and scale. The dorso-plantar thickness of the AbdH muscle was measured perpendicular from the most inferior aspect of the muscle belly to the most superior point of the muscle. The medio-lateral width of the AbdH was measured from the most superficial border to the deepest border also using digital callipers. The muscle cross-sectional area measurement of the AbdH muscle was gained through digital manual tracing of the muscle borders for both diagnostic ultrasound machines.

Data Analysis

The baseline descriptive information obtained from each subject was stored for statistical analysis. An analysis of the reliability of the two ultrasound imaging machines was carried out using SPSS (version 15, SPSS Inc., Chicago, IL) Repeated measures (test-retest) reliability analyses utilised Interclass Correlation Coefficients (ICC, 3.1) and 95% confidence intervals (CI). A previous study reported > 0.90 = excellent, > 0.80-0.89 = high, and >0.70-0.80 = acceptable [7]. As with other reliability coefficients, there is no standard acceptable level of reliability using the ICC [8]. It is stated that any measure should have an ICC of at least 0.6 to be useful [9]. Bland-Altman plots have been used to provide graphical representation of key reliability findings [10,11]. The Bland-Altman method calculates the range within which the difference between the two occasions will lie with a probability of 95% [10,11].

Standard error of the measurement (SEM) calculations were undertaken to assess difference between the actual measured score across trials and an estimated "true" score [12,13]. The smallest real difference (SRD) was calculated from the SEM that indicates the degree of change that would exceed the expected trail to trail variability [13,14].

RESULTS

Descriptive information of the AbdH muscle medio-lateral width, dorso-plantar thickness and cross-sectional area for both US machines are presented in Table 1.

Within Session Reliability

The results for within-session reliability analysis, for both the Philips and Chison ultrasound machines, demonstrated excellent reliability for the three AbdH muscle parameters measured (Table 2). The low SEM and within-session SRD values for dorso-plantar thickness, medio-lateral width and cross-sectional area measurements also indicate extremely low measurement error for both the Philips HD11 and Chison 8300 (Table 2).

Between session Reliability – Single measures

Single measures analysis illustrated excellent reliability for dorso-plantar thickness measurements of AbdH for both the Philips HD11 and Chison 8300 (Table 3). Medio-lateral width measurements were deemed high for the Phillips HD11 and acceptable for the Chison 8300 (Table 3). Reliability for cross-sectional area measurements were below the acceptable level for both machines (Table 3). Low SEM values for both dorso-plantar thickness and medio-lateral width again indicate a low level of measurement error for both ultrasound imaging machines (Table 3). The SEM between-session single measure for cross-sectional area were considerably high when compared to the within session values (Table 2 & 3).

Between Session Reliability –Average measures

Taking the average of three measures demonstrated an excellent reliability agreement of measuring the dorso-plantar thickness of AbdH for both machines (Table 4). An excellent (Philips HD11) and high (Chison 8300) reliability was evident for the AbdH ultrasound images of medio-lateral width measurements (Table 4). Cross-sectional area between-session reliability of the AbdH was acceptable for both US machines (Tables 4). The SEM and SRD values for dorso-plantar thickness, medio-lateral width and cross-sectional area again consistently showed a low level of measurement error (Table 4).

Figure 3 illustrates the Bland & Altman plot for Philips HD11 and Chison 8300 within session results for AbdH dorso-plantar thickness, with a 95% limits of agreement, bias of 0.04 with a SD of bias of 0.46 (Lower limit -0.85, Upper limit 0.94). Figure 4 illustrates the Bland & Altman plot for Philips HD11 and Chison 8300 within session results for AbdH medio-lateral width, with a 95% limits of agreement, bias of -0.08 with a SD of bias of 1.14 (Lower limit -2.31, Upper limit 2.14). Figure 5 illustrates the Bland & Altman plot for Philips HD11 and Chison 8300 within session results for AbdH cross-sectional area, with a 95% limits of agreement, bias of -7.32 with a SD of bias of 19.27 (Lower limit -45.09, Upper limit 30.45).

DISCUSSION

The results of the current study demonstrated that diagnostic US is an effective and reliable clinical tool in utilising a standardised protocol that enables the quantification of the AbdH muscle's using either machine. To the authors knowledge there has been no previous research investigating intrinsic muscle structure using different US machines, therefore the current SRD reflect the potential to detect changes that exceed measurement error for clinical application.

Overall, Philips HD11 and Chison 8300 show excellent to high reliability in measuring dorso-plantar thickness and medio-lateral width using ICCs, SEM and SRD, indicating the potential to utilise these two parameters in order to follow the progression or change of the muscle's architecture. Both US machines demonstrated acceptable between-session reliability when measuring the cross-sectional area; however the SEM and SRD values attained may be secondary to the human error influence of manual tracing of the AbdH muscle borders. Furthermore, the SRD demonstrated higher measurement error when only one measure compared to three measures to obtain a mean measurement. Clinicians should consider obtaining three measures rather than a single measure. Digital/computer generated mapping of the muscles could be a possibility in future research for evaluating cross-sectional area. Reeves et al [15] suggests that measurement error can be reduced by comparing US cross-sectional results to MRI images in order to assure the accuracy of the cross-sectional area. However, this is a costly method to adopt in the clinical setting

The clinical implications of this research include the potential of utilising the affordable, portable US machines in the clinical environment more regularly. Ultrasonography has the potential to be employed to further investigate and undertake measurement analyses of individuals with foot and ankle pathologies. The cost of US equipment has been stated to directly relate to the attained images resolution and quality; this therefore indicates that a high-resolution ultrasonography machine produces higher quality images which are more easily interpreted [16]. However the reliability of the results of this research indicate that images gained and analysed from both the more costly Philips HD11, and less expensive Chison 8300 are very similar in comparison, therefore indicating that it may not be of immediate importance to which machine is used in order to establish basic muscle anatomical parameters. However, caution needs to be applied if the two machines are used interchangeably in practice in order to gain accurate results.

A low SEM value relative to the resting value would imply an ability to detect a real change, without being influenced by measurement error. The smallest real difference (SRD) can be calculated to indicate the degree of change that would exceed the expected trail to trail variability [12,14].

In addition to the findings of excellent within session and average between session reliability for a single assessor, the reported SEM values were low when compared to the resting dorso-plantar thickness and medio-lateral width values of the muscle. This is clinically important, as the most likely application of the measurement could be to assess changes in thickness or width due to muscle contraction or pathology. A low SEM value relative to the resting value would suggest that the ability to detect a real change (exceeding measurement error) would be likely. With respect to between session average reliability, based on the SEM of 0.25mm for the AbdH muscle, dorso-plantar thickness SRD measurement can be calculated by the following formula: $SEM \times \sqrt{2} \times 2.009$ (where 2.009 represents the t value of distribution for a 95% CI (df = 59). If this value is divided by the average dorso-plantar thickness of the muscle (11.56mm) a change in thickness of greater than 3.0% would be required to be 95% confident that a real change has occurred. Further, with regard to medio-lateral width and cross-sectional area, a change greater than 8.8%, and 21.25% respectively would be required to be 95% confident that a real change occurred. The higher percentage seen in cross-sectional area estimation could be due to the added human error possibility in the manual measuring the cross-sectional area.

Conclusions

In summary, the results of the current study suggest that regardless of the type US machine, intra-tester reliability for the measurement the AbdH muscle parameters is high. The results from the current work using US imaging to measure the muscle parameters of dorso-plantar thickness, medio-lateral width and cross-sectional area of the AbdH muscle suggest excellent to high within-session reliability for both the Philips HD11 and Chison 8300, although between-session reliability for cross-sectional measurements was acceptable for both US machines.

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Competing Interests

The authors declare that they have no competing interests.

Authors' contributions

KR and WH conceived and designed the study. AC collected and inputted the data. KR, WH and AC conducted the statistical analysis. KR and WH compiled the data and drafted the manuscript and AC contributed to the drafting of the manuscript. All authors read and approved the final manuscript.

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Figure Captions List

Figure 1. Ultrasound image of Abductor hallucis muscle from Phillips HD11

Figure 2. Ultrasound image of Abductor hallucis muscle from Chison 8300

Figure 3. Bland & Altman plot for Phillips HD11 and Chison 8300 results for AbdH Dorso-plantar thickness

Figure 4. Bland & Altman plot for Phillips HD11 and Chison 8300 results for AbdH medio-lateral width

Figure 5. Bland & Altman plot for Phillips HD11 and Chison 8300 results for AbdH cross-sectional area

Tables

Table 1: Descriptive statistics of Abductor hallucis muscle parameters

	Day	Phillips HD11 Mean ± SD	Chison 8300 Mean ± SD
Dorso-Plantar Thickness (mm)	1	11.56 ± 1.07	11.54 ± 1.13
	2	11.54 ± 1.02	11.60 ± 1.07
Medio-lateral Width (mm)	1	28.98 ± 2.77	28.81 ± 2.75
	2	29.03 ± 2.60	28.97 ± 2.62
Cross-sectional Area (mm^2)	1	269.33 ± 35.99	262.35 ± 38.60
	2	275.99 ± 36.04	270.26 ± 34.31

Table 2: **Within Session Reliability**

	ICC [3.1]	95% CI	SEM	SRD
Phillips HD11				
Dorso-plantar thickness (mm)	0.97	(0.99-0.99)	0.12	0.34
Medio-lateral width (mm)	0.96	(0.95-0.98)	0.87	2.47
Cross-sectional area (mm^2)	0.98	(0.96-0.98)	9.36	26.59
Chison 8300				
Dorso-planatr thickness (mm)	0.99	(0.99-0.99)	0.09	0.26
Medio-lateral length (mm)	0.95	(0.92-0.97)	1.06	3.01
Cross-sectional area (mm^2)	0.99	(0.98-0.99)	6.73	19.12

Table 3: Between Session Reliability: Single measures

	ICC [3.1]	95% CI	SEM	SRD
Phillips HD11				
Dorso-plantar thickness (mm)	0.95	(0.91-0.97)	0.46	1.31
Medio-lateral width (mm)	0.88	(0.81-0.93)	0.28	0.79
Cross-sectional area (mm^2)	0.65	(0.48-0.78)	40.10	113.93
Chison 8300				
Dorso-plantar thickness (mm)	0.92	(0.87-0.95)	0.13	0.37
Medio-lateral width (mm)	0.78	(0.66-0.87)	0.08	0.22
Cross-sectional area (mm^2)	0.64	(0.47-0.77)	35.30	100.29

Table 4: Between Session Reliability: Average measures

	ICC [3.1]	95% CI	SEM	SRD
Phillips HD11				
Dorso-plantar thickness (mm)	0.97	(0.95-0.98)	0.25	0.71
Medio-lateral width (mm)	0.94	(0.90-0.96)	0.90	2.56
Cross-sectional area (mm^2)	0.79	(0.65-0.88)	20.15	57.24
Chison 8300				
Dorso-plantar thickness (mm)	0.96	(0.93-0.97)	0.32	0.91
Medio-lateral width (mm)	0.88	(0.80-0.93)	1.20	3.41
Cross-sectional area (mm^2)	0.78	(0.64-0.87)	21.78	61.88

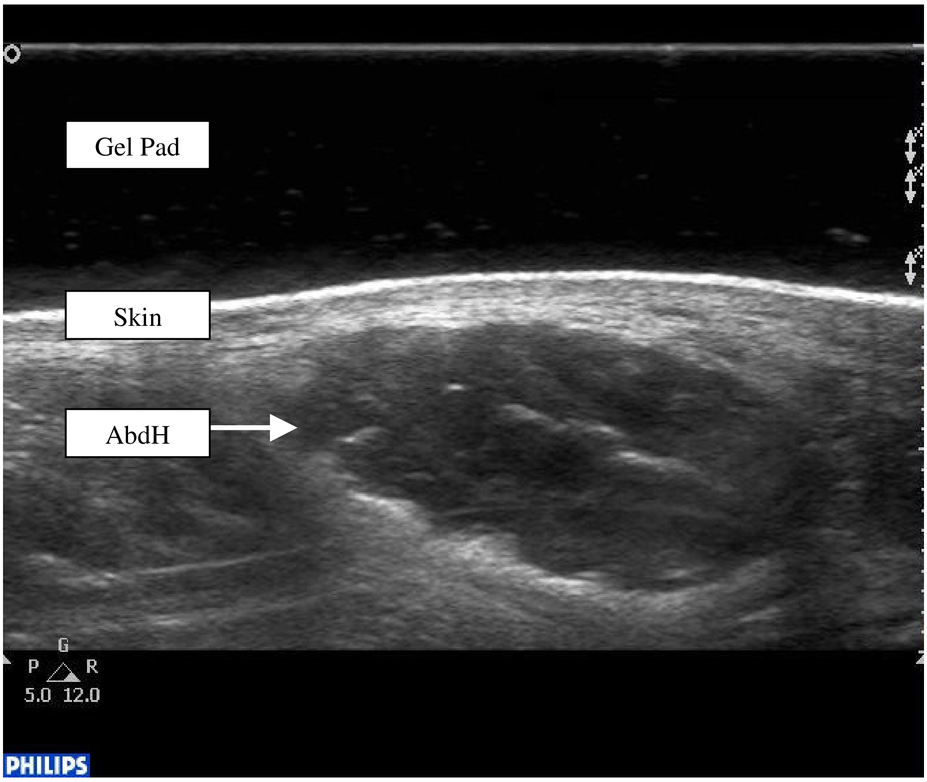


Figure 1

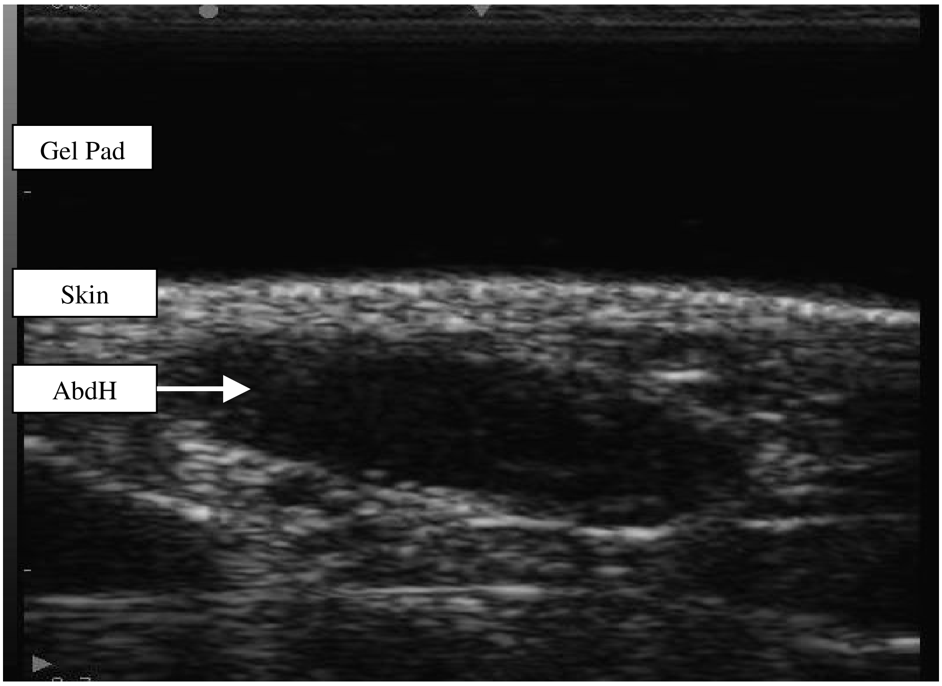


Figure 2

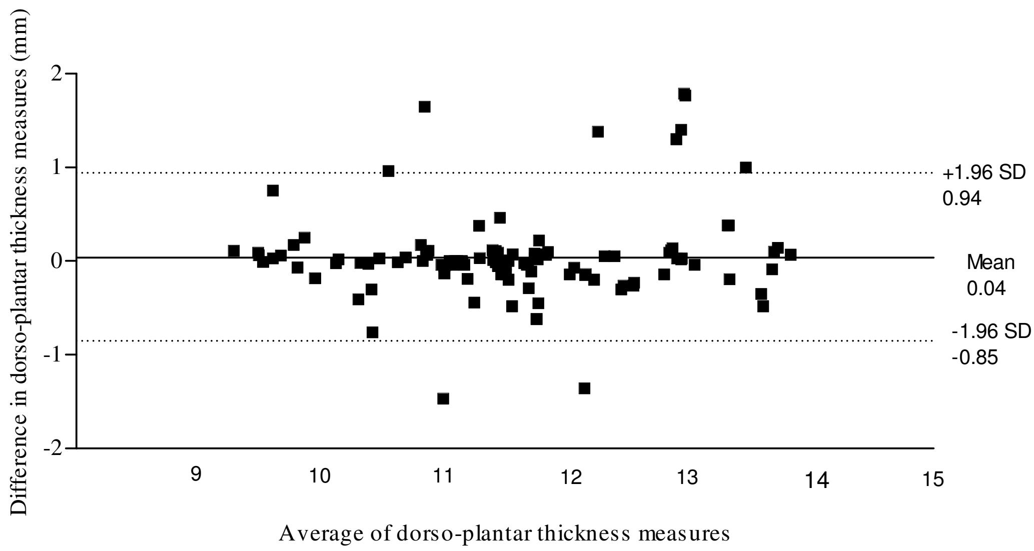
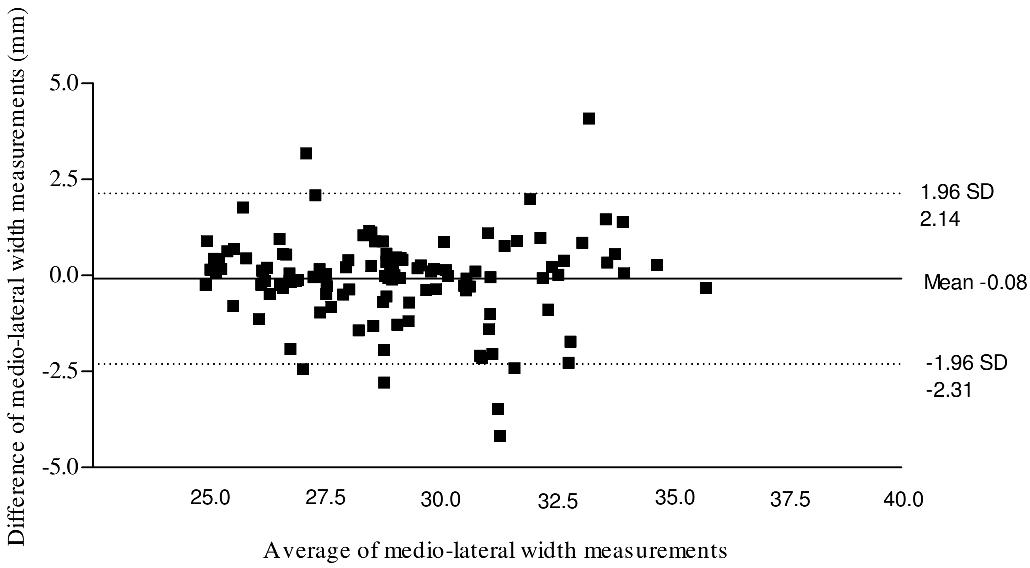
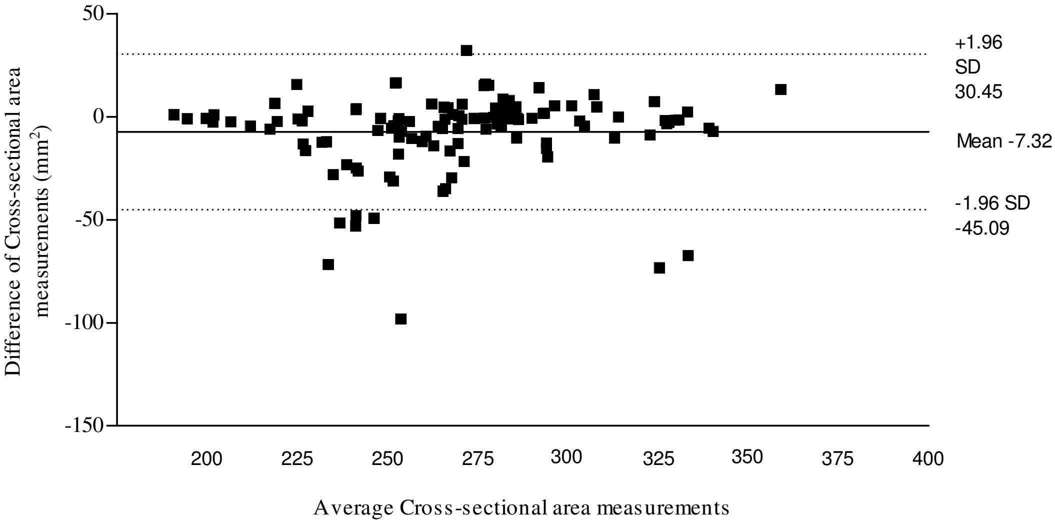

Difference in dorso-plantar thickness measures (mm)
2
1
0
-1
-2
+1.96 SD
0.94
Mean
0.04
-1.96 SD
-0.85
9
10
11
12
13
14
15
Average of dorso-plantar thickness measures

Figure 3



Difference of medio-lateral width measurements (mm)
5.0
2.5
0.0
-2.5
-5.0
25.0
27.5
30.0
32.5
35.0
37.5
40.0
Average of medio-lateral width measurements
1.96 SD
2.14
Mean -0.08
-1.96 SD
-2.31

Figure 4



50
0
-50
-100
-150
Difference of Cross-sectional area measurements (mm^2)
+1.96 SD 30.45
Mean -7.32
-1.96 SD -45.09
200
225
250
275
300
325
350
375
400
Average Cross-sectional area measurements

Figure 5