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The inter-rater and intra-rater reliability of capturing foot parameters utilising a computerised white light three dimensional scanner

HOWARD E. ALEXANDER
(331755)

SCHOOL OF THERAPEUTIC SCIENCES
CENTRE FOR EXERCISE SCIENCE AND SPORTS MEDICINE
UNIVERSITY OF WITWATERSRAND
JOHANNESBURG
SOUTH AFRICA

MSc (Med) in Sport Science

SUPERVISORS:

PROF. D CONSTANTINOU
MBBCH, BSc(Med)(Hons), FFIMS

DR. B ZIPFEL
NHD Pod, NHD PS Ed (Rand), BSc Hons (Brighton), PhD (Wits)

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ABSTRACT

Within the context of sports medicine, biomechanical corrective custom foot orthoses are utilised as a treatment intervention to correct pathological gait disorders. In order to manufacture such corrective devices a replicate model of the patients' foot needs to be obtained. This study aimed to assess both the inter-rater reliability and the intra-rater repeatability of a semi weight bearing foot modelling technique employing a three dimensional white light surface foot scanner.

The sample cohort included twenty healthy male and female subjects with ages ranging from 18-70 years. Six qualified Podiatrists were utilised as raters to perform the foot placements on the white light scanner. All raters and participants were given a ten minute training session to familiarise them with the equipment and scanning procedure. The subjects' left foot was marked and raters positioned and scanned the left foot three times. Digital foot parameter measurements of medial arch height, forefoot width, foot length and rearfoot width were recorded and analysed.

The results from this study showed high inter-rater reliability with intraclass correlation coefficients ranging from 0.997 to 1.00 with the specified foot parameter measurements. Intra-rater repeatability of the same specified foot parameter measurements demonstrated good repeatability with Pearson coefficients of correlation values ranging from 0.973 to 0.997.

The assessment of the reliability of computerised digital white light scanning as an integral first step in the manufacture of custom foot orthoses has a direct effect on Podiatric practice and the outcomes of patient treatments with this therapeutic modality.

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CHAPTER 1: BACKGROUND AND LITERATURE REVIEW

1.1 INTRODUCTION

This chapter identifies relevant information and the importance of the inter-rater reliability and the intra-rater repeatability of a semi-weight bearing digital three dimensional foot modelling technique in the manufacture of custom foot orthoses.

1.2 BACKGROUND OF THE STUDY

The use of three dimensional foot modelling in podiatric medical practice has shown significant technical advancements over the last decade.[1-5] Traditionally several different types of foot modelling techniques have been utilised to obtain negative foot impressions.[1-13] The clinical use of neutral impression casting techniques to gain a replicate foot model has been viewed as a gold standard technique.[1,3-9] This casting technique seeks to obtain a negative foot impression from which a positive foot model is manufactured.[3-5,9,11-13] Neutral impression casting techniques have raised questions on the reliability of the foot parameters captured.[4,5,8,10-12] Recent podiatric practices have moved towards the use of a computerised three dimensional foot modelling techniques due to the advancement and availability of digital scanning equipment.[14-23] Due to the cost and efficiency benefits of this computerised equipment there is a prediction of greater clinical usage of such systems.[21] As noted in literature, three dimensional white light scanning remains under-investigatation.[14,15,21-23]

1.3 LITERATURE REVIEW

1.3.1 Introduction

Within the context of sports medicine, biomechanical corrective custom foot orthoses are utilised as a treatment intervention to correct pathological gait disorders.[1,3,7,8] In order to manufacture such corrective orthotic devices a replicate model of the

patients' foot needs to be obtained.[4,11,14,19] Various casting and computerised scanning methods are detailed in the literature to capture these foot parameters.[3-11,13-23]

1.3.2 Traditional foot casting techniques

Root et al. initially described the sub-talar joint neutral impression casting technique in 1971.[2,9] This technique was employed as a first step in the fabrication of custom foot orthoses.[3,9]

Although there is little to no evidence to suggest that one material is superior to another, the most widely used material in the foot modelling process is plaster of Paris embedded bandage and foam impression boxes.[3,9,11] These methods employ a neutral sub-talar joint positioning technique to obtain repeatable foot position.[8,10,11] The neutral position of the sub-talar joint of the foot is the position in which the joint is neither pronated nor supinated, while the midtarsal joint is in a maximally pronated position.[1-4,9] This neutral position is widely used, and assumed to be a prerequisite for correct foot modelling in the manufacture of custom foot orthoses.[3,4,11]

The weight bearing casting technique is performed while the patient is standing vertically.[3,4,9] The original idea behind the weight bearing casting technique was to replicate the foot in a compensated position, so that the ground reaction forces from the contours of the manufactured orthotic would resist compensatory changes of the foot.[3,7,9]

Questions regarding the efficacy of this casting technique have been raised since the foot orthoses fabricated from weight bearing casts are generally too large to be fitted into a patient's existing shoeware.[4,5] Semi-weight bearing casting, in comparison, is performed while the patient is sitting on a chair with their trunk erect.[3,5] Since the patient's thigh is kept parallel to the floor and the lower leg is at a 90 degree angle to the ground, the patient's talocrural joint is neither dorsiflexed nor plantar flexed.[3,9,10] This semi-weight bearing technique allows the ground reaction force to act as a foot stabliliser.[3]

Non-weight bearing casting is performed while the patient is lying prone on a plinth.[3,4,9] This casting technique is believed to provide the podiatrist with the freedom to manipulate the foot biomechanically in order to identify the forefoot to rearfoot alignment.[4,9] The neutral impression casting technique of a foot in a non-weight bearing or semi-weight bearing position is widely used and is often referred to as the golden standard technique.[4,9]

1.3.3 Reliability of foot casting techniques

To objectively access features of foot modelling, it is imperative to have consistency in the parameters which are selected for comparison.[10,11] Not all foot parameters produce consistently reliable results regardless of the method used.[10]

Current evidence suggests that there are inter-rater reliability issues with these traditional neutral impression casting techniques. [8,9,10,11] These variances are compounded by the type of foot modelling method used, foot parameters obtained and skill level of the clinician.[11,13] Evidence of inter-rater and intra-rater reliability of such three dimensional white light scanning techniques would be beneficial for clinicians who are considering using these technologies in the manufacture of custom foot orthoses.[10,13,14,21,22]

Technical advancements in medical technologies, particularly in three dimensional white light scanners, have made this new technology more end user friendly and accessible.[20,23] This technology allows the practitioner to scan the foot directly, thereby producing an accurate model of the foot shape.[10,13,14,16] This technological development appears to be ideally suited for the further design and manufacture of medical devices such as custom foot orthoses.[16,20,23]

Semi-weight bearing and non-weight bearing methods using plaster of Paris bandage, foam blocks and white light computerised scanning are utilised to manufacture a custom orthotic device; however there is little objective evidence that one method is preferred over another.[18,19] This non preference of the different casting techniques may be attributed to the podiatry training course methods, where

students are introduced to all the different modelling methods and techniques in the learning environment.[4.8]

1.3.4 Material utilised in foot modelling manufacture

Traditionally the choice of materials used is influenced by various factors such as a practitioners' personal preference, experience, material availability and the costs involved.[3,9,11] Materials commonly used to reproduce the patients foot shape, include plaster of Paris embedded bandage, synthetic tubular sock (STS®), foam box and three dimensional digital plantar scanning utilising Computer Aided Design software.[3,9,11] Although there is no evidence to suggest that one material is superior to another, the most widely used material in the cast creation process is plaster of Paris embedded bandage.[3,9,11] Plaster of Paris embedded bandage is a white cotton, open weave bandage which has been impregnated with plaster of Paris.[3]

In order to accurately correct a patient's existing foot abnormalities, a cast must be taken with the foot in its ideal functional position.[3,9] Neutral impression casting is used to manufacture a custom made biomechanical orthotic device in order to correct a number of existing foot abnormalities.[3,8,9]

1.3.5 Three dimensional modelling use in custom orthotic manufacture

Podiatrists employ various foot modelling techniques with the sub-talar joint in the neutral position.[3,5] The foot modelling techniques aid in the manufacture of custom made orthotic devices, in order to correct a number of foot abnormalities.[2-7,9] The use of three dimensional white light scanning technologies to create accurate digitised models may have an influence on the future of custom made orthotic products.[10,20,23] Precise anthropometric measurements, obtained with the use of three dimensional white light scanning technologies, could play an important role in the design, development and manufacture of these custom foot orthoses.[10,13,14]

A custom made orthotic device manufactured from a three dimensional white light surface scanning system of a patient's foot could improve the patient's quality of life, by reducing the compensatory mechanism developed from the foot abnormalities,

and protecting the patient from further biomechanical complications.[10,13,14-16] Podiatrists could utilise any one of many existing techniques in order to produce the foot model.[8] These techniques vary from non-weight bearing through to weight bearing and differ according to joint positioning.[11-16]

1.3.6 Reliability of Three dimensional scanning techniques

Three dimensional surface scanning produces digitised representations of the foot with greater accuracies.[10,13,14,-20] Digital scanning offers an alternative technique to traditional plaster methods with greater reliability.[13,14,21]

Laughton et al. (2002), compared four different methods of obtaining a negative impression of the foot .[21] The methods utilised in this study were non-weight bearing plaster casting, partial weight bearing foam impression, and partial weight bearing and non-weight bearing laser scanning.[21] The reliability of the techniques were determined by the intraclass correlation coefficients (ICC).[21] The ICC for the forefoot to rearfoot relationship for the non-weight bearing plaster casting technique was 0.83, for the foam box 0.59, partial-weight bearing laser 0.79 and non-weight bearing laser 0.65.[21] The study noted good repeatability of foot parameters measured on all modelling techniques, but questioned the repeatability of the three dimensional scanning process due to the possible variance of the different scanning equipment employed and whether white light or laser light was utlised.[21]

In a study conducted by Carroll et al. (2011), comparing digital scanning and suspension casting, good reliability of on measured parameters.[14] Intraclass correlation coefficients values in this study demonstrated digital scanning ranging from 0.81 to 0.99, in both intra and inter-rater reliability with specified foot parameters.[14]

A comparative study by Telfer et al. (2012), reported inconsistent reliability utilising white light scanning when comparing set parameters.[17] Medial arch height was noted to be particularly varied, with intraclass correlation coefficients values below 0.75.[17]

1.3.7 Conclusion

In general three dimensional laser and white light scanned foot measurements are seen to be reproducible but there have been questions raised on the repeatability of foot measurement parameters with differences in commercial software and white light three dimensional scanning equipment. [10,13,21] The literature has found that foot alignment procedures on this equipment demonstrated the most measurer variance.[10,13,14,17]

CHAPTER 2: MATERIALS AND METHODS

2.1 INTRODUCTION

This chapter highlights the research methodology instrumentation and the ethical considerations utilised in order to conduct this study, as well as the methods employed during the data analysis. In addition, it describes the hypothesis of this study.

2.2 PROBLEM STATEMENT

A review of the literature regarding the utilisation and accuracy of three dimensional computerised foot modelling in orthotic manufacture has shown deficiencies in measurable outcomes. The inter-rater reliability and intra-rater reliability of these semi weight bearing foot modelling techniques of specified foot parameters using computerised white light three dimensional foot surface scanning requires further investigation.

2.3 AIM OF THE STUDY

The aim of this study is to determine both the inter-rater reliability and intra-rater reliability of a semi-weight bearing foot modelling technique employing a three dimensional white light surface foot scanner.

2.4 OBJECTIVES OF THE STUDY

- To determine the inter-rater reliability of specified foot parameters amongst podiatrists, utilising a three dimensional white light foot surface scanner.
- To determine the intra-rater reliability of specified foot parameters amongst podiatrists, utilising a three dimensional white light foot surface scanner.

2.5 HYPOTHESIS OF THE STUDY

There is good inter-rater and intra-rater reliability of specified foot parameters using computerised white light three dimensional foot surface scanning.

2.6 SAMPLE AND POPULATION

2.6.1 Rater Sample

The population from which the participant raters were drawn was 240 Podiatrists, registered with the Health Professions Council of South Africa. A total of 6 Podiatrists registered with the Health Professions Council of South Africa were included in this sample.[24] The raters were allowed to withdraw from the study at any given time, for any given reason, without any consequences.

2.6.2 Subject Sample

The study utilised a convenient sampling technique to recruit twenty participants with noncavus foot types for the foot modelling process. A non probability sampling technique was employed to select subjects. A statistical power for the sample size was set at $\pi = 0.8$ to allow a large enough sample to create statistically reliability data. The power analysis was performed by a statistician to determine appropriate sample size.

Participants included in this study, were of a voluntary nature and include both male and female subjects aged between 18 – 70 years. A convenient sampling technique was used to recruit 20 subjects. As per discussion with a statistician, 20 subjects would be able to provide statistically significant results when the p value is equal or less than 0.05. (J. Van Staden, personal communication 2012)

2.6.3 Inclusion Criteria

Podiatrists who had graduated from the University of Johannesburg, Podiatry Department and registered with the Health Professions Council of South Africa were included in the rater sample.[24] The University of Johannesburg is the only Podiatry school in Africa, and therefore all selected podiatrists had standardised training.

2.6.4 Exclusion Criteria

Podiatrists who were not registered with the Health Professions Council of South Africa and not trained at the University of Johannesburg were excluded as possible raters.[24]

Participants with a history of heel pain in the last six months, previous history of lower limb surgery, cavus foot type, foot arthritis, neuropathic disease or if the participant required any walking aids were excluded from the study.

2.7 INSTRUMENTATION AND EQUIPMENT

The following clinical instrumentation and equipment were utilised during the measurement procedures:

A three dimensional computerised white light scanner, FlexScan 3D® (figure 1) was utilised to capture the plantar aspect of the participants foot.[25]

The FlexScan 3D® white light scanner and software programme was used to process all of the scanned semi weight bearing digitised foot images.[25] The white light scanning system has a height resolution of 260 mm, a width resolution of 440 mm, and a length resolution of 870 mm.[23,25]



Figure 1 Graphical image of FlexScan 3D® white light scanner

The following materials and documentation were provided and utilised during the data collection session:

- Information sheet and consent forms for the raters (Appendix A)
- subjects information and consent forms (Appendix B)

2.8 APPROVAL OF STUDY

2.8.1 Ethical approval

Ethical clearance was applied and approved for by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg. Clearance was granted for continuance of the study, certificate number M120969. (Appendix C)

Participation in this study was completely voluntary and anonymous. Participants were able to withdraw from the study at any time.

2.9 DATA COLLECTION

2.1 Setting

The study took place at a medical clinic in Edenvale, Gauteng, (South Africa), where all necessary equipment was available for data collection.

2.2 Procedure

The participants and raters were briefed on the research model and purpose, together with establishment of time and date for data collection proceedings.

2.3 Subject and area marking procedure

The researcher marked participants left foot prior to the commencement of the data collection procedure. Hemi-spherical adhesive markers (figure 2) measuring 5mm in diameter were applied to the relevant landmarks on all subjects left foot. These landmarks included the following;[14]

- The plantar surface of the first and fifth head of metatarsals.
- The plantar surface of the centre of the heel.
- Two corresponding points on the lateral, medial surface and posterior aspect of the heel.
- Plantar surface of the navicular.



Figure 2 Graphical image of hemi-spherical adhesive foot marking

2.4 Measuring tools

The following clinical measuring devices were utilised during measurement procedures:
A three dimensional computerised white light scanner, FlexScan 3D®, was used to capture the plantar aspect of the participants foot.
FlexScan 3D® software was employed to digitise foot scans and measure parameters obtained during foot capturing.

The FlexScan 3D® white light scanner and software program (figure 3) was used to process all of the scanned semi weight bearing foot images. The white light scanning system has a height resolution of 260 mm, a width resolution of 440 mm, and a length resolution of 870 mm.[23,25] The images, of the participants' foot, from the white light scans were transmitted to the computerised software via a Universal serial bus and visual graphics adapter connection.[25]

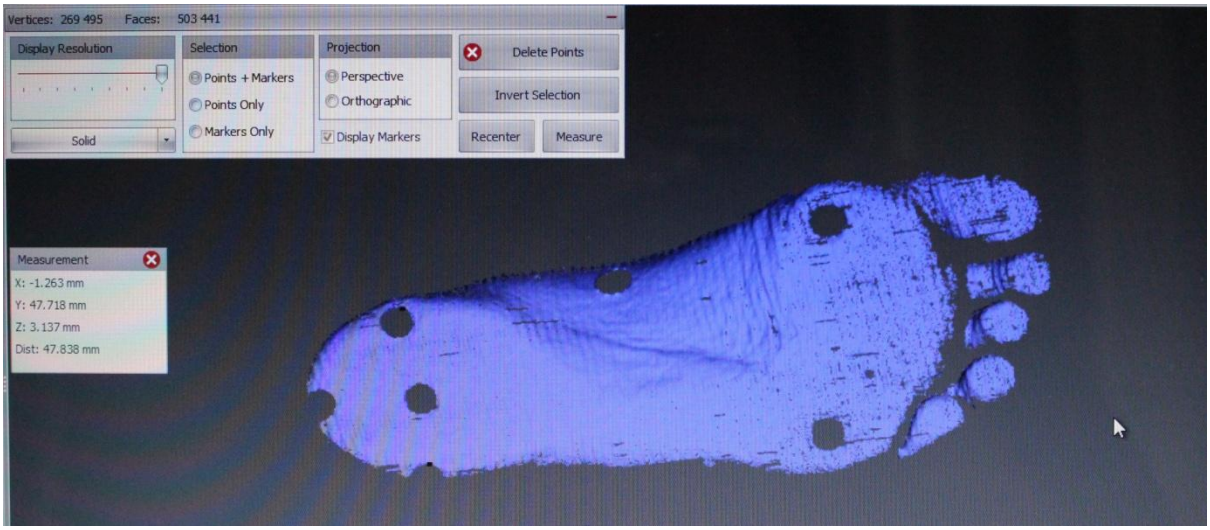

Figure 3 Graphical image of Flexscan 3D® image

2.5 The data collection procedure

Prior to the measuring session, all Podiatrists were given a 10 minute training session, together with a handout (Appendix A) on three dimensional white light scanning capturing procedures. Each rater was given an informed consent document and was assessed by the researcher for foot model capturing proficiency.

Informed consent was obtained from the participants to participate in the study. The test procedure was then demonstrated to subjects (Appendix B).

On the day of data collection, the twenty participants were measured individually. The podiatrists did not capture images of the single participants consecutively; each Podiatrist positioned and captured an image once on each participant. The participant then moved on to the next rater, this process was repeated until all podiatrists had scanned all participants three times. A total of eighteen scanned images were obtained for each participant. The researcher then made use of the FlexScan 3D® software to measure the specified research parameters.

2.6 Foot modeling protocol

Foot modelling was done utilising a three dimensional computerised white light scanner, FlexScan 3D®.

The participants were seated during all measurements procedures (figure 4) with the left hip, knee and ankle flexed to 90 degrees to the weight bearing glass surface of the white light digital scanner. The untested leg was allowed to rest in a comfortable position.

The rater placed the participants left foot on the three dimensional computerised white light scanning surface (FlexScan 3D®). The rater then palpated the medial and lateral aspects of the talus on the participants left foot. The rater then adducted or abducted the knee of the participant to obtain sub-talar joint neutral position. Following this, the foot was scanned and then electronically transferred digitally to the computer software. The participant then move to the next rater for the procedure to be repeated, this continued until all raters had completed three scans of each participants left foot.



Figure 4 Graphical image of Flexscan 3D® scanner subject foot position

2.7 Processing of the foot scans

The researcher utilised the foot scanned images obtained during the data collection to measure specified foot parameters (figure 3). The FlexScan 3D® software measuring tool was employed to quantify specified foot parameter measurements. The hemi-spherical adhesive markers were identified on the scanned images and a marking curser was digitised onto the landmark. The forefoot and heel areas were bisected.

The forefoot width was measured from the plantar medial surface of the first metatarsal head to the plantar lateral surface of the fifth metatarsal head.[13] Medial arch height was measured from the plantar surface of the navicular to a perpendicular line dawn to the bisection of the medial border of the plantar fascia.[13] The rearfoot was measured at thirty percent of the total length from the posterior heel to the forefoot bisection.[13] The foot length was measured from the posterior aspect of the heel to the midpoint on the forefoot bisection line.[13]

2.8 Foot measurement parameters

The main outcome measures parameters of the three dimensional models included the following (figure 5);

- Medial arch height
- Forefoot width
- Foot length
- Rearfoot width

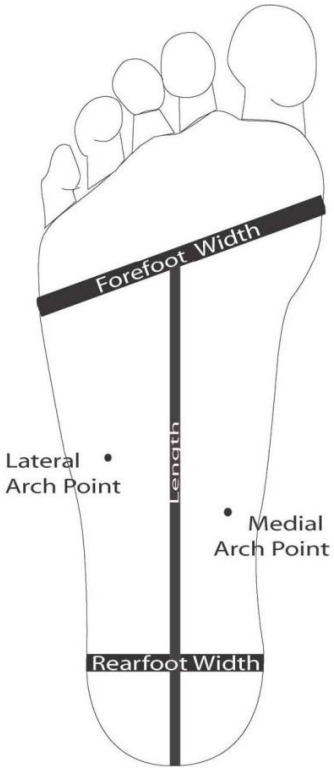

Figure 5 Graphical representation of foot measurement parameters after Carol et. al.[14]

2.9 Statistical analysis

Raw data was captured in a Microsoft® Excel® 2007 document for statistical analysis on the SPSS® statistical programme. All statistical data outcomes were analysed and correlated by the statistical support unit at the University of Johannesburg (Statkon). For each participant, the mean of the three measurements obtained from the white light scanned three dimensional images was used in statistical analysis. The data was analysed in the following ways;

- To assess inter-rater repeatability, the interclass correlation coefficients was used[26-30]
- To analyse the intra-rater reproducibility, the calculations of the Pearson's coefficients of correlation (r) as well as the standard errors of the mean was applied[26-30]
- SPSS statistical software package was used to analyse collected data[26]

Throughout this chapter, the methods and procedures employed to assess the inter-rater reliability and the intra-rater repeatability the measured parameters of the three dimensional models. The FlexScan 3D® software measuring tool was employed to quantify specified foot parameter measurements. All the necessary ethical considerations were maintained throughout this study and the relevant permission obtained. The subjects' personal details were not divulged, and data obtained was utilised purely for quantitative research purpose.

CHAPTER 3: RESULTS

3.1 INTRODUCTION

This chapter highlights the data obtained when six raters positioned and scanned twenty subjects to create a three dimensional foot model. Each rater positioned each subject three times on the computerised digital white light scanner. Inter-rater reliability was established by calculating the Intraclass Correlation Coefficient. Intra-rater repeatability was analysed by interpretation of the data mean, standard deviation, spread of the data, as well as the minimum and maximum values.

Results are presented in tables and box plots. In order to compare reliability of the three dimensional scanned images, the paired sample t-test was employed.

This study intended to determine the inter-rater reliability and the intra-rater repeatability of the foot modelling technique by comparing measures of foot medial arch height, foot length, forefoot width and rearfoot width.

3.2 ASSESSMENT OF INTER-RATER RELIABILITY

The assessment of inter-rater reliability is used to assess the conformity between different raters when performing a specific similar task.[26-36] In addition to this, it is an important measure in determining the effectiveness of a measuring instrument.[26] The statistical analysis of inter-rater reliability included the calculation of the Intraclass Correlation Coefficient (ICC). The Coefficient represents conformity between two or more raters, evaluating the same set of subjects.[26-36]

The interpretation of ICC is as follows: 0-0.2 indicates poor reliability; 0.3-0.4 indicates fair reliability; 0.5-0.6 indicates moderate reliability; 0.7-0.8 indicates strong reliability; and >0.8 indicates near perfect reliability. [27,34]

In order to represent the data obtained from the various raters, the box plot and tables have been made use of. Box plots were used in order to graphically display the variability and spread of the data, as well as the symmetry and skewness.[26,34]

Within the box plots, the box contains the middle 50% of the data, the upper portion of the box indicates the 75'th percentile of the dataset, the lower portion indicates the 25'th percentile and the median is indicated with the bold line and the whiskers indicate the minimum and maximum data values.[26]

3.2.1 Results for the inter-rater reliability of medial arch height measurement

Table 1 Intraclass correlation coefficient of medial arch height amongst raters

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.982[a]	.966	.992	317.314	19	95	.000
Average Measures	.997	.994	.999	317.314	19	95	.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

Table 1 demonstrates the ICC for the rater group's medial arch height measurement from the three dimension foot models taken. The results demonstrate an Intraclass correlation coefficient of 0.997. This is highly significant and demonstrates a high inter rater-reliability amongst the raters.

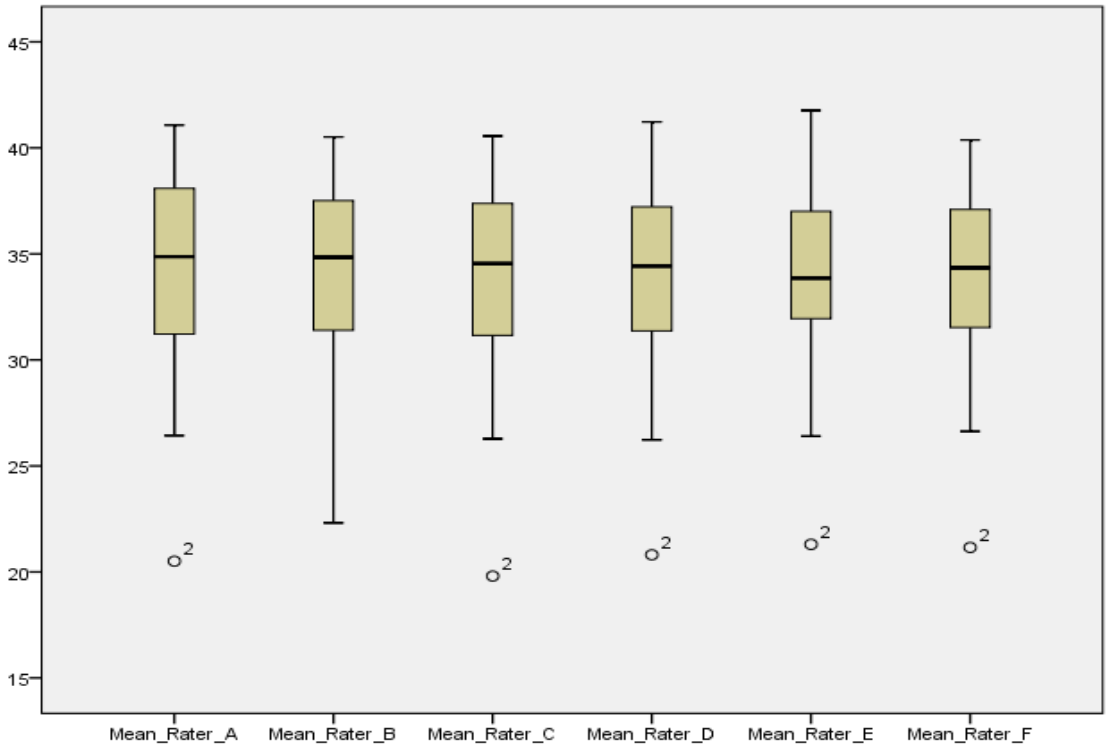

Figure 6 Dataset for all raters of inter-rater reliability of medial arch

Figure 6 represents the range of measurements for all raters for medial arch height. The first data set for rater A demonstrates a median of 34.87 millimetres and range of 20.57 millimetres. The second data set for rater B demonstrates a median of 34.84 millimetres and range of 18.20 millimetres. The third data set for rater C demonstrates a median of 34.55 millimetres and range of 20.75 millimetres. The fourth data set for rater D demonstrates a median of 34.42 millimetres and range of 20.42 millimetres. The fifth data set for rater E demonstrates a median of 33.86 millimetres and range of 20.47 millimetres. The sixth data set for rater F demonstrates a median of 34.35 millimetres and range of 19.22 millimetres. Outlier measurements are noted for subject 2 for raters A, C, D, E and F.

3.2.2 Results for the inter-rater reliability of forefoot width measurement

Table 2 Intraclass correlation coefficient of forefoot width amongst raters

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.987[a]	.976	.994	460.137	19	95	0.000
Average Measures	.998	.996	.999	460.137	19	95	0.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition-the between-measure variance is excluded from the denominator variance.

Table 2 demonstrates the ICC for the rater group's forefoot width measurement from the three dimension foot models taken. The results demonstrate an Intraclass correlation coefficient of 0.998. This is highly significant and demonstrates a high inter-rater reliability amongst the raters.

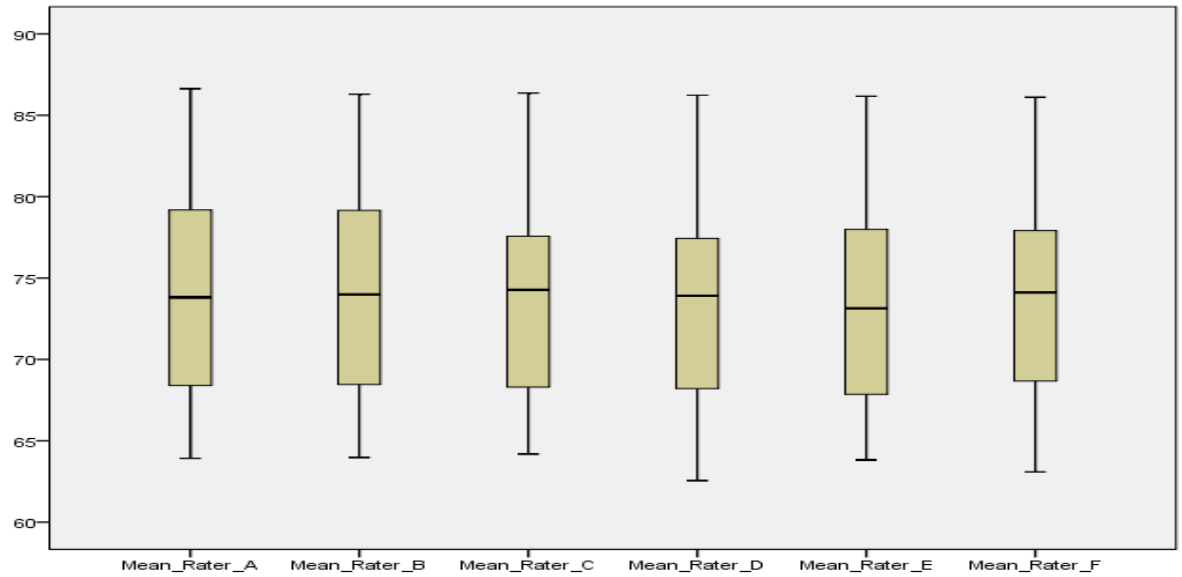

Figure 7 Dataset for all raters of inter-rater reliability of forefoot width

Figure 7 represents the range of measurements for all raters for forefoot width. The first data set for rater A demonstrates a median of 73.39 millimetres and range of 22.71 millimetres. The second data set for rater B demonstrates a median of 73.99 millimetres and range of 22.31 millimetres. The third data set for rater C demonstrates a median of 74.27 millimetres and range of 22.18 millimetres. The forth data set for rater D demonstrates a median of 73.91 millimetres and range of 23.67 millimetres. The fifth data set for rater E demonstrates a median of 73.14 millimetres and range of 22.35 millimetres. The sixth data set for rater F demonstrates a median of 74.12 millimetres and range of 23.03 millimetres.

3.2.3 Results for the inter-rater reliability of foot length measurement

Table 3 Intraclass correlation coefficient of foot length amongst raters

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.998[a]	.996	.999	2608.509	19	95	.000
Average Measures	1.000	.999	1.000	2608.509	19	95	.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

Table 3 demonstrates the ICC for the rater group's foot length measurement from the three dimension foot models taken. The results demonstrate an Intraclass correlation coefficient of 1.000. This is highly significant and demonstrates a high inter-rater reliability amongst the raters.

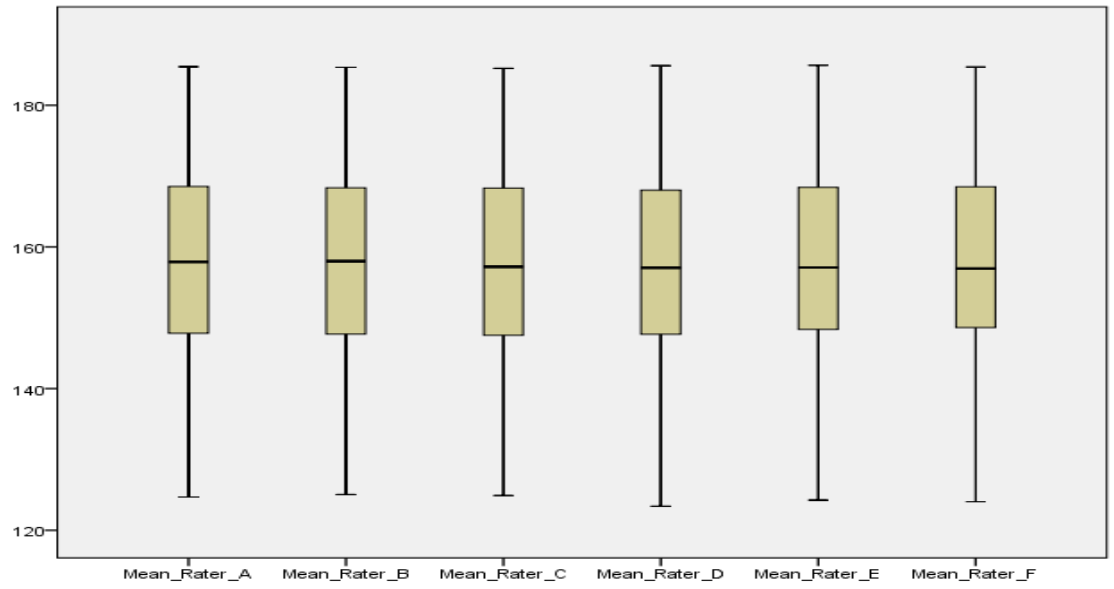

Figure 8 Dataset for all raters of inter-rater reliability of foot length

Figure 8 represents the range of measurements for all raters for foot length. The first data set for rater A demonstrates a median of 157.83 millimetres and range of 60.57 millimetres. The second data set for rater B demonstrates a median of 157.99 millimetres and range of 60.30 millimetres. The third data set for rater C demonstrates a median of 157.20 millimetres and range of 60.32 millimetres. The forth data set for rater D demonstrates a median of 157.06 millimetres and range of 61.38 millimetres. The fifth data set for rater E demonstrates a median of 157.10 millimetres and range of 61.38 millimetres. The sixth data set for rater F demonstrates a median of 156.95 millimetres and range of 61.35 millimetres.

3.2.4 Results for the inter-rater reliability of rearfoot width measurement

Table 4 Intraclass correlation coefficient of rearfoot width amongst raters

		95% Confidence Interval		F Test with True Value 0			
	Intraclass Correlation[b]	Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.980[a]	.964	.991	309.398	19	95	.000
Average Measures	.997	.994	.999	309.398	19	95	.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

Table 4 demonstrates the ICC for the rater group's rearfoot width measurement from the three dimension foot models taken. The results demonstrate an Intraclass correlation coefficient of 0.997. This is highly significant and demonstrates a high inter-rater reliability amongst the raters.

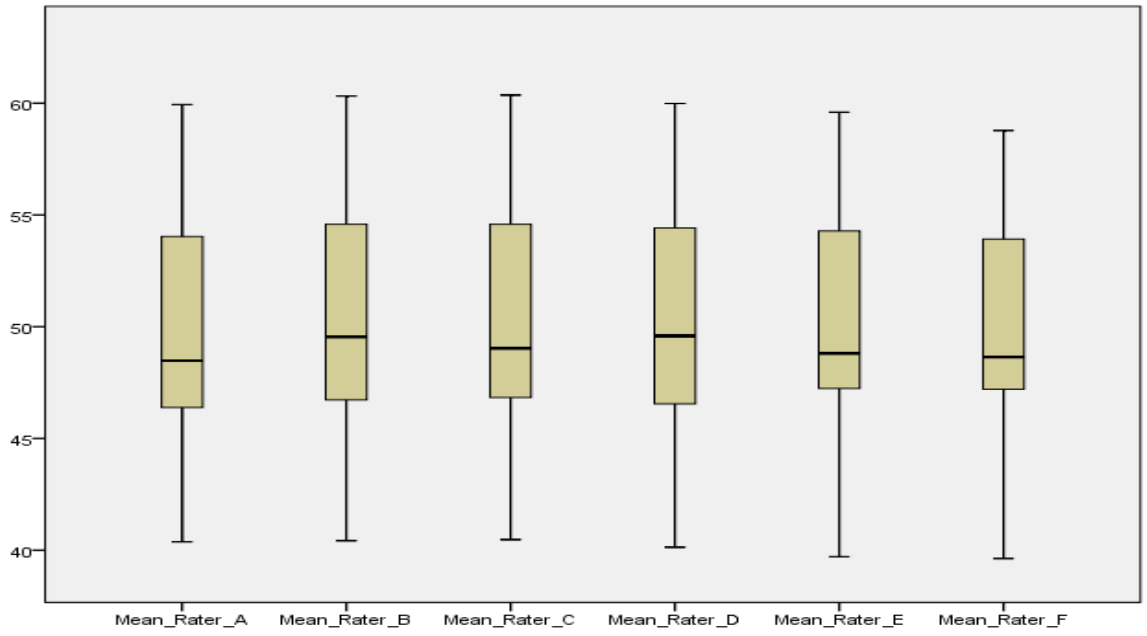

Figure 9 Dataset for all raters of inter-rater reliability of rearfoot width

Figure 9 represents the range of measurements for all raters for rearfoot width. The first data set for rater A demonstrates a median of 48.48 millimetres and range of 19.56 millimetres. The second data set for rater B demonstrates a median of 49.54 millimetres and range of 19.89 millimetres. The third data set for rater C demonstrates a median of 49.03 millimetres and range of 19.89 millimetres. The forth data set for rater D demonstrates a median of 49.59 millimetres and range of 19.86 millimetres. The fifth data set for rater E demonstrates a median of 48.80 millimetres and range of 19.89 millimetres. The sixth data set for rater F demonstrates a median of 48.64 millimetres and range of 19.15 millimetres.

3.3 ASSESSMENT OF INTRA-RATER REPEATABILITY

The assessment of intra-rater repeatability is the gauge of the ability of a single rater to reproduce quantitative outcomes under the same experimental conditions. [26-36] The results from the measurements obtained are compared, by medians of correlations, to obtain a median.[36] The measurement of intra-rater repeatability was analysed with the aid of the means, calculations of the Pearson's coefficients of correlation, standard deviation as well as the standard errors of the mean.[36] Pearson's Correlation is significant at values of 0.01.[36] The mean is the average of all the data obtained and the standard deviation being a measure of the dispersion of a set of data.[26-30] The further apart the spread of the data, the higher the deviation and the lower the standard deviation, than lower the spread of the data and the closer the data is to the median.[26-32]

3.3.1 Results for the intra-rater repeatability of medial arch height measurement

Table 5 Pearson's coefficients of correlation of medial arch height for rater A

Correlations

		RaterA_1	RaterA_2	RaterA_3
RaterA_1	Pearson Correlation	1	.989**	.979**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterA_2	Pearson Correlation	.989**	1	.989**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterA_3	Pearson Correlation	.979**	.989**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater A medial arch height had a mean value of 0.984, which demonstrated a significant correlation of the measures. The standard deviation value was 5.29 and the standard errors of the mean was calculated at 1.18.

Table 6 Pearson's coefficients of correlation of medial arch height for rater B

Correlations

		RaterB_1	RaterB_2	RaterB_3
RaterB_1	Pearson Correlation	1	.985**	.962**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterB_2	Pearson Correlation	.985**	1	.980**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterB_3	Pearson Correlation	.962**	.980**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater B medial arch height had a mean value of 0.975, which demonstrated a significant correlation of the measures. The standard deviation value was 4.88 and the standard errors of the mean was calculated at 1.09.

Table 7 Pearson's coefficients of correlation of medial arch height for rater C

Correlations

		RaterC_1	RaterC_2	RaterC_3
RaterC_1	Pearson Correlation	1	.986**	.985**
	Sig. (2-tailed)		.000	.000
	N	20	19	20
RaterC_2	Pearson Correlation	.986**	1	.977**
	Sig. (2-tailed)	.000		.000
	N	19	19	19
RaterC_3	Pearson Correlation	.985**	.977**	1
	Sig. (2-tailed)	.000	.000	
	N	20	19	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater C medial arch height had a mean value of 0.982, which demonstrated a significant correlation of the measures. The standard deviation value was 5.24 and the standard errors of the mean was calculated at

1.17.

Table 8 Pearson's coefficients of correlation of medial arch height for rater D

Correlations

		RaterD_1	RaterD_2	RaterD_3
RaterD_1	Pearson Correlation	1	.983**	.969**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterD_2	Pearson Correlation	.983**	1	.983**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterD_3	Pearson Correlation	.969**	.983**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater D medial arch height had a mean value of 0.978, which demonstrated a significant correlation of the measures. The standard deviation value was 5.12 and the standard errors of the mean was calculated at 1.15.

Table 9 Pearson's coefficients of correlation of medial arch height for rater E

Correlations

		RaterE_1	RaterE_2	RaterE_3
RaterE_1	Pearson Correlation	1	.969**	.988**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterE_2	Pearson Correlation	.969**	1	.974**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterE_3	Pearson Correlation	.988**	.974**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater E medial arch height had a mean value of 0.977, which demonstrated a significant correlation of the measures. The standard

deviation value was 4.99 and the standard errors of the mean was calculated at 1.12.

Table 10 Pearson's coefficients of correlation of medial arch height for rater F

Correlations

		RaterF_1	RaterF_2	RaterF_3
RaterF_1	Pearson Correlation	1	.964**	.995**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterF_2	Pearson Correlation	.964**	1	.969**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterF_3	Pearson Correlation	.995**	.969**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater F medial arch height had a mean value of 0.978, which demonstrated a significant correlation of the measures. The standard deviation value was 5.12 and the standard errors of the mean was calculated at 1.15.

3.3.2 Results for the intra-rater reliability of forefoot width measurement

Table 11 Pearson's coefficients of correlation of forefoot width for rater A

Correlations

		RaterA_1	RaterA_2	RaterA_3
RaterA_1	Pearson Correlation	1	.990**	.990**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterA_2	Pearson Correlation	.990**	1	.995**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterA_3	Pearson Correlation	.990**	.995**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater A forefoot width had a mean value of 0.991, which demonstrated a significant correlation of the measures. The standard deviation value was 7.27 and the standard errors of the mean was calculated at 1.63.

Table 12 Pearson's coefficients of correlation of forefoot width for rater B

Correlations

		RaterB_1	RaterB_2	RaterB_3
RaterB_1	Pearson Correlation	1	.993**	.991**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterB_2	Pearson Correlation	.993**	1	.988**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterB_3	Pearson Correlation	.991**	.988**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater B forefoot width had a mean value of 0.991, which demonstrated a significant correlation of the measures. The standard deviation value was 7.04 and the standard errors of the mean was calculated at 1.57.

Table 13 Pearson's coefficients of correlation of forefoot width for rater C

Correlations

		RaterC_1	RaterC_2	RaterC_3
RaterC_1	Pearson Correlation	1	.990**	.995**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterC_2	Pearson Correlation	.990**	1	.991**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterC_3	Pearson Correlation	.995**	.991**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater C forefoot width had a mean value of 0.992, which demonstrated a significant correlation of the measures. The standard deviation value was 7.07 and the standard errors of the mean was calculated at 1.58.

Table 14 Pearson's coefficients of correlation of forefoot width for rater D

Correlations

		RaterD_1	RaterD_2	RaterD_3
RaterD_1	Pearson Correlation	1	.986**	.985**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterD_2	Pearson Correlation	.986**	1	.995**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterD_3	Pearson Correlation	.985**	.995**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater D forefoot width had a mean value of 0.988, which demonstrated a significant correlation of the measures. The standard deviation value was 6.84 and the standard errors of the mean was calculated at 1.53.

Table 15 Pearson coefficients of correlation of forefoot width for rater E

Correlations

		RaterE_1	RaterE_2	RaterE_3
RaterE_1	Pearson Correlation	1	.982**	.985**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterE_2	Pearson Correlation	.982**	1	.995**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterE_3	Pearson Correlation	.985**	.995**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater E foot width had a mean value of 0.987, which demonstrated a significant correlation of the measures. The standard deviation value was 7.14 and the standard errors of the mean was calculated at 1.60.

Table 16 Pearson's coefficients of correlation of forefoot width for rater F

Correlations

		RaterF_1	RaterF_2	RaterF_3
RaterF_1	Pearson Correlation	1	.988**	.993**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterF_2	Pearson Correlation	.988**	1	.992**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterF_3	Pearson Correlation	.993**	.992**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater F foot width had a mean value of 0.991, which demonstrated a significant correlation of the measures. The standard deviation value was 7.17 and the standard errors of the mean was calculated at 1.60.

3.3.3 Results for the intra-rater reliability of foot length measurement

Table 17 Pearsons' coefficients of correlation of foot length for rater A

Correlations

		RaterA_1	RaterA_2	RaterA_3
RaterA_1	Pearson Correlation	1	.996**	.994**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterA_2	Pearson Correlation	.996**	1	.995**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterA_3	Pearson Correlation	.994**	.995**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater A foot length had a mean value of 0.995, which demonstrated a significant correlation of the measures. The standard deviation value was 15.00 and the standard errors of the mean was calculated at 3.36.

Table 18 Pearson's coefficients of correlation of foot length for rater B

Correlations

		RaterB_1	RaterB_2	RaterB_3
RaterB_1	Pearson Correlation	1	.997**	.995**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterB_2	Pearson Correlation	.997**	1	.998**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterB_3	Pearson Correlation	.995**	.998**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater B foot length had a mean value of 0.997, which demonstrated a significant correlation of the measures. The standard deviation value was 15.02 and the standard errors of the mean was calculated

at 3.36.

Table 19 Pearsons' coefficients of correlation of foot length for rater C

Correlations

		RaterC_1	RaterC_2	RaterC_3
RaterC_1	Pearson Correlation	1	.997**	.994**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterC_2	Pearson Correlation	.997**	1	.997**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterC_3	Pearson Correlation	.994**	.997**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater C foot length had a mean value of 0.996, which demonstrated a significant correlation of the measures. The standard deviation value was 15.20 and the standard errors of the mean was calculated at 3.40.

Table 20 Pearson's coefficients of correlation of foot length for rater D

Correlations

		RaterD_1	RaterD_2	RaterD_3
RaterD_1	Pearson Correlation	1	.996**	.995**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterD_2	Pearson Correlation	.996**	1	.999**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterD_3	Pearson Correlation	.995**	.999**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater D foot length had a mean value of 0.996, which demonstrated a significant correlation of the measures. The standard

deviation value was 15.26 and the standard errors of the mean was calculated at 3.41.

Table 21 Pearson's coefficients of correlation of foot length for rater E

Correlations

		RaterE_1	RaterE_2	RaterE_3
RaterE_1	Pearson Correlation	1	.996**	.995**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterE_2	Pearson Correlation	.996**	1	.997**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterE_3	Pearson Correlation	.995**	.997**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater E foot length had a mean value of 0.996, which demonstrated a significant correlation of the measures. The standard deviation value was 14.85 and the standard errors of the mean was calculated at 3.32.

Table 22 Pearson's coefficients of correlation of foot length for rater F

Correlations

		RaterF_1	RaterF_2	RaterF_3
RaterF_1	Pearson Correlation	1	.997**	.995**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterF_2	Pearson Correlation	.997**	1	.998**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterF_3	Pearson Correlation	.995**	.998**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater F foot length had a mean value of 0.996, which demonstrated a significant correlation of the measures. The standard deviation value was 14.87 and the standard errors of the mean was calculated

at 3.33.

3.3.4 Results for the intra-rater reliability of rearfoot width measurement

Table 23 Pearson's coefficients of correlation of rearfoot width for rater A

Correlations

		RaterA_1	RaterA_2	RaterA_3
RaterA_1	Pearson Correlation	1	.983**	.976**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterA_2	Pearson Correlation	.983**	1	.983**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterA_3	Pearson Correlation	.976**	.983**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater A rearfoot width had a mean value of 0.978, which demonstrated a significant correlation of the measures. The standard deviation value was 4.91 and the standard errors of the mean was calculated at 1.10.

Table 24 Pearson's coefficients of correlation of rearfoot width for rater B

Correlations

		RaterB_1	RaterB_2	RaterB_3
RaterB_1	Pearson Correlation	1	.992**	.985**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterB_2	Pearson Correlation	.992**	1	.984**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterB_3	Pearson Correlation	.985**	.984**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater B rearfoot width had a mean value of 0.987, which demonstrated a significant correlation of the measures. The standard

deviation value was 4.96 and the standard errors of the mean was calculated at 1.11.

Table 25 Pearson's coefficients of correlation of rearfoot width for rater C

Correlations

		RaterC_1	RaterC_2	RaterC_3
RaterC_1	Pearson Correlation	1	.972**	.967**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterC_2	Pearson Correlation	.972**	1	.994**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterC_3	Pearson Correlation	.967**	.994**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater C rearfoot width had a mean value of 0.977, which demonstrated a significant correlation of the measures. The standard deviation value was 4.86 and the standard errors of the mean was calculated at 1.09.

Table 26 Pearson's coefficients of correlation of rearfoot width for rater D

Correlations

		RaterD_1	RaterD_2	RaterD_3
RaterD_1	Pearson Correlation	1	.960**	.969**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterD_2	Pearson Correlation	.960**	1	.992**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterD_3	Pearson Correlation	.969**	.992**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater D rearfoot width had a mean value of 0.973, which demonstrated a significant correlation of the measures. The standard deviation value was 5.09 and the standard errors of the mean was calculated at

1.14.

Table 27 Pearson's coefficients of correlation of rearfoot width for rater E

Correlations

		RaterE_1	RaterE_2	RaterE_3
RaterE_1	Pearson Correlation	1	.984**	.970**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterE_2	Pearson Correlation	.984**	1	.987**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterE_3	Pearson Correlation	.970**	.987**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater E rearfoot width had a mean value of 0.980, which demonstrated a significant correlation of the measures. The standard deviation value was 5.16 and the standard errors of the mean was calculated at 1.15.

Table 28 Pearson's coefficients of correlation of rearfoot width for rater F

Correlations

		RaterF_1	RaterF_2	RaterF_3
RaterF_1	Pearson Correlation	1	.989**	.989**
	Sig. (2-tailed)		.000	.000
	N	20	20	20
RaterF_2	Pearson Correlation	.989**	1	.990**
	Sig. (2-tailed)	.000		.000
	N	20	20	20
RaterF_3	Pearson Correlation	.989**	.990**	1
	Sig. (2-tailed)	.000	.000	
	N	20	20	20

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's correlation for rater F rearfoot width had a mean value of 0.989, which demonstrated a significant correlation of the measures. The standard deviation value was 5.01 and the standard errors of the mean was calculated at 1.12.

CHAPTER 4: DISCUSSION AND CONCLUSIONS

4.1 INTRODUCTION

This study aimed to gauge the inter-rater reliability and intra-rater reliability within a group of raters utilising a digital white light foot scaner. The intra-rater reliability of the digital white light foot scanner will be discussed with relation to comparisons made between individual raters. The discussion involves comparative analysis with previous findings, as described in literature and recommendations for future studies will also be made.

The results from this study showed high inter-rater reliability with intraclass correlation coefficients has a mean value of 0.998 with the specified foot parameter measurements. Intra-rater repeatability of the same specified foot parameter measurements demonstrated good repeatability with Pearson's coefficients of correlation with mean value of 0.985.

4.2 ASSESSMENT OF COMPUTERISED WHITE LIGHT THREE DIMENSIONAL SCANNING

There are various methods of creating foot models in the preliminary step in the manufacture of custom foot orthosis. [3] Digital white light scanning of the foot has come to the fore front in podiatric orthotic manufacture in the past five years as technology has advanced and equipment costs have reduced.[20] This foot modelling technique allows an accurate alternative to traditional orthotic neutral casting techniques.[13,14] The use of digital scanning enables the creation of an accurate foot model with reliable and measurable parameters.[13]

Research detailing the reliability of parameter measurements of digital scanning demonstrates significantly repeatable parameters measurements.[11,13] Previous studies conducted by Laughton et al. (2002) and Carroll et al. (2011), showed highly significant reliablity Inter-rater reliability Intraclass Correlation Coefficients (ICC's)

ranging from 0.81 to 0.99 and Intra-rater repeatability Intraclass Correlation Coefficients ranging from 0.82 to 0.98 have been noted for digital foot modelling techniques. [11,13,14] However, neutral suspension casting techniques have been shown to be only moderately reliable with Inter-rater ICC ranging from 0.49 to 0.99 and Intra-rater ICC ranging from 0.36 to 0.99.[11,13,14]

The current study was conducted making use of six qualified Podiatrists as raters, who positioned twenty healthy subjects, in a semi-weight bearing position on a digital white light scanner to obtain a three dimensional foot model. Whilst data collection was conducted, there was a minimal chance of a learned response due to the raters measuring each subject once and then moving on to the next subject. This procedure was repeated until three digital foot models were obtained on all twenty subjects. Additionally the raters did not record any measurements; as an independent person measured and documented all data obtained from the digital foot models of the specified foot parameters, to remove any bias.

The results of this study showed a highly significant inter-rater reliability amongst the raters with values of Intraclass Correlation Coefficient ranging from 0.997 - 1.000 and inter-rater reliability of raters with Pearson correlation values of 0.964 – 0.999.

4.3 ASSESSMENT OF INTER-RATER RELIABILITY

As noted in previous studies, inter-rater reliability when performing the digital foot scanning has shown to be reliable .[13] During this study, the calculation of Intraclass Correlation Coefficient showed a highly significant result between raters (0.997 – 1.000). This result is important as it demonstrates that regardless of the rater, the digital foot models have significantly similar foot parameter measurements.

The study that was conducted did however note that the medial arch height measurement did have some inconsistency with the parameters of subject two. These outlier parameter measurements during this study could point to plantar foot pressure on scanning glass plate of the digital white light scanner as the foot is placed. This measurement may well be dependent on the subjects own force applied to the scanner glass by the scanned foot. Clinical significance of this is that

regardless of the rater who positions the foot on the digital white light scanner the foot parameter measurements will be repeatable.

4.4 **ASSESSMENT OF INTRA-RATER REPEATABILITY**

In previous studies, it was demonstrated that there is statistically significant intra-rater reliability when correlating measured foot paramenters.[11,13] A highly significant intra-rater repeatability was noted in this study, as evident by the Pearson correlation values which ranged from 0.964 – 0.999. This result supports the Hypothesis of the study.

4.5 **LIMITATIONS OF THIS STUDY**

Upon completion of this study, certain limitations were identified. The data collection occurred on one day with raters having a recess between subject groups, in order to prevent any type of learned response from occurring, it would have been beneficial to perform the measurements on two separate occasions.

Small sample size of raters and participants may skew the reliability of the collected data. Included participants with diagnosed foot deformity may have contributed to the depth of the data collected, and may have been more representative of daily podiatric practice.

The study also relied on the rater's ability to position subject on the white light scanner correctly, further time and training on the equipment may have been beneficial. This would include having a separate day on which raters could send time working with the white light scanner

Excluding the use of adhesive spherical anatomical markers, figure 2, as they showed tendency of displacing position on the foot. A semi permanent ink marker pen is recommended as an alternative.

The utilisation of a leg stabilization frame and force meter to quantify plantar foot pressure and position would aid in further accuracy of data collected.

The study protocol was limited to one type of white light digital scanner, and assessing different models and calibrations on these models would be beneficial.

4.6 **RECOMMENDATIONS**

This study presents the reliability of the use of white light digital foot scanning in the creation of three dimensional foot model for the manufacture of custom foot orthosis. Deficits that were identified during the study include, inadequate time for raters to familiarise themselves with the use of the scanning equipment, the measuring should also be conducted with subjects being isolated from each other to eradicate any variability. The type of subjects analysed should include subjects who had foot pathology and deformity, as such subjects would be encountered during clinical practice. In conclusion, this study had a limited number of subjects, future studies need to be conducted with a greater cohort size to increase the soundness of the data.

4.7 **CONCLUSION**

This study intended to highlight the inter-rater reliability and intra-rater reliability of specified foot parameters of a three dimensional foot modeling technique. As computerised digital foot modeling is seen as the first step in the manufacturing process of computer aided designed corrective foot orthosis, accuracy of such scans would be imperative. The information obtained from this study would be of significance for the Podiatric community as it highlights that computerised white light scanning technology is reliable.

Assessment of the reliability of computerised digital white light scanning as an integral first step in the manufacture of custom foot orthoses has a direct effect on Podiatric practice. The accuracy of foot modeling would have an effect on the corrective outcomes of such biomechanically corrective foot orthotic devices. These corrective outcomes would include the fitment and tolerance of the completed foot orthotic device, plantar foot pressure offloading, limb length equalisation and sub-

talar joint mobility correction. The digital white light scanner allows semi-weight bearing model creation. This allows foot plantar tissue expansion to occur without further model modification.

Various techniques of foot modelling have been described in literature, however these non digitised described replication techniques have only been shown to be moderately reliable when comparing specified foot parameters.[11,13,14]

In conclusion, the usage of computerised white light foot scanning equipment is said to reliable according to literature. During this study, a highly significant inter-rater reliability and intra-rater reliability of measured foot parameters. In accordance with the findings of this study, the researcher recommends that the clinical usage of such white light foot scanning techniques and equipment be utilised in daily podiatric for the of three dimensional foot modeling.

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APPENDIX A

INFORMATION AND CONSENT FORM FOR RATERS

Dear Podiatrist

I am currently completing an Msc (Med) in Sport Science at University of Witwatersrand and I intend to conduct a research report in partial fulfilment of my degree. The aim of this study is to measure the reliability of a computerised white light scanning technique used in the manufacture of biomechanical foot orthoses. I invite you to participate in this study and to assist me with the furthering of the scientific knowledge of computerised foot modelling and orthotic manufacture.

The study will assess the reliability of a three dimensional white light computerised scanning technique. This will be performed utilising a semi weight bearing position to capture plantar foot models. The reliability of this technique will be assessed employing specified foot parameters.

As a measurer you will be required to scan twenty participants three times, on one occasion, using the white light scanner. Prior to any scanning being done, a briefing session will be held in which I will demonstrate and discuss how the technique will be performed and the proceedings of the session.

As a Podiatrist, your participation in this study will aid in the development of foot modelling techniques that could be utilised in future patient management.

If you consent to take part in this study, please refer to the section below detailing how both modelling techniques are performed

The three dimensional computer modelling procedure includes the following steps;

The participant will be seated during all measurements procedures, with the left hip, knee and ankle flexed to 90 degrees to the floor. The untested leg being able to rest in a comfortable position.

The podiatrist palpates the medial and lateral aspects of the talus on the participants left foot

The podiatrist places the participants foot on the FlexScan 3D® in a subtalar joint neutral position.

Following this, the foot will be scanned and then electronically transferred to computer.

Three scans of each participants left foot will be taken.

The participant will then move to the next podiatrist for the procedure to be repeated, this continue until all podiatrists' have completed three scans of each participants left foot.

Your inclusion in this study is voluntary and your right to confidentiality will be guaranteed. In addition to this, you are free to withdraw at any time without prejudice.

Should you choose to consent to participate in the study, and for the data obtained to be used in this research, please sign and date the line below. If you decide not to participate be assured that you will not be prejudiced in any way. Should you have any questions or complaints regarding the research process, please feel free to contact Human Research Ethics Committee chairperson or secretary on (011) 717-1234 or email anisa.keshav@wits.ac.za.

Signature..... Date.....

Kind regards

Howard E. Alexander
(Student number 331755)
Telephone number: 083 757 3246
Email: howardal@mweb.co.za

APPENDIX B

PARTICIPANT INFORMATION SHEET AND CONSENT FORM

Dear Participant

I am Howard Alexander, a Masters student in Sport Science at University of Witwatersrand. I intend to conduct a research report in partial fulfilment of my degree. I would like to invite you to participate in this study.

The aim on this study is to measure the reliability of a scanning technique used in the manufacture of foot orthoses. The use of these instruments will be pain free and can cause no harm. As a participant you will not directly or immediately benefit from this study, but it is my hope that the evidence gained will be used to aid in the further development of more accurate foot orthoses and benefits of such corrective devices in the future. The marking and measuring process will take approximately two and a half hours to complete. During this time please feel free to enjoy the refreshments provided in the waiting area.

What will be expected from you as a participant?

Should you consent to take part in this study; prior to commencing measurements, I will mark your left foot with five adhesive spherical markers. Following this, you will be seated comfortably in front of the white light scanner. A group of six podiatrists, will on an individual basis, position your left foot on the white light scanner. A three dimensional image of your left foot will then be obtained. This measurement will be repeated three times with the same podiatrist. After which you will be required to move to the next podiatrist for the procedure to be repeated. This process will be repeated until you have had three images taken with all six podiatrists.

You inclusion in this study is voluntary and your right to confidentiality will be guaranteed. In addition to this, you are free to withdraw at any time without prejudice.

Should you choose to consent to participate in the study, and for the data obtained to be used in this research, please sign and date the line below. If you decide not to participate be assured that you will not be prejudiced in any way. Should you have any questions or complaints regarding the research process, please feel free to contact Human Research Ethics Committee Chairperson or Secretary on (011) 717-1234 or email anisa.keshav@wits.ac.za.

Signature..... Date.....

Kind regards

Howard E. Alexander
(Student number 331755)
Telephone number: 083 757 3246
Email: howardal@mweb.co.za

APPENDIX C

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
R14/49 Mr Howard E Alexander

CLEARANCE CERTIFICATE	**M120969**
PROJECT	The Inter Rater and Intra Rater Reliability of Capturing Foot Parameters Utilising a Computerised White Light Three Dimensional Scanner
INVESTIGATORS	Mr Howard E Alexander.
DEPARTMENT	Centre for Exercise and Sports Medicine
DATE CONSIDERED	28/09/2012
DECISION OF THE COMMITTEE*	Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 08/03/2013 **CHAIRPERSON** .....
(Professor PE Cleaton-Jones)

*Guidelines for written 'informed consent' attached where applicable
cc: Supervisor : Dr D Constantinou

DECLARATION OF INVESTIGATOR(S)
To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University.
I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES...

APPENDIX D

Faculty of Health Sciences
Medical School, 7 York Road, Parktown, 2193
Fax: (011) 717-2119
Tel: (011) 717-2076

Reference: Ms Mpumi Mnqapu
E-mail: mpumi.mnqapu@wits,ac.za
07 December 2012
Person No: 331755
PAG

Mr HE Alexander
P.O. Box 17031
SUNWARD PARK
1470
South Africa

Dear Mr Alexander

Master of Science in Medicine (Sports Science): Approval of Title

We have pleasure in advising that your proposal entitled "*The inter-rater and intra-rater reliability of capturing foot parameters utilizing a computerized white light three dimensional scanner*" has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences