Comparison of 3D Body Scanning Mobile Applications: A Study of MeThreeSixty and 3D Look Mobile Apps Body Measurements

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Abstract

The clothing industry around the globe frequently use human body measurements for garment production. This study aims to determine the potential of 3D body scanning feature of mobile application for product development and selection of right size and fitted garment using fashion e-commerce platform. Digital measurement methods have been introduced recently and developed extensively replacing the traditional manual measurement techniques. The paper addresses to determine the practicability of digital measurements acquired from 3D body mobile scanners in terms of reliability and validity. Formerly, for size and fit recommendation and visualisation, using technology driven interfaces user interaction was approached in terms of receiving body size and shape information manually as well as past purchase history of a garment [1]. However, recently the web 3.0 metaverse fashion technology feature such as 3D body mobile scanners have the potential to enhance the fashion virtual size and fit e-commerce platform for online apparel shopping. Therefore, 3D mobile scanners would be helpful to enrich the accuracy of garment size and fit prediction and garment construction for online shoppers without using user's manual information input in the interface. An exploratory quantitative study has been conducted. The two mobile application scanners (3D Look and MeThreeSixty) have been studied for this paper [2] [3]. The digital body measurements have been analysed comparatively to determine the difference of body measurements extracted from both applications for each participant. Reliability comparison have been estimated in terms of standard error of mean measurement (SEM) to ANSUR allowable errors [4]. Validity was analysed according to ISO 20685 [5]. The reliability of 3D body scanning technologies has been evidenced in various studies [4][6] [7][8] [9]. The Pakistani female, age 18-65+ years has been recruited to participate in the study. The data has been collected by self-scanning method using their own smartphones at home [2] [3]. The mobile applications are available free for users on both Android and iOS.

Keywords: Mobile app scanners, Fashion e-commerce, 3D body scanning

1 Introduction

It is necessary to acquire accurate body dimensions for construction of personalised garments as well as for the determination of best fit garment for apparel shopping either purchase is in-store or online [10][11]. Formerly, in fashion industry measurements were collected with tape measurement method. The manual measurement collection method is a time taking process and a professional helper is required to collect full body measurements. To collect body measurements at home by an in-expert consumer is a difficult process because a consumer should know the exact landmarks to collect the right measurements of specific body parts [12]. However, with the introduction of smartphone application scanners at home, this has a possibility to rectify the predicament of traditional measurement techniques. The benefit of mobile application scanner-based methods is that the user can receive hundreds of body dimensions within few minutes in an automatic way by capturing 2D photos via personal smartphone. The technology has been developing extensively and has a possibility of reducing human error of manual measurements method [2] [3].

Formerly, body scanning booths technology were introduced to benefit fashion e-commerce and in-store environments. The booths were expensive and needs technical knowledge to process the scanning. They are confined to be used in luxury or high-end fashion retail stores and specialist sports brands [13]. However, the latest mobile app scanners are offering numerous fashion e-commerce, social and economic benefits to retailers and consumers both. The technology is available to majority of general in-expert public as these mobile applications are user friendly and free to access [14].

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The study seeks to determine the possibility of mobile application 3D body scanning feature for product development and selection of right size and fitted garment using fashion e-commerce platform. The mobile application scanning offers digital body measurements and personalise 3D Avatar of individual users. The consumers can self-scan themselves and can realise their own body shape and size at home. This user-friendly technology has opened new horizons for acquiring personalise services at home for making garment selection and customisation process easier. Moreover, this technology has a potential to improve brand communication and marketing in terms of fashion viewing technologies in e-commerce environment. The study is focused to comparatively analyse the 3D body scanning measurements of two mobile applications. The applications are selected for study because they have been currently used by fashion Industry retailers for product construction and selection via e-commerce platforms. Therefore, the study addresses two research objectives. 1. To find out the difference of digital body measurements of both applications with considerations of the standard error of mean measurement (SEM) to ANSUR allowable errors to determine the reliability of mobile app scanners. 2. To determine the validity of both mobile applications measurements according to BS ISO 20685:2010 [5]. Therefore, this study will help to find out the practicability of both applications commercial usage in fashion Industry to enhance online garment size and fit.

2   Literature Review

The 3D body scanning tool has a potential to enhance and improve the personalised product development process. Recent researchers such as Almalki et al. (2020) and Idrees et al. (2020) have conducted study to establish the consumer behaviour in terms of using 3D body scanning measurements for customisation of garments. Studies have proven that consumers are interested in using body scanning technology for acquiring digital measurements to receive personalise garment construction services [15] [14]. The use of body scanning tool permits buyers to become co-designers, facilitated by online platforms for configuration of a product, to allow user to better indicate products that are customised to their personal style and fitting needs, prior to manufacture. The 3D body scanners provide valuable sizing data that can be used to create highly accurate made-to measure garments [16].

However, there are more advantages that can be achieved by using 3D body scanning technology. Moreover, 3D body scanning metaverse tool has a significant impact to enhance web 3.0 technology tools such as virtual try-on simulations (size and fit visualisation) and size recommendation for online fashion shopping [2]. Online fashion retailers are trying to improve online retail environment by incorporating augmented reality and virtual try-on tools for fashion viewing technology as well as to improve size and fit selection of a garment while online shopping. Such tools can be used to enrich the shopping experience in a way that would have been difficult before body scanning technology and artificial intelligence systems. AR and VR permits buyers to view a live show of physical retail environment. The technology has a potential for use in fashion industry by providing platforms for people to simulate garments or body modifications, and eventually provide a showground where fashion is consumed [17] [18] [19].

3   Materials and Methods

3.1   Equipment

3D Look and MeThreeSixty mobile application has been used for 3D Body Scanning of participants. The apps are chosen because they are offering free 3D body scanning services by using a smartphone. After installation of application user is required to register with their email ID and password. Then, demographic information (3D Look, gender & height) (MeThreeSixty, weight) is required to start the scanning process. Each application has similar mechanism using 1xfront and 1xside scan. The user is required to stand straight in A-pose for front scan and for side scan, the user is required to stand straight in profile view by joining legs and feet together and hands touching the thighs. The user is required to wear tight fitted dress; therefore, the contours of the body can be examined to deliver accurate results.

3D Look: The time for scanning is 1 minute and user can acquire 70+ measurements by using selfie and snapshot scanning modes. 70+ measurements can be obtained by using the paid plan of app. However, a free user can receive eight body measurements with a personalise 3D Avatar with size recommendation by Country (EU and US) for tight fit, regular fit and loose fit.

MeThreeSixty: A person can be scanned fully in 5 min and user can receive 12 body measurements along with body fat percentage, and body surface area with 3D personalise Avatar. It also offers body tracking facility by which user can compare two body measurements charts, to view before and after difference.

3.2   Methodology

The study is exploratory because the mobile application scanners have been developing and are updating extensively after 3 to 6 months by offering various online retailing services to enhance online shopping. To recruit participants, snowball sampling method has been adopted.

3.3   Participants

18 Pakistani female, age 18-65+ years has been recruited to participate in the study. The mechanism of 3D body scanning has been explained to participants before scanning. Further prior scanning, participants completed the consent form. The participants were scanned using the smartphone and measurements were acquired for comparative analysis. The age distribution of participants has been presented in the Figure 1.
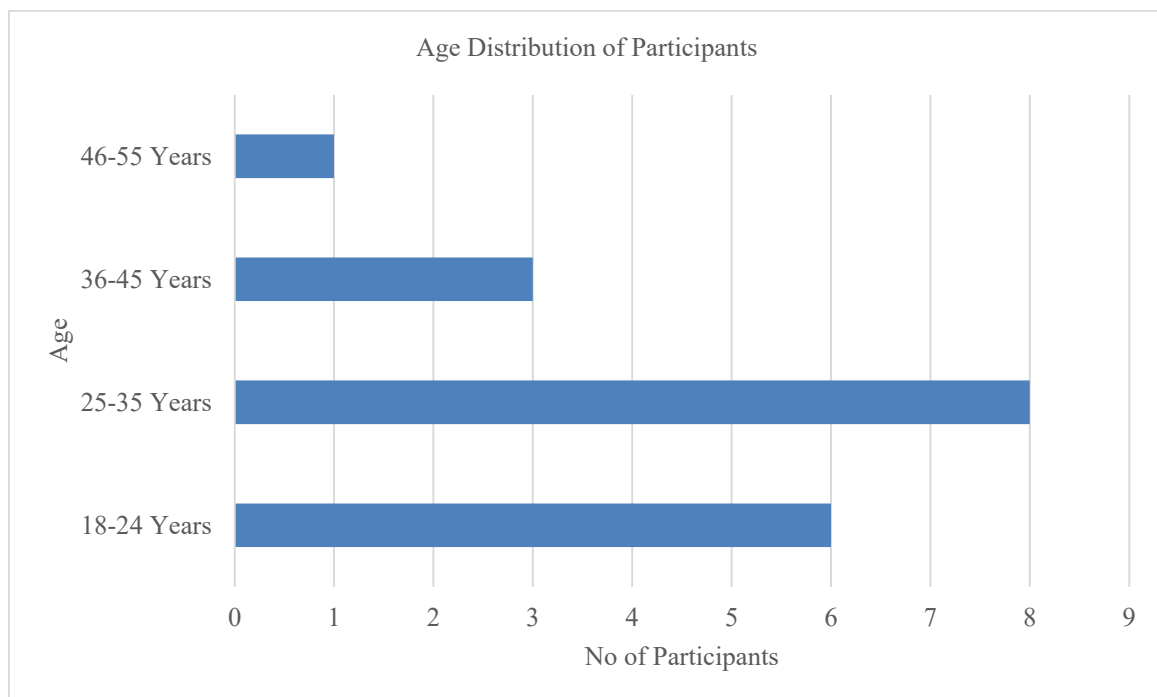

Figure 1 Age Distribution of All 18 Participants

3.4   Body Measurements

3Dlook mobile app scanner deliver 8 body dimensions and 12 body dimensions were received from MeThreeSixty mobile app scanner. To acquire back shoulder width, inseam right, outside leg length right highlighted in red colour in Table 1, the QR code from MeThreeSixty app is scanned and 240 body measurements have been collected from The University of Manchester Size Stream Scanner SS20 set-up. The right-side body measurements and measurements presented by mobile app scanners were used for comparative analysis. The measurements used for study are displayed in the Table 1. Neck to upper hip length offered by 3Dlook cannot be compared with the body dimension of MeThreeSixty mobile application half back centre tape measure because the landmark identification is different in both measurements. In bodice block construction and construction of garment half back centre measurement is used, and 3D look should provide that specific body dimension after scanning so it can be used for garment customisation.

Table 1 Body Measurements for Comparative Study

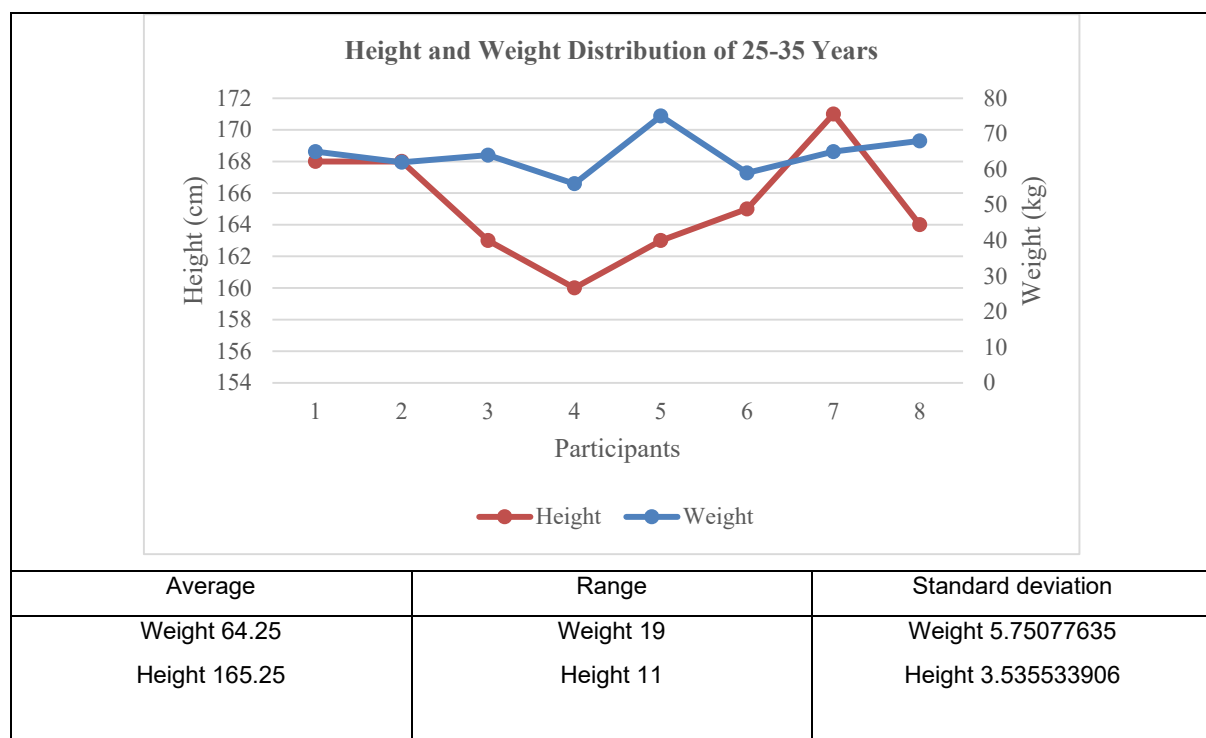| Sr. No	Measurements	Sr. No	Measurements
A	Shoulder width	1	Back Shoulder width
1	Chest/Bust	2	Bust girth
2	Waist	3	Waist girth
3	Stomach		
		4	Upper hip girth
4	Hip	5	Hip girth
B	Inseam right	6	Inside leg length
5	Left Bicep		
6	Right Bicep		
7	Left Thigh		
8	Right Thigh		
9	Left Calf		
10	Right Calf		
11	Left Forearm		
12	Right Forearm		
C	Half Back Centre Tape Measure	7	Neck to upper hip length
D	Outside leg length right	8	Outside leg length
13	Body surface area		
14	Body Fat		

3.5   Height and Weight Distribution of Participants

Subject sample comprised of 18 females, aged from 18 to 65+ years. 6 participants of 18-24 years participated in the study (Table 2). 8 participants of 25-35 years participated in the study (Table 3), 3 participants of 36-45 years participated in the study (Table 4) and 1 participant of 46-55 years participated in the study (Figure 2). Table 2, Table 3, Table 4, and Figure 2 presents average, range and standard deviation of height and weight of 18-24 years, 25-35 years, 36-45 years, and 46-55 years respectively. Each mobile application MeThreeSixty and 3D look scanning was done for each participant once and on the same day. Similar scanning suit was worn by each participant for both app scanners to maintain consistency.
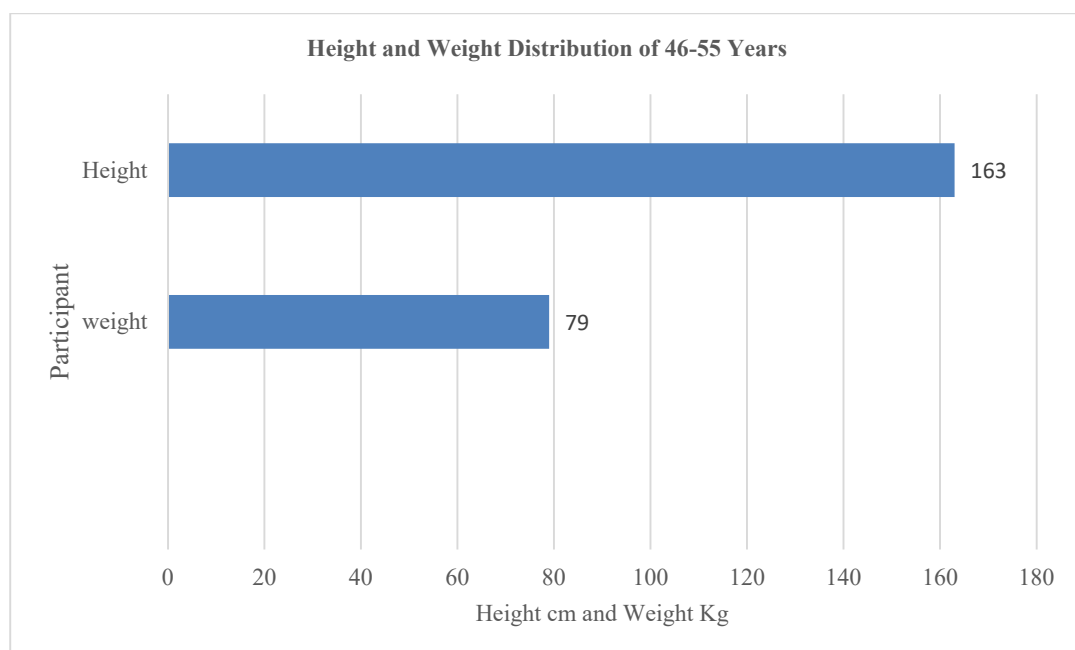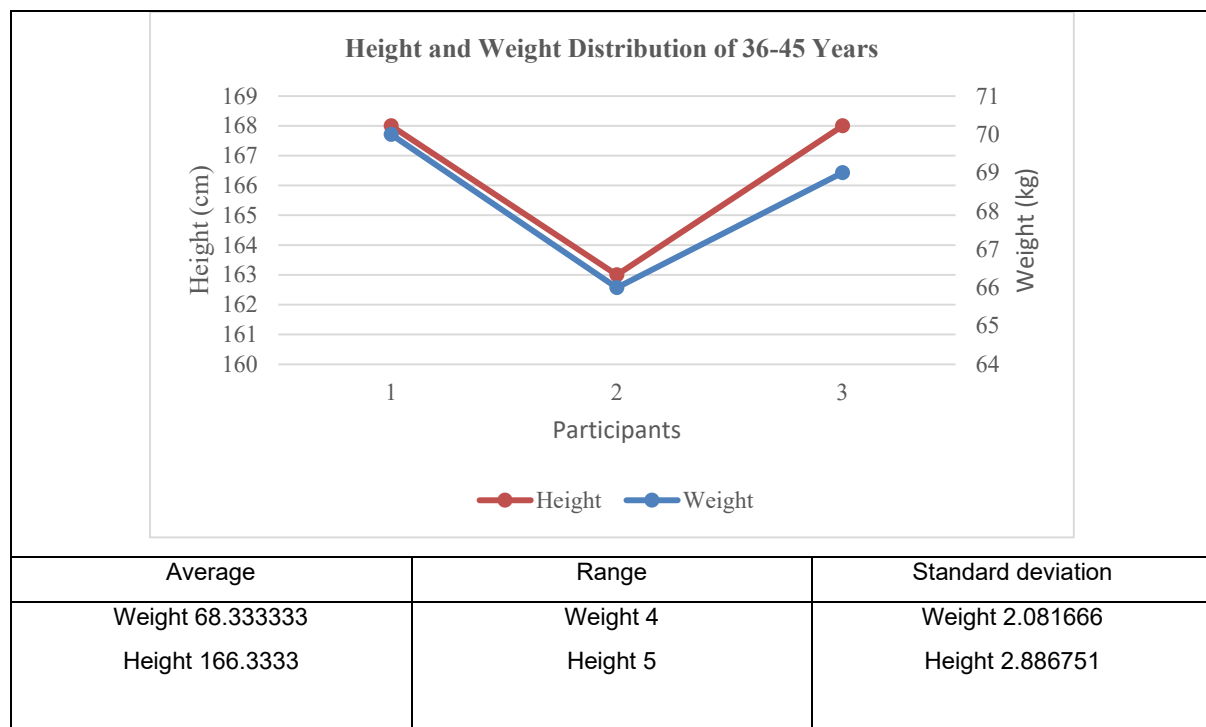
Table 2 Height and Weight Distribution of 18-24 Age Range Participants

Height and Weight Distribution of 18-24 Years

Average	Range	Standard deviation
Weight 51.3	Weight 11	Weight 4.0
Height 166.3	Height 14	Height 5.3
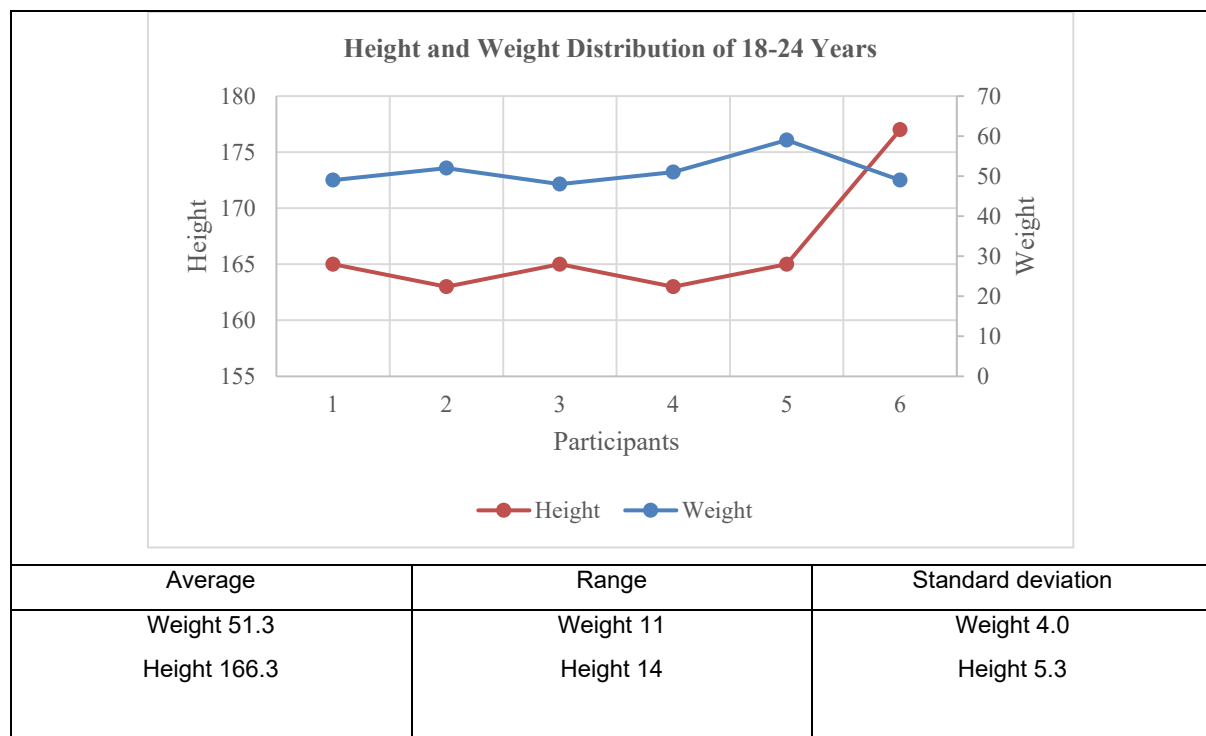
Table 3 Height and Weight Distribution of 25-35 Age Range Participants

Height and Weight Distribution of 25-35 Years

Average	Range	Standard deviation
Weight 64.25	Weight 19	Weight 5.75077635
Height 165.25	Height 11	Height 3.535533906

Table 4 Height and Weight Distribution of 36-45 Age Range Participants

Height and Weight Distribution of 36-45 Years

Average	Range	Standard deviation
Weight 68.333333	Weight 4	Weight 2.081666
Height 166.3333	Height 5	Height 2.886751

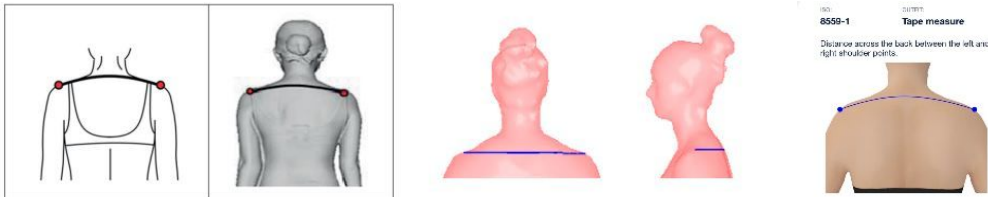**Height and Weight Distribution of 46-55 Years**

Figure 2 Height and Weight Distribution of 46-55 Age Range Participant

4   Reliability of Measurements

The reliability of measurements was analysed by calculating the standard error of mean measurement (SEM) to ANSUR allowable errors. For each body dimension SEM was calculated separately by performing the independent t-test of identical body dimensions employing the SPSS software [11] [4]. The results are presented in the Table 11 and Figure 6. Bust, waist and hip circumference body dimensions, SEM exceeded from the allowable errors with greater variation in measurements. However, the back shoulder width body dimension, SEM presents a lower difference in body dimensions and does not fall completely in the ANSUR allowable error range. The shoulder width body dimension according to ISO 8559-1 is "Distance between the right and left shoulder points. Position: Subject sits or stands erect with shoulders relaxed". The ISO 8559-1 presents that arms are straight and joined with thorax not away from body in the A-pose as suggested by body scanners. The similar landmark definition of ISO 8559-1 is followed by 3Dlook but followed A-pose for scanning "Distance across the back between the left and right shoulder points". Comparably, the shoulder width defined by Size Stream (MeThreeSixty) as "contour measurement from one shoulder point to the other. Can be taken on the horizontal, at 45 degrees, or through the back-neck point". This presents that there is a need to provide definition of landmarking with position of a user in A-pose. There is a possibility of higher body dimension with A-pose. ISO-8559-1 of back shoulder width does not directly relate to the scanner landmarks (Table 5).

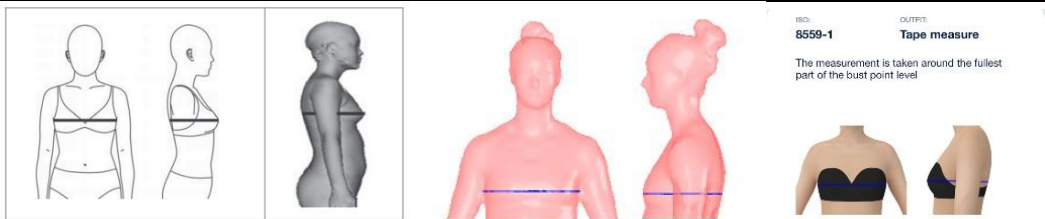*Table 4 Back Shoulder Width Measurements Landmarking Definition*

ISO/APP	Measurements	Definitions
ISO 8559-1	5.4.2 Back shoulder width	Distance between the right and left shoulder points. Position: Subject sits or stands erect with shoulders relaxed.
Me Three Sixty (Size Stream)	Back Shoulder Width	Contour measurement from one Shoulder point to the other. Can be taken on the horizontal, at 45 degrees, or through the Back-Neck point.
3D Look	Back Shoulder Width	Distance across the back between the left and right shoulder points

Back Shoulder width landmarks (ISO 8559-1, MeThreeSixty, and 3D Look)

The higher differences are noted with the bust, waist and hip circumferences. Bust circumference defined by Size Stream as "Horizontal contour circumference measured across the bust points, under the armpits and around the back. circumference". Equally, 3Dlook follows the ISO 8559-1 standard for bust girth landmarking, which is defined as "The measurement is taken around the fullest part of the bust point level" [20]. To calculate the bust circumference using the app scanner there is a need to identify the landmarks of breast height, breast width, bust point width and chest band [21]. There is variation in measurement definition and agreement as to the key points that define each measurement. Scanners tend to take the bust horizontally, something which is unlikely to occur in person measurement as the tape measurement will dip in the back. Kim et al. (2015) presented that when using scan suit the breast tissues are compressed and presents body dimensions smaller as compared to the scanning with the undergarments. Moreover, it also effects the cup size of the breast size and presents smaller cup size when it is scanned with the scan suit. There is also a need to address the accurate scan suit and garments for accuracy in capturing the bust circumference dimensions. Since it is identified by Zamkoff and Price (1996) that the difference of one inch bust girth difference is large enough to change one garment size as the rules of grading for smaller sizes generally increase or decrease by 1.00 inches at main locations [22] (Table 6).
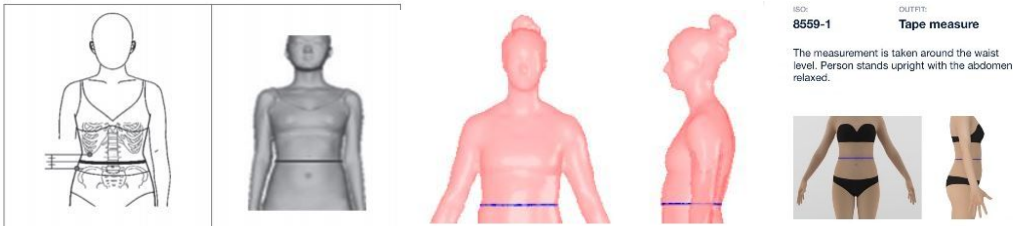
Table 6 Bust Circumference Measurements Landmarking Definition

ISO/APP	Measurements	Definitions
ISO 8559-1	5.3.4 Bust Girth	Horizontal girth measured at bust point level Position: Subject stands erect with arms hanging freely downward.
Me Three Sixty (Size Stream)	Chest/Bust Circumference	Horizontal contour circumference measured across the Bust points, under the Armpits and around the back. Circumference.
3D Look	Bust Girth	The measurement is taken around the fullest part of the bust point level
BS EN ISO 20685:2010 (BS EN ISO 7250-1:2010)	4.4.9 Chest Circumference	Description: Circumference of the torso measured at nipple level. See Method: Subject stands fully erect with feet together, arms hanging freely downwards. Females wear their usual brassiere. Instrument: Tape measure.

Bust circumference measurement landmark points (ISO 8559-1, MeThreeSixty, and 3D Look)

For waist girth, the landmarking of 3D look is defined as "The measurement is taken around the waist level. Person stands upright with the abdomen relaxed". Whereas ISO 8559-1 presents definition as "waist circumference needs to be measured at the level of midway between the lowest rib point and the highest point of the hip bone". According to Size Stream (MeThreeSixty) waist landmarking is defined as "horizontal contour circumference taken at the narrowest torso width between the chest and hips when viewed from the front". Moreover, there are four parameters of waist circumference such as waist girth, high waist girth, waist band and belly circumference [23]. Each landmarking definition of waist circumference shows variability 3D look provided definition does not define that exact waist level and Size Stream pointed out narrowest torso. The point to be noted is each human being has a different position that presents the narrowest torso at different position from another person. Therefore, landmarking position needs to be accurately defined by companies and need to follow the ISO-8559-1 as it presents the exact landmarking of a specific human being to extract the waist circumference. Furthermore, Gill et al., (2014) presented evidence of a clear relationship between the boundaries of the central waist region and the total height of the participant (Gill et al., 2014). Figure 3 presents the large and small waist regions. The study established the mean length of the waist region was between 2.4 and 13.4 cm (M = 6.92, SD = 2.23) (Gill et al., 2014). The ISO 889 provides a narrow region that the current scan definitions do not adhere to. Therefore, there is a likelihood of differences in the landmark's detection of waist circumference from two different mobile app scanners (Table 7).

Table 7 Waist Circumference Measurements Landmarking Definition

ISO/APP	Measurements	Definitions
ISO 8559-1	5.3.10 Waist Girth	Horizontal girth of the body measured at the waist level. Position: Subject stands erect with the abdomen relaxed.
Me Three Sixty (Size Stream)	Narrow Waist circumference	Horizontal contour circumference taken at the narrowest torso width between the chest and hips when viewed from the front.
3D Look	Waist Girth	The measurement is taken around the waist level. Person stands upright with the abdomen relaxed.
BS EN ISO 20685:2010 (BS EN ISO 7250-1:2010)	4.4.10 Waist circumference	Description: Circumference of trunk at a level midway between the lowest ribs and the upper iliac crest. Method: Subject stands fully erect with feet together and is asked to relax the abdominal muscles. Instrument: Tape measure.

Waist Circumference landmarks (ISO 8559-1, MeThreeSixty, and 3D Look)
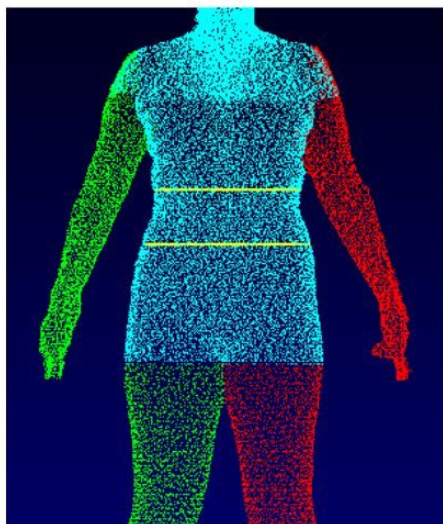

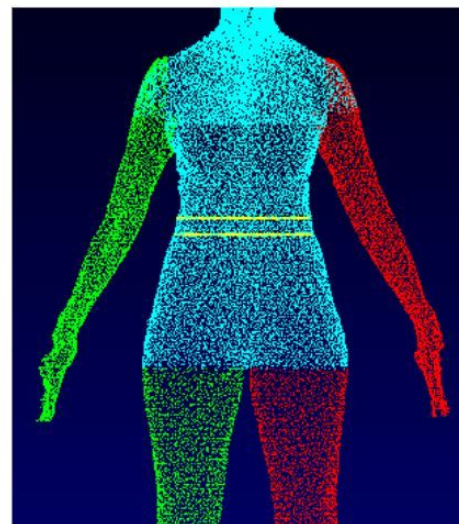Figure 4. Sample scan with a large central waist region

Figure 5. Sample scan with a small central waist region

Figure 3 Large and Small Waist Regions (Gill et al., 2014)

The reason of differences of hip circumference can be analysed by standing position of the person, width of opened legs and the distance of feet from each other from both scanners. Koepke et al. (2017) identified that participants needs to stand in the A-pose with opened legs (hip-wide apart) that allows scanner to accurately identify the crotch body dimension [25]. The width of the feet needs to be selected universally for body scanners and then its differences can be identified accordingly. Jaeschke, Steinbrecher and Pischon (2015) presents five parameters of hip circumference for instance buttock-girth, middle hip, high hip girth, hip girth and hip thigh girth [23]. The landmarking definitions can also be evaluated, the Size Stream defined landmarking of hip circumference as "Maximum contour

horizontal circumference found between the height of the Back Waist landmark and Crotch landmark by size stream". Moreover, 3D look is following the ISO 8559-1 "The measurement is taken around the fullest part of the hip". However, ISO 8559-1 landmarking definition required that person legs should be joined together which might provide smaller measurement as compared to the measurements that are computed with opened legs in A-pose. The definitions presented by mobile app scanner and ISO-8559-1 are not comparable. There is a need to identify the specific parameter of hip circumference in the definition and the crotch position with that specific hip circumference parameter. However, standing position for acquiring body dimension needs to be defined as well. If the requirement is A-pose then the distance of feet from each other should be similar for both scanners, then there is possibility of receiving the accurate body dimensions. Moreover, for garment construction there is need to select an appropriate ease in the pattern when measurements are taken with an A-pose because there is a possibility of receiving higher body dimensions as compared to the manual body dimensions that are acquired according to the ISO 8559-1 (Table 8).
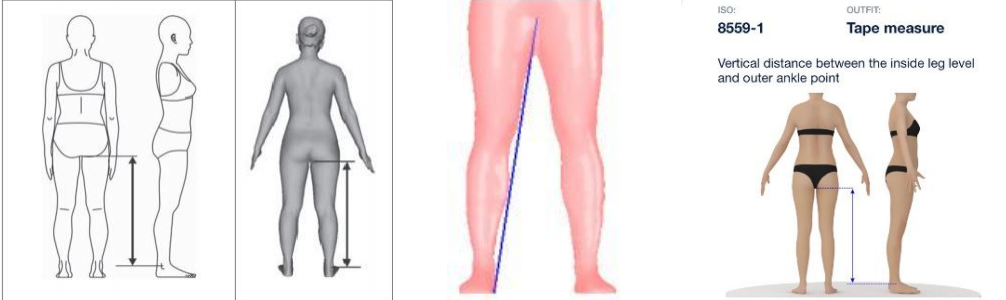
Table 8 Hip Circumference Measurements Landmarking Definition

ISO/APP	Measurements	Definitions
ISO 8559-1	5.3.13 Hip Girth	Horizontal girth of the body measured at the hip level. Position: Subject stands erect with feet together with the abdomen relaxed.
Me Three Sixty (Size Stream)	Hip Circumference	Maximum contour horizontal circumference found between the height of the Back Waist landmark and Crotch landmark.
3D Look	Hip Girth	The measurement is taken around the fullest part of the hip

Hip circumference Landmarks (ISO 8559-1, MeThreeSixty, and 3D Look)

The reliability of mobile scanning techniques can also be evaluated as both app scanners have similar mechanism of scanning as discussed in the section 3.1. Both scanners offered scanning by adjusting the body in the body silhouette provided in the app screen once the scanning process commences. After adjustment of body in the silhouette, the mobile application encapsulates the body image for scanning and presents 3D body avatar and body dimensions. Further, technology of Size Stream scanning is founded on 3D modelling, machine learning. Whereas technology of 3Dlook mobile app scanning is founded on computer vision and deep learning, proprietary statistical modelling, machine learning and 3D matching. Thus, there is possibility of technology used by both scanners to detect the landmark positions to present results.

The inside leg length landmark identification provided by 3Dlook is similar to ISO-8559-1 which is defined as "Vertical distance between the inside leg level and outer ankle point". The Size Stream defined the inseam landmarking definition as "point to point measurement from the Crotch landmark to the inside of the Right Foot on the floor". The SEM does not exceed the provided allowable error for inseam body dimensions. However, the definitions provided by the mobile applications has slight variations that inside leg level need to be properly identified as crotch landmark identified by Size Stream. Furthermore, outer ankle point is described by the 3Dlook and ISO 8559-1 Whereas the Size Stream has provided the landmark of foot on the Floor not ankle point. This is also a main point needs to be addressed by the mobile app scanner companies that which landmarking needs to be universal for the inseam body dimensions. The inseam body dimension is taken as an important dimension in construction of trouser patterns (Table 9).

Table 9 Inseam Measurements Landmarking Definition

ISO/APP	Measurements	Definitions
ISO 8559-1	5.7.6 Inside leg length	Definition: Vertical distance between the inside leg level and outer ankle point. Calculation: Inside leg height minus outer ankle height
Me Three Sixty (Size Stream)	Inseam Right	Point to point measurement from the Crotch landmark to the inside of the Right Foot on the floor.
3D Look	Inside Leg Length	Vertical distance between the inside leg level and outer ankle point

Inseam measurements Landmarks (ISO 8559-1, MeThreeSixty, and 3D Look)

The outside leg length body dimension according to 3Dlook and ISO 8559-1 is "distance down the side of the body from the waist level following the contour to the hip level, then vertically to the ground". Whereas MeThreeSixty explained the outside leg length as "contour measurement of the body from the right-side waist landmark down to hip circumference height and then vertically to the floor". The SEM of outside leg length has exceeded the ANSUR allowable error. As discussed above the landmarking of waist circumference, which shows that there are different waist levels of human body according to the variations of human body waist length. Seventeen waist landmarking definitions are identified by Gill et al. (2014) within the TC2 body scanner software (Figure 4). The waist heights of population have variations. The small of back waist (SOB) is grouped, as established by the torso shape heights and segment lengths are indicated. Large and small central waist region is presented in the figure 3. Further, the small of back waist + 2cm height is the closer definition provided by the ISO 8559-1 (Figure 4). Therefore, there is a need to identify accurate position of waist landmark to enhance the reliability of outside leg length body dimension and to improve the minimum difference in the body dimensions when app scanners are compared (Table 10).

Table 3. Waist Placement Definitions

No.	Waist Placement Definition	No.	Waist Placement Definition
1	Height of Mid Waist Position (Midway [WR1] and [WR2]	10	Small of the Back +6cm_Height_Back
2	Scan Waist Height (Small of the Back +4cm)	11	Small of the Back +8cm_Height_Back
3	Waist_68%_to_CB_neck_Height	12	Small of the Back +10cm_Height_Back
4	Waist_Start68%+4cm_CB_neck_Height_Bk	13	Small of the Back +12cm_Height_Back
5	Waist_70%_to_CB_neck_Height	14	Small of the Back -2cm_Height_Back
6	Waist_72%_to_CB_neck_Height	15	Small of the Back -4cm_Height_Back
7	Waist_Start72%+4cm_CB_neck_Height_Bk	16	Waist-Narrowest_Height_Back
8	Small of the Back _Height_Back	17	Waist_Narrowest-4cm_Height_Back
9	Small of the Back +2cm_Height_Back		

Figure 4 Definitions of Waist Placements (Gill et al., 2014)

The means of scan capture and development of obj file or a personalise avatar (Figure 5) by each scanner has also been noted which is also chief reason of presenting different body dimensions. There is a visible difference of obj file of a participant scanned with both scanners. This visible difference is noted for rest of the participants as well. The 3D look mobile app scanner shows bust, waist and hip circumference are compressed than the MeThreeSixty obj file of the participant. The standing position and distance between feet are also clear that there is visible difference in the standing position and distance between both feet of both scanners have variation.
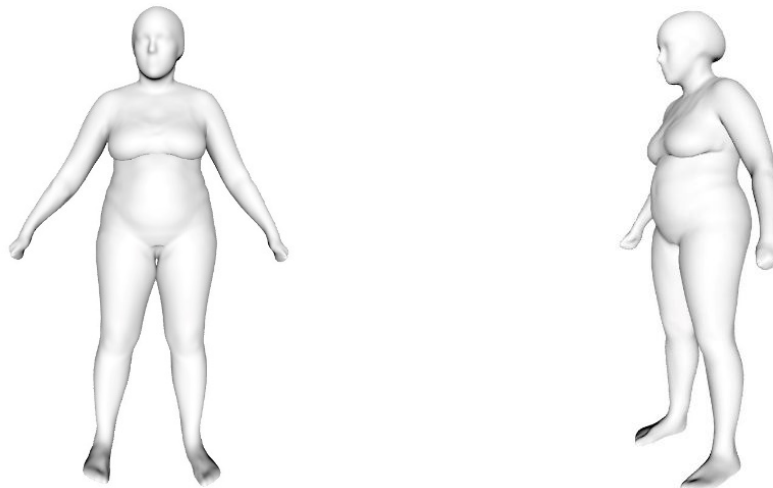
MeThreeSixty obj File of Participant After Scanning
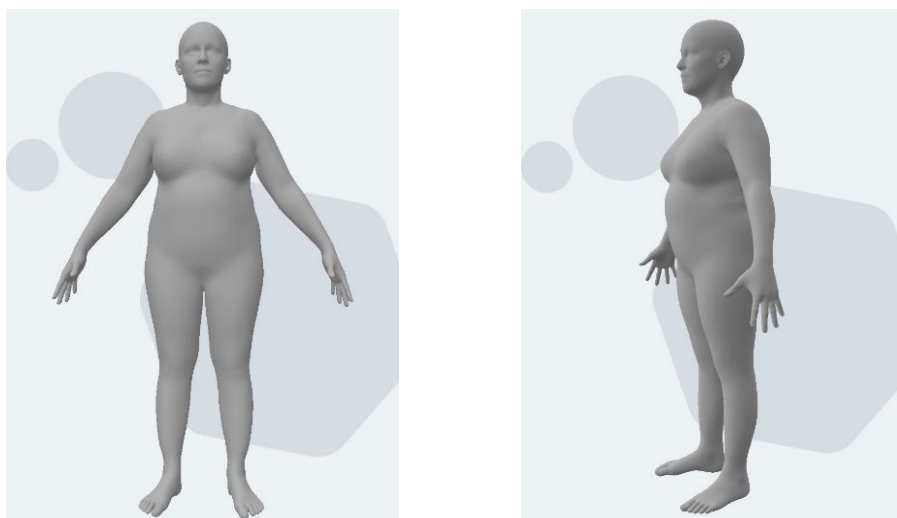
3Dlook obj File of Participant After Scanning

Figure 5 Difference Obj file of A participant From Both Mobile App Scanner

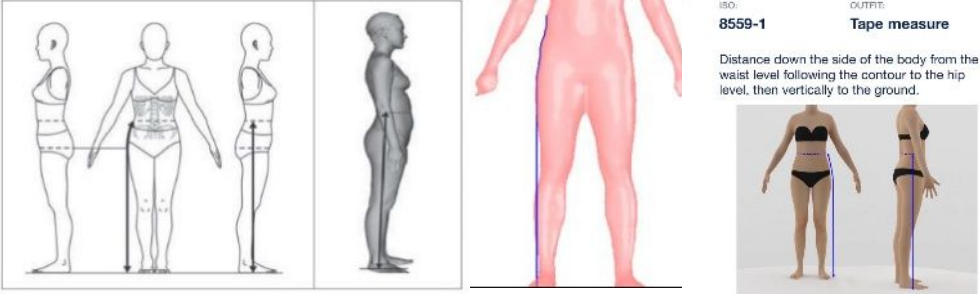*Table 10 Outside leg Length Measurements Landmarking Definition*

ISO/APP	Measurements	Definitions
ISO 8559-1	5.4.22 Outside leg length	Distance down the side of the body from the waist level following the contour to the hip level, then vertically to the ground. Position: Subject stands erect with feet together and arms abducted to form a 20° angle with the side of the body.
Me Three Sixty (Size Stream)	Outside Leg Length Right	Contour measurement of the body from the Right-Side Waist landmark down to Hip Circumference height and then vertically to the floor.
3D Look	Outside Leg Length Right	Distance down the side of the body from the waist level following the contour to the hip level, then vertically to the ground.

Outside Leg Length Measurements Landmarks (ISO 8559-1, MeThreeSixty, and 3D Look)

Table 11 Reliability Analysis of MeThreeSixty and 3D look Mobile Application Body Dimensions (AE and SEM cm)

				95% CIs of Difference		
Sr.	Body Measurements	SEM (cm)	AE (cm)	Lower	Upper	SEM:AE
1	Back Shoulder Width	0.88	0.80	-1.689	1.905	0.88 (SEM) > 0.8 (AE): Different Measurements
2	Chest Bust Circumference/Girth	3.20	1.50	-6.123	6.869	3.20 (SEM) > 1.5 (AE): Different Measurements
3	Waist Circumference/Girth	3.68	1.10	-7.020	7.943	3.68 (SEM) > 1.1 (AE): Different Measurements
4	Hip Circumference/Girth	2.48	1.20	-3.273	6.800	2.48 (SEM) > 1.2 (AE): Different Measurements
5	Inseam Right/Inside Leg Length	0.88	1.00	7.394	10.952	0.88 (SEM) < 1.0 (AE): Same Measurements
6	Outside Leg Length Right	1.09	0.40	7.394	10.952	1.09 (SEM) > 0.4 (AE): Different Measurements

Standard Error of Mean (SEM) vs Allowable Error (AE) - MeThreeSixty vs 3D Look

Figure 6 Reliability Analysis of MeThreeSixty and 3D look Mobile application (AE and SEM cm)

5   Validity of Measurements

The scanner measurements validity was computed in accordance with the ISO 20685 validity algorithm. The body dimensions of MeThreeSixty and 3Dlook were computed for each person. The mean of these differences with its associated standard deviation (σ), sample size, 95% confidence interval (CI) and ANSUR allowable error [11][4] are presented in Table 12 and Figure 6. The body dimensions of shoulder width, bust and waist circumference mean difference does not exceed the limits of ANSUR allowable error [4]. The hip circumference mean difference slightly exceeded the limits of ANSUR allowable error.

The scanning mechanism offered by both scanners is similar by adjusting and standing in the body silhouette presented in the app screen, once the process of scanning initiates. After participant adjusts itself in the body silhouette, the scanner app captures the body image and shows the 3D body avatar and body dimensions. The position of user in front of app scanner can be evaluated. The width of open legs and distance of feet from each foot can be reason of difference of hip circumference body dimensions. There is need to create a standard body silhouette for scanners that allows equal distance of standing position of A-pose to deliver accuracy and validity of body dimensions. Another main reason of presenting the different body dimensions is dependent in the how obj file is built from each scanner app and identification of landmarking of body dimensions (Figure 5).

The mean difference of inseam length shows a higher difference and exceeded the limits of ANSUR allowable error. The landmarking definitions provided by the mobile application scanner has variation 3D look identified inside leg level but does not mention the name of level as provided by the Size stream that is crotch landmark. Moreover, outer ankle point is presented by the 3Dlook whereas Size Stream providing measurement below the ankle point which is floor where feet touch the ground. To create valid body dimensions there is a need to create the universal definitions that is followed by each scanner to provide accuracy in identifying the landmark of body dimensions to provide similar body dimensions.

Furthermore, the mean difference of outside leg length presents a slightly lower difference and slightly exceeded the limits of ANSUR allowable error. The reason concluded that the waist landmarking position needs to be identified as there are seventeen different levels of waist measurement landmarks. Moreover, the waist heights of population have variations. Therefore, there is a possibility of identifying the different waist height levels which causes difference in outside leg length measurements in both scanners.

Table 12 Validity Analysis of MeThreeSixty and 3D look Mobile Application Body Dimensions (AE cm and MD cm)

Sr.	Body Measurements	MD (cm)	SD (cm)	AE (cm)	95% CIs of Difference		MD:AE
					Lower	Upper	
1	Back Shoulder Width	0.11	0.88	0.80	-1.689	1.905	0.11 (MD) < 0.8 (AE): Same Measurements
2	Chest/Bust Circumference/ Girth	0.37	3.20	1.50	-6.123	6.869	0.37 (MD) < 1.5 (AE): Same Measurements
3	Waist Circumference/Girth	0.46	3.68	1.10	-7.020	7.943	0.46 (MD) < 1.1 (AE): Same Measurements
4	Hip Circumference/Girth	1.76	2.48	1.20	-3.273	6.800	1.76 (MD) > 1.2 (AE): Different Measurements
5	Inseam Right/Inside Leg Length	9.17	0.88	1.00	7.394	10.952	9.17 (MD) > 1.0 (AE): Different Measurements
6	Outside Leg Length Right	-1.33	1.09	0.40	7.394	10.952	-1.33 (MD) < -0.4 (AE): Different Measurements

<div align="center">Mean of Difference (MD) vs Allowable Error (AE) - MeThreeSixty vs 3D Look</div>
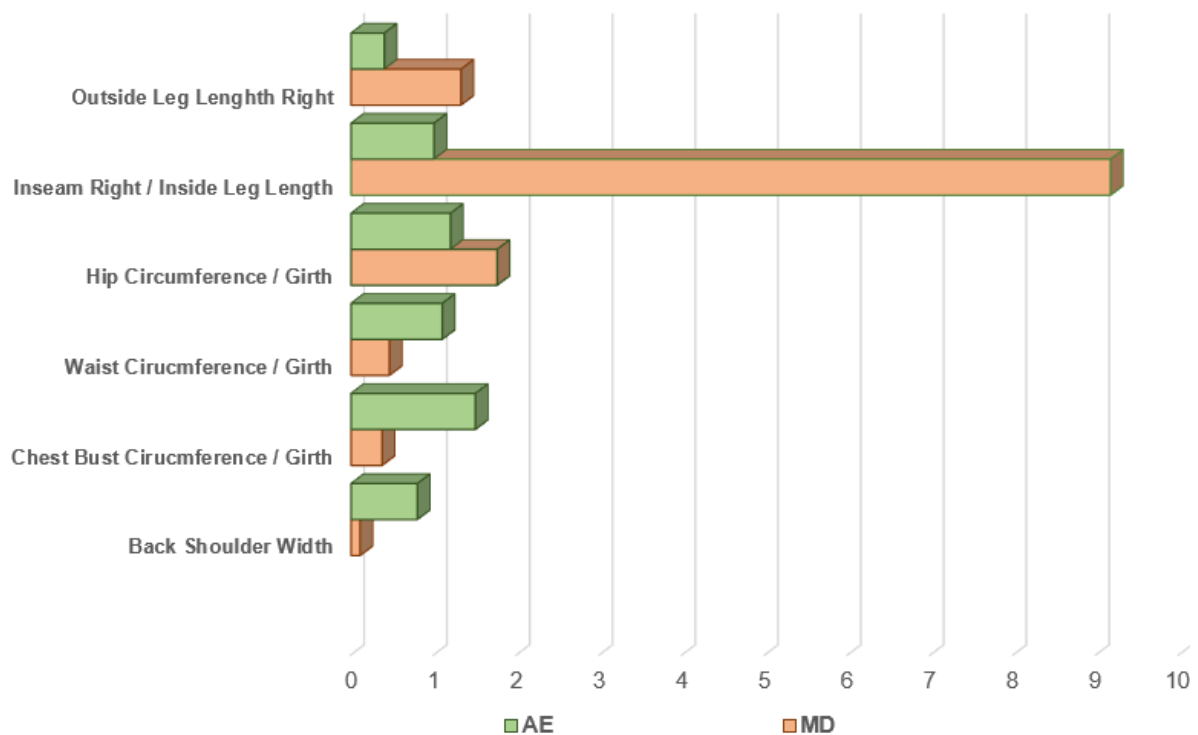

Figure 6 Validity Analysis of MeThreeSixty and 3D look Mobile Application Body Dimensions (AE cm and MD cm)

6   Conclusion

The reliability and validity of measurements of two mobile application scanners has been analysed. The results of reliability standard error of mean measurement (SEM) to ANSUR allowable errors and the scanner measurements validity were computed in accordance with the ISO 20685 validity algorithm. Results concluded that bust, waist and hip body dimensions were exceeded from the allowable errors with higher difference. The main reason noted for the difference in the development of obj file or a personalised avatar. There is a visible difference in the avatars of both scanner output. Therefore, according to this there is a possibility of variations in the identification of landmarks and body

dimensions from two different scanners. This may be to do with how each application renders the model from the initial input data, as well as variations in how measurements are defined between software vendors. It is noted that 3D look provides the landmarking regarding the ISO 8559-1, but the position of a person is straight standing position when measurements are taken whereas, 3D look presents the body dimensions with an A-pose. There is a need to update the landmarking and needs to identify the position of a user as well, as measurement position has been shown to change resulting body morphology and potentially the measurements. For waist measurement as well, there is a need to update the landmarking and this should identify the landmarking definition which is used in mobile body scanners with specific identification of body landmarks of waist. As suggested by Gill et al. (2014) there can be considerable variation in waist definition with up to seventeen waist landmarking definitions because of variations in the waist heights of populations. For hip circumference there is a need to specify distance between the feet for mobile body scanners when body dimensions are taken in A-pose, this is due to the impact of foot width on measurements of the hip. Moreover, there is a requirement to update the definition of landmarking of hip circumference to enhance the accuracy of hip body dimensions. There is a need to suggest ease relative to the possible measurement variation so the user would know the specific ease according to acquired measurement from the mobile scanner app. There is a possibility of acquiring higher body dimensions with an A-pose scanning. For inside leg length there is a need to address the issues of landmarking of acquiring the dimensions which has variation according to provided definition which is the main reason of difference in the body dimensions. Moreover, for outside leg length there is a need to identify the accurate waist landmarks and to update the landmark definition. There is also a requirement to create universal landmarking definitions, therefore the mobile app scanners can show less variability and show more accuracy. Further, there is recommendation to create a scan suit which do not compress the tissues of body which is also a reason of providing different body dimensions. Or scanning can be done in undergarments so an accurate body silhouette can be determined. Moreover, 3D look provides neck to upper hip length which is not employed in the pattern construction. Gill et al. (2015) indicated that all measurements should have some indication of their purpose or application so the user can know why they are taken [26]. The half back centre or back neck to waist measurement is used for construction of garments (bodice block). Therefore, it is required to provide the half back centre body dimension in mobile app scanner which is required for garment customisation. To sum up, Mobile scanning measurements can vary between providers and sometimes these variations can be larger than the tolerances suggested by ANSUR. Moreover, there is variation in how scan companies define their measurements in relation to ISO standards, whilst the standards are not always specific, the scan companies' definition can be even less specific. To gain consistency in measurements very specific definition for measurement placement are necessary. Therefore, it is possible to understand which mobile scanners provide data that is more consistent between different providers.

7   References

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