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Comparison of Human Body Sizing Measurement Data by Using Manual and 3D Scanning Measuring Techniques

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Abstract

In this paper, we analyzed the data of the 17 body sizing measurement parameters of 300 adult male participants who were Shaanxi adult male aged 20∼50, which were collected by using the 3D automatic measurement, 3D interactive measurement and manual measurement. We compared the data of the 3D automatic measurement with those of the 3D interactive measurement and the manual measurement. From the results of the analysis, we can draw the following conclusions: (1) Deviation between the manual measurement and the 3D scanning measurement existed obviously, which cannot be ignored; (2) In the 3D automatic measurement, as the result of the deviation of the identification to the bone location, the measurement data must be checked and modified interactively; (3) The posture of the participant has a significant effect on the measurement data, and the specified basic stance will affect the measurements of shoulder, breast and waist. Therefore, the scanning posture should be standardized based on the need of the study. For example the stance with feet together can make the height measurement more accurate; (4) Many factors would interfere with the accuracy of the manual measure and result the difference with 3D measurement, such as the breathing and posture of the participants, and the measurement skill, experience, position mark etc. (5) There is a linear relation between the manual measurement and the 3D scanning measurement. By establishing the linear regression model the measurement data can be forecasted and calculated.

Keywords: Correlation and Regression Analysis, Manual Measurement, 3D Automatic Measurement, 3D Interactive Measurement

1 Introduction

It is indicated in ISO/DIS 20685 that when using the 3D scanner to measure the human body measurement and to build the human body database, it is needed to compare the accuracy between the 3D scanning measurement and the traditional human body measurement [1].

Many domestic and overseas researchers have studied the comparison of manual measurement and 3D human body scanning measurement.

Two groups of data are acquired by 3D body scanners and manual measurements. To ana1yze and research the relationship between the two groups of data, a curve fitting method based on

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the least-square principle is used. The mapping relationship is acquired between the two groups of data of the body parts which is common1y used in pattern design. By checking the curve goodness of fit, the precision rates of the body parts are discerned and they are above 97.25% [2].

First is comparing the traditional manual body measuring method with the three-dimensional body measuring method. Then an analysis of the repeatability of the data between two measuring methods with statistical methods is conducted. Afterwards it is necessary to probe into the reasons that causes the errors. Finally the key points need to be summarized to avoid errors in the three-dimensional body measuring method [3].

In the former research, the human body measurement experiment was organized [4]. 300 participants were chosen, who were Shaanxi adult male aged 20∼50 years old. To measure the 3D images by automatic measuring and interactive measuring, three sets of data for one subject of the 3D automatic measurements, the 3D interactive measurements, and the manual measurements were collected. By comparing and analyzing the difference of the three sets of the measurement data, the reason of the differences was detected and the relational model was established for the mutual forecast and conversion between the manual measurement and 3D scanning measurement.

2 Data Preparation

2.1 Sample Condition

300 participants were selected, and the average age of the participants was 31.

2.2 Measurement Items

Based on the height, length, girth, width and angle items, 17 typical measurement items were chosen, including Body Height, Cervical Height, Chest Height, Waist Height, Hip Height, Back Length, Arm Length, Neck Base Girth, Chest Girth, Waist Girth, Hip Girth, Whole shoulder Width, Breast Width, Back Width, Chest Depth, Hip Depth, and Shoulder Slope.

2.3 Data Reduction

ScanWorX was the mating measurement software of the Vitus Smart 3D human body scanner. The ScanWorX4.0.1 software can identify the human body gauge point and measure 85 human body parts automatically, and use the tools of line, curve, section, angle, etc to accomplish the interactive measurement.

1. The tool of automatic measuring of ScanWorX4.0.1 software was used to measure the 3D image, and the measurement data was shown as Group 1 (hereinafter as G1).

2. The tool of interactive measuring of ScanWorX4.0.1 software (line, curve, section, angle, ect.) was used to measure the 3D image, and the measurement data was shown as Group 2 (hereinafter as G2).

3. The manual measurements were input into the computer, which was shown as Group 3 (hereinafter as G3).

4. Computer the D-value of each group, Difference between Group 3 and Group 1 (hereinafter as G3-G1), Difference between Group 3 and Group 2 (hereinafter as G3-G2), Difference between Group 2 and Group 1 (hereinafter as G2-G1).

5. Check the data; exclude the missing data, fault data and anomaly data.

3 Data Analysis

In the SPSS software, the statistical analysis of the measurement data was carried out, including the descriptive statistical analysis of three sets of data and the D-value of the data, the correlation analysis, and the one variant linear regression analysis of three sets of data.

3.1 Descriptive Statistic Analysis

Table 1 is the descriptive statistic analysis of the data of the 3D automatic measurement, the 3D interactive measurement, and the manual measurement.

3.2 D-Value Analysis

3.2.1 Overall Situation of D-value

The overall condition of the D-value is shown in Table 2 and Fig. 1.

1. In addition to the hip girth and whole shoulder width, the D-value of the data of 3D automatic measurement and 3D interactive measurement is mainly zero.

2. Comparing the manual measurement and the 3D measurement, in addition to the neck base girth, the D-value of each item is relatively large.

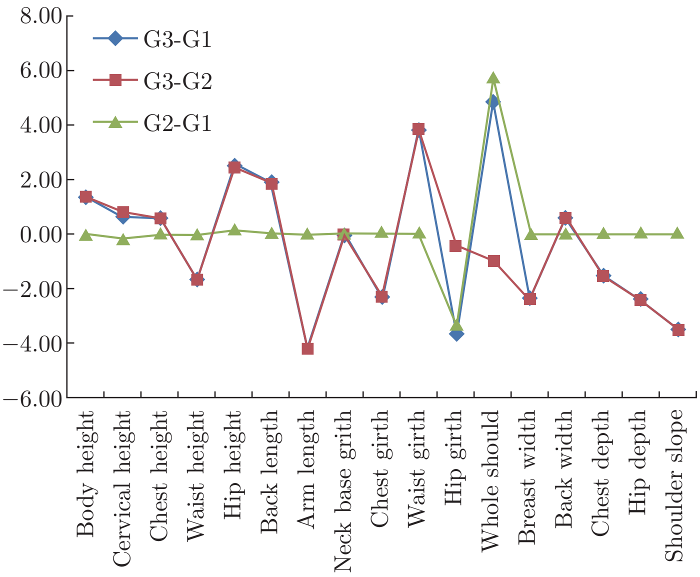

Fig. 1: D-value of three sets of data.

Table 1: Descriptive statistics (cm)

Items		Median	Mean	Std. Error	Std. Deviation	Variance	Minimum	Maximum	Range
Body height	G1	168.30	168.59	0.35	6.11	37.39	154.00	186.50	32.50
	G2	168.30	168.59	0.35	6.12	37.40	154.00	186.50	32.50
	G3	169.90	169.93	0.34	5.95	35.35	154.60	188.60	34.00
Cervical height	G1	143.20	143.43	0.31	5.40	29.20	129.40	160.10	30.70
	G2	142.95	143.25	0.31	5.39	29.02	129.40	160.10	30.70
	G3	143.95	144.06	0.31	5.35	28.66	130.20	160.70	30.50
Chest height	G1	120.70	120.93	0.28	4.88	23.82	108.10	135.50	27.40
	G2	120.70	120.93	0.28	4.88	23.82	108.10	135.50	27.40
	G3	121.40	121.46	0.29	4.99	24.88	108.50	136.50	28.00
Waist height	G1	105.20	105.39	0.24	4.18	17.47	94.10	117.90	23.80
	G2	105.15	105.30	0.25	4.29	18.38	92.80	117.90	25.10
	G3	103.60	103.66	0.27	4.76	22.62	91.70	118.90	27.20
Hip height	G1	81.50	81.72	0.24	4.15	17.22	65.90	95.30	29.40
	G2	81.50	81.90	0.24	4.14	17.11	65.90	95.30	29.40
	G3	84.20	84.20	0.23	4.06	16.47	68.10	97.20	29.10
Back length	G1	39.20	39.29	0.12	2.05	4.21	34.40	46.30	11.90
	G2	39.30	39.32	0.12	2.09	4.36	34.10	45.30	11.20
	G3	43.00	43.09	0.18	3.04	9.24	33.80	52.50	18.70
Arm length	G1	58.65	58.79	0.17	3.01	9.07	49.70	70.90	21.20
	G2	55.50	55.54	0.16	2.83	8.02	49.00	66.40	17.40
	G3	55.20	55.05	0.15	2.58	6.64	48.50	63.70	15.20
neck base girth	G1	40.60	41.00	0.14	2.40	5.78	35.90	49.40	13.50
	G2	40.55	40.99	0.14	2.40	5.76	35.90	49.40	13.50
	G3	42.80	42.81	0.15	2.58	6.66	37.00	50.10	13.10
Chest girth	G1	89.40	90.72	0.38	6.56	43.06	75.80	114.30	38.50
	G2	89.40	90.72	0.38	6.56	43.06	75.80	114.30	38.50
	G3	85.40	86.52	0.35	5.99	35.93	72.90	110.00	37.10
Waist girth	G1	76.10	78.17	0.50	8.70	75.65	62.70	105.80	43.10
	G2	76.10	78.16	0.51	8.83	78.06	61.40	105.80	44.40
	G3	76.20	78.00	0.52	9.01	81.11	61.80	106.00	44.20
Hip girth	G1	90.95	91.77	0.30	5.15	26.51	80.00	110.30	30.30
	G2	90.90	91.77	0.30	5.14	26.45	80.00	110.30	30.30
	G3	88.50	89.41	0.30	5.24	27.42	78.70	109.30	30.60
Whole shoulder width	G1	39.40	39.49	0.12	2.12	4.49	33.10	45.30	12.20
	G2	45.35	45.26	0.16	2.74	7.53	36.20	54.70	18.50
	G3	44.25	44.27	0.14	2.51	6.29	37.20	50.40	13.20

Table 1 continue

Items		Median	Mean	Std. Error	Std. Deviation	Variance	Minimum	Maximum	Range
Breast width	G1	38.30	38.51	0.17	2.99	8.92	28.10	52.70	24.60
	G2	38.30	38.41	0.18	3.07	9.40	28.10	52.70	24.60
	G3	36.10	36.04	0.14	2.46	6.05	26.50	44.60	18.10
Back width	G1	35.90	36.06	0.16	2.72	7.41	29.00	47.10	18.10
	G2	35.90	36.04	0.16	2.73	7.46	29.00	47.10	18.10
	G3	36.60	36.59	0.17	2.93	8.59	27.00	46.30	19.30
Chest depth	G1	22.75	23.13	0.12	2.08	4.32	19.00	30.50	11.50
	G2	22.75	23.13	0.12	2.08	4.32	19.00	30.50	11.50
	G3	21.30	21.51	0.13	2.22	4.93	16.50	28.70	12.20
Hip depth	G1	23.90	24.19	0.12	2.07	4.28	19.60	30.90	11.30
	G2	23.95	24.20	0.12	2.06	4.25	19.60	30.90	11.30
	G3	21.60	21.78	0.12	2.16	4.68	17.40	29.70	12.30
Shoulder slope	G1	26.15	26.13	0.22	3.79	14.33	13.50	35.60	22.10
	G2	26.15	26.12	0.22	3.77	14.25	13.50	35.60	22.10
	G3	23.00	22.61	0.23	4.00	15.98	12.00	34.00	22.00

Table 2: D-value of three sets of data (cm)

Item	G3-G1	G3-G2	G2-G1
Body height	1.33	1.33	0.00
Cervical height	0.63	0.80	−0.18
Chest height	0.53	0.53	0.00
Waist height	−1.74	−1.64	−0.10
Hip height	2.48	2.30	0.18
Back length	1.81	1.83	−0.02
Arm length	−4.20	−4.20	0.00
neck base girth	−0.17	−0.16	−0.02
Chest girth	−2.36	−2.36	0.00
Waist girth	3.80	3.77	0.02
Hip girth	−3.74	−0.49	−3.24
Whole shoulder width	4.78	−0.98	5.77
Breast width	−2.47	−2.38	−0.10
Back width	0.53	0.55	−0.03
Chest depth	−1.62	−1.62	0.00
Hip depth	−2.40	−2.42	0.01
Shoulder slope	−3.52	−3.51	−0.01

3. The D-value has both positive and negative values, which cannot be confirmed by the size of the relationship uniformly.

3.2.2 The Reason of the D-values

The reasons for the D-values are various, which cannot be summarized simply by the accuracy of the 3D scanner or the error of the manual measurement. The reasons can be concluded as follows:

a) The human body is an elastic body, whose size will decrease when the tape measuring was used in the manual measurement, while at the same time it is a rigid body whose size will increase in the 3D scanning.

b) Standing posture. The basic posture in the 3D scanning of the participant is required to stand with the feet separated, while in the manual measurement with the height indicator it is required to stand with the feet together.

c) In the 3D scanning, the participant kept the body tense, and it leads to the following conditions:

   i. The shoulders were back to open.
   ii. There was inhaled or labored breathing to uplift the chest and height bust line.
   iii. There was inhaled breathing, and the Lumbar abdomen shrunk.
   iv. When the belly was out, the lumbar abdomen raised.
   v. The body did not stand up straight, and tilted in the other direction instead.

d) Deviation of the bone location and identification. In the 3D automatic scanning, some skeleton points cannot be identified correctly, even though the gauge points were marked.

e) The measurements were various in different surveyors for different measuring managing calibration, in which the control of elastic tape was inconsistent.

f) Very rare circumstances existed such as manual measurement errors when reading or recording, and computer entry errors.

The condition and reason of the D-value of every part will be analyzed, and the solution will be presented as follows:

1) Body height, Cervical Height, Chest Height, Hip height:

- Analysis:
  a) 3D automatic measurement and 3D interactive measurement had basically no difference.
  b) Manual measurement data was larger than the 3D measurement data.
- Reason:
  a) Standing posture.
  b) Deviation of the cervical location and identification.
- Solution:

a) In the 3D scanning, based on the basic stance, another measuring posture was added (hereinafter as standing posture 2), which is where the participant is required to stand with feet together.

b) The height data of the basic stance can be corrected through reading out the automatic measurement data in the ScanWorX software and simple calculation. For example:

Hypothesis: L1=Body height (ID NO.:0010); L2=Waist height (ID NO.: 0080); L3=Sideseam at waist (ID NO.: 9035/9036);

Corrected body height: body height' =L1-L2+L3;

Similarly, other height variable data can be calculated.

2) Waist Height

- Analysis:

  a) 3D automatic measurement and 3D interactive measurement had basically no difference.

  b) Manual measurement data was smaller than the 3D measurement data.

- Reason:

  Deviation of the Lumbab location and identification.

- Solution:

  a) Before the measuring, the location of the waist line must be accurate, and the gauge point must be marked correctly.

  b) Standing posture 2 or correct the data of the basic stance.

3) Back length

- Analysis:

  a) 3D automatic measurement and 3D interactive measurement had basically no difference.

  b) Manual measurement data was larger than the 3D measurement data.

- Reason:

  Deviation of the cervical and Lumbab location and identification.

- Solution:

  Before the measuring, the location of the cervical and Lumbab must be accurate, and the gauge point must be marked correctly.

4) Arm length

- Analysis:

  a) 3D automatic measurement and 3D interactive measurement had basically no difference.

  b) Manual measurement data was smaller than the 3D measurement data.

- Reason:

  a) Deviation of the posterior armpit point, radiale and stylion radiale location and identification.

  b) In the manual measurement, the arm is stretching, while in the 3D measurement, the arm is bending.

  c) In the 3D software, the digital tape measured the skin in a multipoint curve, which is more smooth and longer than the length in the manual measurement.

- Solution:

  a) Before the measuring, the location of the posterior armpit point, radiale and Stylion radiale must be accurate.

  b) The arm posture in the 3D measurement and the manual measurement must be kept uniformed.

5) Neck base girth

The D-values are small.

6) Chest girth, Hip girth, Breast width, Chest depth, Hip depth

- Analysis:

  a) In addition to "Hip girth", 3D automatic measurement and 3D interactive measurement had basically no difference.

  b) Manual measurement data was smaller than the 3D measurement data.

- Reason:

  In the 3D measuring, the participant opened the shoulders back, and had inhaled or labored breathing, which madethe breast measurement (Chest girth Breast widthChest depth) larger than that in the basic stance. The posture with the feet separated made the Hip girth measurement larger than that in the basic stance.

- Solution:

  a) Correct the posture in the 3D scanning.

  b) Stand posture 2 will lead to a more accurate measurement in the 3D scanning.

7) Waist girth

- Analysis:

  a) 3D automatic measurement and 3D interactive measurement had basically no difference.

  b) Manual measurement data was larger than the 3D measurement data.

- Reason:

  a) Deviation of the Lumbab and waist line location and identification.

b) In the 3D measuring, the participant had inhaled breathing, and made the Waist girth measurement smaller than that in the basic stance. Solution:

c) Before the measuring, the location of the Lumbab and waist line must be accurate.

d) Correct the posture in the 3D scanning.

8) Whole shoulder width

- Analysis:

a) 3D automatic measurements was larger than 3D interactive measurements.

b) Manual measurement data was larger than the 3D measurement data.

- Reason:

a) Deviation of the posterior armpit point location and identification.

b) In the 3D software, the digital tape measured the skin in a multipoint curve, which is more smooth and longer than the length in the manual measurement.

- Solution:

a) Before the measurement, the location of the posterior armpit point must be accurate.

b) In the 3D scanning measured by the digital tape, another gauge point should be marked between the posterior armpit point and the cervical to locate the tested-curve.

9) Back width

- Analysis:

a) 3D automatic measurement and 3D interactive measurement had basically no difference.

b) Manual measurement data were larger than the 3D measurement data.

- Reason:

In the 3D measuring, the participant opened the shoulder back, which made the Back width measurement larger than that in the basic stance.

- Solution:

Correct the posture in the 3D scan

10) Shoulder slope

- Analysis:

a) 3D automatic measurement and 3D interactive measurement had basically no difference.

b) Manual measurement data was smaller than the 3D measurement data.

- Reason:

a) In the 3D measurement, the participant kept arms open, elbows slightly bent, which changed the shoulder location.

b) In the manual measurement, it is hard to locate the Angle Gauge, which lead to inaccurate measurement.

- Solution:

a) Correct the posture in the 3D scan.

b) The correct choice and use of angle gauge.

3.3 Relational Model

The 3D body scanner has been used extensively, however, so far for a large amount of researches, the human body measurements data was collected by manual measuring, and some researches even combined the manual measurement and 3D scanning measurement. As a result, it is needed to further understand the relation between the manual measurement and 3D scanning measurement, and thus establish a relational model.

3.3.1 Correlation Analysis

Through the correlation analysis, the degree and direction of linear correlation of the 3D automatic measurement, the 3D interactive measurement, and the manual measurement can be detected. Numeric area of the correlation coefficient r is $-1\sim1$ and the degree of linear correlation of the two variables increases with the absolute value of r getting closer to 1. The negative value means the direction of the two variables was opposite [5].

It is shown in Table 3 that for most measurement items, the correlation coefficients are larger than 0.5, which means the 3D automatic measurement, the 3D interactive measurement, and the manual measurement have an evident linear relation, which is suitable for a regression model.

3.3.2 Regression Model

By establishing the regression model, the given value of the explanatory variables can be used to conjecture the value and range of the dependent variables, in other words, the 3D scanning measurement can be conjectured by the manual measurement, and vice versa. It is an item of work with extraordinary significance to correct the mixed data (the manual measurement and the 3D scanning measurement).

Table 4 is the one variant linear regression analysis sheet. R is the correlation coefficient and the sig. value is 0, thus smaller than 0.05, which means it is significant to resolve the equations.

The regression equation can be established based on Table 4.

E.g.: the regression equation of “Body Height” $G3=7.725+0.962\times G1$ or $G3=7.737+0.962\times G1$

By the body height measurement of 3D automatic measuring and the 3D interactive measuring, the body height measurement of the manual measurement can be calculated. Conversely, the body height measurement of the 3D scanning measuring can also be calculated by the body height measurement of the manual measuring.

Table 3: Correlations

Item	G1 and G2	G1 and G3	G2 and G3
Body Height	1.000	0.989	0.989
Cervical Height	0.994	0.985	0.984
Chest Height	1.000	0.961	0.961
Waist Height	0.980	0.864	0.860
Hip Height	0.975	0.850	0.866
Back Length	0.937	0.486	0.500
Arm Length	0.726	0.716	0.665
Neck Base Girth	0.995	0.686	0.692
Chest Girth	1.000	0.935	0.935
Waist Girth	0.997	0.962	0.961
Hip Girth	0.999	0.962	0.962
Whole shoulder Width	0.596	0.482	0.723
Breast Width	0.967	0.663	0.644
Back Width	0.995	0.736	0.735
Chest Depth	1.000	0.876	0.876
Hip Depth	0.993	0.812	0.813
Shoulder Slope	0.998	0.296	0.301

Table 4: Regression analysis

Dependent Variable (G3)	G1					G2				
	Intercept	Slope	R	R Square	Sig.	Intercept	Slope	R	R Square	Sig.
Body Height	7.725	0.962	0.989	0.979	0.000	7.737	0.962	0.989	0.979	0.000
Cervical Height	4.109	0.976	0.985	0.970	0.000	4.010	0.978	0.984	0.968	0.000
Chest Height	2.690	0.982	0.961	0.923	0.000	2.690	0.982	0.961	0.923	0.000
Waist Height	0.043	0.983	0.864	0.747	0.000	3.159	0.954	0.860	0.740	0.000
Hip Height	16.275	0.831	0.850	0.722	0.000	14.631	0.849	0.866	0.750	0.000
Back Length	14.823	0.719	0.486	0.236	0.000	14.493	0.727	0.500	0.250	0.000
Arm Length	19.012	0.613	0.716	0.513	0.000	21.462	0.605	0.665	0.442	0.000
Neck Base Girth	12.619	0.736	0.686	0.471	0.000	12.318	0.744	0.692	0.479	0.000
Chest Girth	9.023	0.854	0.935	0.875	0.000	9.023	0.854	0.935	0.875	0.000
Waist Girth	0.131	0.996	0.962	0.925	0.000	1.472	0.979	0.961	0.923	0.000
Hip Girth	−0.399	0.979	0.962	0.926	0.000	−0.478	0.979	0.962	0.926	0.000
Whole shoulder Width	21.766	0.570	0.482	0.232	0.000	14.376	0.661	0.723	0.522	0.000
Breast Width	15.007	0.546	0.663	0.440	0.000	16.190	0.517	0.644	0.415	0.000
Back Width	8.028	0.792	0.736	0.541	0.000	8.182	0.788	0.735	0.540	0.000
Chest Depth	−0.122	0.935	0.876	0.767	0.000	−0.122	0.935	0.876	0.767	0.000
Hip Depth	1.245	0.849	0.812	0.660	0.000	1.160	0.852	0.813	0.661	0.000
Shoulder Slope	14.434	0.313	0.296	0.088	0.000	14.300	0.318	0.301	0.090	0.000

4 Conclusion

This paper analyzed the data of the 17 measurement items of 300 adult males, compared the data of the 3D automatic measuring, the 3D interactive measuring and the manual measuring, and has come to the following conclusions:

1) Deviation between the manual measuring and the 3D scanning measuring obviously existed, which cannot be ignored.

2) In the 3D automatic measuring, as the result of the deviation of the identification to the bone location, the measurement data must be checked and modified, which is the 3D interactive measuring.

3) The posture of the participant has a significant effect on the measurement data, and the specified basic stance will change the measurement data of shoulder, breast and waist. Therefore, to guarantee regular scanning, the scanning posture should be increased based on the need of the study. For example, the stance with feet together can make the height measurement more accurate.

4) Many factors would interfere with the accuracy of the manual measure and result in the difference with 3D measurement, such as the breathing and posture of the testers, and the measurement skills, experience, position mark, etc.

5) There is an evident linear relation between the manual measuring and the 3D scanning measuring. By establishing the linear regression model the measurement data can be forecasted and calculated.

6) In order to detect the accuracy of the 3D scanner better, the comparison of manual measuring and 3D scanning measuring of rigid body will be analyzed in further research.

7) The object was scanned by the equipment of Vitus Smart 3D laser human body scanner made by Germany Human Solution Company, and the 3D measurement was measured in the supplied software of ScanWorX in this study. The conclusion of this study would serve as a guide in the use of the scanning equipment and software, and the method would be a valuable reference for accuracy analysis of other scanning equipment.

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