Sheffield Hallam University

Effect of different standing poses on whole body volume acquisition by three-dimensional photonic scanning

CHIU, Chuang-Yuan, PEASE, David L. and SANDERS, Ross H.

Available from Sheffield Hallam University Research Archive (SHURA) at:

http://shura.shu.ac.uk/16994/

This document is the author deposited version. You are advised to consult the publisher's version if you wish to cite from it.

Published version

CHIU, Chuang-Yuan, PEASE, David L. and SANDERS, Ross H. (2016). Effect of different standing poses on whole body volume acquisition by three-dimensional photonic scanning. IET Science, Measurement & Technology, 10 (6), 553-556.

Copyright and re-use policy

See http://shura.shu.ac.uk/information.html

Sheffield Hallam University Research Archive
http://shura.shu.ac.uk

The Effect of Different Standing Poses on Whole Body Volume Acquisition by Three-dimensional Photonic Scanning

Chuang-Yuan Chiu [1*], David L. Pease [2], Ross H. Sanders [3]

[1] Institute for Sport, Physical Education & Health Sciences, The University of Edinburgh, Edinburgh, Scotland, UK
[2] Australian Institute of Sport, Canberra, Australia
[3] Faculty of Health Sciences, The University of Sydney, Sydney, Australia
[*] thorsten.chiu@gmail.com

Abstract: The present study compared whole body volumes obtained by 3D photonic scanning of two different poses and discussed its effect on body composition estimation. Pose A with large angles of shoulder abduction and feet separated and Pose B with shoulders abducted slightly, the elbows extended and heels together. Sixteen male and thirteen female participants were scanned twice in each pose using a 3D scanner. The mean of whole body volume and the mean of body composition obtained with Pose B was corrected by a regression equation and compared with the results obtained from Pose A. After correction, the whole body volumes acquired with these two poses were similar (limit of agreement = (-0.71 l,0.71 l)) but the body compositions obtained with Pose A and Pose B were different (limit of agreement = (-4.4%,4.4%)).The results indicated that scanning using either pose gives reliable estimations for whole body volume and body composition. The whole body volume obtained from different poses can be adjusted using the regression equation but small volumetric differences translate into much more substantial differences in body fat percentage. Hence, it is recommended to use the same scanning pose consistently when monitoring individuals longitudinally.

1. Introduction

Body composition has been widely applied to evaluate athletes' training and nutritional interventions [1, 2] since it relates closely to sport performance [3]. Different measurements have been developed to understand body composition including laboratory methods [4] and portable methods [5]. According to a recent review [4, 5], the laboratory methods include cadaver analysis, underwater weighing, air displacement plethysmography, isotope dilution methods, medical imaging methods, DXA and 3D photonic scanning (3DPS). The portable methods include anthropometry, near infrared interactance, bioelectrical impedance, and ultrasound.

Among these analysis methods, 3DPS is a newer, emerging technology. It can acquire multiple anthropometric characters in one rapid scanning process [6, 7]. The 3D photonic scanners with corresponding software can measure anthropometric measurements including segmental length, height, breadth and girth [8, 9] and body volume such as whole body volume and segmental volume [7, 10]. The whole body volume in conjunction with body mass can be used to estimate the body composition [4] by referring to the known densities of body tissues [11, 12]. Multiple anthropometric measurements can provide important information relevant to health, obesity, nutrition, and sport performance, etc. For instance, Schranz et al. [13] and Schranz et al. [14] indicated that using multiple anthropometric measurements obtained from 3DPS can contribute to predicting sport performance potential. The other advantage of 3DPS is that the body shape change can be visualised. This information of body measurements and the visualization of body shapes can motivate people to reduce weight [15] since people are interested in the appearance of their bodies [6].

Wang et al. [7] and Collins [10] have shown that 3DPS can be used to obtain whole body volume accurately. The body density can be calculated from mass divided by volume to enable body composition, which is the amount of fat and fat-free tissue, to be estimated as the densities of lean and adipose tissues are nearly constant relative to the difference between them. Wang et al. [7] indicated that there is no significant difference in body fat percentage determined by underwater weighing and 3DPS. However, Wang and colleagues reported that some of their children had difficulty in complying with instructions to maximally expire during the underwater weighing procedure. In addition, they could not be sure that lung volumes were equivalent for the underwater weighing and 3D scanning. The small errors for volumes would lead to large errors in calculation of body composition. Methods to ensure that these errors are reduced are required in future studies, particularly those involving children.

In previous research, 3DPS have been conducted for whole body volume acquisition with the pose similar to that shown in Fig. 1 (Pose A). This pose with wider stance provides more stability and less body movement during the scanning procedure so it is the recommended pose for most uses. Some participants with long arms could be easily adopt this pose in the normal size scanning booth. In addition, Pose A can avoid most occlusion problems [16] which might increase the manual post-processing time for 'hole-filling'.

Another common standing scanning pose as shown in Fig. 1 (Pose B) is similar to the pose used for body measurement [17] and photoscopic somatotype [18]. This pose without large angles of shoulder abduction and with the elbows extended is more natural and effortless which might help some participants with shoulder pain such as C5-6 radiculopathy or shoulder rotator cuff tear complete scanning comfortably. The shoulder injuries are common in many sport events including baseball [19], volleyball [20], cricket [21], swimming [22], and weight lifting [23]. Pose B is similar to the standing pose while applying the protocol of the International Society for the Advancement of Kinanthropometry (ISAK) [24] to measure statures so the pose might be applied to obtain accurate stature and arm length measurements. These are important dimensions for health assessment and in sports science research [13]. Furthermore, the 3D scanning results could generate the images for physique analysis by somatotype. However, no validation of this pose regarding the accuracy and reliability of 3DPS has been reported in the extant literature. The attached segments (e.g. feet, thighs) might generate some error for volume acquisition.

The effect of different scanning poses on whole body volume and body composition has not been discussed. The purpose of this study was to compare whole body volumes and body compositions obtained by 3D photonic scanning of two different poses.

2. Method

This study involved 16 male (age: mean value = 33.69, s = 0.49 years, body mass: mean value = 80.73, s = 9.26 kg, height: mean value = 181.79, s = 7.75 cm; BMI: mean value = 24.42, s = 2.28 kg/ m^2) and 13 female participants (age: mean value = 35.62, s = 13.24 years, body mass: mean value = 70.94, s = 12.76 kg, height: mean value = 170.12, s = 4.61 cm; BMI: mean value = 24.49, s = 4.20 kg/ m^2). All participants signed the informed consent form. Ethics approval was given by Moray House School of Education Ethics Committee at the University of Edinburgh for human investigation. The body composition is calculated from ISAK measurements which were measured by an accredited anthropometrist. All participants signed the informed consent form. They were requested to wear close fitting suits such as triathlon pants and sports tops (for female) and a polyester swimming cap before scanning.

A calibrated 3D photonic scanner (Vitus smart XXL, Human Solutions GmbH, Kaiserslautern, Germany) was used to obtain individual 3D human models. Participants were requested to stand in the scanner booth with each of the two poses (Pose A and Pose B as shown in Fig. 1). Participants were scanned twice in each pose with the order, Pose B 1st trial (Pose B1), Pose B 2nd trial (Pose B2), Pose A 1st trial (Pose A1), Pose A 2nd trial (Pose A2). To avoid the breathing effect, participants were asked to breathe out the air in their lungs to end tidal level before the commencement of scanning and hold their breath until the test process finished (approximately 10 seconds).

The 3D human models obtained from the 3D scanner were processed by the 3D mesh edit software Cyslice (headus 3D, Perth, WA, Australia) to delete noise, fill the holes and smooth the mesh as shown in Fig. 1 which refers to the process in previous literature [10]. To lessen the effect of human interpretation, the operator (second author) who is familiar with the specific software completed all manual processing for 3D scanning data in this study. The repeated reliability between the two trials of each pose was also determined to ensure the effect for the human interpretation was small.

After that, the 3D mesh files were exported to Polygon File Format (Stanford Triangle Format, PLY) files. Each 3D human model mesh consists of thousands of triangles. The 3D software, Blender (Blender Foundation), transferred the PLY mesh file to STereoLithography (STL) file and the protocol developed by Zhang and Chen [25] was applied to calculate the volume of the whole mesh which is the whole body volume. The protocol developed by Zhang and Chen [25] divided 3D meshes into small tetrahedrons, and the volume of the 3D mesh was calculated by totalling the computation results of these tetrahedrons. The body composition was estimated by following the formula presented by Siri [12] with an estimated lung volume [26].

$$\text{Body Fat percentage} = \left(\frac{4.95}{\rho} - 4.50\right) \times 100\%$$

where ρ stands for the whole body density which is calculated by following equation.

$$\rho = \frac{Mass}{(V - r)}$$

where the $Mass$ is the total body mass, V represents the whole body volume and r stands for the residual volume of air in the lungs within the body.

The statistical analyses were conducted with commercial software (IBM SPSS® Statistics version 21.0, Armonk, NY, USA and Microsoft® Excel 2013, Redmond, WA, USA) and free software (R; https://www.r-project.org/). Four values of body volume ($\mathrm{BV_i^{PoseA1}}$, $\mathrm{BV_i^{PoseA2}}$, $\mathrm{BV_i^{PoseB1}}$ and $\mathrm{BV_i^{PoseB2}}$) and four values of body composition ($\mathrm{BC_i^{PoseA1}}$, $\mathrm{BC_i^{PoseA2}}$, $\mathrm{BC_i^{PoseB1}}$ and $\mathrm{BC_i^{PoseB2}}$) were acquired for each participant (i) with the two different poses in separate trials (Pose A1, Pose A2, Pose B1 and Pose B2). The means of whole body volumes ($\mathrm{BV_i^{PoseA1}}$ and $\mathrm{BV_i^{PoseA2}}$ or $\mathrm{BV_i^{PoseB1}}$ and $\mathrm{BV_i^{PoseB2}}$) acquired from the two trials for each participant in Pose A ($\mathrm{MV_i^a}$) and Pose B ($\mathrm{MV_i^b}$) were used for linear regression analysis. The adjusted whole body volumes ($\mathrm{MV_i^c}$) were obtained by applying the regression model to correct the values of $\mathrm{MV_i^b}$. Since it has been shown that the whole body volumes obtained from 3DPS with Pose A yield little error [10], the values of $\mathrm{M_i^a}$ were regarded as the references to compare the values of $\mathrm{MV_i^b}$ and the adjusted values of $\mathrm{MV_i^c}$. Similarly, the mean of body composition in Pose A, $\mathrm{MC_i^a}$, were used to compare with the mean of body composition in pose B, $\mathrm{MC}_\mathrm{i}^{b}$, and the estimate from the adjusted whole body volume ($\mathrm{MV_i^c}$), $\mathrm{MC}_\mathrm{i}^{c}$. Paired t-tests and Bland and Altman analyses ($\mathrm{MV_i^a}$ vs $\mathrm{MV_i^b}$ and $\mathrm{MV_i^a}$ vs $\mathrm{MV_i^c}$; $\mathrm{MC_i^a}$ vs $\mathrm{MC_i^b}$ and $\mathrm{MC_i^a}$ vs $\mathrm{MC_i^c}$) were conducted.

The differences between $\mathrm{MV_i^a}$ and $\mathrm{MV_i^b}$, and $\mathrm{MV_i^a}$ and $\mathrm{MV_i^c}$ were representative as the inter-method relative technical error of measurement (inter TEM) by following formula [27]

$$\text{inter TEM} = \frac{\sqrt{\frac{\sum_{i=1}^{N}\left(\mathrm{MV_i^a} - \mathrm{MV_i^{Scan}}\right)^2}{2 \times N}}}{\frac{\sum_{i=1}^{N}\left(\mathrm{MV_i^a} + \mathrm{MV_i^{Scan}}\right)}{2 \times N}} \times 100\%$$

where N is representative of the number of participants, MV_i^{Scan} denotes MV_i^b (for MV_i^a vs MV_i^b), or MV_i^c (for MV_i^a vs MV_i^c).

The differences between MC_i^a and MC_i^b, and MC_i^a and MC_i^c were representative as the inter-method absolute technical error of measurement (inter ATEM) by following formula [27]

$$\text{inter ATEM} = \sqrt{\frac{\sum_{i=1}^{N}\left(MC_i^a - MC_i^{Scan}\right)^2}{2 \times N}}$$

where N is representative of the number of participants, MC_i^{Scan} denotes MC_i^b (for MC_i^a vs MC_i^b), or MC_i^c (for MC_i^a vs MC_i^c).

The intra-pose reliability of body volume acquisition for each pose was representative as the relative technical error of measurement (intra TEM) by following formula [27]

$$\text{intra TEM} = \frac{\sqrt{\frac{\sum_{i=1}^{N}\left(BV_i^{Scan1} - BV_i^{Scan2}\right)^2}{2 \times N}}}{\frac{\sum_{i=1}^{N}\left(BV_i^{Scan1} + BV_i^{Scan2}\right)}{2 \times N}} \times 100\%$$

where N is representative of the number of participants, BV_i^{Scan1} and BV_i^{Scan2} denote whole body volume acquired from 1st and 2nd scanning separately obtained for the i^{th} participant with Pose A (BV_i^{PoseA1} and BV_i^{PoseA2}) or Pose B (BV_i^{PoseB1} and BV_i^{PoseB2}).

The intra-pose reliability of body composition for each pose was representative as the absolute technical error of measurement (ATEM) by following formula [27]

$$\text{intra ATEM} = \sqrt{\frac{\sum_{i=1}^{N}\left(BC_i^{Scan1} - BC_i^{Scan2}\right)^2}{2 \times N}}$$

where N is representative of the number of participants, BC_i^{Scan1} and BC_i^{Scan2} denote body composition obtained from 1st and 2nd scanning separately obtained for the i^{th} participant with Pose A (BC_i^{PoseA1} and BC_i^{PoseA2}) or Pose B (BC_i^{PoseB1} and BC_i^{PoseB2}).

3. Results

The whole body volume acquired from 3D photonic scanning (MV_i^a and MV_i^b) and the linear regression lines are shown in Fig. 2. The Pearson's regression coefficient (r) and the standard error of the estimate (SEE) were 1.000 and 0.368 respectively. Table 1 shows the result of the regression analysis. The paired t-test revealed that the whole body volume obtained with Pose A was slightly larger than the ones acquired with Pose B (MV_i^a - MV_i^b mean = 0.60 l; standard deviation = 0.39 l; 95% confidence interval of difference = (0.45 l, 0.77 l); P-value<0.001, limit of agreement = (-0.17 l, 1.36 l)). After adjusted by regression models, there was no difference between the whole body volume acquired with Pose A and the corrected values (MV_i^a - MV_i^c mean = 0.002 l; standard deviation = 0.36 l; 95% confidence interval of difference = (-0.136 l, 0.139 l); P-value = 0.979, limit of agreement = (-0.71 l, 0.71 l)). The inter TEM for MV_i^a vs MV_i^b, MV_i^a vs MV_i^c were 0.65% and 0.32% respectively and the intra TEM for Pose A, Pose B were 0.46% and 0.44% accordingly.

The paired t-test showed that the body composition values acquired with Pose A were larger than those acquired with Pose B (MC_i^a - MC_i^b mean = 3.84%; standard deviation = 2.3%; 95% confidence interval of difference = (2.99%, 4.68%); P-value<0.001, limit of agreement = (-0.54%, 8.21%)). When used the adjusted body volume acquired with Pose B, there was no difference between the body composition obtained with Pose A and the corrected values (MC_i^a - MC_i^c mean = 0.03%; standard deviation = 2.24%; 95% confidence interval of difference = (-0.82%, 0.88%); P-value = 0.948, limit of agreement = (-4.36%, 4.42%)). The inter ATEM for MC_i^a vs MC_i^b, MC_i^a vs MC_i^c were 3.12% and 1.56% respectively and the intra ATEM for Pose A, Pose B were 2.36% and 2.20% respectively.

4. Discussion

The purpose of this study was to compare whole body volumes and body composition obtained by 3D photonic scanning of two different poses. The differences between of body volume acquisition with these two poses are mostly systematic as the results were highly correlated. The small amount of random error indicated by the intra TEM could be due mostly to differences in the amount of air in participants' lungs and human errors in post-processing (deleting noise, filling the holes and smoothing the mesh). The systematic error indicated by the inter TEM is due to the pose effect. In Pose B, the arms are close to the torso and the two feet are close together during the scanning process. This tends to cause some occlusions between the arm and torso, and the thighs which generate some error for shape determination and volume calculation.

The whole body volume acquired with Pose A is a validated method by comparing the results of underwater weighing [7, 10]. Hence, it can be regarded as the reference and the relative TEM between M_i^a and M_i^b indicates the accuracy of the whole body volume estimation of Pose B. Not surprisingly, the TEM between Pose A and corrected Pose B shows that the regression equation can reduce the error effectively from 0.65% to 0.32%. The error 0.32% is within the range of the repeated measurement difference (0.46% and 0.44%). The corrected volume acquired with Pose B can also decrease the difference of body composition estimation between Pose A and Pose B from 3.12% to 1.56%. However, the 1.56% error is larger than the precision error (0.4%) which referred to by Rolland [4]). The possible reason might be that the formula for calculating body composition from whole body volume is sensitive to small errors in whole body volume which leads to larger errors in estimates of body composition [7]. Thus, researchers should be aware that different results might be obtained while using different scanning poses to estimate body composition even though a conversion equation can create equivalent volumetric value as required.

The intra-pose reliability is high for the volumetric acquisitions with poses A and B, having low error (0.46% and 0.44% respectively), similar to the results in previous reliability tests for Pose A [10]. Therefore, both poses can be used for long-term monitoring of whole body volume variation. The intra-pose ATEMs were acceptable for the body composition estimation with Poses A and B (2.36% and 2.20%). Evans et al. [28] mentioned that a four month dieting programme might reduce body fat by more than 6%. Thus, using 3DPS with Poses A and B could be used for detecting the effectiveness of similar long-term diet programmes. Nevertheless, researcher should be aware that the body composition obtained from different poses cannot be adjusted by the regression equation for comparison so it is recommended to use the same scanning pose consistently when monitoring individuals longitudinally.

5. Conclusion

This study compared the whole body volume and body composition obtained from 3D photonic scanning with two different poses. According to the results of the statistical analysis, the choice of pose affects the results of whole body volume acquisition and body composition estimation. The magnitude of the differences in body volume was small, but the variation in body composition was considerably larger. The reliability of these two scanning poses is very good for body volume acquisition and is acceptable for body composition estimation. Thus, researchers should be aware that different results might be obtained while using different scanning poses to estimate body composition even though a conversion equation can create equivalent volumetric value as required. To ensure reliability of body composition for clinical examination and monitoring, using the same scanning poses recommended.

6. Acknowledgments

The authors would like to thank Ned Brophy-Williams for operating the 3D scanner.

7. References

1. Duthie, G.M., 'A Framework for the Physical Development of Elite Rugby Union Players', International Journal of Sports Physiology and Performance, 2006, 1, (1), pp. 2-13.

2. Juzwiak, C.R., Amancio, O.M.S., Vitalle, M.S.S., Pinheiro, M.M., and Szejnfeld, V.L., 'Body Composition and Nutritional Profile of Male Adolescent Tennis Players', Journal of Sports Sciences, 2008, 26, (11), pp. 1209-1217.

3. Withers, R.T., Craig, N.P., Bourdon, P.C., and Norton, K.I., 'Relative Body Fat and Anthropometric Prediction of Body Density of Male Athletes', European Journal of Applied Physiology and Occupational Physiology, 1987, 56, (2), pp. 191-200.

4. Rolland, C., Laboratory Methods of Body Composition Analysis', in D. Stewart, A. and Sutton, L. (eds.), Body Composition in Sport, Exercise, and Health, (Abingdon, UK: Routledge, 2012)

5. Mulholland, Y. and Rolland, C., Portable Methods of Body Composition Analysis', in D. Stewart, A. and Sutton, L. (eds.), Body Composition in Sport, Exercise, and Health, (Abingdon, UK: Routledge, 2012)

6. Treleaven, P. and Wells, J., '3d Body Scanning and Healthcare Applications', Computer, 2007, 40, (7), pp. 28-34.

7. Wang, J., Gallagher, D., Thornton, J.C., Yu, W., Horlick, M., and Pi-Sunyer, F.X., 'Validation of a 3-Dimensional Photonic Scanner for the Measurement of Body Volumes, Dimensions, and Percentage Body Fat', American Journal of Clinical Nutrition, 2006, 83, (4), pp. 809-816.

8. Jun-Ming, L. and Wang, M.J.J., 'The Evaluation of Scan-Derived Anthropometric Measurements', Instrumentation and Measurement, IEEE Transactions on, 2010, 59, (8), pp. 2048-2054.

9. Heuberger, R., Domina, T., and MacGillivray, M., 'Body Scanning as a New Anthropometric Measurement Tool for Health-Risk Assessment', International Journal of Consumer Studies, 2008, 32, (1), pp. 34-40.

10. Collins, J.: 'Volumetric Analysis of Human Bodies', University of South Australia School of Health Sciences, 2006

11. Brožek, J., Grande, F., Anderson, J.T., and Keys, A., 'Densitometric Analysis of Body Composition: Revision of Some Quantitative Assumptions', Annals of the New York Academy of Sciences, 1963, 110, (1), pp. 113-140.

12. Siri, W., Body Composition from Fluid Spaces and Density: Analysis of Methods', Techniques for Measuring Body Composition, (1961)

13. Schranz, N., Tomkinson, G., Olds, T., and Daniell, N., 'Three-Dimensional Anthropometric Analysis: Differences between Elite Australian Rowers and the General Population', Journal of Sports Sciences, 2010, 28, (5), pp. 459-469.

14. Schranz, N., Tomkinson, G., Olds, T., Petkov, J., and Hahn, A.G., 'Is Three-Dimensional Anthropometric Analysis as Good as Traditional Anthropometric Analysis in Predicting Junior Rowing Performance?', Journal of Sports Sciences, 2012, 30, (12), pp. 1241-1248.

15. Boelaert, K., Palin, S., Field, A., Rahim, A., and Barnes, R., 'The Impact of 3d Body Images on Motivating Weight Loss in Overweight Individuals', in, Endocrine Abstracts, (2008)

16. Daniell, N., Olds, T., and Tomkinson, G., 'Technical Note: Criterion Validity of Whole Body Surface Area Equations: A Comparison Using 3d Laser Scanning', American Journal of Physical Anthropology, 2012, 148, (1), pp. 148-155.

17. Ma, Y., Kwon, J., Mao, Z., Lee, K., Li, L., and Chung, H., 'Segment Inertial Parameters of Korean Adults Estimated from Three-Dimensional Body Laser Scan Data', International Journal of Industrial Ergonomics, 2011, 41, (1), pp. 19-29.

18. Carter, J.L. and Heath, B.H., Somatotyping: Development and Applications, (Cambridge University Press, 1990)

19. Collins, C.L. and Comstock, R.D., 'Epidemiological Features of High School Baseball Injuries in the United States, 2005–2007', Pediatrics, 2008, 121, (6), pp. 1181-1187.

20. Briner, W., Jr. and Kacmar, L., 'Common Injuries in Volleyball', Sports Medicine, 1997, 24, (1), pp. 65-71.

21. Orchard, J., James, T., Alcott, E., Carter, S., and Farhart, P., 'Injuries in Australian Cricket at First Class Level 1995/1996 to 2000/2001', British Journal of Sports Medicine, 2002, 36, (4), pp. 270-274.

22. Pink, M.M. and Tibone, J.E., 'The Painful Shoulder in the Swimming Athlete', Orthopedic Clinics of North America, 2000, 31, (2), pp. 247-261.

23. Neviaser, T.J., 'Weight Lifting. Risks and Injuries to the Shoulder', Clinics in Sports Medicine, 1991, 10, (3), pp. 615-621.

24. Stewart, A., Marfell-Jones, M., Olds, T., and Ridder, H.d., International Standards for Anthropometric Assessment, (International Society for the Advancement of Kinanthropometry, 2011)

25. Zhang, C. and Chen, T., 'Efficient Feature Extraction for 2d/3d Objects in Mesh Representation', in, 2001 International Conference on Image Processing, (2001)

26. Ganong, W., Review of Medical Physiology, (McGraw-Hill Professional , Lange Medical Books 2003, 21 edn)

27. Perini, T.A., Oliveira, G.L.d., Ornellas, J.d.S., and Oliveira, F.P.d., 'Technical Error of Measurement in Anthropometry', Revista Brasileira de Medicina do Esporte, 2005, 11, (1), pp. 81-85.

28. Evans, E., Mojtahedi, M., Thorpe, M., Valentine, R., Kris-Etherton, P., and Layman, D., 'Effects of Protein Intake and Gender on Body Composition Changes: A Randomized Clinical Weight Loss Trial', Nutrition & Metabolism, 2012, 9, (1), pp. 55-63.

Figure Captions

Fig. 1 The scanning result with two common poses used in previous research and this study.
a the scanning model obtained with Pose A after post-processing.
b the scanning model obtained with Pose B after post-processing.
c the original model obtained with Pose A contained noise and holes and rough faces
d the original mesh obtained with Pose B contained noise and holes and rough faces

Fig. 2 The whole body volume acquired from 3D photonic scanning ($\boldsymbol{MV_i^a}$and $\boldsymbol{MV_i^b}$) and the linear regression equation.

Table Caption

Table 1 The linear regression analysis results