Health Science Monitor

ORIGINAL RESEARCH ARTICLE

Comparative Analysis of the Scaniverse 3D Scanning and Manual Methods for Measuring Facial Anthropometric Dimensions

Negar Semyari[1], Teimour Allahyari[1], Vahid Alinejad[2]

Published: 30 August 2025

Abstract

Background Anthropometry provides quantitative measurements of body dimensions, including those of the head and face, and is applied in fields such as dentistry, medicine, plastic surgery, and the design of head and face protective equipment.

Methods In this study, the usability of the 3D scanning software, Scaniverse, version 5.0.1, for iPhones was investigated to measure 10 dimensions of facial anthropometric features in comparison with the manual method (digital caliper). Then, the obtained data were compared with T-tests. In the absence of significant differences and the validation of the software method, it is possible to measure facial anthropometric dimensions more easily and quickly in the target populations.

Result The study included 188 participants, with a mean age of 23.20 years. The results showed that out of the 10 dimensions measured, there was a statistically significant difference in five dimensions using the manual method and Scaniverse software (p-value < 0.05). In the other dimensions measured by the two methods, there was no difference in the mean (p-value > 0.05). The internal reliability and agreement of the measurements obtained using the two methods were assessed using the correlation coefficient, which yielded values ranging from 0.90 to 0.97, indicating high agreement and correlation.

Conclusion While statistically significant differences were observed in five of the 10 facial dimensions, the Scaniverse software showed high agreement (ICC: 0.90-0.97) with manual measurements in all dimensions. These findings indicate that Scaniverse is a suitable alternative for measuring most facial anthropometric dimensions.

Keywords 3D scanning, Anthropometry, Facial dimensions, Manual measurement, Scaniverse software

✉ Teimour Allahyari
allahyari@umsu.ac.ir

1. Department of Occupational Health, School of Public Health, Urmia University of Medical Sciences, Urmia, Iran
2. Department of Statistics and Epidemiology, School of Public Health, Urmia University of Medical Sciences, Urmia, Iran

Received: 13 May 2025/ Revised: 21 July 2025/ Accepted: 10 August 2025

1 Introduction

Head and face anthropometry is the study and measurement of the anatomical dimensions and features of the human head and face.[1] This branch of anthropometry provides precise information about the variability and individual differences in head and face morphology.[2] This information has diverse applications in various fields, including product design, medicine, dentistry, and even legal issues.[3] Accurate head and face anthropometric and craniometric measurements play an important role in the design of products such as glasses, hats, masks, and even personal protective equipment.[4]

Anthropometric studies can be performed using manual anthropometry, 2D photography, and 3D photography.[5] Manual anthropometry is considered the most common and simplest measurement method in this field. In this method, various body dimension measurements are performed using appropriate tools such as goniometers, calipers, and tape measures.[6,7] The characteristics of manual anthropometric measurements include ease of implementation, accessibility of the required tools, and relatively high measurement accuracy.[8] However, this method has disadvantages due to limitations in measuring some body dimensions and the influence of human factors in the measurement. For this reason, other measurement methods such as photogrammetry or 3D scanners are used to obtain more accurate information.[9,10]

One of the anthropometric methods is the 2D method. In this method, a 2D photograph of the person being measured is taken, and various body dimensions are extracted from these images using specialized software.[11] In addition to eliminating the limitations of the manual method, the photo anthropometric method also increases individual cooperation due to the short measurement time and the minimal contact between the measuring instrument and the body.[12] Measuring facial dimensions with the photo anthropometric method is very convenient and requires less skill, and also allows for repeatability.[13] However, the 2D method of anthropometric photography also has limitations. For example, the accuracy of measurements in this method is lower than in traditional methods, and the images taken can be affected by several factors, including the number of images recorded, the angle of view, the deviation of the camera lens when taking the picture, and the ambient lighting conditions.[6] For this reason, in some cases, the use of 3D anthropometric methods such as 3D scanning can provide more accurate results.[14]

In this method, 3D information about the shape and dimensions of the person's body is obtained using 3D scanning equipment. In this method, the 3D position of landmarks on the body is recorded by electromechanical and electromagnetic probes.[15] With the advancement of technology, the dimensions of the human body can be measured indirectly by the 3D method. The 3D scanning method is developed from advanced optical technologies. The 3D scanner system comprises a light source, sensors, and a controller.[6,16] The use of the 3D method in anthropometry has several advantages over the traditional method, which involves the use of calipers and tape measures. 3D measurement reduces the inherent errors of the manual method, especially those related to pressure on the facial soft tissue.[17] The 3D methods can also collect additional information, such as volume measurements, which traditional methods cannot. Another advantage of this method is the ability to archive an exact copy of the sample's face for future use.[18,19]

Other advantages include high accuracy, the ability to record and store accurate body dimension information, and the ability to retrieve and analyze measured data. Despite the above advantages, the 3D method of anthropometric measurement also requires some consideration. For example, the fixed and variable costs of implementing this method are higher than traditional anthropometric methods. Also, the need for advanced equipment and trained specialists in this field is considered a limitation of this method.[20] However, considering its advantages, the 3D method of anthropometric measurement is used in many applications as an accurate and suitable method.[21]

This software enables the creation and analysis of 3D models of the human body and can be used to measure and record different body dimensions with high accuracy.[22] Among these advantages are the ability to access accurate and comprehensive body dimension information, store and retrieve data, and perform advanced analyses on 3D models. These features have wide applications, especially in the fields of design and medicine.[23] Using 3D software to measure dimensions in addition to saving time allows for the preparation of an archive of photographs for future research. To date, studies have been conducted in this regard, for example, using a digital camera to measure the anthropometric dimensions of the foot, using calipers, compasses, tape measures, and multi-purpose goniometers to measure the anthropometric dimensions of the head and face,[24] and using the 2D photo anthropometry method to measure the anthropometry of the hand,[12] each of which has its advantages and disadvantages.

Scaniverse is a free 3D scanning app available on iOS devices with a LiDAR sensor. The app utilizes infrared laser technology, known as LiDAR, to measure distances from various angles and build a 3D geometric model, while also creating a colored texture to display on the model.[25,26] Therefore, this study aims to compare the two manual methods and the Scaniverse app for measuring facial anthropometric dimensions. This study could be the starting point for further and more accurate investigations to establish a facial anthropometric database for designing respiratory masks or other devices used in the facial area for the Iranian working population.

2 Methods

Participants

The study included a total of 188 participants, comprising 94 men and 94 women, who were selected through convenience sampling. This calculation was performed using the data from a study by Salvarzi et al.[2] as follows.

$$\mu 1\text{-}\mu 2=0.43 \qquad \delta=1/055 \qquad \alpha=0/05$$

$$N=\frac{2\delta^2\left(Z_{1-\alpha/2}+Z_{1-\beta}\right)2}{(\mu_1-\mu 2)^2}=\frac{2\times(1.113)^2\times(2.8)^2}{(0.43)^2}=94$$

The conditions for inclusion of the samples in the study were: (i) Individual consent to participate in the study; (ii) Male and female students; (iii) No significant changes in the mouth and teeth and no abnormalities such as acne or scars on the face; (iv) No history of facial surgeries such as rhinoplasty; (v) No beard in men.

Measuring protocols

The dimensions measured in the study were selected based on the study by Han et al., which was designed for the design of a half-face mask.[1] These dimensions include the Bizygomatic Breadth (ZYGO)(Face Width), Bigonial Breadth (GONI), Menton-Nasal Root Length (MNRL)(Face Length), Menton-Subnasal Length (MSNL) (Lower Face Length), Subnasal-Nasal Root Length (SNRL), Nose Width (NOSW), Lip Length (LIPL), Bitragion-Subnasal Arc (TRNA), Bitragion-Menton Arc (TRMA), Nose Protrusion (NOSP). This study was conducted in the ergonomics laboratory of the School of Public Health at Urmia University of Medical Sciences.

These 10 dimensions are illustrated in the Figure 1 and Figure 2.

It appears that when optimal and standard measurement conditions are observed in both manual methods and 3D scanning, the correlation coefficient between the two methods can be improved. These conditions are stated in various scientific texts and include the following: Each manual measurement should be repeated three times, with the average value calculated. The sample must be illuminated with sufficient and uniform lighting. Two observers should perform measurements, and if discrepancies arise, the average of their measurements should be recorded. A digital caliper should be used instead of a conventional one. The distance between the sample and the scanner camera must remain constant and identical throughout the process. An adjustable chair should be used to position the sample correctly.

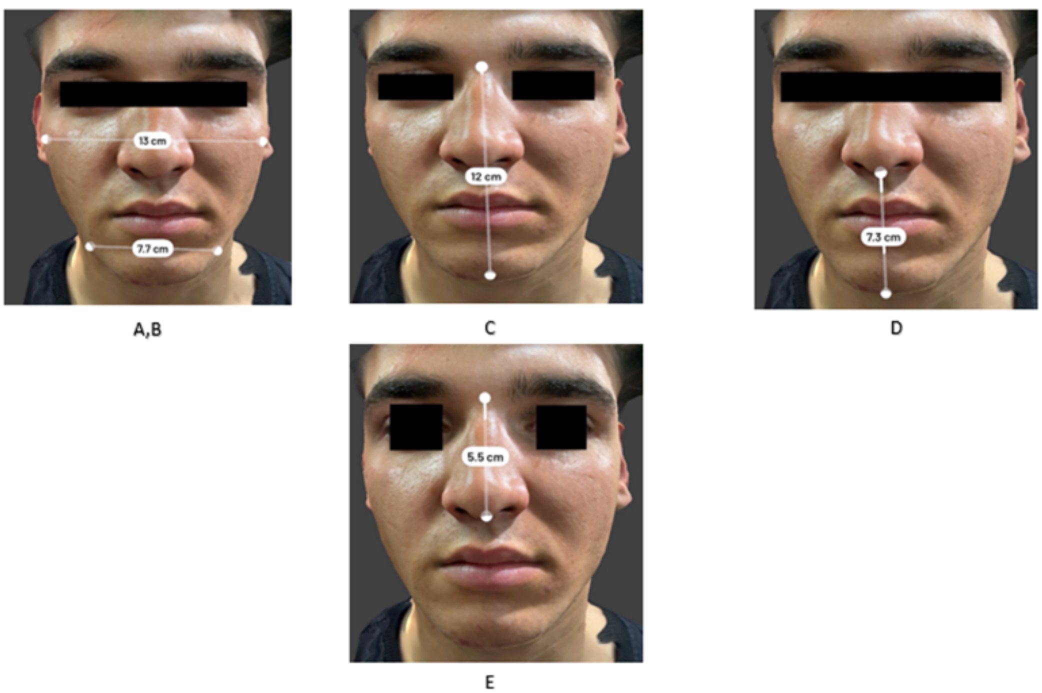

Figure 1 A. Bizygomatic Breadth (Face Width); B. Bigonial Breadth (GONI); C. Menton-Nasal Root Length (MNRL) (Face Length); D. Menton-Subnasal Length (MSNL) (Lower Face Length); E. Subnasal-Nasal Root Length (SNRL)

Consistent sampling conditions must be maintained for all samples, and there should be adequate contrast between the sample, the environment, the tools, and the standard equipment.

To measure 10 specific facial dimensions, a device equipped with LiDAR (Light Detection and Ranging) technology was required. Accordingly, an iPhone 12 Pro Max (or newer) or an iPad Pro was used. The 3D scanning application Scaniverse (version 5.0.1) was downloaded and installed from the Apple App Store. This software enables high-precision three-dimensional facial scanning compatible with LiDAR-enabled devices. To perform the task using the software, the Mesh option was selected, and considering the subject's dimensions (a human), the Medium Object option was chosen. The range was then set to less than 2.5 meters, and the phone was moved by rotating 360 degrees around the subject's face, who was seated and stationary on a chair, until all red areas on the image disappeared. The collected data was then processed using one of three modes: Speed, suitable for fast processing; Area, ideal for scanning rooms and large spaces; and Detail, suitable for objects with textured surfaces. The Detail mode was selected in this study due to the use of face scanning. The point cloud, which provided geometric dimension information, was generated in the desired format. Finally, using the software's measurement tool, the distances between facial dimensions were measured. For manual measurement of dimensions, we used a digital caliper (manufactured by Asimeto, Germany) with an accuracy of 0.01 mm.

Measurement conditions in the software method and manual method include the following: The number of lighting sources should be constant and appropriate, a stable chair with a backrest should be used to ensure that the head and spine are in a stable position, long hair should be kept away from the face, manual and software measurements should be performed in the morning and when the person is not tired. Subjects were asked not to smile or frown. In the software method, maintaining the appropriate distance from the sample to the camera, using the same camera height for all samples, and ensuring the correct position of the body relative to the camera are crucial.

Statistical Analysis

Descriptive statistics, including the mean and standard deviation of the measured values, were determined. To determine the appropriate statistical test for analyzing the relationships between variables, the data distribution was examined, which was found to be normal according to the Kolmogorov-Smirnov test. Therefore, the Paired Samples T-Test was used to compare the mean of facial anthropometric dimensions in the manual and software methods. Additionally, to assess the level of agreement between the methods used to measure facial anthropometric dimensions in this study, the Intra-Class Correlation Coefficient (ICC) was employed.

To compare the manual and software methods, it can be said that using the 3D Scaniverse method, in addition to saving time (the time measurement using the

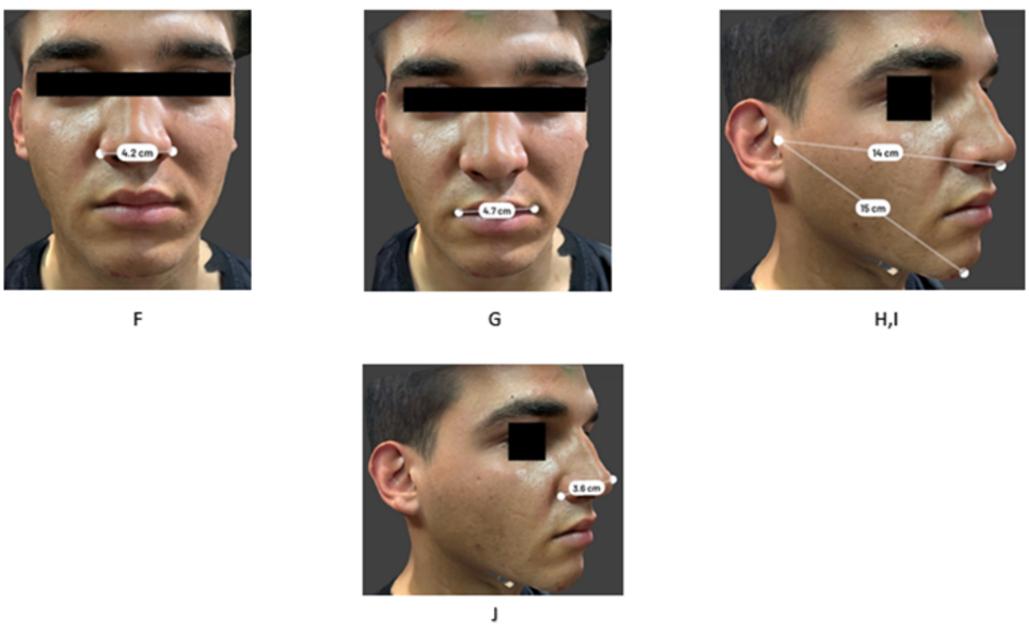

Figure 2 F. Nose Width (NOSW); G. Lip Length (LIPL); H. Bitragion-Subnasal Arc (TRNA); I. Bitragion-Menton Arc (TRMA); J. Nose Protrusion (NOSP)Root Length (MNRL)(Face Length); D. Menton-Subnasal Length (MSNL) (Lower Face Length); E. Subnasal-Nasal Root Length (SNRL)

software method was about 5 minutes for each person, while the manual method required at least 15 minutes for measurement), is easy to implement, store, and retrieve data. Another advantage is that this software is free. Given the research gap in the field of measuring facial dimensions using 3D scanning software in Iran and considering the sanctions that prevent the entry of expensive scanning devices into the country, this method can be a suitable alternative to the manual method.

Table 1 Comparison of average facial anthropometric dimensions in students using the manual method and Scaniverse software (n = 188)

Items	Measured dimensions	Measurement method	Mean and standard deviation (centimeters)	P-value*	t
1	Bizygomatic Breadth (ZYGO) (Face Width) A	Manual	0.81± 13.72	0.001 >	-4
		Scaniverse	0.84± 13.80		
2	Bigonial Breadth (GONI) B	Manual	0.87 ± 10.36	0.001 >	-4.2
		Scaniverse	0.90 ± 10.45		
3	Menton-Nasal Root Length (MNRL) (Face Length) C	Manual	0.86± 11.93	0.009	-2.6
		Scaniverse	0.93± 11.98		
4	Menton-Subnasal Length (MSNL) (Lower Face Length) D	Manual	0.76± 7.04	0.64	-0.47
		Scaniverse	0.75± 7.05		
5	Subnasal-Nasal Root Length (SNRL) E	Manual	0.43± 5.32	0.48	-0.7
		Scaniverse	0.43± 5.33		
6	Nose Width (NOSW) F	Manual	0.35± 3.49	0.001 >	-13.5
		Scaniverse	0.49± 3.63		
7	Lip Length (LIPL) G	Manual	0.44± 4.71	0.303	-1
		Scaniverse	0.42 ± 4.72		
8	Bitragion-Subnasal Arc (TRNA) H	Manual	0.78± 12.68	1	0
		Scaniverse	0.79± 12.68		
9	Bitragion-Menton Arc (TRMA) I	Manual	0.82± 13.98	0.001 >	-3.8
		Scaniverse	0.86 ± 14.06		
10	Nose Protrusion (NOSP) J	Manual	0.28 ± 3.34	0.212	-1.2
		Scaniverse	0.33± 3.37		

*Sig < 0.05

3 Results

In this study, 188 individuals (94 women and 94 men) were evaluated according to the established inclusion criteria. The average age of the participants in the study was 23.20 years. Additionally, the average age was 23.08 ± 5.26 in the female group and 23.32 ± 4.74 in the male group.

Measurement of facial anthropometric dimensions was performed using the manual method as a reference, and then the Scaniverse software. According to the objectives of the present study, the mean and standard deviation of the measured values, along with their comparison, are listed in Table 1. To determine the appropriate statistical test for analyzing the relationships between variables, the data distribution was examined, which was found to be normal in this study. Therefore, to compare the mean values of facial anthropometric dimensions obtained using the manual method with those obtained using the software, the Paired Samples T-Test statistical test was employed.

As shown in Table 1, the average Bizygomatic Breadth (ZYGO) (Face Width) was calculated to be 13.72 using the manual method and 13.80 using the software. The average analysis revealed a statistically significant difference between the measurement of this facial dimension using the manual method and the software (p-value < 0.05). In addition, in parameter B, the average measured using the manual method and the software was 10.36 and 10.45 cm, respectively, which indicates a significant difference between these two measurement methods (p-value < 0.05). Additionally, regarding Menton nasal root length (MNRL) (face length), the calculated average measurements using the manual and software methods were 11.93 cm and 11.98 cm, respectively, with a statistically significant difference (p-value < 0.05). In dimensions D, E, G, J, and H, there was no significant difference in the average measurements obtained using the two methods (p-value > 0.05). There is also a substantial difference in the average measurements of Nose Width (NOSW) and Bitragion-Menton Arc (TRMA) obtained by both manual and software methods (p-value < 0.05).

Figure 3 shows a comparison of the average distances of 10 dimensions of the face in both manual and software modes, showing that the distances of these values are very close to each other.

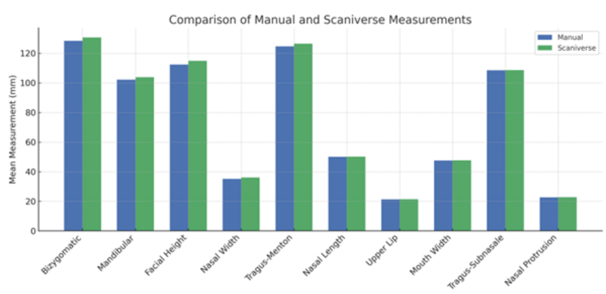

Figure 3 Comparison of the average distances of ten10 dimensions of the face in both manual and software modes

To examine the agreement between measurements, the ICC was calculated for the data (Table 2). The intra-class reliability and agreement of the measurements were assessed using the ICC, which ranged from 0.90 to 0.97 for the two methods, indicating high agreement and correlation. To examine the correlation between the results obtained from the two manual methods and the Scaniverse software in measuring facial dimensions, a Pearson correlation test was used.

The results of the correlation coefficients and p-values are presented in Table 2. As the table results show, the values exhibit a strong and positive correlation (close to 1). This means that the Scaniverse software can be used to measure facial dimensions instead of the manual method, yielding results of acceptable accuracy.

4 Discussion

This study aimed to compare two methods of measuring facial dimensions—manual and 3D scanning—and to introduce the 3D software Scaniverse. To achieve this goal, 10 dimensions of the facial dimensions required for the design of elastomeric masks were measured. Today, most anthropometric studies are performed using photography techniques and image analysis with 2D and 3D softwares. Several studies have been conducted on the validity of photo anthropometry and 3D scanning methods compared to traditional dimensional measurement methods.[27]

In 2020, Salvarzi et al. conducted a study titled Application of the Digimizer Image Analysis Software in Facial Anthropometry. This study employed a descriptive-analytical approach, with a sample size of 12 individuals. Two methods, manual and photographic, were used to measure the facial dimensions of the samples, and data analysis was performed using SPSS version 19 software and descriptive-analytical tests. The results showed that out of the 10 measured dimensions, significant differences were observed in three dimensions: the distance between the root of the nose and the septum (nose length), the distance between the root of the nose and the chin (face length), and the arch of the earlobe (tragus) to the chin. No significant differences were observed in the remaining dimensions. The ICC for the two methods was obtained within the range of 0.56 to 0.94.[2]

However, in our study, the results of the measurement values using the manual method and the Scaniverse software showed that there was a statistically significant difference in the average measurements of the distance between the cheeks (A), the distance between the jaw angles (B), the distance from the root of the nose to the chin (C), the width of the nose (F), and the arc of the auricle to the chin (I) using the manual method and the Scaniverse software (p-value < 0.05), and there was no difference in the average of the other dimensions measured with the two methods (p-value > 0.05). And for the agreement between the measurements, the ICC was used, the value of which was obtained for the two methods in the range of 0.97-0.90, which indicates high agreement and correlation. The results of our study showed a higher correlation than the Digimizer image analysis software method of Chobineh's study. The superiority of 3D software can be attributed to its ability to complete 3D modeling in real-time, allowing for the analysis of volume and form. Sometimes, the volume and protrusion of some facial tissue components can affect the distance between facial dimensions, which is not available in 2D software. The viewing angle and measurement view in the Scaniverse software include all angles (full face and profiles). In contrast, in the Digimizer, only a specific view (for example, front or profile) is shown. Also, the low quality of the images, image distortion, perspective error, and lack of scale in the Digimizer software can have an adverse effect on the measurements. The results of this study show a lower correlation coefficient than our study. In other words, using the Scaniverse software can replace manual and photographic methods and has acceptable accuracy in addition to saving time (the measurement time using the software method was about 5 minutes for each person, while the manual method required at least 15 minutes for measurement). It is also easy to implement and can store and retrieve data. Another advantage is that this software is free. Given the research gap in the field of measuring facial dimensions, using 3D scanning software in Iran, and the existence of some sanctions that prevent the entry of expensive scanning devices into Iran, this method can be a suitable alternative to the manual method.[2]

Düppe et al. found that facial anthropometric assessment using 3D photogrammetry (3DMDtrio) and direct measurement techniques were consistent in terms of reliability and agreement.[15] A study aimed to validate a 3D craniofacial stereophotogrammetry imaging system (3DMDface) by comparing it with manual facial surface anthropometry and found that there was good agreement between facial measurements using the 3DMDface system compared to manual anthropometry.[28] Minawi et al. showed that measurements of facial dimensions were in acceptable agreement with both direct (caliper-based) and indirect (3DCrisalix software) anthropometric analysis methods.[29] Habibi et al.'s study aimed to evaluate the accuracy of measuring hand anthropometric dimensions using the 2D Digimizer software and directly measuring these dimensions with a digital caliper. Statistical results showed no significant difference between direct and 2D photography measurements.[12] The results of a study by Strunevich et al. showed that mobile applications used to

Table 2 Correlation between facial dimensions measured manually and by software among participants

Items	Measured dimensions	Correlation Coefficient	P-value*
1	Bizygomatic Breadth (ZYGO) (Face Width) A	0.951	< 0.001
2	Bigonial Breadth (GONI) B	0.947	< 0.001
3	Menton-Nasal Root Length (MNRL) (Face Length) C	0.952	< 0.001
4	Menton-Subnasal Length (MSNL) (Lower Face Length) D	0.970	< 0.001
5	Subnasal-Nasal Root Length (SNRL) E	0.908	< 0.001
6	Nose Width (NOSW) F	0.927	< 0.001
7	Lip Length (LIPL) G	0.919	< 0.001
8	Bitragion-Subnasal Arc (TRNA) H	0.932	< 0.001
9	Bitragion-Menton Arc (TRMA) I	0.939	< 0.001
10	Nose Protrusion (NOSP) J	0.917	< 0.001

*Sig < 0.001

measure body dimensions can be considered acceptable measurement systems.[30]

In this study, there were no limitations in the field of data collection and extraction with the Scaniverse software. According to the above-mentioned information, to measure anthropometric dimensions more accurately and determine the correlation between the two manual methods and 3D scanning, a larger sample size can be used, or the Scaniverse software can be compared with other existing 3D scanning software to make a more informed and practical selection. It is suggested that an extensive study be conducted in the future on the reliability of Scaniverse among evaluators, so that the relevant software can be used to design and manufacture personal protective equipment and ergonomic tools, or to implement ergonomic interventions in real-world settings, such as industrial environments. Additionally, given the emergence of new anthropometric methods worldwide, 3D photography methods and, consequently, dynamic anthropometry must be utilized in Iran with the necessary funding from relevant organizations to make anthropometry more practical.

5 Conclusion

Based on the results of the present study and previous studies, it can be concluded that the use of measurement software can replace manual and 2D methods, yielding acceptable accuracy. These studies can serve as an introduction to the use and application of digital techniques and 3D software in measuring the entire body's anthropometric dimensions. Additionally, the application of this software and methods based on artificial intelligence can facilitate the creation of an anthropometric database for the Iranian population, which is crucial for future studies. The availability of an anthropometric database can also be used for the design and manufacture of various equipment, including the design of elastomeric masks or the design of any other device in the field of medicine, advanced jaw, skull, and face surgery, to the field of safety and personal protective equipment.

Declarations

Acknowledgments
This article is based on the thesis of Ms. Negar Semyari, a master's student in Occupational Health and Safety Engineering at Urmia University of Medical Sciences. We would also like to thank the participants in this study.

Authors' Contributions
Negar Semyari developed the research idea and study design, collected the data, performed data analysis, and prepared the initial draft of the manuscript. Timur Allahyari supervised and guided the research and participated in reviewing and editing the article. Vahid Alinejad did the statistical analysis.

Availability of Data and Materials
The data that support the findings of this study are available on request from the corresponding author.

Conflict of Interest
There are no conflicts of interest between the authors.

Consent for Publication
All authors have read and approved the final manuscript and have provided their consent for publication.

Funding
The author has no funding to report.

Ethical Considerations
The study protocol was approved by the Institutional Ethics Committee of Urmia University of Medical Sciences, Urmia, Iran, with the code IR.UMSU.REC.1403.054.

References

1. Han DH, Rhi J, Lee J. Development of prototypes of half-mask facepieces for Koreans using the 3D digitizing design method: A pilot study. Ann Occup Hyg. 2004 Nov;48(8):707–14.
2. Salvarzi E, Choobineh A, Jahangiri M, Keshavarzi S. Application of Digimizer Image Analysis Software In Facial Anthropometry. J Ergon. 2020;8(2):61–71.
3. Mojaverrostami, S.Najibi, A.Mokhtari, TahminehMalekzadeh, MehrnoushHassanzadeh G. The Importance and Application of Anthropometry in Medical Sciences and Related Industries: A Narrative Review. Journal of Rafsanjan University of Medical Sciences. 2019;18(6):606–589.
4. Sarač -Hadžihalilović A, Jaković K, Musić M, Šljuka S, Hasanbegović I, Hadžiselimović R, et al. Anthropometric Studies of Head Diameters in Bosnian High School Students Title: Anthropometric Studies of Head Diameters in Bosnian High School Students. Acta Medica Saliniana. 2020; 50(1/2):23-30.
5. Relethford JH. Craniometric variation among modern human populations. Am J Phys Anthropol. 1994;95(1):53–62.
6. Dianat I, Molenbroek J, Castellucci HI. A review of the methodology and applications of anthropometry in ergonomics and product design. Ergonomics. 2018;61(12):1696–720.
7. Conkle J, Keirsey K, Hughes A, Breiman J, Ramakrishnan U, Suchdev PS, et al. A collaborative, mixed-methods evaluation of a low-cost, handheld 3D imaging system for child anthropometry. Matern Child Nutr. 2019 Apr 1;15(2).
8. Rumbo-Rodríguez L, Sánchez-Sansegundo M, Ferrer-Cascales R, García-D'urso N, Hurtado-Sánchez JA, Zaragoza-Martí A. Comparison of body scanner and manual anthropometric measurements of body shape: A systematic review. Int J Environ Res Public Health. 2021; 18(12):6213.
9. Koepke N, Zwahlen M, Wells JC, Bender N, Henneberg M, Rühli FJ, et al. Comparison of 3D laser-based photonic scans and manual anthropometric measurements of body size and shape in a validation study of 123 young Swiss men. PeerJ. 2017;5:e2980.
10. Utkualp N, Ercan I. Anthropometric measurements usage in medical sciences. Biomed Res Int. 2015(1):404261.
11. Flores MRP, Machado CEP, Gallidabino MD, de Arruda GHM, da Silva RHA, de Vidal FB, et al. Comparative Assessment of a Novel Photo-Anthropometric Landmark-Positioning Approach for the Analysis of Facial Structures on Two-Dimensional Images.

J Forensic Sci. 2019;64(3):828–38.

12. Habibi E, Soury S, Zadeh AH. Precise Evaluation of Anthropometric 2D Software Processing of Hand in Comparison with Direct Method. J Med Signals Sens. 2013;3(4):256-61.

13. DiLiberti JH, Olson DP. Photogrammetric evaluation in clinical genetics: Theoretical considerations and experimental results. Am J Med Genet. 1991;39(2):161–6.

14. Seo YS, Jo KH, Kim JY, Kwon JH. Comparing reliability between 3D imaging and 2D photography for external nasal anthropometry. Sci Rep. 2022;12(1).

15. Düppe K, Becker M, Schönmeyr B. Evaluation of Facial Anthropometry Using Three-Dimensional Photogrammetry and Direct Measuring Techniques. J Craniofac Surg. 2018;29(5):1245–51.

16. Feathers DJ, Paquet VL, Drury CG. Measurement consistency and three-dimensional electromechanical anthropometry. Int J Ind Ergon. 2004;33(3):181–90.

17. Niu J, Li Z, Salvendy G. Multi-resolution description of three-dimensional anthropometric data for design simplification. Appl Ergon. 2009;40(4):807–10.

18. Joe PS, Ito Y, Shih AM, Oestenstad RK, Lungu CT. Comparison of a novel surface laser scanning anthropometric technique to traditional methods for facial parameter measurements. J Occup Environ Hyg. 2012;9(2):81–8.

19. Mandalidis D, Glakousakis G, Kalatzis P. An anthropometric-based method for the assessment of pelvis position in three-dimensional space. MethodsX. 2022;9:101616.

20. Liu H, Li Z, Zheng L. Rapid preliminary helmet shell design based on three-dimensional anthropometric head data. J Eng Des. 2008;19(1):45–54.

21. Chong Y, Li J, Liu X, Wang X, Huang J, Yu N, et al. Three-dimensional anthropometric analysis of eyelid aging among Chinese women. J Plast Reconstr Aesthetic Surg. 2021;74(1):135–42.

22. Lu JM, Wang MJJ. Automated anthropometric data collection using 3D whole body scanners. Expert Syst Appl. 2008;35(1–2):407–14.

23. Thelwell M, Chiu CY, Bullas A, Hart J, Wheat J, Choppin S. How shape-based anthropometry can complement traditional anthropometric techniques: a cross-sectional study. Sci Rep. 2020;10(1): 12125.

24. Farahvash Mohammad Reza, Rohollah Yegane, Khorasani Ghasemali, Mina Ahmadi BF. Anthropometric analysis of faces and heads of 18 to 30-year old Persians and its comparison with Caucasian ethnic group. Tehran University of Medical Sciences Journal. 2011;69:359–65.

25. Dickinson T, Liu J, Metascan MR. The affordances of 3D imaging modalities for forensic facial identification. In: 19th Biennial Meeting of the International Association for Craniofacial Identification, Virtual Event. 2022.

26. Othman SA, Majawit LP, Wan Hassan WN, Wey MC, Razi RM. Anthropometric study of three-dimensional facial morphology in Malay adults. PLoS One. 2016;11(10): e0164180.

27. Mahmoudi M. Validity of photo anthropometric method for clinical and objective description of facial structures. Journal of Inflammatory Diseases. 2005;8(4):65–72.

28. Naini FB, Akram S, Kepinska J, Garagiola U, McDonald F, Wertheim D. Validation of a new three-dimensional imaging system using comparative craniofacial anthropometry. Maxillofac Plast Reconstr Surg. 2017;39(1):23.

29. El Minawi H, El Saloussy Y, Sabry M, Wahdan W, El Sharkawy O. Facial Anthropometry and Analysis in Egyptian Women. Plast Reconstr Surg Glob Open. 2022;10(5):e4333.

30. Strunevich E, Detering-Koll U, Quattelbaum B. Investigation of usability and measurement accuracy of 3D body scanning mobile applications. Commun Dev Assem Text Prod. 2020;1(2):130–40.