ISSN: 2476-6909; Modares Mechanical Engineering. 2025;25(03):155-161.

Tarbiat Modares University

Extraction of Foot Anthropometric Dimensions Using a Markerless 3D Scanner Based on Big Data Analysis in East Azerbaijan Province

ARTICLE INFO

Article Type
Original Research

Authors
Azghani M.[1*],
Hazrati E.[1],
Partovi Fard A.[1],
Gadimi A.[1],

How to cite this article
Azghani M, Hazrati E, Partovi Fard A, Gadimi A, Extraction of foot anthropometric dimensions using a markerless 3D scanner based on big data analysis in East Azerbaijan Province. Modares Mechanical Engineering; *2025;25(03):155-161.*

[1] Department of Biomedical Engineering, Sahand University of Technology, Tabriz, Iran

***Correspondence**
Address: Department of Biomedical Engineering, Sahand University of Technology, Tabriz, Iran.

azghani@sut.ac.ir

Article History
Received: March 17, 2025
Accepted: May 04, 2025
ePublished: May 19, 2025

ABSTRACT

Background
Anthropometry, the scientific discipline concerning precise human body measurements, plays a pivotal role across various industries, particularly in medical applications where accurate data are essential for prosthetic and orthotic design. Conventional anthropometric data acquisition methods are often time-intensive and costly. This study establishes a comprehensive anthropometric database of Iranian ethnic groups utilizing three-dimensional scanning technology coupled with a Python-based algorithm for markerless foot measurement.

Methods and Materials
This cross-sectional study was conducted at the Iranian Foot Anthropometry Research Center (Sahand University of Technology, Faculty of Biomedical Engineering). The study population comprised 4,312 participants (2,527 males and 1,785 females), aged 6 to 76 years (mean 36.35 ± 14.76) from East Azerbaijan Province. A Python program has been developed to extract 35 anthropometric foot indices from three-dimensional scans without the need for physical markers. For validation purposes, 400 participants were randomly selected for two-dimensional foot scanning, with five foot-length indices and two foot-width indices extracted from both two-dimensional and three-dimensional scans. An independent samples t-test was performed using SPSS 26 to assess measurement reliability.

Results
Statistical analysis revealed that all indices demonstrated P-values exceeding 0.05, confirming the reliability of data extracted by the Python algorithm and establishing the methodological robustness of the three-dimensional scanning approach.

Conclusion
This study successfully validates the reliability of a Python-based algorithm for extracting anthropometric foot indices from three-dimensional scans, providing an efficient and accurate tool for foot measurement in clinical and research applications.

Keywords Foot Anthropometry, 3D Scanning, 2D Scanning, Reliability

CITATION LINKS

1- 16 Laser Scanning: The Future. 2- Advanced computer aided technologies for …. 3- Anthropometric dimensions of foot in …. 4- ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES AS RISK FACTORS FOR …. 5- Foot shape of older people: implications for …. 6- A systematic review on ear anthropometry and …. 7- ANTROPOMETRIC FOOT MEASUREMENTS OF …. 8- Evaluation of foot arch in adult women: …. 9- Risk factors for work-related musculoskeletal disorders among workers in …. 10- Comparing 3D foot scanning with …. 11- Foot Anthropometry by Digital Photography and the …. 12- Comparison of body scanner and …. 13- Ethnic differences in forefoot shape and …. 14- Quantitative morphology of …. 15- Foot dimensions and foot shape: differences due to …. 16- Sex-related differences in foot shape. 17- Validation of an Automated Optical Scanner for a …. 18- Fast, portable and low-cost 3D foot digitizers: Validity and reliability of …. 19- The use of 3D surface scanning for …. 20- A low cost 3D foot scanner for custom-made …. 21- Robotic 3D scanner as an alternative to …. 22- 3D scanning applications in medical field: a literature-based review. 23- Determining sample size for research activities. 24- Comparison of foot dimension measurement (anthropometry) using …. 25- Investigation of the relationship between the degree of the longitudinal arch and …. 26- Foot anthropometry using digital photography method and …. 27- Comparison of foot anthropometric measuremeants in …. 28- Foot anthropometry using digital photography and its importance in boot design. 29- Gender differences of foot characteristics in …. 30- Anthropometric dimensions of …. 31- Gender differences in foot shape: ….

1. Introduction

1.1 Epidemiology

Three-dimensional scanning technology has revolutionized anthropometric measurement by significantly enhancing data accuracy. The global market for three-dimensional scanning technologies reached $86.2 million in 2003 for hardware, software, and related services, representing a 22% growth compared to 2002(1). Compared with traditional methods, three-dimensional scanning systems offer superior precision and more efficient data collection(2). In Iran, implementing three-dimensional scanning technology in clinical settings, particularly for diagnosing foot pathologies, could substantially improve healthcare delivery(3).

1.2 Importance of Foot Anthropometry

Foot anthropometry serves as a critical component in understanding human biomechanics and designing ergonomic footwear, orthotics, and prosthetics. Precise measurement of foot dimensions—including length, width, and arch height—is essential for reducing biomechanical stress and preventing chronic conditions such as structural foot deformities(4). Advances in three-dimensional scanning technology have enabled the creation of sophisticated models capable of measuring complex parameters including arch height and toe angulation(5). High-resolution models prove particularly valuable in clinical settings for diagnosing and managing conditions such as pes planus and cavus foot deformities, where measurement precision is paramount(6). Footwear constitutes an essential element of daily life with widespread implications across multiple domains(7,8). Ill-fitting footwear may contribute to musculoskeletal disorders affecting both the feet and spine(9). A primary challenge in this field involves accurate foot data acquisition, as foot morphology directly influences the comfort and functionality of associated equipment.

Traditional anthropometric measurement techniques, while widely accessible, demonstrate limitations including suboptimal accuracy, time inefficiency, and operator dependence. Even with technological advancements such as three-dimensional scanners, persistent challenges include marker requirements and substantial equipment costs(10,11). These limitations have motivated researchers to develop novel methods for markerless anthropometric data acquisition that maintain high accuracy while reducing costs. Current approaches to foot anthropometric data acquisition fall into three primary categories: manual techniques, three-dimensional scanner-based methods, and markerless methodologies. Each approach holds distinct advantages and applications within anthropometric research.

1.3 Manual Methods

Manual measurement techniques represent the earliest approach to anthropometric data collection. These methods typically employ basic instruments including calipers, tape measures, and digitizers for assessing foot length and width(12). For instance, House et al. (1994) utilized calipers and digitizers to measure foot dimensions in a North American Caucasian male population, providing comprehensive data on toe length and foot width(13,14). Similarly, Koushi et al. (1998) employed manual instruments to examine gender and ethnic variations in foot morphology, analyzing their implications for footwear design(15). While cost-effective and straightforward, these methods demonstrate limitations including operator dependence, measurement variability, and time requirements that restrict their application for complex measurements. These constraints prompted the development of more advanced technologies.

1.4 Three-Dimensional Scanner-Based Methods

The introduction of three-dimensional scanners marked a paradigm shift in anthropometric measurement accuracy and efficiency. This technology provides detailed three-dimensional reconstructions and enables rapid data collection, offering significant advantages over manual methods. Krauss et al. (2008) employed three-dimensional scanners to analyze ethnic and gender differences in foot morphology, identifying structural variations with implications for equipment design(16). Michael et al. (2010) demonstrated that three-dimensional scanning technology provides superior accuracy compared to traditional methods for ergonomic footwear design(5). Despite these advantages, challenges persist including marker requirements for anatomical reference points and substantial equipment costs. Additionally, the need for trained operators contributes to increased operational expenses, motivating the development of markerless alternatives.

1.5 Markerless Methods

Markerless methodologies were developed to eliminate manual reference point identification while improving measurement accuracy and efficiency. These approaches utilize advanced image processing algorithms and machine learning techniques for automated foot feature extraction and analysis. Ricardo et al. (2023) combined three-dimensional scanning with image processing algorithms to eliminate marker requirements while significantly improving measurement accuracy(17). Ballester (2017) developed a hybrid methodology comparing three-dimensional scanner data with manual measurements, demonstrating that markerless methods improve both accuracy and reliability while reducing time and cost requirements(18). By eliminating marker and operator dependence, these approaches represent a promising direction for future anthropometric research with potential applications in ergonomic design and clinical studies. Historically, anthropometric data collection has employed both simple and specialized instruments, typically limited to few parameters. Technological advancements have produced innovative tools capable of providing rapid, reliable anthropometric data to specialists(19). This innovative approach shows particular promise for ergonomic equipment design, orthopedic footwear production, and clinical analysis, potentially transforming these fields. Furthermore, these methods may be adapted for other anatomical regions and anthropometric applications(20–22). Given the limitations of traditional methods and the need for improved efficiency, markerless technique development has attracted considerable research attention. This study presents an innovative method for markerless foot anthropometric data acquisition using three-dimensional scanning technology. This approach enables more precise data collection, reduced costs, and eliminated operator dependence. It is hypothesized that the foot dimensions obtained through markerless three-dimensional scanning and Python-based analysis will not show statistically significant differences when compared to two-dimensional foot measurements, thereby validating this approach for anthropometric research.

2. Methodology

This study aimed to extract foot geometric characteristics—including length, width, circumference, area, and angular measurements—using three-dimensional and two-dimensional scanning data from participants in Tabriz, East Azerbaijan province. Data collection occurred between October 2021 and January 2023 through random sampling of the target population. This section details data collection procedures, preprocessing, feature extraction, computational methods, and validation protocols.

2.1 Equipment and Input Data

The study utilized the three-dimensional foot scanning database from the Anthropometry Research Center at Sahand University of Technology. The dataset includes 4,312 three-dimensional foot scans from participants aged 6 to 76 years (2,527 males and 1,785 females) in East Azerbaijan Province, with a mean age of 36.35 ± 14.76 years. For validation, 400 randomly selected two-dimensional scans were analyzed along with participant metadata including weight, height, age, and gender.

Two scanner types were employed:

The three-dimensional scanner (PT-3D) utilizes laser technology with six cameras to record foot geometry with 0.1 mm accuracy, storing (X, Y, Z) coordinate data. Participants maintained a standardized standing position during scanning, with a wooden alignment device positioned at the foot's medial aspect to ensure consistency (Figure 1, Sections A and B). The two-dimensional scanner (PT-2D PLANTAR) generated 1700×1200 pixel images for footprint morphology and surface area analysis. Collected PLY-format data served as input for subsequent analysis.

2.2 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria were designed to ensure the accuracy and reliability of the study results. Participants were required to be in good general health and capable of standing independently during the 3D scanning process. Exclusion criteria included individuals with musculoskeletal, neurological, or cardiovascular disorders, as well as those with physical injuries, as these conditions may affect foot anatomy and biomechanics, potentially distorting the data. Additionally, participants who experienced discomfort, fatigue, or were unable to complete the scanning process due to technical issues were excluded.

Certain samples were further excluded for the following reasons:

1. Inaccurate foot positioning during scanning (rotation >5°) was excluded to ensure consistent and reliable foot alignment.
2. Poor scan quality, including excessive noise or distortion that could not be corrected through preprocessing, was excluded to maintain data integrity.
3. Incomplete anatomical data, such as scans with more than 5% missing data points or missing key foot landmarks, were excluded to ensure full representation of foot geometry.

These measures were implemented to minimize bias and ensure the consistency of the data.

2.3 Sample Size Calculation

Using the Krejcie-Morgan method(23), the minimum required sample size for East Azerbaijan province was calculated as 384 participants (margin of error = 0.05, confidence level = 95%). To enhance accuracy, the sample size was doubled to account for:

1. Broad age representation (6-76 years)
2. Inclusion of both healthy participants and those with specific conditions
3. Increased dataset precision

After applying these adjustments, the final sample size was determined as 3,072 participants.

2.4 Data Preprocessing

Preprocessing improved data quality through noise reduction using filtering algorithms. Foot data points were segmented into three regions: heel, arch, and toes. Files were named systematically (e.g., 1004-ML-M.PLY for male participant 1004's left foot).

2.5 Three-Dimensional Feature Extraction

Key anthropometric parameters—including length, width, area, circumference, and angles—were extracted using computational models (Figure 1, Section C). Detailed calculation methods are provided in the Appendix (Sections 1-4).

2.6 Programming and Data Processing

A custom Python algorithm was developed to automate data extraction and processing. The pipeline imports PLY-format scan data, extracts 3D point coordinates, and implements geometric computations to derive anthropometric parameters. Extracted measurements and associated metadata (including gender, age, and laterality) are systematically stored in a relational database. This markerless methodology eliminates the need for physical reference points while ensuring measurement precision.

2.7 Statistical Analysis and Data Validation

All analyses were conducted using SPSS (version 26). An independent samples t-test compared three-dimensional and two-dimensional scan measurements (Figure 1, Section D). Randomization techniques minimized selection bias in the validation dataset. Weight was considered a potential confounder, with statistical adjustments applied to ensure measurement comparisons were unbiased.

3. Results

This section presents anthropometric data analysis results from Python processing and compares them with two-dimensional scanner measurements. The primary objective was evaluating the proposed method's accuracy, precision, and reliability through extracted values, statistical comparisons, and key findings.

3.1 Demographic Characteristics

Table 1 presents demographic data for 4,312 participants (2,527 males, 1,785 females) aged 6-76 years (mean 36.35 ± 14.76). Males averaged 37.35 ± 15.22 years, females 34.93 ± 13.97 years. Mean height was 167.75 cm (males: 173.58 cm, females: 159.50 cm).

3.2 Python Program and Two-Dimensional Scanner Output

The Python algorithm successfully extracted 35 anthropometric indices from three-dimensional scans without physical markers, including longitudinal and transverse foot measurements. For validation, seven indices (five longitudinal, two transverse) were compared between three-dimensional and two-dimensional modalities.

3.3 Statistical Analysis

Results demonstrated the Python program's accuracy for markerless anthropometric extraction. Strong agreement between three-dimensional and two-dimensional measurements validated the method's reliability. The automated approach significantly reduced analysis time and minimized human error (Table 2). Independent samples t-test analysis revealed no significant differences between measurement methods (all P-values > 0.05), supporting the algorithm's reliability. Mean values and standard deviations fell within expected ranges (Table 3). Cohen's d values were all less than 0.2, indicating negligible effect sizes, which further supports the equivalence of the two measurement methods.

4. Discussion and Conclusion

This study validates a Python-based algorithm for reliable anthropometric index extraction from three-dimensional foot scans. Statistical analysis revealed no significant differences between three-dimensional and two-dimensional measurements, achieving the study's primary objective. This method shows particular promise for prosthetic and orthotic design applications. However, unmeasured variables including physical activity levels may influence results—a study limitation. Future research should address these factors to enhance measurement accuracy.

These findings from East Azerbaijan province participants (age 6-76 years) require validation in diverse demographic populations. The unstratified sample limits generalizability to specific subgroups, necessitating further multinational research. The Python algorithm provides an accurate, efficient alternative to traditional marker-based techniques with applications in medical, engineering, and industrial design fields. For validation, 400 foot scans were analyzed. After excluding scans with excessive noise or missing indices, 204 samples were retained for length and width analysis.

4.1 Foot Length Index Analysis

4.1.1 FL1 Analysis

Upon reviewing the FL1 length tables for both feet, the Sig. (2-tailed) value was 0.24. The average data from both the 2D scan and the Python program output revealed an accuracy of approximately 0.1 mm, confirming the program's accuracy in calculating FL1 length. A comparison of FL1 and FL2 lengths indicated that in 85% of cases, FL1 was longer than FL2. Since the Python program uses the longest FL to calculate the conversion factor (from pixels to millimeters) after image processing, any error in measuring FL1 could affect the calculation of other FL lengths.

4.1.2 FL2 Analysis

The independent t-test for FL2 showed a Sig. (2-tailed) value of 0.15. The average data for both the 2D scan and Python program output indicated a length of 253 mm. In 14% of samples, FL2 was longer than FL1, and this value is used as the conversion factor for other FL lengths.

FL2 represents the distance between the heel tip and the second toe tip along the Y-axis. Accurate localization of the second toe tip is crucial to avoid foot rotation errors, and the results showed the program's precision in this task.

4.1.3 FL3 Analysis

For FL3, the Sig. (2-tailed) value was 0.58. The average difference between the 2D scan and Python program output was 0.3 mm, indicating high accuracy in FL3 measurement.

4.1.4 FL4 Analysis

The Sig. (2-tailed) value for FL4 was 0.93, with an average difference of 1.0 mm between the 2D scan and Python program output. Some foot images revealed an issue where the fourth toe was positioned beneath the third or second toe, preventing the formation of a proper curvature at the tip of the fourth toe. This caused an error in FL4 measurement, which was later corrected by modifying the program's algorithm.

4.1.5 FL5 Analysis

For FL5, the Sig. (2-tailed) value was 0.76, with a 1.0 mm difference between both outputs. While FL5 is crucial for the program, challenges arose in determining its exact location, particularly due to toe deformation. However, this measurement significantly influences other indices, which will be discussed in the analysis of subsequent indices.

4.1.6 Summary of FL Analysis

The average foot length in this study was 258.16 mm, which closely aligns with measurements by Jozkani (259.9 ± 13 mm) and digital camera measurements (258.05 ± 14.1 mm)(24). Mortezavi's study reported foot lengths ranging from 251 mm to 271 mm, and Ghassami's study reported an average of 263.17 ± 11.7 mm(25).

The minor errors in the FL measurements can be minimized by implementing improvements such as using markers to prevent foot rotation, utilizing scanners that capture both feet simultaneously to reduce soft tissue deformation, and enhancing the quality of 2D images (above 100 DPI).

4.2 Foot Width Analysis

Reviewing the independent t-test tables for the HW index demonstrated better performance compared to the FL indices. The P-value for each foot was 0.26. The average difference between the 2D scanner outputs and the Python program results was approximately 0.3 mm.

The ABW, representing the second transverse foot index, was analyzed using an independent t-test. The results indicated that the P-values for the left and right feet were 0.23. The mean difference between the 2D scanner and the Python program outputs was about 0.3 mm. Accurately determining the ABW proved challenging in certain cases due to the flatness of the metatarsophalangeal joint area, even during manual measurements with a 2D scanner. The program occasionally struggled to identify the precise location of the big toe joint, especially when the lateral protrusion along the X-axis exceeded the joint bulge. Nevertheless, this issue was largely resolved by integrating additional constraints into the program.

Another observed issue was foot rotation, particularly on the right side. It was noted that the right foot exhibited a greater rotation angle compared to the left foot during data acquisition. Although the program implemented algorithms to correct foot rotation, slight deviations (less than 5 degrees) were still observed in some final outputs.

The width indices for both feet were also calculated and reviewed, showing excellent consistency. Compared to the FL indices, width measurements presented significantly fewer errors. The average heel width in this study was 74 mm, compared to 64 mm and 71.9 mm reported by Ghassemi and Mortezavi, respectively(25,26).

The mean ABW for the right and left feet in this study was 102 mm and 110 mm, respectively, closely matching previous findings by Ghassemi and Mortezavi, who reported 106 mm and 107 mm. In Jozkani's study (24) , the mean ABW was 104.15 mm based on manual measurement and 107 mm using photographic methods. The observed differences in width measurements may be attributed to variations in the age distribution of participants. Both Mortezavi (26) and Ghassemi(25) focused on participants aged 18–25 years, whereas the current study included individuals of all age groups (both male and female) predominantly from East Azerbaijan province.

Overall, the findings of this study highlight the extensive capabilities of the proposed method across various fields. In medicine, it can be utilized for designing and manufacturing customized orthotics and prosthetics based on precise anthropometric data. In engineering and fashion industries, it facilitates the design of better-fitting clothing and footwear tailored to individuals' anatomical characteristics. Additionally, anthropometric researchers can employ this method to analyze diverse populations and establish new standards.

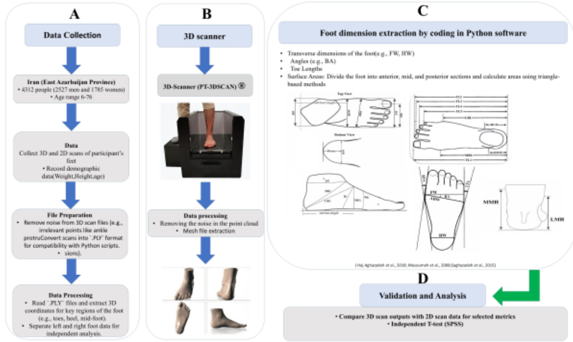

Fig. 1) summary of the methodology

A) Selecting appropriate data (data screening)

B) Data extraction and processing

C) Dimensionality extraction

D) Statistical analysis (independent T-test)

Table 1) Demographic information of males and females

		Weight (kg)	Height (cm)	Age (years)
Male (2527 individuals)	Minimum	22	107	6
	Maximum	114	198	76
	Mean	80.73	173.58	37.35
	Standard Deviation	17.96	10.12	15.22
Female (1785 individuals)	Minimum	20	108	6
	Maximum	92	188	76
	Mean	66.87	159.50	34.93
	Standard Deviation	15.27	8.57	13.97

Table 1) Mean and standard deviation of indices extracted from 3D scanner and 2D scanner images

Pair	Dimension	Mean	Count	Standard Deviation	Standard Error of the Mean
Pair 1	FL1 2D R	258.16	205	16.52	1.15
	FL1 3D R	258.54	205	17.63	1.23
Pair 2	FL2 2D R	253.53	205	16.50	1.15
	FL2 3D R	253.07	205	17.49	1.22
Pair 3	FL3 2D R	241.10	205	16.29	1.13
	FL3 3D R	241.89	205	16.89	1.17
Pair 4	FL4 2D R	224.47	205	14.99	1.04
	FL4 3D R	224.51	205	16.07	1.12
Pair 5	FL5 2D R	200.94	205	13.55	0.94
	FL5 3D R	201.06	205	14.04	0.98
Pair 6	HW 2D R	44.16	204	4.07	0.28
	HW 3D R	44.60	204	5.94	0.41
Pair 7	ABW 2D R	110.30	204	7.50	0.40
	ABW 3D R	110.66	204	9.40	0.50
Pair 8	FL1 2D L	258.16	205	16.52	1.15
	FL1 3D L	258.54	205	17.63	1.23
Pair 9	FL2 2D L	253.53	205	16.50	1.15
	FL2 3D L	253.07	205	17.49	1.22
Pair 10	FL3 2D L	241.10	205	16.24	1.13
	FL3 3D L	240.89	205	16.89	1.17
Pair 11	FL4 2D L	224.47	205	14.99	1.04
	FL4 3D L	224.51	205	16.07	1.12
Pair 12	FL5 2D L	200.94	205	13.55	0.94
	FL5 3D L	201.06	205	14.04	0.98
Pair 13	HW 2D L	44.16	204	4.07	0.28
	HW 3D L	44.60	204	5.94	0.41
Pair 14	ABW 2D L	110.66	204	9.40	0.50
	ABW 3D L	110.30	204	7.50	0.40

Table 2) Comparison of indices extracted from 3D and 2D scanners using Independent t-test

Comparison	Mean	Sample Size	Standard Deviation	Standard Error of Mean	t	P-Value	Cohen's d
Between FL1 2D R and FL1 3D R	-0.37	204	4.63	0.32	-1.16	0.24	-0.16
Between FL2 2D R and FL2 3D R	0.45	204	4.55	0.31	1.44	0.15	0.19
Between FL3 2D R and FL3 3D R	0.20	204	5.47	0.38	0.54	0.58	0.07
Between FL4 2D R and FL4 3D R	-0.35	204	6.07	0.42	-0.08	0.93	-0.06
Between FL5 2D R and FL5 3D R	-0.12	204	5.90	0.42	-0.29	0.76	-0.02
Between HW 2D R and HW 3D R	0.42	203	5.52	0.38	1.12	0.26	0.11
Between ABW 2D R and ABW 3D R	0.36	203	5.62	0.30	1.20	0.23	0.06
Between FL1 2D L and FL1 3D L	-0.37	204	4.63	0.32	-1.16	0.24	-0.16
Between FL2 2D L and FL2 3D L	0.45	204	4.55	0.31	1.44	0.15	0.19
Between FL3 2D L and FL3 3D L	0.20	204	5.47	0.38	0.54	0.58	0.07
Between FL4 2D L and FL4 3D L	-0.30	204	6.07	0.42	-0.08	0.93	-0.05
Between FL5 2D L and FL5 3D L	-0.12	204	5.90	0.41	-0.29	0.76	-0.02
Between HW 2D L and HW 3D L	0.43	203	5.53	0.38	1.12	0.26	0.11
Between ABW 2D L and ABW 3D L	0.36	203	5.61	0.29	1.20	0.23	0.06

R means right and L means left foot dimensions.

5. Acknowledgements
This article acknowledges the Ministry of Science and Research, as well as the Education, Research, Technology, and Innovation Committee (APFAN) of East Azerbaijan Province. We also recognize the role of East Azerbaijan Industrial Estate Co. Finally, we appreciate the support of Sahand University of Technology. We extend our gratitude to Sharif University of Technology for providing access to the SPSS 26 statistical software license.

6. Declaration of competing interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

7. Funding
The study found sponsorship from East Azerbaijan Industrial Estate Co (11-5227), the Ministry of Science and Research (m/81227), and APFAN of East Azerbaijan Province (105/3376) to disseminate its findings.

8. Authors' contribution
MR.A,E.H and A.G contributed to the conceptualization and design of the study. A.PF and E.H contributed to data collection, data interpretation, and MR.A critically drafted and revised the manuscript. All authors have read and approved the article and agree with the authors' presentation order.

Ethical Statement
The content of this manuscript is original, based on the authors' research, and has not been published or submitted elsewhere, either in Iranian or international journals.

Conflict of interest
The authors declared that they have no conflicts of interest to this work.

References

1- Large ARG, Heritage GL, Charlton ME. 16 Laser Scanning: The Future. Laser Scanning Environ Sci. 2009;262.
2- Raffaeli R, Germani M. Advanced computer aided technologies for design automation in footwear industry. Int J Interact Des Manuf. 2011;5(3):137–49.
3- Hajaghazadeh M, Minaei RE, Allahyari T, Khalkhali H. Anthropometric dimensions of foot in Northwestern Iran and comparison with other populations. Health Scope. 2018 Aug 1;7(3):14063.
4- Melloni MA, San-Martin JE, de Oliveira Barbeta CJ, Gonçalves EM, Júnior GG. ANTHROPOMETRIC AND BODY COMPOSITION VARIABLES AS RISK FACTORS FOR MUSCULOSKELETAL INJUREIS IN ATHLETES AND MILITARY PERSONNEL: A SYSTEMATIC REVIEW. Revista Contemporânea. 2024 Jun 28;4(6):e4898-.
5- Mickle KJ, Munro BJ, Lord SR, Menz HB, Steele JR. Foot shape of older people: implications for shoe design. Footwear Science. 2010 Sep 1;2(3):131-9.
6- Fu F, Luximon Y. A systematic review on ear anthropometry and its industrial design applications. Human Factors and Ergonomics in Manufacturing & Service Industries. 2020 May;30(3):176-94.
7- Hong Y, Wang L. ANTROPOMETRIC FOOT MEASUREMENTS OF CHINESE ADULTS WITH DIFFERENT BMI. InISBS-Conference Proceedings Archive 2007 Dec 11.
8- Shariff SM, Manaharan T, Shariff AA, Merican AF. Evaluation of foot arch in adult women: Comparison between five different footprint parameters. Sains Malaysiana. 2017 Oct 1;46(10):1839-48.
9- dos Santos Leite WK, da Silva Araújo AJ, da Silva JM, Gontijo LA, de Araújo Vieira EM, de Souza EL, Colaço GA, da Silva LB. Risk factors for work-related musculoskeletal disorders among workers in the footwear industry: a cross-sectional study. International Journal of Occupational Safety and Ergonomics. 2021 Apr 3.
10- Lee YC, Lin G, Wang MJ. Comparing 3D foot scanning with conventional measurement methods. Journal of foot and ankle research. 2014 Dec;7:1-0.
11- Mortazavi SB, Khavanin A, Mirzaei R, Rasoolzadeh Y, Mansourizadeh M, Mohseni M. Foot Anthropometry by Digital Photography and the importance of its application in Boot Design. Journal of Military Medicine. 2022 Oct 26;10(1):69-80.
12- 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. International journal of environmental research and public health. 2021 Jun 8;18(12):6213.
13- Hawes MR, Sovak D, Miyashita M, Kang SJ, Yoshihuku Y, Tanaka S. Ethnic differences in forefoot shape and the determination of shoe comfort. Ergonomics. 1994 Jan 1;37(1):187-96.
14- Hawes MR, Sovak D. Quantitative morphology of the human foot in a North American population. Ergonomics. 1994 Jul 1;37(7):1213-26.

15- Kouchi M. Foot dimensions and foot shape: differences due to growth, generation and ethnic origin. Anthropological Science. 1998;106(Supplement):161-88.
16- Krauss I, Grau S, Mauch M, Maiwald C, Horstmann T. Sex-related differences in foot shape. Ergonomics. 2008 Nov 1;51(11):1693-709.
17- Sacco R, Munoz MA, Billuart F, Lalevée M, Beldame J. Validation of an Automated Optical Scanner for a Comprehensive Anthropometric Analysis of the Foot and Ankle. Bioengineering. 2023 Aug 16;10(8):968.
18- Ballester A, Piérola A, Parrilla E, Izquierdo M, Uriel J, Nácher B, Ortiz V, Gonzalez JC, Page A, Alemany S. Fast, portable and low-cost 3D foot digitizers: Validity and reliability of measurements. Proceedings of 3DBODY. TECH. 2017 Oct 11:11-2.
19- Telfer S, Woodburn J. The use of 3D surface scanning for the measurement and assessment of the human foot. Journal of foot and ankle research. 2010 Dec;3:1-9.
20- Taha Z, Aris MA, Ahmad Z, Hassan MH, Sahim NN. A low cost 3D foot scanner for custom-made sports shoes. Applied Mechanics and Materials. 2014 Jan 6;440:369-72.
21- Chromy A, Zalud L. Robotic 3D scanner as an alternative to standard modalities of medical imaging. SpringerPlus. 2014 Dec;3:1-0.
22- Haleem A, Javaid M. 3D scanning applications in medical field: a literature-based review. Clinical Epidemiology and Global Health. 2019 Jun 1;7(2):199-210.
23- Krejcie RV, Morgan DW. Determining sample size for research activities. Educational and psychological measurement. 1970 Sep;30(3):607-10.
24- Jozkani J. Comparison of foot dimension measurement (anthropometry) using digital photography and manual methods. J Ilam Univ Med Sci. 2008;16(3):1-10. (In Persian).
25- Ghasemi Paindehi W, Rajabi A, Ali Zadeh R, Rostami D, Kamali K, et al. Investigation of the relationship between the degree of the longitudinal arch and some anthropometric foot dimensions with dynamic balance. J Appl Physiol Sport Sci. 2015;11(21):23-36. (In Persian).
26- Mortezavi B, Khaani M, Mirzaei R, Rasoulzadeh R, et al. Foot anthropometry using digital photography method and its application in boot design. J Mil Med. 2022;10(1):69-80. (In Persian).
27- JOZ KM, Mortazavi SB, KHAVANIN A, MIRZAEI R, RASOULZADEH Y, MANSOURIZADEH M. Comparison of foot anthropometric measuremeants in two digital and manual approaches.
28- Mortezavi S, Jamkhah S. Foot anthropometry using digital photography and its importance in boot design. J Mil Med. 2008;69-80. (In Persian).
29- Saghazadeh M, Kitano N, Okura T. Gender differences of foot characteristics in older Japanese adults using a 3D foot scanner. Journal of foot and ankle research. 2015 Dec;8:1-7.
30- Emamgholizadeh Minaei R, Hajaghazadeh M, Allahyari T, Khalkhali H, Keramat M. Anthropometric dimensions of foot in students. Iranian Journal of Ergonomics. 2016 Jun 10;4(1):28-38.
31- Hong Y, Wang L, Xu DQ, Li JX. Gender differences in foot shape: a study of Chinese young adults. Sports biomechanics. 2011 Jun 1;10(02):85-97.