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Comparative Analysis of Technological Measurement Tools Used In the Creation of Anthropometric Tables in Honduras

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Abstract **–**This report presented a comparative study of different anthropometric measurement methods used at the Faculty of Engineering of the Central American Technological University (UNITEC), Tegucigalpa. The identified problem was the lack of accurate and representative anthropometric data for the Honduran population, which negatively impacts ergonomic design and public health. To address this issue, three measurement methods were used: traditional, photogrammetry with iPhone LiDAR technology, and 3D scanning with the EinScan H Shining 3D.
The study's methodology included tests of repeatability and reproducibility, pilot tests, and feasibility analysis to evaluate the accuracy of each technique. A sample of 20 volunteer students from the Faculty of Engineering was selected, and all three methods were applied to them. Additionally, a statistical analysis using ANOVA was conducted to compare the results between the different methods and determine which provided the most consistent and precise measurements. The study also identified the specific advantages and limitations of each technique, facilitating a more comprehensive evaluation.
The results allowed for an assessment of the accuracy and reliability of each method. The methodologies were validated through expert triangulation, confirming compliance with the international standard ISO 7250-1:2017. These findings provide a solid foundation for future recommendations in ergonomics, industrial design, and occupational health in Honduras, contributing to the development of ergonomic policies based on reliable local data.

***Keywords*:** Anthropometry, photogrammetry, ergonomics, 3D scanner, method comparison

1. Introduction

This study aimed to determine which of the technological tools used for anthropometric measurements, whether LiDAR photogrammetry or the EinScan H Shining 3D scanner, offers the highest degree of accuracy, reliability, and effectiveness, by directly comparing them with the traditional method of measuring body dimensions.

To achieve this objective, an exhaustive statistical analysis was carried out to evaluate and compare the results obtained by each tool under different measurement scenarios, with the goal of identifying which one provides more consistent and precise data, minimizing the margin of error inherent in manual measurement methods [1].

In order for the anthropometric data to be valid, the reliability of the methodologies and techniques used for collecting traditional anthropometric measurements was verified by applying tests for repeatability and reproducibility, ensuring the consistency of the techniques and minimizing measurement errors [2].

Additionally, a series of pilot tests were conducted to standardize the measurements [3]. carried out by the researchers who would later collect the final anthropometric measurements from volunteers at the Faculty of Engineering of the Central American Technological University (UNITEC). The final data collection was done using the three different measurement methods. Each measurement parameter was collected and executed according to the established ergonomic principles and following the guidelines of ISO 7250-1:2017, ensuring technical rigor in obtaining the data for comparison of the measurements [4].

Once the measurement data was obtained, the accuracy of the technological tools used was analyzed by comparing the measurements from photogrammetry and 3D scanning with the traditional method, using inferential statistics through analysis of variance (ANOVA). This approach helps identify significant differences between the methods, and the use of ANOVA will facilitate the evaluation of variations within and between the different measurement groups, providing a clear view of which tool offers greater reliability in the context of anthropometric measurements [5].

Validation by experts would contribute to increasing the credibility of the study and ensure that the evaluated technological tools can be implemented in future studies and practical applications across various industries [6]. For this reason, the study was validated by three experts in ergonomics, anthropometry, and technology, who reviewed the procedures to ensure their appropriateness.

The research aims to make an impact in Honduras in the field of ergonomics, supporting the design of workspaces, as it improves working conditions and enhances the health and well-being of workers [7]. Given the notable absence of local anthropometric tables in the country, a recent study was conducted in Honduras focused on gathering initial data to create a local anthropometric database, which will allow the creation of tables specific to the country. The study found significant differences in 15 measurements compared to U.S. anthropometric tables, highlighting the importance of having local data [8]. The results of this study could serve as a foundation for future anthropometric research and applications using technology for data collection.

In Honduras, the issue of anthropometric measurements has gained relevance recently. A study conducted at Central American Technological University (UNITEC) in Tegucigalpa, Honduras, in 2023 compared three methods of anthropometric measurement: the traditional method, 3D scanning using the Kinect v1 sensor, and photogrammetry using the mobile application ImageMeter. The results of this study demonstrated a 32% reduction in time spent with photogrammetry compared to the traditional method [9].

Similarly, a study conducted at the Polytechnic University of Valencia sought to validate two 3D scanning techniques: the AVATAR 3D application and DOMEscan for foot anthropometric measurements. The reliability was studied by calculating the associated error and Intraclass Correlation Coefficient (ICC), yielding high reliability values, indicating that the methods provided adequate measurements of the studied variables [10].

The sections of the report will be as follows: an introduction to the study, presenting the problem addressed and the background of the research, both internationally and regionally, followed by the methodology section, which outlines the scope, population, sample, as well as the parameters analyzed, techniques, and instruments. Finally, the results obtained for each objective will be presented, concluding with the conclusions and applicability of the study.

2. Methodology

2.1. Approach and Scope

In this study, a quantitative approach was chosen, characterized by its scientific rigor and the use of the scientific method to evaluate phenomena with precision. This approach focuses on data collection with the purpose of corroborating hypotheses through the use of numerical metrics and statistical techniques [11]. Its scope is descriptive in nature, concentrating on providing a detailed view of the characteristics and dimensions of a specific phenomenon, without analyzing relationships between variables. The aspects to be measured and the data to be collected are precisely established, allowing for the creation of a clear profile of the phenomenon in question [11].

2.2. Population and Sample

The finite population used for this study consisted of 20 volunteer students from the Faculty of Engineering at the Central American Technological University (UNITEC), in the Tegucigalpa campus. The selection of this population was determined by the availability of time to conduct the study, as the time required to carry out all the anthropometric measurements using the three methods on each participant was a key limiting factor in defining the population size.

A non-probabilistic convenience sampling will be used due to the limitations imposed by the study, which include the time required to perform the measurements, the limited availability of specialized equipment, and the participation of only two researchers in data collection. These factors prevented the selection of a larger sample and reduced the possibility of generalizing the results. However, the data obtained with greater measurement accuracy allows for increased statistical power in the study's analysis [12]. This approach will optimize the available resources, focusing the measurements on a representative group that facilitates obtaining meaningful results within the time and conditions set for the project. Despite these limitations, the sampling will ensure the collection of valuable data for method comparison.

2.3. Analyzed Parameters

The study evaluated a series of anthropometric parameters in both standing and sitting positions, with the aim of comparing the accuracy and reliability of three measurement methods: the traditional method, photogrammetry using an iPhone with LiDAR technology, and the EinScan H 3D scanner by Shining 3D. Specific areas of the body, when compared statistically with direct anthropometric measurements, can be analyzed using statistical software [13].

In the standing position, parameters such as height, eye height, and shoulder height were analyzed. In the sitting position, aspects like seated height, the distance between the elbow and knee, and hip width were measured. These parameters allowed for a detailed comparison of the differences in accuracy between each of the evaluated methods, providing key information to determine the most suitable technology for anthropometric data collection.

Table 1: Standing position parameters.

Parameters in standing position and sectioned parts (Hand, Foot, Head, and Waist)							
1	Stature (body height)	5	Elbow height	9	Foot breadth	13	Hand length (stylion)
2	Eye height	6	Fist (grip axis) height	10	Foot length	14	Head length
3	Shoulder height	7	Elbow-grip length	11	Waist circumference	15	Head breadth
4	Thorax Depth	8	Hip breadth, standing	12	Hand breadth at metacarpals	16	Head circumference

The parameters obtained in a standing position proved crucial for capturing key measurements related to vertical posture, which are essential in the ergonomic design of workspaces, furniture, and equipment that involve continuous interaction of a person in that posture. These measurements included elements such as total height and shoulder height, which allowed for adjusting the dimensions of products and work areas to ensure proper posture, increased comfort, safety, and efficiency in their use. With these measurements, both productivity and physical well-being of workers can be optimized.

Table 2: Seated position parameters.

Parameters in seated position							
17	Sitting height (erect)	20	Knee height, sitting	23	Elbow height, sitting	26	Shoulder (bideltoid) breadth
18	Eye height, sitting	21	Popliteal height, sitting	24	Thigh clearance	27	Hip breadth, sitting
19	Shoulder height, sitting	22	Buttock-knee length	25	Elbow-to-elbow breadth		

On the other hand, measurements in the seated position were of great importance for the ergonomic development of work areas and furniture where users had to sit for long periods. These measurements provided valuable information for the optimal configuration of chairs, desks, and other elements, ensuring a correct posture that significantly reduced the possibility of muscle fatigue or long-term injuries, such as musculoskeletal disorders. The selected parameters follow the guidelines established in the ISO 7250-1:2017 standard, which provides a detailed framework for defining essential anthropometric measurements in ergonomic design and comparing data across different populations [14].

2.4. Instruments and Techniques Applied

In this study, various instruments were used to perform the anthropometric measurements. Among them, the anthropometric tape and the anthropometer were employed to measure circumferences and body dimensions, respectively, while the tape measure was used for heights and lengths. To obtain more advanced measurements, the iPhone app "Measure" was used for photogrammetry, and the EinScan H1 Shining 3D scanner was employed to capture three-dimensional body models. The data were organized and analyzed in Microsoft Excel, processed in EXScan H 1.2.1.1 software, and exported to SolidWorks to obtain accurate dimensions. Additionally, a stopwatch was used to record the time for the measurements.

The techniques applied included ISO 7250-1:2017, which provided standardization for the anthropometric measurements, ensuring consistency in data collection. For data analysis, Minitab software was used to perform an analysis of variance (ANOVA), which allowed for the identification of significant differences between the measurement groups, using the hypotheses shown in the following equation:

$$\begin{gathered} \mathrm{Ho}{:}\mu_{\mathrm{tradicional}} = \mu_{\mathrm{photogrammetry}} = \mu \\ H_A{:}\mu_{\mathrm{i}} \neq \mu_j \textit{ for at least one pair of i,j} \end{gathered} \tag{1}$$

(where $\mu_i \neq \mu_j$ represents the mean of the measurements for the different methods)

Additionally, inferential and descriptive statistical techniques were applied to analyze and summarize the obtained data, facilitating the interpretation of the results and conclusions of the study.

Regarding the materials used, a table was employed as a boundary for the measurements, a pencil to mark reference points on the body, and a wooden seat for conducting measurements in a seated position. These materials complemented the use of technologies and instruments, ensuring that the measurements were taken accurately and properly.

3. Results

3.1. Traditional Method

Pilot Test - Traditional Method

During the pilot test of the traditional method, conventional anthropometric tools, such as a measuring tape and a 90° wooden angle, were used to improve the accuracy of measurements. Four volunteers were measured by a single operator, focusing on repeatability and consistency. The average time per subject was 20 minutes, which showed that, although accurate, this method is slow. Adjustments were made, such as the use of adhesive reference points, but it was concluded that it is not practical for large-scale studies, highlighting the need for more efficient methods.

Data Collection - Traditional Method

Data collection focused on evaluating the accuracy and consistency of anthropometric measurements, considering their repeatability. Factors such as measurement time, the precision obtained using traditional tools, and the operator's experience were taken into account. The use of a single operator for all measurements allowed control of variables related to the measurement technique and ensured consistency in the results.

Results Obtained - Traditional Method

The results showed that the traditional method can provide accurate and consistent measurements, although the time required for each measurement session is considerably high. This limitation makes it difficult to scale the study to larger samples, as the method is not efficient enough. Despite the time constraints, the adjustments implemented have helped improve the overall accuracy of the measurements. This method is still used in anthropometric studies, provided that the measurements are performed by a researcher trained in the proper techniques. However, the prolonged duration of measurements highlights the need to explore the adoption of more advanced technologies to achieve greater efficiency in future research.

3.2. Photogrammetry Method

Pilot Test - Photogrammetry Method

During the pilot test, the iPhone photogrammetry application with LiDAR technology was used, allowing for the quick capture of anthropometric data and enabling measurements to be taken at a distance [15]., without direct contact with the four volunteer participants. The pilot test process helped identify aspects that would provide a controlled environment to minimize external variations that could influence the measurement results.

Data Collection - Photogrammetry Method

The data were collected through a series of images taken from different angles around each volunteer. During the test, variations in data quality were observed depending on factors such as lighting and camera position, which affected the accuracy of the measurements. Controlled environments and improvements in camera stability were used to try to mitigate these variations. Visible reference points on the volunteers' bodies were key to ensuring consistency in the measurements.

Results Obtained - Photogrammetry Method

The results obtained showed acceptable reliability in some parameters under controlled conditions, although inconsistencies were evident in environments with variable lighting. Despite these limitations, photogrammetry proved to be efficient in quickly capturing data without physical contact, suggesting its potential for large-scale measurements. However, difficulties in measuring circumferences and lower accuracy in certain parameters indicate that its application is not generalized, as only some results are statistically equivalent to traditional methods. Nevertheless, to determine whether more consistent and accurate results could be achieved, it would be useful to expand the analysis of this tool and evaluate if, through adjustments in the environment setup and improvements in device positioning, more parameters could be accepted, thus facilitating a broader use of this methodology.

3.3. 3D Scanning Method

Pilot Test - 3D Scanning Method

During the pilot test with the Shining EinScan H 3D scanner, measurements were taken on four volunteers, focusing on capturing high-precision data and achieving a high-quality scan [16]. The process included the detailed calibration of the scanner and the optimization of the protocol, which allowed for reducing the number of scans needed from six to four without compromising measurement accuracy. The equipment was chosen due to its ability to capture detailed three-dimensional models in a short period of time, with the aim of assessing its viability in anthropometric studies.

Data Collection - 3D Scanning Method

Data collection was conducted in a controlled environment, as it was observed that external factors such as lighting could significantly affect the quality of the scans. To mitigate these effects, ambient lighting was adjusted, and the stability of the scanner was improved. The complementary software, SolidWorks, was used to accurately analyze the circumferences, specifically the waist and head circumference parameters, enabling a detailed analysis of the captured measurements.

Results Obtained - 3D Scanning Method

The 3D scanning method proved to be a high-tech approach, prioritizing user comfort and minimizing the time needed for measurements. It has shown that 3D scanning provides remarkable accuracy in certain parameters, especially in linear measurements. The reproducibility of these results largely depends on the correct use of the software and scanner by the operator. In total, 17 parameters were identified and accurately determined with the 3D scanner, suggesting that, with improvements in software handling and measurement conditions such as clothing and subject positioning, this method could become a reliable option for anthropometric measurements. The scanner provides quite accurate scans in terms of scales and textures. SolidWorks was used for circumference measurements, facilitating a more detailed analysis and clearer visualization of the data. However, further studies are needed to enhance techniques and evaluate the applicability of the method in large-scale anthropometric research, standardizing the method to allow for reliable measurements of all parameters.

3.4. ANOVA Results (Analysis of Variance)

The analysis of the results, conducted using ANOVA and the Tukey test, analyzed with Minitab software, evaluated hypotheses on three measurement methodologies: traditional, photogrammetry, and 3D scanning, for parameters of different body parts such as hand, foot, head, and waist, as well as parameters in sitting and standing positions. The obtained p-values allowed the identification of significant differences between the methodologies and determined whether the null hypothesis, which stated that the measurements were the same, was rejected. In cases where significant differences were found, the Tukey test helped identify the methodologies that presented discrepancies in the measurements, providing a solid basis for interpreting the effectiveness of each technique in obtaining accurate measurements.

Results of the ANOVA Analysis on the Standing Position Parameters

As a result of the comparison of the measurements using analysis of variance, it can be observed in Table III that seven out of the eight parameters can be measured using the Shining EinScan H 3D scanner, and five of these parameters can be measured with either of the two technologies, as the null hypothesis is not rejected.

Table 3: Table of ANOVA results for standing position parameters

Parameters in standing position												
No	1			2			3			4		
Parameters	Stature (body height)			Eye height			Shoulder height			Thorax depth		
Method	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry
Mean	165.88	166	165.42	153.81	154.36	152.75	136.51	136.99	135.84	25.721	24.977	24.895
Std deviation	8.61	8.78	8.62	8.2	8.52	8.71	7.25	7.33	6.78	2.657	2.157	3.635
p-value (ANOVA)	p=0.36			p=0.070			p=0.078			p=0.407		
p-value (Tukey)												
No	5			6			7			8		
Parameters	Elbow height			Fist (grip axis) height			Elbow-grip length			Hip breadth, standing		
Method	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry
Mean	101.83	101.2	99.63	70.55	72.56	72.805	35.24	35.225	34.3	35.265	37.197	34.85
Std deviation	5.98	5.06	5.46	5.18	4.77	3.76	2.719	3.028	3.23	3.01	3.123	3.265
p-value (ANOVA)	p=0.001			p=0.002			p=0.124			p=0.000		
p-value (Tukey)		p=0.504	p=0.001		p=0.925	p=0.004					p=0.000	p=0.631

Results of the ANOVA Analysis on Sectioned Part Parameters

The analysis of variance revealed that the 3D scanner proved to be an effective tool for measuring four of the eight evaluated parameters, specifically in the regions of the hand and foot. However, the complexity of the cranial shape and interindividual variability limited the acquisition of precise and consistent data for the head parameters, compared to traditional methods that rely on direct physical contact with the individual.

Table 4: Table of ANOVA results for Sectioned Part Parameters

Parameters for sectioned parts (Hand, Foot, Head, and Waist)												
No	9			10			11			12		
Parameters	Foot breadth			Foot length			Waist circumference			Hand breadth at metacarpals		
Method	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner		Traditional	3D scanner	Photogrammetry
Mean	9.115	9.374	9.5	24.016	24.193	24.316	86.85	81.26		7.858	7.758	7.789
Std deviation	0.82	0.669	0.889	1.617	1.596	1.336	12.36	11.83		0.579	0.68	0.713
p-value (ANOVA)	p=0.05			p=0.386			p=0.000			p=0.663		
p-value (Tukey)		p=0.226	p=0.044					p=0.000				
No	13			14			15			16		
Parameters	Hand length (stylion)			Head length			Head breadth			Head circumference		
Method	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	
Mean	17.468	17.086	17.737	18.942	20.03	20.263	15.175	15.947	15.2	56.4	58.14	
Std deviation	1.14	1.168	1.485	0.747	0.687	1.195	0.537	0.511	1.152	1.349	1.501	
p-value (ANOVA)	p=0.006			p=0.000			p=0.001			p=0.000		
p-value (Tukey)					p=0.000	p=0.000		p=0.004	p=0.993		p=0.000	

Results of the ANOVA Analysis on Sitting Position Parameters

As a result of the comparison between the measurements obtained through the traditional method and the studied technologies, it was observed that only six of the eleven parameters analyzed in the sitting position can be captured with the 3D scanner. The postures required to measure these parameters are more uncomfortable, which makes the scanning process more difficult, and thus, the measurement taking. Table 5 shows the parameters that can be effectively captured with this technology, those whose p-value is greater than 0.05

Table 5: Table of ANOVA results for Sitting Position Parameters

Parameters in seated position												
No	17			18			19			20		
Parameters	Sitting height (erect)			Eye height, sitting			Shoulder height, sitting			Knee height, sitting		
Method	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry
Mean	87.715	88.962	90.15	75.878	75.762	77.667	58.94	58.227	58.15	49.805	51.053	49.8
Std deviation	4.103	3.646	4.428	4.121	3.459	3.956	3.224	2.628	3.843	3.481	3.571	3.533
p-value (ANOVA)	p=0.000			p=0.000			p=0.231			p=0.05		
p-value (Tukey)		p=0.017	p=0.000		p=0.965	p=0.001					p=0.012	p=1.000
No	21			22			23			24		
Parameters	Popliteal height, sitting			Buttock-knee length			Elbow height, sitting			Thigh clearance		
Method	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry
Mean	40.916	39.637	38.895	58.079	58.358	57.579	24.461	23.251	22.944	14.884	15.789	17.1
Std deviation	1.891	2.058	2.826	4.047	3.618	4.221	2.23	1.689	2.182	2.654	2.631	2.918
p-value (ANOVA)	p=0.000			p=0.406			p=0.009			p=0.000		
p-value (Tukey)		p=0.003	p=0.000					p=0.046	p=0.010		p=0.191	p=0.000
No	25			26			27					
Parameters	Elbow-to-elbow breadth			Shoulder (bideltoid) breadth			Hip breadth, sitting					
Method	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry	Traditional	3D scanner	Photogrammetry			
Mean	46.11	47.55	44.25	44.4	46.35	44	39.365	39.497	40.7			
Std deviation	4.55	5.07	5.32	4.34	4.91	4.38	2.994	3.357	3.373			
p-value (ANOVA)	p=0.002			p=0.000			p=0.004					
p-value (Tukey)		p=0.222	p=0.091		p=0.001	p=0.713		p=0.944	p=0.006			

4. Conclusion

Conducting a pilot test before the collection of anthropometric data is crucial to optimizing the process. In this study, the pilot test improved the comfort of the subjects and reduced measurement time by up to 62.5% when measuring 27 parameters with three different methods. This not only facilitates the procedures but also increases data accuracy by refining the collection techniques.

The final data collection resulted in 1,580 measurements from 20 individuals (12 women and 8 men), enabling a thorough comparison of the tools studied. The quantity and quality of the data ensure that the study's conclusions are relevant and well-founded.

The comparative analysis of the measurements obtained through photogrammetry and 3D scanning versus the traditional method, conducted using inferential statistics and ANOVA, demonstrates that both technologies exhibit comparable accuracy in several studied parameters. The results show no significant differences in 63% of the parameters measured with the 3D scanner compared to the traditional method, supporting the validity of these measurements. However, in the parameters where differences were found, 8 of them showed low (differences/SE) values. This indicates that, with improvements in methods, techniques, and calibration, it is feasible to reduce error and achieve measurement consistency similar to that of the traditional method.

The absence of a prior pilot test in anthropometric measurement studies can lead to inefficiency and errors, while its implementation improves measurement accuracy. Furthermore, the validation of the study through expert triangulation increases the credibility of the findings. Continuous supervision by experts in statistics, 3D software, and methods has strengthened the methodology, ensuring more robust and reliable results.

In general, the study revealed that the use of the EinScan H Shining 3D scanner as a methodology for collecting anthropometric measurements is a viable alternative. This scanner demonstrated acceptable accuracy in 17 of the evaluated parameters and offers significant opportunities to improve data collection techniques and methods. The main differences observed are due to controllable factors, such as the subject's clothing, environmental lighting, and experience in using the software. With the standardization of these processes, the scanner could become an even more effective method for capturing measurements, not only because of its potential accuracy but also due to its data recording capabilities and other applications.

Applicability

The project proposes implementing anthropometric measurements in the Industrial Engineering Laboratory of UNITEC Tegucigalpa, using the EinScan H scanner from Shining 3D and the iPhone Measure app, focusing on those measurements that have demonstrated high accuracy compared to traditional methods, according to an ANOVA comparison of methods. The validity of the study was confirmed through repeatability and reproducibility tests, as well as a pilot test with volunteers, following ISO 7250-1:2017 standards. The results, validated by experts, are applicable to other institutions with the appropriate space and ergonomic equipment conditions.

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