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ORIGINAL

Reliability of Hand Anthropometric Measurements in Venezuelan Workers: A Pilot Study

Confiabilidad de mediciones antropométricas de la mano en trabajadores venezolanos: un estudio piloto

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ABSTRACT

Introduction: hand anthropometry is fundamental for ergonomic design and prevention of occupational injuries. In Venezuela, there is a significant gap in specific anthropometric data for the working population, which hinders the adequate design of tools and work equipment.
Method: a quantitative, non-experimental, field pilot study with a descriptive-cross-sectional scope was conducted on 60 workers at a food company in Cagua, Venezuela. Intra- and inter-rater reliability of hand anthropometric measurements (length, width, and circumference) was evaluated using the Intraclass Correlation Coefficient (ICC). The sample size for a larger study was calculated according to the Colombian Technical Standard NTC 5654.
Results: intra-rater reliability showed excellent ICC values for circumference (0,997), width (0,980), and length (0,873). Inter-rater reliability was also excellent: length (0,997), width (0,990), and circumference (0,982). The sample size calculation determined that 184 participants are required for hand length, being the most efficient metric for larger studies.
Conclusions: the measurement methods employed demonstrated high reliability and reproducibility. Hand length emerged as the most suitable variable for anthropometric studies in the Venezuelan working population, requiring a sample of 184 participants stratified by age and gender to ensure population representativeness.

Keywords: Anthropometry; Hand; Pilot Test; Ergonomics; Occupational Health.

RESUMEN

Introducción: la antropometría de la mano es fundamental para el diseño ergonómico y la prevención de lesiones laborales. En Venezuela existe un vacío significativo de datos antropométricos específicos de la población laboral, lo que dificulta el diseño adecuado de herramientas y equipos de trabajo.
Método: se realizó un estudio piloto cuantitativo, no experimental, de campo, con alcance descriptivo-transversal en 60 trabajadores de una empresa de alimentos en Cagua, Venezuela. Se evaluó la confiabilidad intra e inter-evaluador de mediciones antropométricas de la mano (longitud, ancho y circunferencia) mediante el Coeficiente de Correlación Intraclase (ICC). El tamaño muestral para un estudio mayor se calculó según la Norma Técnica Colombiana NTC 5654.
Resultados: la confiabilidad intra-evaluador mostró valores ICC excelentes para circunferencia (0,997), ancho (0,980) y longitud (0,873). La confiabilidad inter-evaluador también fue excelente: longitud (0,997), ancho (0,990) y circunferencia (0,982). El cálculo muestral determinó que se requieren 184 participantes para la longitud de mano, siendo la métrica más eficiente para estudios mayores.

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Conclusiones: los métodos de medición empleados demostraron alta confiabilidad y reproducibilidad. La longitud de la mano emergió como la variable más adecuada para estudios antropométricos en población laboral venezolana, requiriendo una muestra de 184 participantes estratificados por edad y género para garantizar representatividad poblacional.

Palabras clave: Antropometría; Mano; Prueba Piloto; Ergonomía; Salud Ocupacional.

INTRODUCTION

Anthropometry of the hand is fundamental in multiple areas such as ergonomics, product engineering, forensics and biomechanics. This field of study focuses on the measurement of the physical dimensions of the human hand, and the data obtained are essential for the design of tools, equipment and products that are properly adapted to human morphology, improving quality of life and preventing injuries.[1,2]

In the field of ergonomics, having accurate anthropometric data makes it possible to design workstations, tools and equipment to suit the physical characteristics of users.[3] This not only improves efficiency and comfort, but also reduces the risk of accidents and musculoskeletal disorders.[4,5] Product engineering benefits from creating objects that are functional and safe for a wide variety of users.[1]

In Venezuela, the need for anthropometric data specific to the working population is particularly relevant.[5] To date, existing studies in the country have focused on the general population or on specific groups, leaving a significant gap in the information available on workers who use their hands intensively. This lack of data is a considerable obstacle to designing tools and equipment that are safe and effective for this specific population.[1]

The problem is compounded when considering that the Venezuelan working population includes workers in industries such as manufacturing, construction, agriculture and other sectors where intensive use of the hands is common.[5] Without accurate data, the risks of occupational injuries increase, affecting not only the health and well-being of workers, but also productivity and the economy. The absence of specific anthropometric data can lead to inadequate tool and equipment designs, increasing the risk of injury and decreasing work efficiency.[6,7]

The study by Bayraktar and Özşahin[1] highlights the importance of having up-to-date anthropometric data specific to different populations. They emphasize how differences in morphology between different populations can influence product and equipment design. In the absence of local data, there is a risk of using inadequate references that do not reflect the true needs of the Venezuelan population. The systematization of specific anthropometric data is crucial to develop tools and equipment that are adequately adapted to the physical characteristics of workers.[3]

Despite the recognized importance of hand anthropometry in various areas, in Venezuela there have been no comprehensive studies that collect and systematize anthropometric data specific to the working population.[5] In this sense, Hertzog[8] emphasizes the importance of pilot studies in scientific research. These preliminary studies are crucial to identify and correct methodological problems before conducting a large-scale investigation. In the context of hand anthropometry, a pilot study can help ensure that the data collected are of high quality and can be used effectively to design tools and equipment that improve safety and efficiency on the job.

Given the context outlined, it is worth citing various studies related to the subject, where the study by Ron and Escalona,[5] who conducted a systematic review whose objective was to synthesize the evidence available worldwide on studies of anthropometric characterization of the hand in working populations between 2009-2019, prevails. To this end, they explored bibliographic databases such as PubMed, Scielo, Bireme, Lilacs, as well as gray literature sources such as theses and technical reports.

This same review evidenced the scarcity of research in Venezuela, the only local reference being the doctoral thesis of Burgos in 2017[8], whose focus was centered on general anthropometric variables but not specific to the hand, measuring only length and width.

From this premise, anthropometry is defined as the study of the dimensions and proportions of the human body. This field is crucial to several disciplines, including ergonomics, industrial design and medicine, providing essential data that enable the creation of products and environments that are properly adjusted to the physical characteristics of users. In the context of ergonomics, anthropometry enables the design of tools and spaces that maximize user efficiency and comfort, reducing the risk of injury and improving performance.[3]

In this sense, it is important to know some theories that account for the so-called pilot tests, where their design and implementation in anthropometry of the hand are fundamental to evaluate the feasibility and adequacy of the procedures before a large-scale study. The pilot study should be designed as a preliminary trial, generally of a descriptive and cross-sectional nature. This type of study allows the methodology and logistics to be evaluated prior to conducting a large-scale study. Sample selection will be random or by convenience, ensuring representativeness in terms of age, sex and other relevant characteristics. An adequate sample size for a pilot study is usually between 20 and 50 participants, sufficient to identify possible methodological and

logistical problems.[9]

On the other hand, measurement protocols must be standardized to ensure consistency and reliability of the data collected. These procedures include clearly defining how the subject should be positioned during the measurement, whether sitting or standing, with the hand in a relaxed or extended position. In addition, the exact techniques for taking each measurement should be specified, using specific anatomical points as references. For example, hand length is measured from the tip of the middle finger to the proximal wrist crease.[10] It is also essential to ensure that measurements are taken under controlled environmental conditions to minimize variations due to external factors such as temperature and humidity.[3]

The study of hand anthropometry in Venezuelan labor populations allows, in turn, the company studied to adjust from the legal point of view to various national regulations in force, which include: a) The Constitution of the Bolivarian Republic of Venezuela[11] in which Art. 87 establishes the right to work in conditions of safety, hygiene and adequate working environment. b) Organic Law of Prevention, Conditions and Working Environment (LOPCYMAT) Article 59: Obliges that work be carried out in adequate conditions that ensure the highest degree of physical and mental health for workers, adapting the methods and systems used to their characteristics and Art. 60: Specifies that employers must adapt the work methods and tools used to the anthropometric characteristics of workers, indicating that relevant studies must be carried out to introduce changes in existing jobs and when implementing new technologies.[12]

In this order, the nominal (c) of the Technical Standard for the Control of Manual Load Handling, Lifting and Transfer (NT-03) Art 1: Establishes the need to regulate the manual handling, lifting and transfer of loads considering the characteristics of the work process and the environment, in order to prevent musculoskeletal injuries l and Art. 11, which highlights the obligation to adapt machinery, equipment and tools to the anthropometric, physical and psychological conditions of workers, in order to facilitate the handling, lifting and transfer of loads.[13]

Due to the above, the objective of this research was to evaluate the anthropometric measurements of the hand and to establish a methodological process that guarantees the obtaining of reliable and validated data in the Venezuelan working population. To achieve this purpose, it was proposed to determine the reliability of the measurements both intra- and inter-evaluator, to evaluate their reproducibility and to establish the optimal sample size to ensure the representativeness of the anthropometric parameters in this population.

METHOD

This quantitative study followed a non-experimental field design, with a descriptive-cross-sectional scope, focused on the working population of a food company located in Cagua, Aragua state, Venezuela. The sample, calculated according to the criteria of Viechtbauer et al.[14], was established at 60 individuals, with a gender distribution of 67 % men and 33 % women, stratified by age groups: 32,5 % (20-29 years), 35,0 % (30-39 years), 23,1 % (40-49 years) and 9,4 % (50-59 years), following the methodology of Burgos and Escalona [(8)].

The inclusion criteria established were: adult workers aged 20-59 years; men and women; workers with no pre-existing medical conditions significantly affecting hand strength or musculoskeletal function; workers in various occupations requiring regular use of hand strength; minimum of 6 months in current position; voluntary participation with signature of informed consent; and willingness to attend repeated measurement sessions on different days.

Measurements were performed following a standardized protocol.[10] Participants were evaluated in a seated position, with the forearm resting on a flat surface, the elbow flexed at 90 degrees and the hand extended horizontally. For general hand measurements, the fingers were held in adduction (together), while for individual measurements, abduction (separated) was requested.

A digital vernier caliper (accuracy ±0,01 mm) was used for linear measurements and a flexible tape measure for circumferences. The anatomical reference points were previously marked with a demographic pencil to guarantee the consistency of the measurements. Each dimension was measured three times by the same evaluator, with a 2-minute interval between measurements, recording the average value. For the inter-evaluator analysis, a second examiner performed the same procedure independently, without knowing the previous results.

Measurements were performed under controlled environmental conditions. Data were immediately recorded on standardized forms and subsequently transferred to a digital database for analysis.

Evaluators received training in the correct use of measurement instruments, standardized measurement practices, and periodic evaluations to maintain a high level of competence and accuracy in data collection.[15]

Reliability Testing

To evaluate the consistency and reproducibility of anthropometric hand measurements (length, width and circumference), intraclass correlation coefficients (ICC) were calculated under two models: intra-evaluator (ICC (3,1)) and inter-evaluator (ICC (2,1)). The ICC (3,1) was used to determine within-rater reliability across

repeated measurements, while the ICC (2,1) assessed consistency between two independent raters. These metrics are widely accepted in reliability and reproducibility studies, as they allow decomposing the variance attributable to different sources and quantifying overall consistency.[16,17]

To assess intra-rater consistency, three consecutive measurements of each dimension were made by a single rater, using the mixed-effects model (ICC (3,1)). This model considers the individuals as a fixed population and the measurements as assessor-specific, excluding the variance attributed to the interaction between the two.[17] On the other hand, the inter-rater analysis was performed by measuring each dimension in each participant by at least two different raters, applying the random effects model (ICC (2,1)). This model allows the results to be generalized to a larger population of raters and participants, considering the variances between raters and participants as principal components.[16]

In addition, 95 % confidence intervals and F tests were generated to evaluate the statistical significance of the results ($p<0,05$).

The interpretation of the CCI values followed the Landis and Koch scale.[18]

Table 1. Interpretation of ITC values according to the Landis and Koch (1977) scale

ICC value	Level of Agreement
< 0,00	Poor
0,00 - 0,20	Slight
0,21 - 0,40	Acceptable
0,41 - 0,60	Moderate
0,61 - 0,80	Substantial
0,81 - 1,00	Excellent

To estimate the sample size required in a larger investigation, the procedure described in the Colombian Technical Standard NTC 5654[19], recognized for its effectiveness in anthropometric studies, was applied. The method considers the interaction between the coefficient of variation (CV) and the confidence level to ensure statistically representative results. As a reference variable, the initial measurement of right hand strength of evaluator A was used, selected for its ability to characterize the target population and its optimal variability for the application of this methodology, particularly appropriate for anthropometric variables that follow a normal distribution.

The method defines the formula for estimating the sample size (n) as:

$$n = \left(\frac{Z \cdot CV}{a}\right)^2$$

Where:

Z: Critical value associated with the confidence level (e.g., Z=1,96 for a confidence level of 95 %).

CV: Coefficient of variation, calculated as the ratio between the standard deviation (σ) and the mean (μ).

α: Relative precision or admissible error, defined in this case as 5 % (α=0,05).

Statistical analysis was performed using SPSS version 26, including measures of central tendency, dispersion and F tests to assess variability. The study was conducted under the ethical guidelines established in the Fonacit Code of Bioethics,[20] guaranteeing the confidentiality and informed consent of the participants.

RESULTS AND DISCUSSION

Three measurements of hand length, width and circumference were made by two evaluators in 60 healthy subjects, for the right hand as it was the predominant dominant hand in the sample (88,33 %), resulting in 1080 measurements in total. The average age of the study subjects was 34,6 years, with a standard deviation of ±10,8 years. The gender distribution of the subjects was 20 women and 40 men.

Intra-rater reliability

Intra-rater consistency, assessed by the Intraclass Correlation Coefficient (ICC), allows us to determine the degree of stability of repeated measurements made by a single rater. This analysis is part of a pilot test aimed at validating the measurement methods used to assess three key variables of the right hand: length, width and circumference. The results of this validation will be decisive for their implementation in larger studies. The results obtained from the analysis of the repeated measurements are presented in table 2.

Table 2. Intraclass Correlation Coefficients (ICC) for Intra-rater consistency of Anthropometric Hand Measurements

Metrics	ICC (3,1)	ICC (3,k)	Lower Limit 95 % CI	Upper Limit 95 % CI	F-value	p-value
Length	0,873	0,954	0,813	0,917	21,575	<0,001
Width	0,980	0,993	0,969	0,987	146,479	<0,001
Circumference	0,997	0,999	0,995	0,998	864,862	<0,001

Accordingly, circumference stands out as the most reliable metric, with an ICC (3,1) of 0,997 and an ICC (3,k) of 0,999. These values reflect near-perfect reliability for both individual and averaged measurements. The narrow confidence intervals (0,995-0,998) reinforce the stability of the measurements and indicate that the method used to perform the measurements on the three variables is robust and can be used for larger studies.

Width also shows excellent intra-rater consistency, with an ICC (3,1) of 0,980 and an ICC (3,k) of 0,993. Although slightly lower than girth, the values obtained indicate that width measurements are highly reliable. The confidence intervals (0,969-0,987) are narrow, ensuring stability in the individual and average measurements. The high value of the F-statistic (146,479, p<0,001) supports the significance of the observed consistency.

Length, although less consistent than the other metrics, has an ICC (3,1) of 0,873 and an ICC (3,k) of 0,954. These values are indicative of excellent consistency by ICC interpretation standards (ICC>0,90). However, length shows greater variability compared to width and girth, which could be due to anatomical factors. The confidence intervals (0,813-0,9170) are wider than for the other metrics.

For all three measured variables, the ICC (3,k) of averages is consistently higher than the individual ICC, indicating that averaging the measurements reduces random error and improves reliability. This is particularly relevant for length, where the increase in consistency is remarkable.

Inter-rater reliability

In anthropometric studies, assessing the consistency of measurements between different assessors is essential to ensure the reproducibility of the data and the validity of the methods used. The intraclass correlation coefficient (ICC) is a widely accepted indicator to assess inter-rater reliability. This analysis, performed in the context of a pilot test, included three key hand variables: length, width and circumference.

Table 3. Intraclass Correlation Coefficients (ICC) for Inter-rater Reliability of Anthropometric Hand Measurements

Metrics	ICC (2,1)	ICC (2,k)	Lower Limit 95 % CI	Upper Limit 95 % CI	F-value	p-value
Length	0,997	0,999	0,995	0,998	727,475	<0,001
Width	0,99	0,995	0,984	0,994	208,756	<0,001
Circumference	0,982	0,991	0,97	0,989	111,668	<0,001

Table 3 shows the results of the inter-rater analysis for the measurements of length, width and circumference of the right hand and, according to the results, high levels of reliability are evident. The length presented an ICC (2,1) =0,997 and an ICC (2,k)=0,999, indicating almost perfect reliability in both individual and averaged measurements. The fairly narrow confidence intervals (0,995-0,998) reinforce the stability of the data across evaluators. The value of the F-statistic (727,475, p<0,001) supports the observed consistency, thus confirming that inter-rater differences are insignificant. This positions length as a robust and reproducible metric for studies requiring multiple raters.

The width also showed excellent inter-rater reliability, with an ICC (2,1)=0,990 and an ICC (2,k)=0,995. Although slightly lower than the length, the confidence intervals are consistent, which ensures stability in the measurements. The value of the F statistic (208,756 p<0,001) confirms the high statistical significance of the results. This indicates that the method used to measure width is reliable and suitable for implementation in larger studies.

In the same vein, the circumference presented an ICC (2,1)=0,982 and an ICC (2,k)=0,991ICC, which also indicates good reliability for both individual and averaged data. The confidence intervals (0,970-0,989) are somewhat wider, reflecting greater relative inter-rater variability, however, the value of the F statistic supports the robustness of the method, validating the circumference as a reliable metric in an inter-rater context.

In comparison, length shows the highest values of inter-rater reliability, followed by width and, finally, by circumference. These differences could be attributed to the intrinsic characteristics of each metric and the

ease of standardizing the measurement procedure. Although all three metrics are highly reliable, the results indicate that length is the most suitable metric for use in studies requiring high reproducibility.

Sample calculation and stratification

Sample size is a critical element in the design of anthropometric studies, as it directly influences the accuracy and validity of the results. In this investigation we calculated the sample sizes necessary to measure with a 1 % admissible margin of error three key variables of the right hand: length, width and circumference. The results shown in Table 4 reflect the differences in variability inherent in each metric and the implications of this variability on sample requirements.

Table 4. Sample sizes required for anthropometric measurements of the human hand in Venezuelan labor populations

Variable	Average (mm)	Standard Deviation (mm)	Margin of Error (1 %) (mm)	Sample Size
Length	184,38	12,75	1,84	184
Width	81,27	21,22	0,81	2,619
Circumference	207,18	17,12	2,07	262

The results show that length, with a mean of 184,38 mm and a standard deviation of 12,75 mm requires a sample size of 184 participants, standing out as the most efficient and stable metric. On the other hand, width, with a mean of 81,27 mm and a standard deviation of 21,22 mm, requires a sample size of 2,619 participants to achieve the same level of precision, reflecting a high variability that can be attributed to anatomical heterogeneity or the complexity of the measurement method. Finally, circumference, with a mean of 207,18 mm and a standard deviation of 17,12 mm, requires an intermediate sample size of 262 participants.

However, based on the results obtained, length is shown to be the most appropriate metric for anthropometric studies of the human hand in Venezuelan labor populations due to its balance between consistency and efficiency. The analysis of the intraclass correlation coefficient (IC) supports this choice: length showed a high intra-rater reliability (ICC(3,1)=0,873 and an almost perfect inter-rater consistency (ICC(2,1)=0,997). The latter metric is especially relevant in studies involving multiple operators, where inter-rater reproducibility is critical (Shrout & Fleiss, 1979; Koo & Li, 2016). In addition, the smaller sample size required to achieve a 1 % margin of error highlights the efficiency of length versus width and girth, optimizing resources without compromising accuracy.

To ensure that the sample is representative of the population, the size calculated for hand length (n =184) was distributed proportionally according to the age and gender groups recommended by Labrador (2023) [21] for the industrial working population in Venezuela. This method ensures that the composition of the sample adequately reflects the demographic characteristics of the target population, achieving a balanced distribution in terms of gender and age ranges. The final stratification results are presented in Table 5.

Table 5. Distribution of the sample by sex and age

Age (years)	Men	Women	Total
20-29	22	9	31
30-39	36	12	48
40-49	56	11	67
50-59	33	5	38
Totals	147	37	184

CONCLUSIONS

- The results of this pilot test validate the methods used to measure the length, width and circumference of the right hand. The high consistency observed supports its implementation in larger studies where multiple evaluators are involved. In addition, its high accuracy should be considered in critical applications such as ergonomic studies or biomechanical designs.
- Circumference showed the highest intra-rater consistency, with an ICC (3,1)=0,997, which positions it as the most reliable metric within a single rater.
- The length showed the highest inter-rater reliability, with an ICC (2,1)=0,997, being highly reproducible between different raters.
- Length, with a required sample size of n=184 for a 1 % margin of error, is the most suitable variable for larger studies due to its balance between consistency, reproducibility and methodological efficiency.

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- The sample calculated for the length was stratified proportionally by age and gender, ensuring representativeness and external validity for the Venezuelan industrial worker population.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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