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ORIGINAL

Use of predictive models in anthropometric measurements in workers standing upright

Uso de modelos predictivos en las mediciones antropométricas en trabajadores en bipedestación

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ABSTRACT

This study proposes the use of predictive models as an efficient and economical alternative to anthropometric measurements in workers who stand for long periods, especially in contexts with technological and budgetary limitations. The objective of this research is to propose the use of predictive models as a viable alternative to anthropometric measurements. A quantitative, cross-sectional, and descriptive study was conducted between 2021 and 2023, using the state of Aragua and its industrial areas as the population base. Within this survey, 3,125 workers were obtained, with a sample of 185 industrial workers. The sampling for this research is simple random probability sampling stratified by age and sex. The observation technique was used through an estimation scale, anthropometric tables for measurement, and Minitab 17 software to obtain multiple linear regression models, considering variables such as height at the acromion, elbow, and eye, categorized by sex and age group. The results showed high accuracy in the predictions, with coefficients of determination (adjusted R^2) between 75,68 % and 98,73 %, and statistical significance of 95% ($p < 0,05$). The equations generated allow key measurements to be estimated from height, validated by comparison with actual data without significant differences. It is concluded that the use of predictive models is a technically and scientifically viable alternative to traditional anthropometric measurements.

Keywords: Anthropometry; Predictive Models; Prediction; Health; Work; Standing.

RESUMEN

Este estudio propone el uso de modelos predictivos como alternativa eficiente y económica para las mediciones antropométricas en trabajadores en bipedestación, especialmente en contextos con limitaciones tecnológicas y presupuestarias. El objetivo de esta investigación es proponer el uso de modelos predictivos como una alternativa viable en las mediciones antropométricas. Se realizó una investigación cuantitativa, transversal y descriptiva entre 2021 y 2023, Se tomó como base poblacional el estado Aragua y sus zonas industriales. Dentro de este sondeo se obtuvieron 3125 trabajadores, con una muestra de 185 trabajadores industriales. El muestreo de esta investigación es de tipo probabilístico aleatorio simple y estratificado por edad y sexo, Se usó la técnica de la observación a través de escala de estimaciones, el uso de tablas antropométricas para la medición y el software Minitab 17 para la obtención de los modelos de regresión lineal múltiple, considerando variables como altura al acromio, al codo y al ojo, categorizadas por sexo y grupo etario. Los resultados mostraron alta precisión en las predicciones, con coeficientes de determinación (R^2 ajustado) entre 75,68 % y 98,73 %, y significancia estadística del 95 % ($p < 0,05$). Las ecuaciones generadas permiten estimar medidas clave a partir de la altura, validándose mediante comparación con datos reales sin diferencias significativas. Se concluye que el uso de modelos predictivos constituye una alternativa técnica y científicamente viable frente a las mediciones antropométricas tradicionales.

Palabras clave: Antropometría; Modelos Predictivos; Predicción; Salud; Trabajo; Bipedestación.

INTRODUCTION

Anthropometric measurements play a fundamental role in workplace design, as workers seek to adapt their design to their physical characteristics. This process considers various aspects related to physical space, especially the interaction between the operator and their work environment, i.e., the person–machine relationship within a given work environment.[1]

In this sense, anthropometric measurements focus on measuring and applying the statistics necessary to obtain the average values of anthropometric variables. This means that time must be available to take the measurements and that the associated costs of conducting this type of research must be covered. On the other hand, there are now alternatives using technology that allows measurements to be taken digitally or with the use of 3D body scanners, mobile applications, and computers or depth sensors.

However, these digital models are expensive (ranging from $1 000 to $40 000),[2] depending on the type of equipment and technology. This proposal for digital measurement models is costly in most Latin American countries given the lack of technology, budgets, and specialized research programs or institutes in the field of ergonomics.[3]

Taking the above into account, there are alternative predictive models that allow for a reduction in the time and costs associated with anthropometric measurements in studies that require a significant number of anthropometric measurements in large populations, which can be reduced with advances associated with statistical models or artificial intelligence (AI).

In this regard, there are few studies in Latin America related to prediction in occupational anthropometry, of which we can highlight the following: artificial neural networks to predict the anthropometric variables of workers who work in a sedentary position;[4] prediction of anthropometric dimensions and aerobic capacity in Venezuelan industrial manual laborers, applicable to ergonomic design;[5] estimation of anthropometric measurements of the hand for the design of sewn gloves, based on the scale relations method;[6] an anthropometric profile using proportional-scale models; and[7] prediction of anthropometric dimensions in standing position and physical fitness in Venezuelan direct industrial laborers (MODIV).[3]

The objective of this research is to propose the use of predictive models as a viable alternative in anthropometric measurements.

METHOD

A quantitative, predictive, cross-sectional, and descriptive study was conducted on an accessible or sampled population of standing industrial direct labor workers during the period (2021–2023) located in the industrial areas of the state of Aragua, Venezuela. This survey included 3,125 workers, which is the population that meets the homogeneous characteristics in terms of genetics and percentage of mixture that anthropometric measurements must have.[8,9]

To determine sample sizes in anthropometric studies, it is important that the populations be like the population being studied. This involves considering aspects such as sex, age, geographic location, socioeconomic status, and other relevant characteristics.[3] In the case of an industrial workforce, their anthropometric dimensions should be homogeneous in terms of their genetic characteristics, which tend to follow a normal or near-normal distribution, according to the central limit theorem.

On the basis of this assumption, the sample size is calculated following the guidelines of the Colombian technical standard NTC 5654 (2008): general requirements for the establishment of an anthropometric database, [10] which establishes the criteria for creating an anthropometric database. In addition, to statistically analyze the collected data, minimum, maximum, average, median, standard deviation, and 5th, 50th, and 95th percentile values are considered. According to this standard, for a minimum sample that includes the 95th percentile and has a relative accuracy of 1%, taking the above into account, the sample calculation was as follows:

$N= ((1{,}96 * Cv)^2 / \alpha) * 1534^2$

N= 185 trabajadores (H:131; M:54) (1)

The sampling for this research is simple random probability sampling stratified by age and sex. On the other hand, inclusion criteria were considered, covering direct labor workers in the industry, and exclusion criteria included those with physical disabilities or who had difficulties performing anthropometric measurements. In addition, informed consent was obtained from participants or collaborators. The observation technique involved an estimation scale, and anthropometric tables were used for measurement.

Models were developed using predictive techniques that facilitated the calculation and implementation of the variables of interest in the study. To this end, multivariate linear regression models were used, considering this methodology as the main proposal for the analysis. The statistical package used was Minitab 17. In the methodology used to perform the calculations of the multiple regression models, statistical assumptions based on the hypothesis related to the regression coefficients β were considered.

RESULTS

Predictor equations for workers in a standing position

Considering the calculations of the regression models using the Minitab 17 statistical package, the following tables are presented: Tables 1 and 2 show the results of the regression models for both male and female workers by age group.

Table 1 presents the equations developed to predict the anthropometric measurements of Venezuelan workers, which were classified by age group. To determine the quality and scope of each equation, the adjusted R^2 was calculated with Minitab-17 software. The equations that showed the best fit (values closest to 1) for most age groups were selected, which reached values between 75,681 % and 98,73 %. Importantly, to establish the predictive variables of these equations, the Pearson model was first used to analyze the relationship between each anthropometric variable and its regression coefficient.

Table 1. Predictor equations for workers in a standing position

Age group	Dependent Variable	Regression Model	Standard Error (EEE)	Adjusted R2 (%)	p
20–29	Alt	Alt = 8,8 + 0,3263 AO + 0,7780 AA	1,5	93,86	<0,001
20–29	Alt	Alt = 37,5 + 1,244 AC	2,58	81,82	<0,001
20–29	AO	AO = 31,6 + 1,541 Alt − 1,258 AC	3,23	67,1	0,002
20–29	AC	AC = 5,04 + 0,7244 AA	1,1	93,83	<0,001
20–29	AA	AA = −16,6 + 0,9269 Alt	2,08	87,77	<0,001
30–39	Alt	Alt = 14,98 + 0,5977 AO + 0,281 AA + 0,2505 AM	0,87	98,33	<0,001
30–39	Alt	Alt = 32,3 + 1,284 AC	3,33	75,68	<0,001
30–39	AO	AO = −22,61 + 0,9938 Alt + 0,1248 AI	1,13	97,57	<0,001
30–39	AO	AO = −16,57 + 1,2356 AA	1,83	93,67	<0,001
30–39	AA	AA = 2,31 + 0,8198 Alt	1,35	94,33	<0,001
30–39	AC	AC = 3,62 + 0,7338 AA	1,93	82,29	<0,001
40–49	Alt	Alt = 22,31 + 1,1900 AO − 0,291 AA	1,96	93,27	<0,001
40–49	AO	AO = −13,04 + 0,6758 Alt + 0,4004 AA	1,48	96,17	<0,001
40–49	AO	AO = 10,4 + 1,0404 AA	3,3	81	<0,001
40–49	AC	AC = 1,67 + 0,360 AO + 0,347 AA	1,99	86,06	<0,001
40–49	AA	AA = 1,39 + 0,8299 Alt	2,61	85,29	<0,001

Legend: Alt: Height; A.O: Eye Height; A: Acromion Height; AC: Elbow Height; AI: Iliac height; D: Dactylion height; A.M.: Wrist height; L.P.: Forearm length; L.B.: Arm length; L.A.. Minitab-17 p<0.05. EEE: Estimated standard error of regression.
Source: Labrador (2023). Prediction of anthropometric dimensions in standing position and physical fitness of Venezuelan industrial workers.

Predictive equations for workers in a standing position

Table 2 presents regression models for female workers with good goodness-of-fit (98,20 %-82,72 %) and a highly significant model (P value<0,05). Similarly, the EEE (estimated standard error) is very close to that of the model, with little dispersion across the different age groups.

Table 2. Predictive equations for workers in standing positions

Age group	Dependent Variable	Regression Model	Standard Error (EEE)	Adjusted R2 (%)	p
20–29	Alt	Alt = 2,8 + 1,0674 AO	1,51	94,35	<0,001
20–29	AO	AO = −0,78 + 0,373 Alt + 0,668 AA	0,75	98,31	<0,001
20–29	AA	AA = 8,7 + 0,7724 Alt	1,77	88,43	<0,001
20–29	AC	AC = −2,7 + 0,020 Alt + 0,762 AA	1,83	82,72	<0,001
30–39	Alt	Alt = 23,03 + 0,629 AA + 0,516 AC	1,59	94,47	<0,001
30–39	Alt	Alt = 25,72 + 1,3171 AC	2,07	91,98	<0,001
30–39	AO	AO = −15,1 + 0,808 Alt + 0,366 AI	1,46	96	<0,001
30–39	AO	AO = 2,88 + 1,0818 AA	1,4	90,94	<0,001
40–49	Alt	Alt = 17,7 + 0,472 AO + 0,542 AA	1,78	85,39	<0,001
40–49	Alt	Alt = 10,1 + 1,126 AA	1,89	87,29	<0,001
40–49	AO	AO = −22,7 + 1,0689 Alt	0,9	94,42	<0,001
40–49	AA	AA = 2,21 + 0,5168 Alt + 0,4745 AC	1,46	85,39	<0,001
40–49	AA	AA = 9,8 + 0,7662 Alt	1,53	80,06	<0,001
40–49	AC	AC = 2,8 − 0,511 Alt + 1,353 AA	1	96,6	<0,001
50–59	Alt	Alt = 11,66 + 0,9970 AO	1,29	94,4	<0,001
50–59	Alt	Alt = 1,3 + 1,1873 AA	0,84	97,54	<0,001
50–59	AO	AO = −10,04 + 0,525 Alt + 0,559 AA	1,05	96,23	<0,001
50–59	AO	AO = −9,38 + 1,1827 AA	0,72	97,41	<0,001
50–59	AA	AA = 12,50 + 0,6158 AO + 0,287 AC	1,06	94,4	<0,001
50–59	AA	AA = 5,51 + 0,7998 Alt	1,54	86,44	<0,001
50–59	AC	AC = −14,1 + 0,875 AA			<0,001

Legend: Alt: Height; A.O: Eye Height; A: Acromion Height; AC: Elbow Height; AI: Iliac height; D: Dactylion height; A.M.: Wrist height; L.P.: Forearm length; L.B.: Arm length; L.A.. Minitab-17 p<0.05. EEE: Estimated standard error of regression.
Source: Labrador (2023). Prediction of anthropometric dimensions in standing position and physical fitness of Venezuelan industrial workers.

Combination of predictive models

Table 3 below shows the combination of predictive models for both male and female workers, considering the different age groups.

Table 3. Possible combination of prediction equations for standing

Age group	Primary predictor variable	Stimed variables
Workers 20–29	Height (Alt)	AC, AA, AO
Workers 30–39	Acromion Height (AA)	AC, Alt, AO
Workers 40–49	Height (Alt)	AA, AO, AC
Workers 50–59	Height (Alt)	AA, AO, AC
Workers women 20–29	Height (Alt)	AC, AA, AO
Workers women 30–39	Acromion Height / Alt	AC, Alt, AO
Workers women 40–49	Height (Alt)	AA, AO, AC
Workers women 50–59	Height (Alt)	AA, AO, AC

Legend: Alt: Height; A.O: Eye Height; A.A: Acromion Height; AC: Elbow Height; AI: Iliac height; D: Dactylion height; A.M.: Wrist height; L.P.: Forearm length; L.B.: Arm length; L.A.

Source: Labrador (2023). Prediction of anthropometric dimensions in standing position and physical fitness of Venezuelan industrial workers.

DISCUSSION

Among the predictive models obtained for workers, strong correlations were detected between height and the heights of the orbit (eye), acromion (shoulder), and elbow. Of these, height and acromion height (shoulder) proved to be the most effective variables for predicting other dimensions. Similarly, a notable relationship was observed with elbow height in the first three age groups. These results coincide with the findings of Ardila, Castro & Sarmiento,[11] who also reported links between height and elbow height, as well as between orbital height and acromion height, with the latter (shoulder) standing out as a strong predictor variable.

In the case of female workers, the prediction equations use the same predictor variables (specifically height and acromion height) as those observed in male workers do, and the resulting equations are also consistent. From this, it can be inferred that the sample (n=185) used in the study meets the homogeneity requirement. This homogeneity is based on the fact that this group is highly representative of the population of the Central Region of Venezuela.[8]

Taking the above into account, the usefulness of these models is to have few measurements and obtain the rest from predictive models. In this sense, height is taken as an example in the case of workers in the 20–29 age group as a predictor or independent variable, as observed in the following models:

With height (Alt), the acromion height (A.A) can be obtained as follows: A.A = 8,7 + 0,7724 Alt (2)

Given that the acromion height (A.A) is known, the following model can be used to calculate another anthropometric dimension, such as elbow height (A.C): EC = 5,04 + 0,7244 AH. With the height to the elbow (HE) and the height or height (H), the height to the orbital (HO) can be obtained as follows: A.O. = -0,78 + 0,373 Alt. + 0,668 A.A

The usefulness of the models has been demonstrated through their use.

Notably, to validate the equations or predictive models, they were modeled by comparing actual values measured directly on the worker with those obtained through the predictive models. To do this, Student's t test was applied, which revealed that there were no significant differences, making them excellent approximations in terms of predicting anthropometric variables for Venezuelan workers in a standing position.

Finally, given that only height or stature is the easiest measurement to obtain, other variables can be obtained through predictive models that, given their location on the body, may be difficult or time-consuming to measure, such as eye height, acromion or shoulder height, and elbow height, thus reducing measurement time. This strategy is especially valuable in studies with large populations, as it seeks to reduce the total number of measurements. In doing so, the process is optimized, significantly saving time in research and reducing the costs associated with data collection.

CONCLUSIONS

It is concluded that the use of predictive models is a technically and scientifically viable alternative to traditional anthropometric measurements, taking into account that models are proposed by sex and age. The results show that these models allow accurate estimates to be obtained with a minimum margin of error, optimizing data collection times without compromising the reliability of the indicators evaluated.

CONFLICT OF INTEREST

There are no conflicts of interest.

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