



Original

Validation of a new formula for predicting body weight in a Mexican population with overweight and obesity

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Abstract

Introduction: Body weight measurement is of critical importance when evaluating the nutritional status of patients entering a hospital. In some situations, such as the case of patients who are bedridden or in wheelchairs, these measurements cannot be obtained using standardized methods. We have designed and validated a formula for predicting body weight.

Objectives: To design and validate a formula for predicting body weight using circumference-based equations.

Methods: The following anthropometric measurements were taken for a sample of 76 patients: weight (kg), calf circumference, average arm circumference, waist circumference, hip circumference, wrist circumference and demispan. All circumferences were taken in centimeters (cm), and gender and age were taken into account. This equation was validated in 85 individuals from a different population. The correlation with the new equation was analyzed and compared to a previously validated method.

Results: The equation for weight prediction was the following: $\text{Weight} = 0.524 (\text{WC}) - 0.176 (\text{age}) + 0.484 (\text{HC}) + 0.613 (\text{DS}) + 0.704 (\text{CC}) + 2.75 (\text{WrC}) - 3.330$ (if female) - 140.87. The correlation coefficient was 0.96 for the total group of patients, 0.971 for men and 0.961 for women ($p < 0.0001$ for all measurements).

Conclusion: The equation we developed is accurate and can be used to estimate body weight in overweight and/or obese patients with mobility problems, such as bedridden patients or patients in wheelchairs.

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VALIDACION DE UNA NUEVA FÓRMULA DE PREDICCIÓN DE PESO EN POBLACIÓN MEXICANA CON SOBREPESO Y OBESIDAD

Resumen

Introducción: La medición del peso corporal resulta de suma importancia en la evaluación del estado nutricional de los pacientes que ingresan a una institución hospitalaria. En algunas situaciones, estas mediciones no pueden obtenerse por los métodos estandarizados, como es el caso de los pacientes encamados o en silla de ruedas. Nosotros diseñamos y validamos una fórmula de predicción del peso corporal.

Objetivos: Diseñar y validar una fórmula de predicción del peso corporal utilizando circunferencias.

Métodos: Se realizaron las siguientes medidas antropométricas en una muestra de 76 pacientes: peso en kg (P), circunferencia de pantorrilla (CP), circunferencia media de brazo (CMB), cintura (CC), cadera (CCad), circunferencia de muñeca (CM) y media envergadura (ME) todas las circunferencias fueron tomadas en cm y así mismo se tomó en cuenta el género y la edad. De estas mediciones obtuvimos una ecuación de predicción del peso corporal. Esta ecuación se validó en 85 individuos de una población diferente. Se realizó un análisis de la correlación de la nueva ecuación contra un método previamente validado.

Resultados: La ecuación de predicción de peso fue la siguiente: $\text{Peso} = 0,524 (\text{CC}) - 0,176 (\text{edad}) + 0,484 (\text{CCad}) + 0,613 (\text{ME}) + 0,704 (\text{CP}) + 2,75 (\text{CM}) - 3,330$ (si es mujer) - 140,87. El coeficiente de correlación fue de 0,96 para el grupo de pacientes totales y de 0,971 para hombres y 0,961 para mujeres (todos $p < 0,0001$).

Conclusión: La ecuación desarrollada en nuestro trabajo, es precisa, y puede emplearse para estimar el peso corporal en pacientes con sobrepeso y/o obesidad que tengan problemas de movilidad como pacientes encamados, o en sillas de ruedas.

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Palabras clave: *Peso corporal. Obesidad. Sobrepeso. Validación. Predicción.*

Introduction

Body weight and height are the most frequently used anthropometric measurements. These measurements are used to calculate the body mass index, which is a widely used indicator of nutritional status because of its accessibility. Weight loss greater than 5% of the habitual weight constitutes a risk factor for moderate malnutrition, and a loss of 10% represents a high risk of malnutrition. For this reason, the use of body weight as an indicator is of highest importance.^{1,2}

Body weight is also the basis for planning and implementing diagnostic and therapeutic interventions, such as estimating nutritional requirements and calculating pharmacological doses or volume for resuscitation and pulmonary capacities in ventilated patients. However, in many health institutions, proper instruments are not available, or the scales in hospitals are not calibrated. Furthermore, the measurement of body weight is difficult under certain conditions, such as when patients are prostrated or in wheelchairs.

Consequently, various authors have suggested obtaining these parameters through prediction formulas based on various anthropometric variables.³⁻¹⁰ It is important that predictive formulas are valid for the population in which they will be used and that the equations cover the characteristics of that population.

The goal of this study was to generate a formula for predicting body weight in the overweight and obese adult Mexican population.

Methods

The study was conducted at the National Institute for Medical Sciences and Nutrition "Salvador Zubirán" (Mexico, D.F.). Outpatients were evaluated between March 2009 and August 2011 upon consultation at the Nutrition Clinic and after being diagnosed with overweight or obesity. This study was approved by the hospital's ethics committee, and all of the participants signed a letter of informed consent.

Variables analyzed

The analyzed variables included weight; height; waist, hip, wrist and calf circumference; average arm circumference; demispan; arm length; and knee height. Measurements were conducted under fasting conditions.

Anthropometry

The anthropometric measurements were conducted by a trained and certified nutritionist. Stature was measured while the subject stood with feet together, arms at sides, legs straight, shoulders relaxed and head in the Frankfort horizontal plane, with the heels, buttocks,

shoulder blades and back of the head resting against a vertical wall. These measurements were taken in centimeters using a Seca Model 206 wall stadiometer.

Weight was evaluated using a Gambio scale with gradations of 0.1 kg. The subject was weighed while seated without shoes and with his or her back reclining on the chair and feet elevated.

All circumferences were taken with a Seca measuring tape, Model 201.

Knee height: This value was measured using a measuring tape while the subject was seated in a chair. The right leg was measured with the knee positioned at a 90-degree angle. The measurement was taken from the lateral epicondyle of the femur to the lower outer edge of the foot.¹¹

Calf circumference: The maximum perimeter of the calf was located on the internal leg above the gastrocnemius muscles on a plane perpendicular to the longitudinal axis of the leg.

Wrist circumference: With the patient's arm extended at an angle of approximately 45° relative to the body axis and the hand in an anthropometric position, we measured the perimeter of the area between the distal end of the forearm (immediately below the ulnar styloid process and the radius) and the proximal end of the carpus.

Waist circumference: Because all of the subjects were overweight and obese, and given the probable variability of points of measurement, we decided to measure waist circumference at the level of the umbilical scar for all patients.

Hip circumference: With the subject standing and facing the right side, the measurement was taken at the level of the greatest posterior protuberance of the buttocks, a position that in most cases coincides with the pubic symphysis.

Arm average circumference: The circumference was taken at the middle point between the acromion and olecranon with the subject standing and relaxed with his/her arms at the sides.

Demispan: This value is half the distance between the ends of the middle finger of the right hand and the left hand, expressed in centimeters.

Statistical analysis

The continuous variables are expressed as numbers representing the means and standard deviations, and the dichotomous variables are expressed as frequencies and percentages. The continuous variables were evaluated using the Kolmogorov-Smirnov Z test to analyze their statistical distribution. When the data did not have a normal distribution, a logarithmic transformation was performed prior to the analysis. The numerical variables for the design group and the validation group of the model formulae were compared using Student's t-test for independent samples, while the qualitative variables were compared with the chi-squared test.

Table I
Clinical and demographic characteristics
of study participants

Variable	Design	Validation
N	76	85
Female	51.3% (39)	55.3% (47)
Age, years	48.6 ± 13.9	50.7 ± 14.3
Body weight, kg	90.3 ± 19.2	85.2 ± 14.8
Height, cm	161 ± 8.72	159 ± 10.4
Waist circumference, cm	110 ± 13.5	108 ± 12.0
Hip circumference, cm	114 ± 12.0	111 ± 10.9
Arm span, cm	38.4 ± 3.66	36.2 ± 2.64*
Mid arm, cm	36.6 ± 4.47	35.7 ± 3.90
Demispan, cm	84.0 ± 5.08	82.8 ± 5.65
Calf circumference, cm	40.7 ± 4.43	39.3 ± 3.94
Leg length, cm	53.1 ± 3.48	51.4 ± 3.98*
Wrist circumference, cm	17.4 ± 1.46	16.8 ± 1.11
Body mass index, kg/m ²	34.5 ± 5.62	33.3 ± 4.82

The values show the means ± DE. The data were analyzed using Student's t-test.
*p < 0.05

Weight was considered a dependent variable. An equation for weight was obtained using multiple linear regression based on the remaining anthropometric measurements that were evaluated, and those measurements that gave the best precision to the model were selected. The Pearson correlation was applied to calculate the correlation between the weight estimate and the actual weight. Then, the real and the estimated weight were compared using Student's t-test for paired data. The one-tailed *p*-value of significance was determined as *p* < 0.05. The data were analyzed using SPSS (Version 15.00; SPSS, Inc., Chicago, IL).

Results

The study was conducted with 76 patients, 48.6 ± 13.9 years of age, who formed the design group of the model formulae. Subsequently, a second group of 85 patients who were subjected to measurements under the same conditions was formed to validate the formulae. Table I shows the general and anthropometric characteristics of the groups. The measurements of both groups were homogeneous, with the exception of arm length and leg length, which were significantly different.

Table II shows the equation of the resulting statistical model, which obtained an R² equal to 0.937 for all the participants. When the patients were separated according to sex, R² was equal to 0.94 and 0.92 for men and women, respectively. This formula has an estimated error of ± 4.32 kg. When real and estimated weight were compared, no statistically significant difference was observed; in this case, the coefficient of correlation was 0.96 (*p* < 0.0001) for all participants

Table II
Equation for estimating the weight of obese Mexicans

	Equation	R ²	SEE
All participants	W = 0.524 (WC) - 0.176 (Age) + 0.484 (HC) + 0.613 (DS) + 0.704 (CC) + 2.75 (WrC) - 3.330 (if female) - 140.87	0.937	4.32
Men		0.943	4.36
Women		0.924	4.07

WC: Waist circumference, cm; A: Age, years; HC: Hip circumference, cm; DS: Demispan, cm; CC: Calf circumference, cm; WrC: Wrist circumference, cm; SEE: Standard error of the estimate.

Table III
Comparison and correlation of patients' actual
and estimated weights

	Actual	Estimated	R*	p**
All participants	87.6 ± 17.2	86.9 ± 18.2	0.968	0.0001
Men	93.5 ± 18.1	93.1 ± 18.2	0.971	0.0001
Women	82.5 ± 14.6	81.6 ± 16.7	0.961	0.0001

Mean ± SD.

The patients' actual and estimated weights were compared using a t-test.

*The correlation coefficients were determined using Pearson's correlation.

**p significant (correlation).

(0.97 for men and 0.96 for women, both of which were significant; table III).

Discussion

Visual estimation is commonly used to predict body weight; however, the accuracy of this method is rather poor (approximately 50%) and dependent on the observer, and visual estimation is particularly complex in the case of obese patients.¹¹⁻¹⁴

At hospitals, patients are weighed and measured upon admission as part of their clinical history. These measurements are fundamental data that support a complete nutritional evaluation and the design and implementation of a nutritional care plan for the hospitalized patient, including the estimation of energy and protein requirements.¹

Furthermore, body weight is needed to calculate the doses of various drugs, intravenous liquids and other substances. Knowledge of the body weight increases the safety and effectiveness of medical and/or pharmacological interventions. However, various situations make it difficult or even impossible to obtain a patient's body weight, particularly among patients who are prostrated or in wheelchairs. In those cases, it is necessary to use predictive formulas based on other anthropometric measurements.

The formula obtained in this study involves variables for age, sex, average calf circumference, wrist circumference, hip circumference, waist circumference,

and demispan. All of these variables are easily measured with a measuring tape, which is an accessible and economical method that can be applied at any level of care. The equation obtained has a high index of regression, indicating its reliability for predicting body weight.

Anthropometric characteristics can be affected by various factors, such as age, sex, nutritional status and race. These effects may explain the variability in estimating these values in various studies.¹⁵⁻¹⁷ Moreover, this article describes the first study to develop a formula for predicting weight via anthropometric variables in an overweight/obese adult Mexican sample population.

The study has limitations. First, it was designed and validated with ambulatory patients. Although its results may be applicable to prostrate patients, they should be validated in this population. Nonetheless, the predictive equation is a proposal for resolving the problems that arise when health personnel need to estimate weight in the absence of proper tools, especially in Mexico, where there is a high prevalence of overweight and obesity.¹⁸

Conclusions

The equation validated in this study showed an excellent correlation between estimated and real weight in ambulatory patients with overweight and obesity. It could be highly useful in clinical practice when necessary instruments are not available to measure real weight. It could also be crucial for the medical management of patients whose exact weight cannot be determined, such as those who are prostrate or in wheelchairs, although the equation should be validated with this group of patients in future studies.

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