Weight and height prediction of immobilized patients

Estimativa de peso e altura de pacientes hospitalizados e imobilizados

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A B S T R A C T

Objective

To confirm the adequacy of the formula suggested in the literature and/or to develop appropriate equations for the Brazilian population of immobilized patients based on simple anthropometric measurements.

Methods

Hospitalized patients were submitted to anthropometry and methods to estimate weight and height of bedridden patients were developed by multiple linear regression.

Results

Three hundred sixty eight persons were evaluated at two hospital centers and five weight-pre-dicting and two height-predicting equations were developed from the measurements ob-tained. Among the new equations developed, the simplest one for weight estimate was: Weight (kg) = 0.5759 x (arm circumference, cm) + 0.5263 x (abdominal circumference, cm) + 1.2452 x (calf circumference, cm) -4.8689 x (Sex, male = 1 and female = 2) -32.9241 (r = 0.94); and the one for height estimate was: Height (cm) = 58.6940 - 2.9740 x (Sex) -0.0736 x (age, years) + 0.4958 x (arm length, cm) + 1.1320 x (half- span, cm) (r = 0.88). The estimates thus calculated did not differ significantly from actual measurements, with p = 0.94 and 0.89 and a mean error of 6.0 and 2.1% for weight and height, respectively.

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Conclusion

We suggest that these equations can be used to estimate the weight and height of bedridden patients when necessary or when these parameters cannot be measured with a scale and a stadiometer.

Indexing terms: body weight; body height; anthropometry; linear models.

RESUMO

Objetivo

Verificar a adequação das fórmulas sugeridas na literatura, e desenvolver equações preditivas de peso e altura para a população hospitalizada brasileira, a partir de medidas antropométricas usuais.

Métodos

Realizou-se antropometria e bioimpedância de pacientes hospitalizados. Por meio de regressão linear múltipla, desenvolveram-se fórmulas com o objetivo de prever o peso e a altura. Os resultados foram comparados com os obtidos de fórmulas da literatura e com as medidas reais.

Resultados

Foram avaliadas 368 pacientes e desenvolvidas equações preditivas do peso e da altura, ou seja: para estimativa de peso, peso (kg)= 0,5759 x (circunferência do braço, cm) + 0,5263 x (circunferência abdominal, cm) + 1,2452 x (circunferência da panturrilha, cm) -4,8689 x (Sexo, masculino= 1 feminino= 2) -32,9241 (r= 0,94, p<0.001); e altura (cm)= 58,6940 -2,9740 x (Sexo) -0,0736 x (idade, anos) + 0,4958 x (comprimento do braço, cm) + 1,1320 x (meia envergadura, cm) (r= 0,88, p<0.001). As estimativas realizadas foram estatisticamente semelhantes às medidas reais, p= 0,94 e 0,89 e erro médio de 6,0% e 2,1%, respectivamente para o peso e altura. Quando aplicadas as formulas preconizadas pela literatura, os resultados encontrados foram estatisticamente diferentes do real (p<0,001).

Conclusão

Sugere-se que estas equações sejam utilizadas para prever peso e altura de pacientes acamados.

Termos de indexação*: peso corporal; estatura; modelos lineares.*

INTRODUCTION

Body weight, in addition to being an indicator of nutritional status, is necessary for drug and nutrient therapy prescription. Regarding weight, for example, it is not only possible to estimate energy expenditure, but also to plan the amount of nutrients, such as protein and lipids, for enteral/parenteral nutritional therapy. Weight is also fundamental for the pharmacological prescription of drugs[1] for both clinically stable and intensive care patients. Literature data[2] indicate that errors of calculation occur when weight and height are estimated only by visual observation.

Anthropometry, which is a simple, noninvasive and objective method for the nutritional evaluation of patients, can be used to determine the adequacy of the main body components[3]. The use of anthropometric measurements to predict body weight of bedridden immovable patients has been reported[4], but the equation proposed was created by measuring elderly American individuals, and cannot be generalized to other groups of patients.

Thus, the objective of the present study was to propose equations based on the anthropometric data of hospitalized immovable Brazilian patients that would be most appropriate to predict body weight and height. In addition, we intend to examine and compare the adequacy of the formulas already proposed in the literature against the current values.

METHODS

The patients were submitted to anthropometry and bioimpedance and the results were analyzed statistically in order to obtain predictive formulas for weight and height. The measurements were made on the wards of the *Hospital das Clínicas, Faculdade de Medicina de Ribeirão Preto, Universidade de São Paulo*, and at the *Hospital Universitário Evangélico de Curitiba*, Brazil, over a period of 4 months. The study was approved by the Ethics Committee of both institutions and all patients gave written informed consent to participate. All measurements were made only once by two duly trained professionals.

All patients, of both sexes, older than 18 years and able to walk were selected at random. Those with amputated or immobilized limbs, pregnant women, puerperae, patients with edema and/or ascites were excluded.

The patients were evaluated under fasting conditions. The measurements were made on the left side of the body in triplicate and the mean value was calculated. The parameters measured were:

a) height (H, cm) and weight (W, kg)[5] using a stadiometer and a platform scale with 0.1cm and 100g divisions, respectively;

b) knee height (KH, cm)[6] using a children's stadiometer;

c) arm length (AL, cm)[7], calf circumference (CC, cm)[4], arm circumference (AC, cm)[7], abdominal circumference (AbC, cm)[5], and half-span (HS, cm)[8], using a rigid tape with 0.1cm graduation;

d) bicipital (BST), tricipital (TSF), suprailiac (IST), subscapular (SST) skinfold thickness[9] (mm) and thickness of the adductor muscle of the thumb (AMT) (mm)[10] were measured with a calibrated caliper with a constant pressure of 10g/mm^2;

e) electrical bioimpedance was measured with a Quantum BIA 101 Q instrument, RJL Systems, Michigan, USA, which uses a current of 800 micro-amperes and 50kHz, to obtain resistance (Re, Ω) and reactance (Rc, Ω)[11]. Patients receiving intravenous hydration were excluded

The equations for height and weight prediction were obtained by multiple linear regression. The first step was to determine which of the above variables were correlated with weight or height. After the equations were established, the residues (errors) between the actual measurements and the estimated ones were calculated and were compared by the paired "t" test against the actual value[12].

The results obtained with these equations were compared to those obtained with the formulas suggested in the literature[4,6] as follows:

H (cm) = 64.19 - (0.04 x Age) + (2.02 x KH);

H (cm) = 84.88 - (0.24 x Age) + (1.83 x KH);

H (cm) = 2 x half-span[8].

W (kg) = (1.73 x AC) + (0.98 x CC) + (0.37 x SST) + (1.16 x KH) - 81.69;

W (kg) = (0.98 x AC) + (1.27 x CC) + (0.40 x SST) + (0.87 x KH) - 62.35, for men and women, respectively.

RESULTS

The study was conducted on 368 patients (47% females) proportionally divided among the study sites. The mean age of the sample (standard deviation SD) was 49, SD=17 years (Table 1). Among the anthropometric and bioimpedance measurements, the variables showing a significant positive correlation (p<0,05) with weight were height, resistance, abdominal circumference, arm circumference, calf circumference, and subscapular skinfold thickness. The variables that significantly correlated (p< 0,05) with height were sex (S: 1= male, and 2= female), age (A, years), arm length, and half-span. On the basis of these measurements, five equations were developed to predict weight and two equations were developed to predict height, being simplified on the basis of the larger number of variables and the need for equipment (Table 2). Table 2 shows the average % error, its standard deviation and 10th, 25th, 50th and 75th percentiles. As an example for clarification, the prediction obtained with equation I gave a mean error of ±5.1% with a standard deviation of 6.6%. In addition, 10% of the individual value had an estimated error of less than 0.6% (P_{10}) and 75% of all estimates calculated with formula I had an error of 6.3% or less (P_{75}), and so on.

Table 1. Anthropometric characteristics and bioimpedance measurements (mean and standard deviation) HCFMRP and HUEC, 2004.

Sample size (n)	368		173 (47%)*		195 (53%)**	
	mean***	SD*	mean	SD	mean	SD
Abdominal circumference (AbC - cm)****	89.1	13	87.7	16	90.3	13
Age (years)§	49.0	16	46.6	17	51.0	16
Arm circumference (AC - cm)****	28.0	5	28.6	5	28.8	4
Arm length (AL - cm)§	36.4	2	35.0	2	37.7	2
Bicipital skin fold (BST - mm)	9.5	6	12.7	7	6.7	4
Body mass index (BMI - kg/m^2)	24.6	5	25.1	6	24.0	4
Calf circumference (CC - cm)***	33.9	4	33.5	5	34.2	4
Half span (HS - cm)****	83.4	5	79.6	5	87.0	4
Height(H - cm)	163.1	9	156.8	7	168.9	7
Knee height (KH cm)	50.4	4	48.1	3	52.4	3
Reactance (Rc - Ω)	62.0[a]	16	64.0	14	59	17
Resistance(Re - Ω)****	614.0[a]	125	666.0	123	566.0	106
Subscapular skinfold (SST - mm)****	17.4	9	19.2	10	15.7	8
Suprailiac skinfold (IST - mm)	17.3	10	19.6	11	15.7	7
Thumb adductor muscle (AMT mm)	10.5	4	9.5	3	11.5	4
Tricipital Skin fold (TSF - mm)	16.5	9	21.3	9	12.2	6
Weight (W- kg)	65.5	15	61.6	14	68.9	14

* From HCFMRP (Ribeirão Preto University Hospital); ** From HUEC (Curitiba Universtiy Hospital); *** Mean and standard deviation; **** Significant variable for weight and height prediction (p<0.001, see Table 2); [a]the patients receiving intravenous hydration were excluded (n= 222).

Table 2. Equations proposed to predict height and weight based on the anthropometric measurements and bioimpedance.

Equations for weight prediction (kg)	
I	0.5149 (H) + 0.7416 (AC) + 0.308 (AbC) + 0.5317 (CC) + 0.364 (SST) -0.0137 (Re) -82.723
II	0.4550 (AC) + 0.3867 (AbC) + 0.7826 (CC) + 0.2654 (SST) -0.0238 (Re) +1.6760
III	0.5030 (AC) + 0.5634 (AbC) + 1.3180 (CC) + 0.0339 (SST) -43.1560
IV	0.4808 (AC) + 0.5646 (AbC) + 1.3160 (CC) -42.2450
V	0.5759 (AC) + 0.5263 (AbC) + 1.2452 (CC) -4.8689 (S) ± 32.9241
Equations for height (cm)	
VI	58.6940 -2.9740 (S) -0.0736 (A) + 0.4958 (AL) + 1.1320 (HS)
VII	63.525 -3.237 (S) -0.06904 (A) + 1.293 (HS).

Statistical data - actual x predict

Equations	$R_{multiple}$	Average % error*	Standard deviation	P_{10}**	P_{25}	P_{50}	P_{75}
I	0.9457	5.1	6.6	0.6	1.4	3.3	6.3
II	0.9005	8.0	7.2	1.6	3.2	6.5	10.7
III	0.9272	7.0	5.9	1.0	2.5	5.4	10.2
IV	0.9271	6.7	5.6	1.1	2.4	5.4	9.6
V	0.9414	6.0	5.0	1.0	2.1	4.7	8.0
VI	0.8809	2.1	1.7	0.3	0.8	1.8	3.1
VII	0.8765	2.2	1.7	0.4	0.8	1.7	3.2

A= age (years); AbC= abdominal circumference (cm); AC= arm circumference (cm); AL= arm length (cm); CC= calf circumference; H= height (m); HS= half span (cm); Re= resistance (Ω); S= sex (1= male and 2= female); SST= subscapular skinfold (mm); * The mean percent error from the actual value. This table shows the average % error, its standard deviation and 10th, 25th, 50th and 75th percentiles; ** Percentile.

Table 3. Statistical evaluation of weight and height obtained from the literature prediction equations and compared to the paired actual value.

Equations	Weight (kg)		*p* value
	mean	SD	actual x predicted value
Actual sample weight	65.53	14.7	
Chumlea et al.[8]	59.71	15.4	<0.001
Proposal I*	63.44	13.9	Ns**
Proposal II*	63.47	13.3	Ns
Proposal III*	65.68	13.1	Ns
Proposal IV*	65.46	13.1	Ns
Proposal V*	65.47	13.8	Ns
	Height (cm)		
Actual sample height	163.1	9.3	
Chumlea et al.[6]	165.0	7.4	<0.001
Mitchell & Lipschitz[8]	166.0	11.0	<0.001
Proposal VI*	163.2	8.2	Ns
Proposal VII*	162.7	8.2	0.033

* Equations described in Table 2; ** ns = no significant difference between the estimated against the paired actual value ($p > 0.05$); SD: standard deviation.

The equations for weight and height estimates proposed in the present study were tested against those described in the literature in terms of their adequacy for the prediction of weight and height (Table 3).

DISCUSSION

The difficulties in constructing equations from anthropometric data for the prediction of weight and height are important because they may compromise the estimate of weight and height of bedridden immobilized patients. In addition, another possible limitation of the use of these equations is the availability of the necessary equipment. Scales for weighing a patient in bed, electrical bioimpedance and adipometers are not part of the reality of most health institutions[13]. For the purpose of this prediction, the equation described by Chumlea et al.[4] was developed based on a sample of white American elderly subjects and its application to persons of other ages and races may be compromised. Sampaio et al.[13] obtained concordant results for weight estimate by the equation of Chumlea et al.[4] and actual weight for patients from Fortaleza, Brazil. However, the characteristics of the Fortaleza sample were different from those of the present patients even though the mean age of the patients in the two studies was similar. The Fortaleza patients were shorter and thinner, with a mean BMI of 22kg/m^2, compared to the present patients, whose mean BMI was 24kg/m^2. As confirmed in the present study, when this equation[4] was applied to this sample, the mean was statistically different from the actual one.

In view of these limitations, new equations were developed for weight prediction. The first equation takes into consideration anthropometry and bioimpedance, and three instruments are needed to collect the data: an adipometer, a measuring tape and an electrical bioimpedance analyzer. In addition, this equation requires knowing the height of the patient. Although it showed the best general correlation with actual weight, it was not appropriate for patients with a BMI of more than 30kg/m^2. In view of the complexity involved in making the measurements and the number of instruments necessary, the equations were simplified starting from equation I to V, with a gradual removal of measurements according to the complexity of their execution.

On this basis, equation 2 does not require previous knowledge of an individual's height and does not present limitations of its use according to BMI. Equation 3 does not require the use of bioimpedance. Equations 4 and 5 only require a flexible measuring tape and the sex of the patient to estimate weight and height, and also do not show a significant difference according to BMI.

Methods for the estimate of body composition such as bioimpedance have limitations when they are applied to patients with excess body fat since obese individuals present a significantly increased proportion of fluid compared to non-obese individuals[14]. This factor may explain why equation I was not appropriate for obese patients.

Regarding skinfold, there are technical difficulties for the measurements because of the morphological changes caused by the excess of adipose tissue in obese individuals. In addition, an excessive opening of the caliper may change the pressure of the compressible spring, with a consequent significant underestimate of the results. Another difficulty regarding the application of this technique is to find the bone protuberances that direct the identification of the standard site for skin fold measurement[14]. These technical difficulties may compromise the variable measurement to be applied in three of the equations suggested in the present study and in the equation described by Chumlea et al.[4].

Circumference measurements used in equations 4 and 5, obtained with a measuring tape, were found to provide a practical method for weight estimate with an error of less than 10% for 75% of the individuals evaluated (Table 2). Height estimate based on knee height is a technique with limitations when the lower limbs are immobilized, especially for trauma patients. In addition, there are differences between actual height and height estimated by these equations[6,8] which may be explained by the fact that both equations were developed for, and evaluated in, elderly people. Height loss is detected over the years and the application of these formulas to individuals in other age ranges is not recommended[15]. Thus, age becomes a fundamental factor for the estimate of height.

Information about patient height is important for the evaluation of nutritional status and for the prediction of energy expenditure. On this basis, two equations were developed for height estimate of patients of both sexes, older than 18 years. Both equations consider age and sex as variables. Equation 6 also used two measurements, i.e., arm length and half-span, which can be obtained simply by using a measuring tape. Equation 7 uses the measurement of the half-span to estimate the height of an individual, as is also the case for the method suggested by Mitchell & Lipschitz[8]. The method suggested by these authors, however, yields measurements that differ significantly from actual height, a fact that makes their use unviable.

Both the equations for the estimate of weight and height can be used according to the needs of the patient, with equation 6 being suggested for patients whose lower limbs are immobilized. They can be options for institutions that are not equipped with bed scales and stadiometers.

CONCLUSION

The application of weight and height predicting equations that use a measuring tape as the only tool is a viable, simple and safe alternative for the estimation of weight and height of bedridden individuals temporarily or definitively unable to walk. Complementary studies are needed to evaluate the applicability of these equations to the estimate of weight and height in other samples from the same region and from other regions of Brazil.

ACKNOWLEDGMENTS

The authors wish to thank the head of the Service of Nutrition and Diet of *Hospital Universitário Evangélico de Curitiba*, Karina K. Paciornick, and the other nutritionists of this service for receptivity and collaboration, and *Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)* and *Fundação de Amparo à Pesquisa do Estado de São Paulo* (FAPESP) for partial financial support of this study.

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Received on: 1/7/2005
Final version resubmitted on: 1/9/2006
Approved on: 3/10/2006