# Different equations for determining height among the elderly: the Bambuí Cohort Study of Aging

## Diferentes equações para determinação da estatura em idosos: Estudo de Coorte de Idosos de Bambuí

*Vanessa de Oliveira Siqueira* [1]
*Bruna Vieira de Lima Costa* [1]
*Aline Cristine Souza Lopes* [1,2]
*Luana Caroline dos Santos* [1]
*Maria Fernanda Lima-Costa* [3]
*Waleska Teixeira Caiaffa* [2]

[1] *Escola de Enfermagem, Universidade Federal de Minas Gerais, Belo Horizonte, Brasil.*
[2] *Faculdade de Medicina, Universidade Federal de Minas Gerais, Belo Horizonte, Brasil.*
[3] *Núcleo de Estudos em Sáude Pública e Envelhecimento, Fundação Oswaldo Cruz/Universidade Federal de Minas Gerais, Belo Horizonte, Brasil.*

**Correspondence**
*A. C. S. Lopes*
*Departamento de Enfermagem Materno-Infantil e Saúde Pública, Escola de Enfermagem, Universidade Federal de Minas Gerais.*
*Av. Alfredo Balena 190, 4º andar, sala 420, Belo Horizonte, MG 30130-100, Brazil.*
*aline@enf.ufmg.br*

## Abstract

*The aim of this study was to compare measured height with estimates of height derived from equations using half arm-span measurements and assess how this affects the calculation of the body mass index (BMI) among elderly individuals. Direct height measurements of a subsample of elderly individuals from the baseline sample of the Bambuí Project were compared with estimates of height derived from equations proposed by Bassey and the WHO. The data was analyzed using the McNemar test, Lin concordance correlation coefficient (CCC) and Bland-Altman method (p < 0.05). Estimates of height using the WHO method showed a low CCC in relation to measured height. For BMI, the concordance was greater. However, with this method height was found to be underestimated so leading to the overestimation of BMI. The Bassey equation showed high concordance with measured height in elderly people over 80 years of age. With respect to BMI, the WHO method resulted in a much greater prevalence of overweight, whereas the estimates derived from the Bassey method did not differ from the results obtained from direct height measurement. Height estimates using the Bassey equation were similar to the results obtained from direct measurements, suggesting that this method is applicable.*

*Anthropometry; Aged; Nutrition Assessement*

## Introduction

One of the most prominent physiological changes of the aging process is found in body composition, such as diminution in height [1]. The process, which is different in men and women, begins around the age of 40, with a height reduction of 2 to 3cm per decade increasing progressively with age [2,3].

Physiological changes and illness characteristics associated with aging are important factors among the possible causes of height reduction, including: flattening of the vertebrae, reduction in intervertebral disc thickness, dorsal kyphosis, scoliosis, bowing of the legs, and flattening of the plantar arch [3].

Height reduction has an important impact on the calculation of the body mass index (BMI), which describes body weight relative to height. BMI is a widely used measure of nutritional status because it is easy to use inexpensive and yields small intra or inter-rater variation [1,4].

However, when *used alone*, this index is deemed to have limited effectiveness as a good indicator of nutritional status in the elderly because it does not reflect body fat redistribution and excludes height reduction [1,4]. Reductions in height may lead to an overestimation of BMI, with consequent overestimation of overweight and underestimation of underweight.

The possible impact of height on BMI indicates that there is a need to develop alternative ways of estimating height among elderly who are bedridden, confined to wheelchairs, and unable to stand for benchmarking. Improving estimations of height allows for a more accurate definition of BMI. Several alternative methods for estimating height are mentioned in the literature, such as measurements of arm-span [5,6,7], half arm-span [8,9] and knee height [10,11].

Hickson & Frost [12] found moderate correlation between direct height measurements and other methods for estimating height: half arm-span ($r = 0.86$; $p < 0.01$), arm-span ($r = 0.87$; $p < 0.01$) and knee height ($r = 0.89$; $p < 0.01$). In a study of adults and children with cancer, Dock-Nascimento et al. [13] also found a moderate correlation between direct measured height and knee height ($r = 0.76$; $p < 0.01$) and arm span ($r = 0.74$; $p < 0.01$).

However, these alternative methods for estimating height also have limitations. Their accuracy may be affected by diseases such as chronic obstructive pulmonary disease, that affects the shape and geometry of the chest wall, and bone abnormalities caused by arthritis and other bone diseases. Furthermore, differences in body proportions and methodological issues intrinsic to the equations used affect accuracy [5,14,15].

Different equations for estimating height based on half arm-span now exist. Two of the most prominent alternatives are those proposed by the World Health Organization (WHO) [9] and Bassey [8]. However, these equations also have limitations. The equation proposed by WHO [9] was developed for bedridden patients, while the Bassey equation [8] was developed to estimate maximum height (obtained at around 30 years of age) and involved a study sample of only 125 individuals.

It is difficult to measure changes in body composition associated with aging and disability in bedridden or wheelchair bound elderly since they are unable to stand to calibrate measurements, thus leading to erroneous measurements of height. Given the impact of physiological changes over time as indicators of nutritional status, this study used the baseline sample of a prospective study to compare heights derived from direct measurement (traditional method) with estimates of height derived from the measurement of half arm-span using two different equations [8,9] and how this influences the calculation of BMI of elderly people.

## Methods

The present study formed part of the Bambuí Cohort Longitudinal Study of Aging carried out among the elderly population (≥ 60 years) living in Bambuí, State of Minas Gerais, Brazil. The baseline population data analyzed here was from 1996 and 1997.

At the time of data collection, the municipality of Bambuí had a population of 20,573, of which 73% were living in the urban area of the municipality, and the main economic activities were agriculture, including dairy farming, and commerce [16].

The results presented here relate to a subsample ($n = 262$) of elderly people (≥ 60 years) living in Bambuí in 1996 and 1997, that form part of the baseline data of the longitudinal study ($n = 1{,}742$). Individuals were considered eligible for the subsample where complete information on directly measured height and half arm-span was available.

Sociodemographic variables such as sex, age, schooling and income were used for the analysis along with the following anthropometric data: height measured using an anthropometer; height estimated from the measurement of half arm-span; and weight. The sociodemographic data was obtained from the results of a questionnaire carried out at the baseline [17]. All anthropometric measurements were taken by a trained appraiser after appropriate standardization.

The anthropometric measurements were standardized following the techniques proposed by Jelliffe [18]. The mean was taken from three measurements, and standardized equipment was used (CMS Weighing Equipment Ltd., London, UK) [17].

To measure body weight, the subjects had to remove their shoes and use as little clothing as possible. An electronic balance with a capacity of 150kg and precision of 100g was used.

Height was determined using a stadiometer with a 220cm measuring tape marked in millimeters. Subjects were measured barefoot or only wearing socks in an upright posture, looking forward without raising the head, with their feet placed together and heels against the rod of the stadiometer.

The half arm-span measurement was taken as the distance between the sternum and the distal phalanx of the middle finger of one of the hands, using the demispan system. To estimate height, the following equations were used: (1) WHO [9]: [height in meters = 0.73 x (2 x half-span) + 0.43]; (2) Bassey [8]: women [height in cm = (1.35 x half-span) + 60.1] and men [height in cm = (1.40 x half-span) + 57.8].

The height measurements were used to calculate BMI, defined as the weight in kilograms divided by the square of the height in meters. The BMI was classified by using criteria established by Lipschitz [19] that use age and sex specific cut off points for the elderly.

The analysis was carried out using the following age group classification proposed by Veras [20]: 60 to 69 years; 70 to 79 years; and ≥ 80 years. Direct height measurements were used as the reference for the equations for estimating height using the half arm-span measurement, as proposed by WHO [9] and Bassey [8].

Descriptive analysis, the chi-square and McNemar tests were performed to compare the differences between the nutritional assessments. The Bland-Altman concordance analysis [21,22] and the Lin concordance correlation coefficient (CCC) were used (adopting a 5% significance level) to analyze the concordance between the methods used to measure height and calculations BMI . The SAS software, version 8.02 (SAS Inst., Cary, USA), was used for the analyses. Linear regression analysis using univariate and multivariate models and stepwise variable selection was used to study the factors associated with height.

The Bambuí Cohort Study of Aging was approved by the Ethics Research Committee of the Oswaldo Cruz Foundation (Fundação Oswaldo Cruz), Rio de Janeiro, and all the participants signed a free and informed consent statement [22].

## Results

A total of 177 (64.5%) of the 262 participants were female. The mean age of the sample was 69.2 ± 0.5 years: 60.3% were 60 to 69 years of age; 29.0%, 70 to 79 years; and 10.7%, ≥ 80 years. In relation to schooling, 84.7% of the participants had completed the fourth year of elementary school. Regarding family income, 64.6% of the subjects earned the equivalent of less than four minimum monthly salaries.

These results and socioeconomic and demographic characteristics are similar to the findings of population-based cohort studies carried out by Lima-Costa et al. [16] and Giacomin et al. [23] in the town of Bambuí, also using data collected in 1996.

On analyzing the estimates made using the equation proposed by WHO [9], a low CCC was obtained for height for all ages and genders, with higher values for the ≥ 80 years age group (CCC = 0.66). With respect to BMI, the correlation coefficient was higher, ranging from 0.61 to 0.80, with both coefficients being statistically different ($p < 0.001$) (Table 1). The Bland & Altman analysis (Table 1) showed that there was an underestimation of height, especially among men (DM = -0.126m, 95%CI: -0.242; -0.010m). The analysis of the results obtained using the Bassey method for height calculation [8] showed differences for men (CCC = 0.57) and a difference in the BMI in the case of both men and women (women: CCC = 0.93; men: CCC = 0.89) (Table 2). Using the Bland & Altman analysis to analyze the results from the use of the equation proposed by Bassey [8], insignificant discrepancies were noted in the values for the differences in average height (Table 2).

The Bland & Altman analysis of BMI calculations showed an overestimation of the index when the WHO equation was used [9]. A greater overestimation of the index for men was observed with the use of the Bassey equation [8] [mean difference (MD) = 0.772, 95% concordance limit (95%CL): -2.852; 4.396], while in women there was an underestimation of the index (MD = -0.399, 95%CL: -4.039; 3.241).

The Lin concordance correlation coefficient provides corroboration that the BMI calculated using the Bassey method [8] and the BMI calculated using measured height show a high level of concordance. However, the estimated values, especially for men, tend to be overestimated compared to the measured values, suggesting that the estimates are best for individuals with BMI < 30kg/m$^2$.

Figure 1 shows that BMI calculated using the WHO height estimate [9] indicated a much greater prevalence of overweight (59.9%) than the index calculated using direct height measurements (33.6%) ($p < 0.01$). On the other hand, the prevalence of overweight calculated using the Bassey method [8] (32.4%) was similar to that obtained using direct height measurement ($p = 0.761$). There was a statistically greater prevalence of underweight when using direct height measurements in comparison to the WHO estimate (measured BMI: 26.3%; WHO BMI: 11.5%; $p < 0.01$). There was no difference in the assessment of nutritional status according to BMI between the methods described for both men and women (Figure 2).

The multivariate regression analysis showed that the predictors were hemi-height size, sex, weight and family income (Table 3). Good agreement was observed between predicted height and the methods: the correlation coefficient used to assess agreement between measurement methods was 0.491 for the WHO method and 0.889 for the Bassey method.

## Discussion

Height estimates using the Bassey method [8] showed greater agreement with direct measurements, thus suggesting that both methods were applicable to this sample. However, in contrast to other studies with different populations, the

Table 1

Lin and Bland-Altman concordance analyses of height and BMI from direct anthropometric measurements and estimates using the World Health Organization (WHO) equation [9], according to sex and age group. Bambuí, Minas Gerais State, Brazil, 1996 to 1997.

| Variable/Sample | WHO equation [9] Mean ± SD | Lin analysis CCC | Bland-Altman analysis MD (95%CL) |
|---|---|---|---|
| Height (m) | | | |
| Total | 153.0 ± 7.9 | 0.44 | -0.097 (-0.220; 0.026) |
| Sex | | | |
| Women | 149.0 ± 5.6 | 0.32 | -0.080 (-0.196; 0.036) |
| Men | 161.0 ± 5.9 | 0.21 | -0.126 (-0.242; -0.010) |
| Age (years) | | | |
| 60-69 | 154.0 ± 7.6 | 0.42 | -0.094 (-0.219; 0.031) |
| 70-79 | 153.0 ± 7.9 | 0.40 | -0.108 (-0,230; 0,014 |
| ≥ 80 | 153.0 ± 10.0 | 0.66 | -0.079 (-0.189; 0.031) |
| BMI (kg/m2) | | | |
| Total | 26.9 ± 5.1 | 0.74 | 3.431 (-1.302; 8.164) |
| Sex | | | |
| Women | 27.2 ± 5.5 | 0.80 | 3.001 (-1.658; 7.660) |
| Men | 26.4 ± 4.4 | 0.61 | 4.212 (-0.290; 8.714) |
| Age (years) | | | |
| 60-69 | 27.3 ± 5.0 | 0.74 | 3.399 (-1.530; 8.328) |
| 70-79 | 27.1 ± 5.6 | 0.75 | 3.834 (-0.733; 8.401) |
| ≥ 80 | 24.4 ± 3.7 | 0.73 | 2.515 (-0.989; 6019) |

BMI: body mass index; CCC: concordance correlation coefficient; MD: mean difference; SD: standard deviation; 95%CL: 95% concordance limit.

use of the WHO equation [9] significantly increases the prevalence of overweight, thereby masking diagnoses of underweight.

Direct measurement of height is the method recommended by WHO [24], because it is simple and easy to use. The high concordance correlation coefficients and the similarity between the height measurements obtained using the Bassey predictive equation [8] and anthropometry suggest that direct measurement may be the method of choice for this group.

In contrast to most studies, the WHO method [9] was not the first-choice method for estimating height. This shows the need for further investigation of height reduction over time through cohort studies. Furthermore, other factors may have influenced the measurements, such as age, socioeconomic condition, nutritional status, sex and ethnicity, given that the studies described in the literature are concerned with people from different age groups and populations, such as hospitalized or non-hospitalized elderly people [12,25,26]. This reinforces the need of specific equations for estimating height among healthy elderly individuals, such as the equations evaluated here.

There were few studies of non-institutionalized or non-hospitalized elderly individuals with which to compare the present study. In a study of non-institutionalized elderly people in Spain, Weinbrenner et al. [27] found similarities between the results of the half arm-span method and direct height measurement. However, in a study of elderly people in Viçosa, Minas Gerais, Cervi [28] found that the arm-span and half arm-span methods overestimated height. It should be noted that both of these studies used specific equations.

On the other hand, in a study of adults and elderly people conducted in the Clinics Hospital (Hospital das Clínicas), in Porto Alegre, State of Rio Grande do Sul, Brazil, Beghetto et al. [29] found that heights estimated using the WHO equation [9] (1.65 ± 0.075m) were greater than direct height measurements (1.62 ± 0.089m) ($p < 0.01$), thereby suggesting that height was underestimated under the traditional method.

Likewise, in a study of hospitalized elderly individuals, Hickson & Frost [12] found that estimated heights (1.64 ± 0.076m) were greater than measured heights (1.61 ± 0.096m), despite high

Table 2

Lin and Bland-Altman concordance analyses of height measured using anthropometry and respective body mass index in relation to height estimated using the Bassey method [8], according to sex and age group. Bambuí, Minas Gerais State, Brazil, 1996 to 1997.

| Variable/Sample | Bassey method [8] Mean ± SD | Lin analysis CCC | Bland-Altman analysis MD (95%CL) |
|---|---|---|---|
| Height (m) | | | |
| Total | 158.0 ± 0.79 | 0.75 | 0..000 (-0.118; 0.118) |
| Sex | | | |
| Women | 154.0 ± 5.0 | 0.56 | 0.014 (-0.098; 0.126) |
| Men | 166.0 ± 6.0 | 0.60 | -0.024 (-0.136; 0.088) |
| Age (years) | | | |
| 60-69 | 159.0 ± 7.6 | 0.73 | 0.002 (-0.116; 0.120) |
| 70-79 | 158.0 ± 7.9 | 0.75 | -0.010 (-0.128; 0.108) |
| ≥ 80 | 158.0 ± 10.0 | 0.86 | 0.017 (-0.087; 0.121) |
| BMI (kg/m$^2$) | | | |
| Total | 25.2 ± 4.8 | 0.92 | 0.017 (-3.774; 3.808) |
| Sex | | | |
| Women | 25.5 ± 5.1 | 0.93 | -0.399 (-4.039; 3.241) |
| Men | 24.7 ± 4.1 | 0.89 | 0.772 (-2.852; 4.396) |
| Age (years) | | | |
| 60-69 | 25.6 ± 4.7 | 0.91 | -0.034 (-3.940; 3.872) |
| 70-79 | 25.4 ± 5.3 | 0.93 | 0.316 (-3.432; 4.064) |
| ≥ 80 | 22.9 ± 3.5 | 0.90 | -0.510 (-3.509; 2.489) |

BMI: body mass index; CCC: concordance correlation coefficient; MD: mean difference; SD: standard deviation; 95%CL: 95% concordance limit.

correlation coefficients between direct height measurements and estimates using the Bassey equation [8]. Furthermore, in a study of non-institutionalized elderly covered by the Health Survey for England (HSE), Hirani & Mendel [30] found that heights estimated using the Bassey equation [8] (men: 1.71 ± 0.053m; women: 1.59 ± 0.049m) were greater than measured heights, particularly among women (men: 1.70 ± 0.066m; women: 1.56 ± 0.064m). In a study among elderly people in Nepal, Das et al. [31] also found that heights estimated using the Bassey equation were greater [8].

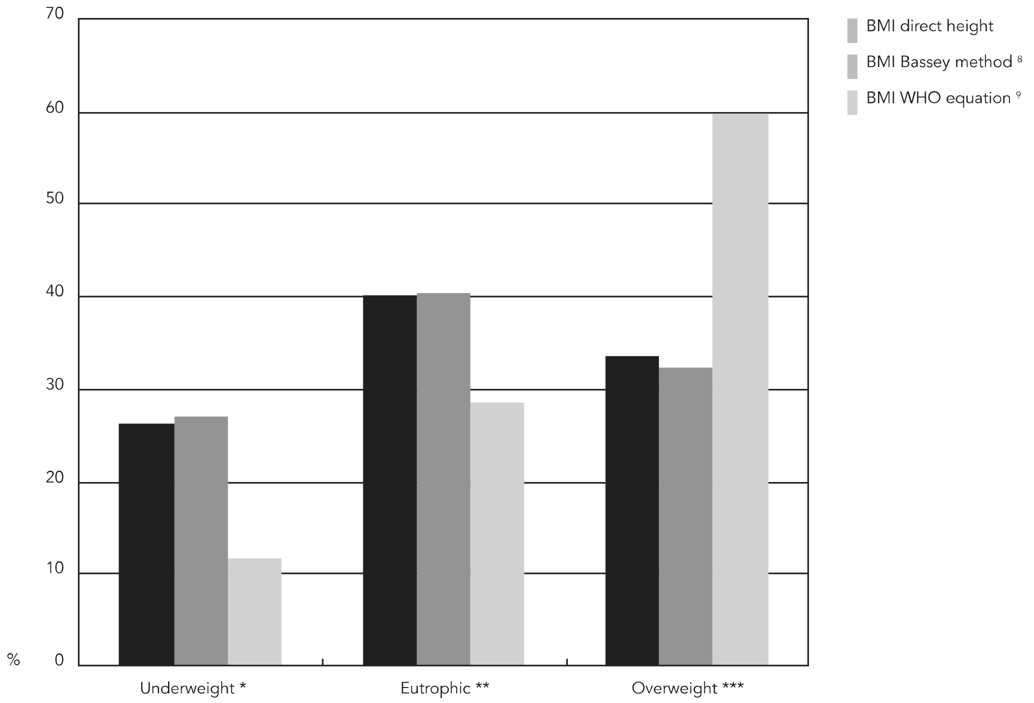
Several studies have shown that height reduces with advancing age [2,3,4] and that height loss is even greater after 80 years [32]. However, in the present study, a higher degree of concordance between measured height and heights estimated using the Bassey equation [8] was observed in this age group. The height of this study group did not appear to significantly diminish with advancing age, although this observation should be viewed with caution given the cross-sectional study design.

Effective nutritional diagnoses of elderly individuals based on BMI require accurate height measurements in order to avoid distortions [12,30]. The prevalence of nutritional disorders found using the Bassey equation [8] was close to that found using direct height measurement. On the other hand, the WHO equation [9] resulted in overestimation of diagnoses of overweight, to the detriment of underweight. However, studies show that BMI calculated using both the Bassey [8] and WHO [9] height estimates are lower than that calculated using direct height measurements [12,28,29,31]. It should be noted that many of these studies were conducted among frail elderly individuals, in contrast to the present study which focused on healthy elderly people. This study suggests that BMI calculated using direct height measurements or Bassey estimates [8] are the methods of choice for this group.

The present study proposes the use of a regression model to predict the relationship between the main variables and hemi-scale, sex, weight and family income. This model shows good agreement with measured height, indicating its potential for use in other studies. However, the number of participants in this sample (sample size n = 16) is small due to the lack of information on

Figure 1

Nutritional status of the subjects according to three different methods for determining height. Bambuí, Minas Gerais State, Brazil, 1996 to 1997.




BMI: body mass index.

* Direct height versus Bassey ($p = 0.832$); direct height versus WHO ($p < 0.01$);

** Direct height versus Bassey ($p = 1.000$); direct height versus WHO ($p < 0.01$);

*** Direct height versus Bassey ($p = 0.761$); direct height versus WHO ($p < 0.01$).

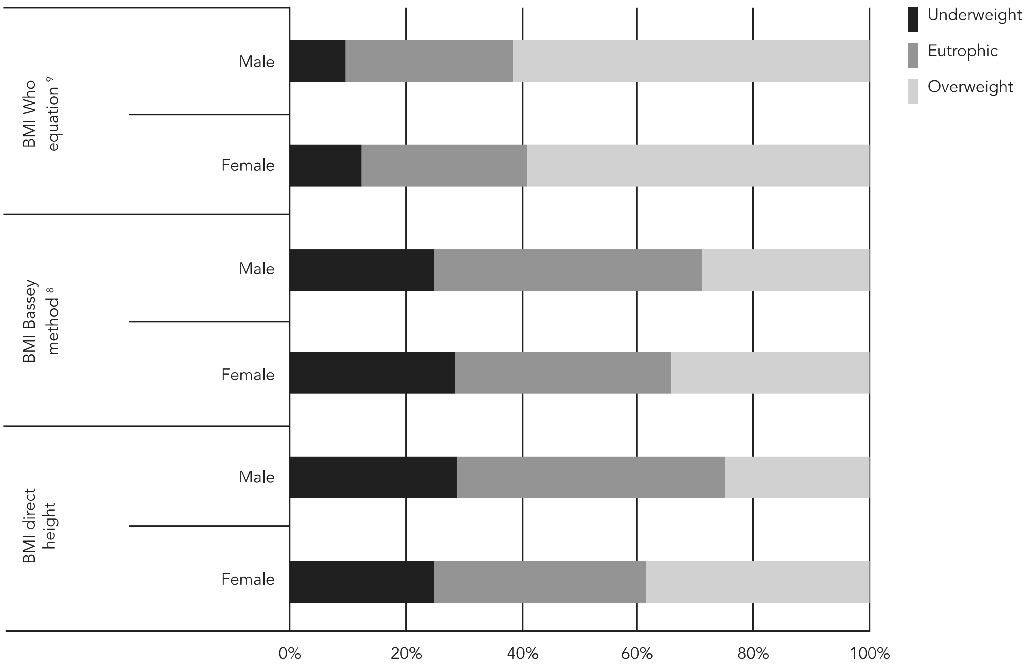
all variables in the univariate analysis and therefore these results should be viewed with caution.

Despite these important findings, this study has the following limitations: First, the equations used are commonly used for different populations, such as hospitalized elderly individuals, thereby making data comparisons difficult [30]. Second, due to period that the data was collected (1996 to 1997), it is necessary to assume that the determinant characteristics for predicting BMI and height remain constant over the years, in order to compare different methods for measuring height [33]. Finally, given the time elapsed between collection and analysis, it is not possible to account for technical errors in measuring intra and inter observer variability made when standardizing the benchmarks for the measurements. It should be noted, however, that all data was evaluated for consistency and the findings in this article are relevant.

Studies of this nature are important given that elderly people constitute a group at considerable nutritional risk and therefore erroneous diagnoses could lead to deterioration in the state of health of individuals in this group. Data from the Brazilian Household Budget Survey (POF 2002/2003) indicated that, while the prevalence of overweight and obesity increased with age, it decreased in age groups over the age of 65 years. The most important nutritional disorder among elderly individuals over 70 years of age was found to be malnutrition [34]. It should be noted that malnutrition is associated with higher mortality rates, greater susceptibility to infections and lower quality of life. A study conducted in Brazil between 1980 and 1997 showed that 36,955 deaths among the elderly were due to malnutrition [35], indicating the need for more accurate estimates of height to facilitate more accurate diagnosis of nutritional status.

Figure 2

Nutritional status stratified by sex of the subjects according to three different methods for determining height. Bambuí, Minas Gerais State, Brazil, 1996 to 1997.




BMI: body mass index.

## Conclusion

Few studies have investigated height trends among elderly people. Great care should be taken in estimating the height of elderly individuals in order to obtain an accurate estimation of BMI, with direct measurement being the most appropriate method. Given the inability of many elderly to assume a standing position, due to being bedridden or confined to wheelchairs, viable alternative forms of measurement may be required. This study found that BMI established using heights calculated under the method proposed by Bassey showed better agreement than that obtained from using direct measured height. The use of the WHO equation led to an underestimation of stature which can negatively affect the BMI classification, increasing the prevalence of an overweight diagnosis. In this scenario, it is suggested that the Bassey equation generates more accurate results for height and BMI.

Finally, obtaining information, particularly anthropometric data, about the physiological changes that affect this age group is a challenge. The results of such investigations contribute towards improving the reliability of population-based diagnoses and more effective public healthcare planning and policies for healthy aging.

### Key points

Alternative methods for height determination are made necessary due to height reductions as a result of aging.

In the present study, there was a high concordance between height estimates using the Bassey method [8] and direct height measurements, thus suggesting that both of these methods could be used. On the other hand, the equation proposed by WHO [9] seemed to underestimate height, thereby increasing the prevalence of overweight and masking underweight.

Studies of this nature are important, given that elderly people constitute a group at considerable nutritional risk, and therefore erroneous diagnoses could lead to deterioration in the state of health of individuals in this group.

Table 3

Multivariate linear regression analysis of height (in meters), not much missing data variables (n = 260).

| Selected variables/Categories | Beta (SE) | p-value | Partial $R^2$ |
|---|---|---|---|
| Half arm-span (cm) | | | |
| Continuous variable | 0.0068 (0.0007) | **< 0.001** | 0.5420 |
| Sex | | | |
| Female (reference) | - | - | - |
| Male | 0.084 (0.007) | **< 0.001** | 0.1444 |
| Weight (kg) | | | |
| Continuous variable | 0.0013 (0.0002) | **< 0.001** | 0.0370 |
| Family income (MW) | | | |
| < 2.00 (reference) | - | - | - |
| 2.00-3.99 | 0.001 (0.007) | 0.860 | - |
| 4.00-5.99 | 0.016 (0.009) | 0.078 | - |
| 6.00-9.99 | 0.002 (0.010) | 0.859 | - |
| ≥ 10.00 | 0.032 (0.012) | **0.010** | 0.0108 |

Beta: estimate or value of the slope (slope) in the regression line; MW: minimum wage; $R^2$: coefficient of determination SE: standard error of beta.

Note: criteria stepwise variable [total $R^2$: 0.7342; intercept (SE): 0972 (0047), p-value < 0.001].

## Resumo

*O objetivo foi comparar a estatura mensurada com a obtida por equações baseando-se na semienvergadura do braço, e avaliar o impacto sobre o índice de massa corporal (IMC). Comparou-se a medida direta da estatura e a obtida pelas equações propostas por Bassey e pela Organização Mundial da Saúde (OMS), em subamostra de idosos da linha de base do Estudo de Coorte de Idosos de Bambuí. A análise constou de testes de McNemar, coeficientes de correlação de concordância de Lin (CCC) e método de Bland & Altman (p < 0,05). Pela fórmula da OMS verificou-se baixo CCC para altura mensurada e concordância superior para IMC. Constatou-se subestimação da altura e consequente superestimação do IMC. Na fórmula de Bassey foi encontrada forte concordância com a altura mensurada em idosos com mais de 80 anos. Para o IMC (OMS) observou-se prevalência bastante superior de sobrepeso. Já a prevalência de sobrepeso (Bassey) não diferiu daquela obtida pela medida direta. A estimativa da altura obtida pela fórmula de Bassey foi semelhante à medida direta, sugerindo aplicabilidade. Já a fórmula da OMS parece subestimar a altura.*

*Antropometria; Idoso; Avaliação Nutricional*

## Contributors

V. O. Siqueira worked on the analysis and interpretation of the data and compilation of the paper. B. V. L. Costa worked on interpretation of the data and compilation of the paper. A. C. S. Lopes participated in designing the study, drawing up the instruments and compiling the manuscript. L. C. Santos worked on statistical analysis and revising and compiling the paper. W. T Caiaffa contributed through drawing up the instruments and revising and compiling the paper. M. F. Lima-Costa worked on revising and compiling the paper.

## Conflict of interests

None declared.

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