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Anthropometry fails in classifying bone mineral status in postmenopausal women

G. BEDOGNI, G. SIMONINI, S. VIAGGI, L. BELLOI, F. FERRARI, N. BATTISTINI and G. SALVIOLI

University of Modena and Reggio Emilia, Modena, Italy

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Summary. This study tested two hypotheses: (1) that simple anthropometric parameters can be used to identify patients at risk of decreased bone mineral content and (2) that an inverse relationship exists between waist:hip ratio (WHR) and bone mineral density (BMD). Bone mineral content (BMC) and BMD were evaluated by dual-energy X-ray absorptiometry in 1873 free-living women. Of these, 1819 (97%) were post-menopausal. One thousand and thirteen women (54%) had normal BMD, 705 (38%) osteopenia and 155 (8%) osteoporosis. Body weight (Wt), body mass index and arm muscle and fat areas were significantly lower in osteoporotics than osteopenics ($p < 0.0001$) and in these latter than controls ($p < 0.0001$). However, values of WHR were similar in all groups ($p =$ ns). Body weight was the anthropometric parameter better correlated with BMC (rho = 0.650, $p < 0.0001$) and only Wt and age were identified as significant predictors of bone mineral status (normal-BMD/osteopenic/osteoporotic) at polytomous logistic regression ($p = 0.0001$ for each). However, Wt could not be employed as an indicator of bone mineral status at the individual level because of high variations in BMC for the same level of Wt. Under- (< 5th percentile) and normal-Wt (5th–95th percentile) women had the same frequency of osteopenia (39%) while it was lower in over-Wt (> 95th) women (13%). The frequency of osteoporosis was higher in under- than normal-Wt women (37 *vs* 7%) and none of the over-Wt women had osteoporosis. This study shows that: (1) simple anthropometric measurements cannot be used to select subjects at risk of decreased BMC and, (2) BMD does not vary with WHR.

1. Introduction

Osteoporosis is a disease in which low bone mass and micro-architectural deterioration of bone tissue lead to an increase risk of fractures (Christiansen 1995). Bone mineral density (BMD), as evaluated by absorptiometric techniques, has been found to predict the risk of bone fractures. For this reason, dual-energy X-ray absorptiometry (DXA) is increasingly used for the diagnosis and follow-up of osteoporosis (WHO 1994). However, the high cost of DXA and the time required to perform a single analysis of bone mineral content (BMC; 20–40 min) tend to restrict the use of DXA to already selected populations, i.e. subjects considered to be at risk of osteoporosis (Michaelsson, Bergstrom, Mallmin *et al.* 1996).

Since osteoporosis is influenced by nutritional status (Prentice 1997), a screening of osteoporotic subjects has been proposed on the basis of simple anthropometric parameters such as body weight (Wt) or body mass index (BMI) (Wardlaw 1996). For example, based on their own study of 175 women, Michaelsson *et al.* (1996) have suggested that Wt may be used to exclude women from a screening program for postmenopausal osteoporosis.

Arm muscle and fat areas (AMA and AFA) offer additional information on body composition and can be easily calculated in the clinical setting (Frisancho 1990).

Thus, along with Wt and BMI, they are ideal candidates to be studied for their ability to discriminate between normal, osteopenic and osteoporotic subjects.

Body fat distribution, as determined by the ratio between waist and hip circumferences, has been linked to a variety of diseases (Van Itallie 1992, Seidell 1996). Blaauw, Albertese and Hough (1996) observed significantly higher values of waist-hip ratio (WHR) in 56 osteoporotic *vs* 125 controls and Daniel and Martin (1995) observed an inverse relationship between BMD and WHR in a sample of 52 young women. However, in a larger sample of women ($n = 342$), Slemenda, Hui, Williams *et al.* (1990) did not find any association between WHR and bone mineral status. The relationship between WHR and BMD has therefore not been thoroughly investigated in large samples of subjects.

The aim of this study was to establish whether anthropometric indicators of body composition (Wt, BMI, AMA and AFA) and fat distribution (WHR and the triceps: subscapular skinfold ratio, TSR) could be used to identify subjects with normal BMD, osteopenia or osteoporosis in a large sample of women.

2. Materials and methods

2.1. *Subjects and study protocol*

One thousand eight hundred and seventy three Italian free-living women were consecutively studied at the Geriatric Evaluation and Research Centre of Modena University. The study protocol was approved by the Ethical Committee at Modena University and all subjects gave their informed consent. The women were recruited through advertisements in local newspapers or were sent to the Centre by their primary physicians. To be eligible for the study, they had to be 18 years of age and free of diseases other than primary osteoporosis. Women already carrying a diagnosis of osteoporosis were allowed to enter the study (this diagnosis was not based on total-body bone mass measurements in most cases, however). The majority of women with this diagnosis were taking anti-osteoporotic drugs such as vitamin D or biphosphonates. A preliminary analysis of the data did not reveal significant differences in the variables of interest (including BMC and BMD) between women taking anti-osteoporotic drugs and those not taking them (Mann-Whitney *U*-test, $p =$ ns; data not shown). For this reason, osteoporotic women were considered as a whole group in further analyses.

2.2. *Assessment of bone mineral status*

Bone mineral content was measured using a Lunar DPX-L densitometer (Lunar, Madison, Wisconsin, USA). Following WHO (1994) criteria, women were classified as normal, osteopenic or osteoporotic on the basis of their T-scores of BMD. The T-score is calculated as $(BMD_{subject} - \text{mean } BMD_{population})/(\text{SD of } BMD_{population})$. A T-score < -2.5 defines osteoporosis, one between -2.5 and -1.0 osteopenia, and one > -1.0 normal BMD. Values of $BMD_{population}$ and $SD_{population}$ were obtained from a population of healthy Italian young women made available by the DPX software (values were unadjusted for body size). BMD is obtained from densitometers by dividing BMC per bone width or area. As pointed out by Prentice, Parsons and Cole (1994), this may lead to spurious associations of BMD with body composition. For this reason, we focused on BMC and its relationship with body composition in the pooled sample.

2.3. Anthropometry

Weight, height (Ht), triceps skinfold (TSF), subscapular skinfold (SSF), arm circumference (AC), waist circumference (WC) and hip circumference (HC) were measured following the Anthropometric Standardization Reference Manual (Lohman, Roche and Martorell 1988). BMI was calculated as Wt (kg)/Ht^2 (m^2) (Garrow and Webster 1985). AMA (cm^2) and AFA (cm^2) were calculated from AC and TSF as described by Frisancho (1990). WHR was calculated as WC (cm)/HC (cm) and TSR as TSF (mm)/SSF (mm) (Lohman *et al.* 1988, Van Itallie 1992).

2.4. Statistical analysis

Statistical analysis was performed using SPSS 7.0 (SPSS Inc., Chicago, USA) and SAS 6.12 (SAS Institute, Cary, NC, USA) for Windows. Since some anthropometric variables were not normally distributed (as detected by the Kolmogorov–Smirnov–Lilliefors test) and/or their between-group variances were not homogenous (as detected by the Levene's test) and not improved by transformation, non-parametric tests were employed for between-group comparisons. The test of Kruskal–Wallis was used to establish whether a significant difference was present among groups; when such a difference was detected, the Mann-Whitney *U*-test with Bonferroni's correction was used to identify the groups contributing to it (Glantz 1981). Correlation between two variables was evaluated by using the Spearman's rho correlation coefficient. The Pearson's Chi-square was used to test the independence of bone–mineral status (normal-BMD, osteopenia, osteoporosis) from Wt status (underweight, normal-weight, overweight). Finally, stepwise polytomous logistic regression was used to verify whether multiple variables could improve the prediction of bone-mineral status coded as 0: normal-BMD, 1: osteopenia and 2: osteoporosis (Hosmer and Lemeshow 1989).

3. Results

The results of the measurements are given in table 1. One thousand and thirteen women (54%) had normal BMD, 705 (38%) osteopenia and 155 (8%) osteoporosis. Of the 1873 women, 1819 (97%) were postmenopausal. Not surprisingly, age was significantly higher in osteoporotics than osteopenics and in the latter than normal-BMD subjects ($p < 0.0001$). In the 1819 postmenopausal women, age at menopause was significantly lower in osteopenics than osteoporotics ($p < 0.05$) but similar in osteopenics and normal-BMD subjects ($p =$ ns).

All indicators of nutritional status (Wt, Ht, BMI, AFA and AMA) were significantly lower in osteoporotics than osteopenics and in the latter than normal-BMD subjects ($p < 0.0001$). As one would expect, Ht was significantly lower in osteoporotics than osteopenics and in the latter than normal-BMD subjects ($p < 0.0001$). Differences in TSR were seen only between normal-BMD subjects and osteoporotics ($p < 0.05$) and no differences were seen in WHR ($p =$ ns). The poorer bone mineral status of osteoporotics *vs* osteopenics and of the latter *vs* normal-BMD subjects as determined by their values of BMD ($p < 0.0001$) and BMC ($p < 0.0001$) was confirmed by values of BMC standardized per Kg Wt ($p < 0.0001$; data not shown).

Among the anthropometric indicators, Wt showed the best correlation with BMC for the pooled sample (figure 1, table 2). To improve the classification of their bone–mineral status, women were classified as underweight, normal-weight and overweight on the basis of their Wt percentiles (calculated on the pooled sample,

Table 1. Characteristics of the study subjects. Values are given as percentiles (5th, 50th and 95th).

	Normal BMD (n = 1013)			Osteopenia (n = 705)			Osteoporosis (n = 155)		
	5th	50th	95th	5th	50th	95th	5th	50th	95th
Age (y)	49.0	60.0[a]	74.0	55.0	64.0[b]	76.0	57.8	67.0[c]	77.4
Age at menopause (y)[1,2]	38.0	50.0[a]	56.0	38.0	50.0[a]	56.0	39.0	49.0[b]	54.0
Wt (kg)	53.0	66.0[a]	81.0	50.2	61.0[b]	74.0	45.0	55.0[c]	67.2
Ht (m)	1.48	1.58[a]	1.68	1.47	1.57[b]	1.67	1.45	1.54[c]	1.67
BMI (kg/m^2)	21.8	26.5[a]	32.4	20.8	24.9[b]	30.4	19.1	23.3[c]	27.8
AFA (cm^2)	16.2	28.0[a]	40.9	14.5	24.6[b]	36.8	11.8	21.0[c]	30.5
AMA (cm^2)	26.6	39.8[a]	55.4	24.8	36.9[b]	53.6	24.7	33.8[c]	47.3
TSR[1]	0.68	1.01[a]	1.60	0.70	1.05[a]	1.64	0.71	1.07[b]	1.72
WHR	0.74	0.83[a]	0.93	0.74	0.83[a]	0.94	0.72	0.82[a]	0.96
BMC (g)	1949	2319[a]	2843	1623	1927[b]	2254	1325	1581[c]	1896
BMD (g/cm^2; area density)	1.034	1.097[a]	1.217	0.921	0.987[b]	1.029	0.810	0.880[c]	0.917

[a,b,c]Variables not sharing the same superscript are significantly different at the $p < 0.0005$ level, with the exception of [1] TSR and age at menopause for which $p < 0.05$.
[2] Given for the 1819 post-menopausal women (97% of the study sample) who were enrolled into the study.
BMD = bone mineral density; Wt = body weight; Ht = body height; BMI = body mass index; AFA = arm fat area; AMA = arm muscle area; TSR = triceps:subscapular skinfold ratio; WHR = waist:hip circumference ratio; BMC = bone mineral content.

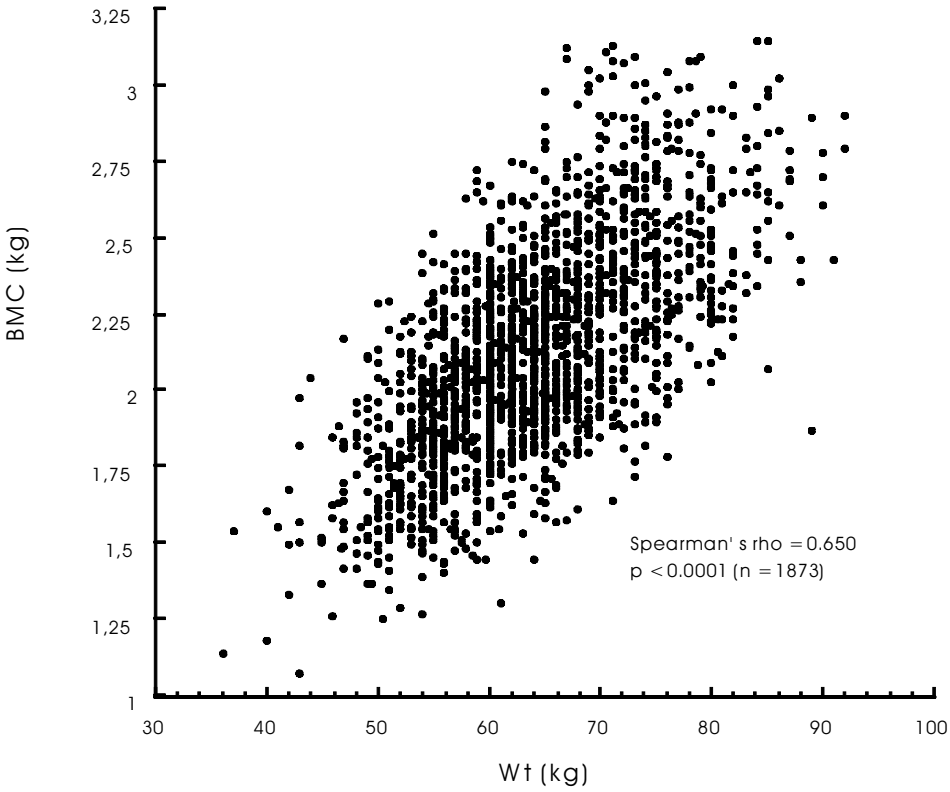

Figure 1. Correlation between bone mineral content and body weight in the pooled sample.

Table 2. Correlations between bone mineral content (BMC) and anthropometric indicators of body composition and fat distribution ($n = 1873$).

	Spearman's rho	p
Wt	0.650	< 0.0001
Ht	0.476	< 0.0001
BMI	0.415	< 0.0001
AFA	0.351	< 0.0001
AMA	0.302	< 0.0001
TSR	– 0.057	< 0.05
WHR	– 0.016	ns

Wt = body weight; Ht = body height; BMI = body mass index; AFA = arm fat area; AMA = arm muscle area; TSR = triceps:subscapular skinfold ratio; WHR = waist:hip circumference ratio.

Table 3. Frequency of normal bone mineral density (BMD), osteopenia and osteoporosis at different percentiles of body weight (Wt; $n = 1873$).

	Wt percentile		
	< 5th (underweight)	5th–95th (normal-weight)	> 95th (over-weight)
n	92	1687	94
normal BMD (%)	24	54	87
osteopenia (%)	39	39	13
osteoporosis (%)	37	7	0

$n = 1873$). Weight was chosen to classify women because of its better correlation with BMC as compared to the other anthropometric dimensions. A value of Wt < 5th percentile (51.0 kg) was used to define underweight, one between 5th and 95th normal-weight and one > 95th (80.0 kg) overweight. Table 3 reports the frequency of normal-BMD, osteopenia and osteoporosis for the women so classified.

Osteopenia had the same frequency in under- and normal-weight women (39%) and a lower frequency in overweight women (13%). The frequency of osteoporosis was higher in under- than normal-weight women (37 *vs* 7%) and none of the overweight women had osteoporosis. The association between BMD status and Wt status was statistically significant ($p < 0.0005$).

Polytomous logistic regression using bone mineral status (0: normal-BMD, 1: osteopenia; 2: osteoporosis) as the dependent variable confirmed the results of the between-groups comparisons obtained with non-parametric analyses (data not shown; cf. table 1). In a stepwise polytomous logistic regression model using anthropometric variables (Wt, Ht, BMI, AFA, AMA, WHR and TSR), age and age at menopause as predictors, only Wt ($p = 0.0001$) and age ($p = 0.0001$) contributed to explain bone mineral status.

4. Discussion

Of the anthropometric indicators studied, Wt showed the best correlation with BMC (figure 1). It was also the only anthropometric variable along with age to remain among the predictors when bone mineral status was predicted by stepwise

polytomous logistic regression. Despite this evidence, the data argue against the use of Wt as an indicator of bone mineral status at the individual level because of the large variations in BMC that can be seen for the same level of Wt (figure 1). The assessment of bone mineral status was only slightly ameliorated by classifying women on the basis of their Wt percentiles (table 3) since the same frequency of osteopenia (39%) was found in under- and normal-Wt subjects. The classification was better for osteoporotic women since only 7% of them were normal-weight and none of the overweight women had osteoporosis. However, the diagnosis of osteopenia is very important to prevent osteoporosis and its higher fracture risk. Thus, according to the results in this study, Wt cannot be used to select women at risk of decreased BMC and therefore subjects that would benefit from DXA measurements of BMC. This study's results are thus in contrast with those of Michaelsson *et al.* (1996) who suggested that Wt could be used to exclude women from a prevention programme for osteoporosis.

Body mass index was less well correlated with BMC than Wt (table 2), as commonly observed in the literature. It is nonetheless of interest that these data confirm the observation that values of BMI < 22–24 kg/m^2 are associated with lower values of BMD and that values of BMI > 24–26 kg/m^2 confer a limited protection from osteoporosis (Wardlaw 1996).

Arm fat area and arm muscle area were similarly correlated with BMC (table 2) and were not superior to BMI in predicting bone mineral status. This study's data are nonetheless in agreement with those of Farmer, Harris, Madans *et al.* (1989) and Slemenda *et al.* (1990) showing an inverse correlation between TSF (and SSF) and bone mass in large samples of women ($n = 3595$ and $n = 342$ respectively). (This study preferred to use AMA and AFA instead of TSF because they are obtained by combining two measurements—AC and TSF—and thus are commonly perceived as betters indicators of nutritional status than TSF alone.)

This study does not support the hypothesis that WHR is different in normal-BMD, osteopenic and osteoporotic subjects. That body fat distribution as detected by anthropometry is not associated with bone mineral status is also suggested by the fact that TSR was not different in normal-BMD and osteopenic subjects. Thus, in agreement with Slemenda *et al.* (1990) this study also found no association between WHR and bone mineral status.

In summary, body weight allows a better classification of bone mineral status as compared to body mass index, arm fat area and arm muscle area. However, weight should not be used to classify bone mineral status at the individual level. Finally, there is no evidence that WHR varies with bone mineral status.

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Address for correspondence: G. Bedogni, Human Nutrition Chair, Department of Biomedical Sciences, Via Campi 287, 41000 Modena, Italy.

Zusammenfassung. In der vorliegenden Studie wurden zwei Hypothesen überprüft: (1) einfache anthropometrische Parameter können nicht herangezogen werden, um Patienten mit hohem Risiko für einen verminderten Knochenmineralgehalt zu identifizieren und (2) zwischen dem Taillen-Hüftumfangs-Verhältnis (WHR) und der Knochenmineraldichte (BMD) besteht ein negativer Zusammenhang. Der Mineralgehalt der Knochen (BMC) und die BMD wurden an 1873 Frauen, darunter 1819 (97%) mit postmenopausalem Status, mittels dualer X-ray-Absorptionsmetrie bestimmt. Eine normale BMD hatten 1013 Frauen (54%), 705 (38%) wiesen eine Osteopenie auf und 155 (8%) eine Osteoporose. Das Körpergewicht (Wt), der Body Mass Index sowie die Muskel- und die Fettfläche des Armes waren bei den Osteoporose-Patientinnen signifikant kleiner als bei den Osteopenie-Patientinnen ($p < 0.0001$), bei letzteren waren diese Maße wiederum kleiner als bei den Kontrollen ($p < 0.0001$). Die Werte für das Verhältnis von Taillen- und Hüftumfang (WHR) waren jedoch in allen Gruppen ähnlich ($p =$ ns). Das Körpergewicht ist die anthropometrische Variable, die besser mit dem BMC korreliert ist (rho = 0.650, $p < 0.001$). In einer multiplen Regressionsanalyse erwiesen sich lediglich das Körpergewicht und das Alter als signifikante ($p = 0.0001$ für beide Variablen) Prädiktoren des Knochenmineralstatus (normale BMD/Osteopenie/Osteoporose). Da sich bei gleichem Gewicht erhebliche Variationen im BMC beobachten liessen, konnte das Gewicht auf der Ebene des Individuums nicht als Indikator des Knochenmineralstatus herangezogen werden. Bei untergewichtigen (< 5. Perzentil) und normalgewichtigen (5.–95. Perzentil) Frauen war die Häufigkeit von Osteopenie gleich groß (39%), während sie bei übergewichtigen Frauen (> 95. Perzentil) geringer war (13%). Die Prävalenz von Osteoporose war bei untergewichtigen Frauen größer als bei normalgewichtigen (37 vs 7%), bei den übergewichtigen Frauen wurde keine Osteoporose beobachtet. Diese Untersuchung zeigt, (1) dass einfache anthropometrische Maße nicht herangezogen werden können, um Frauen mit einem hohen Risiko für einen erniedrigten BMC zu identifizieren und (2) dass die BMD nicht mit dem WHR variiert.

Résumé. Cette étude éprouve deux hypothèses : (1) que de simples paramètres anthropométriques peuvent être utilisés afin d'identifier les patients à risque de perte minérale osseuse et (2) qu'une relation inverse existe entre le rapport taille-hanches (RTH) et la densité minérale osseuse (DMO). Le contenu minéral de l'os (CMO) et la DMO ont été évalués par absorpiométrie de rayons X d'énergie double chez 1873 femmes menant une vie normale dont 1819 (97%) étaient ménopausées. 1013 femmes (54%) avaient une DMO normale, 705 (38%) une ostéopénie et 155 (8%) une ostéoporose. Le poids corporel, l'indice de

masse corporelle et les parts musculaires et adipeuses du bras étaient significativement plus basses chez les ostéoporotiques que chez les ostéopéniques ($p< 0,0001$) et chez ces dernières que chez les contrôles ($p< 0,0001$). Cependant, les valeurs du RTH étaient semblables dans tous les groupes ($p=$ n.s.). Le poids corporel était le paramètre anthropométrique le plus corrélé avec le CMO ($(= 0,650, p< 0,0001)$ et seuls le poids et l'âge étaient identifiés comme des prédicateurs significatifs du statut minéral de l'os (DMO normale / ostéopénique / ostéoporotique) par une régression logistique polytomique ($p< 0,0001$ pour chacun). Cependant, le poids ne peut être employé comme indicateur du statut minéral de l'os au niveau individuel, à cause des fortes variations du CMO pour de mêmes valeurs de poids corporel. Les femmes de faible poids corporel (< $5^{ème}$ percentile) et celles de poids normal (du $5^{ème}$ au $95^{ème}$ percentile) avaient les mêmes fréquences d'ostéopénie (39%) tandis qu'elle était plus basse chez les femmes ayant du surpoids (> $95^{ème}$ percentile). La fréquence de l'ostéoporose était plus forte chez les femmes ayant un poids faible que chez celles de poids normal (respectivement 37% et 7%) et aucune des femmes avec du surpoids ne présentait d'ostéoporose. Cette étude montre que (1) de simples mesures anthropométriques ne peuvent pas être utilisées pour sélectionner les sujets à risque de perte de CMO et (2) que la DMO ne varie pas avec le RTH.