# Vertebral morphometry reference data by X-ray absorptiometry (MXA) in Iranian women

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ORIGINAL ARTICLE

# Vertebral morphometry reference data by X-ray absorptiometry (MXA) in Iranian women

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**Abstract** The anterior, medial, and posterior heights and the A/P and M/P ratios of the spine (T5–L4) in 41 normal premenopausal Iranian women were determined using an imaging densitometer (Expert XL) and dual energy X-ray absorptiometry (DXA) method. All the women were healthy (age 20–39 years, and height 149–171 cm), without any signs of vertebral fractures, and with normal bone mineral density (BMD) of the spine and femoral neck (*T*-score>−1.5). The vertebral heights were normalized using the Expert XL software, and the average vertebral height for the L2–L4 vertebrae was taken to minimize the effect of variation of body size among the subjects. The *Z*-score for all vertebral heights (T5–L4) averaged −0.68, with the A/P and M/P ratios coming to +0.34 and +0.49, respectively. It showed the normalization procedure not to correct the differences of vertebral heights in Iranian women. The average of the three heights ($H_{avg}$) correlated fairly well with the stature of the subject ($r$=0.47, $p$<0.05), but no correlation was found between $H_{avg}$ and subject age ($p$>0.05). The lower vertebral heights in older women in comparison with the younger women (0.4 mm) obtained in our study can be attributed to the relatively shorter stature of older women (mean 154 vs 159 cm for younger women, $p$<0.05). It was concluded that the normalization procedure used in the software does not equally apply to Iranian women due to their having different heights than those of American and northern European women, from whom the reference data for the Expert XL software have been gathered. The reference values thus obtained are therefore not accurate for our population group and a separate study with a bigger and more varied sample group is needed for obtaining more definitive results.

**Keywords** Morphometry X-ray absorptiometry · Reference values · Vertebral height

The study was conducted at Sina Hospital affiliated with Tehran University of Medical Sciences in Tehran, Iran.

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## Introduction

Osteoporotic fractures result in considerable mortality, morbidity, and high medical cost [1, 2]. The vertebral bodies, proximal femur, hip, and distal forearm are among the most commonly affected skeletal sites [3–5]. Women with a vertebral osteoporotic fracture have double the risk for future skeletal fractures and three times the risk for future vertebral fractures compared with patients with the same bone mineral density (BMD) but without vertebral fractures [6]. Accurate identification of fractures is therefore very important in the clinical management of osteoporotic patients. Unlike hip and wrist fractures, which are easy to identify, no reliable criteria are available for the identification of osteoporotic fractures of the spine.

Methods currently available for the detection of osteoporotic vertebral fractures include qualitative assessment of spinal radiographs, quantitative vertebral morphometry using morphometric radiography (MRX), and morphometric X-ray absorptiometry (MXA). Over the past few years, advances in dual energy X-ray absorptiometry (DXA) have provided semiautomatic measurement of the vertebral dimensions [7]. MXA has several advantages over MRX: (1) lower radiation dose, (2) no films are needed, and (3) rapid acquisition and analysis of data [8].

Empirical data on normal subjects are essential for the detection of abnormal vertebral shapes in patients suspected of having osteoporotic fractures. Several studies have examined normative data for MRX and MXA using different approaches [9–13]. Determining reference ranges from premenopausal women with a low risk of deformity is an ideal approach for selecting a population group with normal vertebrae [14, 15]. Although MXA densitometer manufacturers provide reference values, the values do not take into account the variations in vertebral heights due to racial differences [16–18]; it is therefore not clear if these normative data apply to all populations. Also, the vertebral body heights from T4 to L5 are directly correlated with the lumbar BMD [19]. On the other hand, the BMD is affected by genetic background and geographic variation in different countries [20]. Accordingly, the BMD of the spine and femor in normal Iranian women is lower than the reference values provided by Hologic for the female Caucasian population of the USA of the same age group [21]. Considering the influence of racial factors on the vertebral heights and the bone mass density values, and the effect of the BMD on the vertebral heights, it appears essential that the reference data specific to the population under study be used. In the present study, the vertebral dimensions in normal premenopausal Iranian women were determined using the Expert-XL instrument to examine the applicability of the software's normalization procedure in Iranian women. The influence of age and height of the subjects on the vertebral dimensions were also investigated and the MXA results compared with the data reported by Rea et al. [14], which were the first set of MXA reference data gathered, and those by Bagur et al. [15].

## Materials and methods

Forty-one healthy premenopausal Iranian women ages 20–39 years (mean 29±5.6 years) were studied. No incidence of vertebral fractures of the crush, wedge, biconcave, or deformed types, was seen in the MXA images of the lateral spine. Exclusion criteria included (1) pregnancy or menopause; (2) presence of skeletal, rheumatic, endocrine, renal, hepatic, or gastrointestinal disorders; (3) chronic use of corticosteroids, drugs for treatment of osteoporosis, thyroid disorders, or seizure; (4) prolonged immobilization (longer than 3 weeks in the last 5 years). All subjects gave informed written consent, and the study was approved by the Ethics Committee of Tehran University of Medical Sciences.

Morphometric X-ray absorptiometry was performed using an imaging densitometer (Expert; Lunar, Miami, FL, USA). This instrument uses the dual-energy X-ray absorptiometry (DXA) method, which cannot only measure BMD but also the vertebral dimensions. The Expert-XL uses a high-resolution array detector coupled to an X-ray tube in fan-beam geometry. During the examination, the patient lies in a supine position with the knees slightly raised and hands placed over the head. The instrument provides a lateral view of the T4 to L4 vertebrae. Scanning time is less than 1 min and with low radiation [8]. Because the T4 was not clearly visible in about 30% of the cases, its values were omitted from the analysis.

The Expert XL software (version 1.62) automatically places the points in the anterior, middle, and posterior endplates of the vertebrae. Additionally, the anterior/posterior (A/P) and middle/posterior (M/P) ratios, and the average ($H_{avg}$) of the three heights were automatically obtained from the Expert software. The software also provides a *Z*-score based on the manufacture's reference values for the heights and ratios. The expected heights were normalized in each case for the total height of the L2–L4 sequence. Theoretically, this normalization should allow the software to be used in individuals and populations of varying stature.

The effect of age on the vertebral dimensions was assessed by dividing the subjects into two groups according to age: 20–29 years (mean height 159±5.8 cm) and 30–39 years (mean height 154±3.4 cm). Differences between the age groups were investigated using independent sample test and correlation between $H_{avg}$ to height and age investigated using one-way ANOVA. One sample test was run to compare the mean vertebral dimensions obtained with the MXA data published by Rea et al. [14] and those by Bagur et al. [15].

Statistical analysis was performed in SPSS for windows version 11.5.

## Results

A total of 41 women were selected for this study. The height (157±5.5 cm) and body weight (63.4±9.9 kg) of the subjects were typical of Iranian women.

Table 1 shows the mean values for anterior, middle and posterior heights, A/P and M/P ratios, and the average of the three vertebral heights from T5 to L4.

Table 2 gives the average *Z*-scores for the anterior, middle, and posterior vertebral heights as well as the A/P and M/P ratios from T5 to L4. The values were less than expected considering to normal women without any vertebral fractures and *T*-scores for the spine and femoral neck BMD more than −1.5 SD (mean 0.70 and 0.60, SD 1.33 and 1.09). Also the BMD of both spine (mean 1.146 g/cm$^2$, SD 0.15) and femoral neck (mean 0.959 g/cm$^2$, SD 0.12) were in the normal range for healthy Iranian women [21].

Table 3 shows the vertebral heights and ratios for T5–L4 for the two age groups (20–29 and 30–39 years) with different heights (159±5.8 vs 154±3.4 cm, $p<0.05$). At all levels, the vertebral heights were found to be larger in the younger subjects than it was in the older women. The difference was significant for only the anterior and middle heights of the mid-thoracic vertebrae (T7, T8, and T11, $p<0.05$). No significant difference was found among the groups for the A/P and M/P ratios (except A/P ratio for L3). The average vertebral height in women over 30 years was ~0.4 mm less than women 20–29 years; the correlation of the total spine $H_{avg}$ with age was not significant ($p>0.05$), but it correlated fairly well ($r=0.47$, $p<0.05$) with stature. The regression coefficient was 0.08 mm for each centimeter of stature; so the 5-cm difference between younger and older women could be taken to correspond to a difference of ~0.4 mm in $H_{avg}$.

Table 4 shows the average total heights and ratios for the entire spine as well as for the thoracic and lumbar segments separately in our population compared with the reference data obtained by Rea et al. [14] and Bagur et al. [15]. In our study, the total height of the spine (T5–L4) was lower than in the two previous studies ($p<0.05$), and the difference was greater in the thoracic spine. The difference was greater in the posterior than in the anterior height compared with the data given by Bagur et al. [15], but it was almost the same in the posterior and anterior heights as the data reported by Rea et al. [14], and greater in the middle height.

**Table 1** Morphometric vertebral values of anterior, middle, and posterior heights, anterior/posterior and middle/posterior ratios, and average heights from T5 to L4 in normal women between 20–39 years

| | Anterior height (mm) | Middle height (mm) | Posterior height (mm) | Average height (mm) | A/P ratio | M/P ratio |
|---|---|---|---|---|---|---|
| T5 | 15.7 | 15.6 | 16.3 | 15.9 | 0.96 | 0.96 |
| T6 | 16.6 | 16.3 | 17.1 | 16.7 | 0.96 | 0.95 |
| T7 | 16.8 | 16.3 | 17.4 | 16.8 | 0.96 | 0.93 |
| T8 | 17.4 | 16.8 | 18.1 | 17.5 | 0.95 | 0.92 |
| T9 | 18.4 | 17.8 | 19.1 | 18.4 | 0.96 | 0.93 |
| T10 | 19.3 | 18.7 | 20.1 | 19.3 | 0.96 | 0.93 |
| T11 | 20.6 | 20.1 | 21.9 | 20.8 | 0.93 | 0.91 |
| T12 | 22.6 | 22.0 | 23.5 | 22.7 | 0.95 | 0.93 |
| L1 | 24.1 | 23.2 | 24.8 | 24.0 | 0.97 | 0.93 |
| L2 | 25.1 | 23.8 | 25.2 | 24.6 | 1.00 | 0.94 |
| L3 | 25.3 | 23.5 | 24.5 | 24.5 | 1.03 | 0.96 |
| L4 | 25.1 | 23.3 | 23.1 | 23.8 | 1.09 | 1.01 |

**Table 2** *Z*-score (average±SD) of the anterior, middle, and posterior vertebral heights, average heights, and anterior/posterior and middle/posterior ratios of the vertebral heights from T5 to L4

| Anterior height | Middle height | Posterior height | Average height | A/P ratio | M/P ratio |
|---|---|---|---|---|---|
| −0.51 ±0.50 | −0.61 ±0.58 | −0.90 ±0.49 | −0.68 ±0.50 | +0.49 ±0.37 | +0.34 ±0.37 |

Figure 1 shows the average A/P and M/P ratios for each vertebral body from T5 to L4 in our study compared with the normative data reported by Rea et al. [14] and Bagur et al. [15]. The average A/P ratio in our study was lower than those obtained by Rea et al. [14] (but not significantly, $p>0.05$), but higher than those reported by Bagur et al. [15] ($p<0.05$). The difference was greater in the upper thoracic area and lower in the lumbar region. The average M/P ratio is also lower than data reported by Rea et al. [14] and higher than those reported by Bagur et al. [15] ($p<0.05$).

## Discussion

The present study was carried out on 41 normal premenopausal Iranian women 20–39 years of age, and not affected by the exclusion criteria. The average *Z*-scores for the vertebral heights and ratios were close to zero after applying the normalization procedure devised by the software designers and corrected for the differences in skeletal dimensions for the specific population group being studied. The subjects were selected from normal premenopausal women, as well as previous studies' suggestion [14, 15], not affected by the exclusion criteria and not presenting with any signs of vertebral fractures of the crush, wedge, or biconcave types. On the other hand, it is well documented that vertebral deformities and fractures are associated with low axial BMD [22, 23]; and, in our study, the BMD of the spine and femoral neck were determined to be in the normal range for healthy Iranian women [21] (*T*-score>−1.5). Therefore, despite the "normal" status of the women in our study, the *Z*-scores obtained (shown in Table 2) strongly suggested the presence of vertebral fractures. It suggests that the normalization procedure used in the software does not accurately apply to Iranian women having different stature than American and northern European women, for whom the normalization procedure

**Table 3** Morphometric vertebral values of anterior, middle, and posterior heights, anterior/poster and middle/ posterior ratios, and average heights from T5 to L4 in 20–29 and 30–39 years old women

| | Anterior height | | Middle height | | Posterior height | | Average height | | A/P ratio | | M/P ratio | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20–29 | 30–39 | 20–29 | 30–39 | 20–29 | 30–39 | 20–29 | 30–39 | 20–29 | 30–39 | 20–29 | 30–39 |
| T5 | 15.7 | 15.8 | 15.7 | 15.6 | 16.3 | 16.3 | 15.8 | 15.9 | 0.95 | 0.97 | 0.97 | 0.95 |
| T6 | 16.6 | 16.6 | 16.3 | 16.3 | 17.1 | 17.1 | 16.7 | 16.6 | 0.96 | 0.97 | 0.95 | 0.95 |
| T7 | 17.0 | 16.5 | 16.8 | 16.7* | 17.7 | 17.0 | 17.2 | 16.4* | 0.95 | 0.97 | 0.95 | 0.92 |
| T8 | 17.7 | 16.9* | 17.3 | 16.2* | 18.4 | 17.8 | 17.8 | 17.0* | 0.96 | 0.95 | 0.94 | 0.91 |
| T9 | 18.5 | 18.2 | 18.0 | 17.6 | 19.3 | 18.7 | 18.6 | 18.2 | 0.95 | 0.97 | 0.93 | 0.94 |
| T10 | 19.3 | 19.3 | 18.8 | 18.4 | 20.4 | 19.7 | 19.5 | 19.1 | 0.94 | 0.98 | 0.92 | 0.93 |
| T11 | 21.0 | 19.9* | 20.5 | 19.5 | 22.2 | 21.4 | 21.2 | 20.3* | 0.94 | 0.92 | 0.92 | 0.90 |
| T12 | 22.6 | 22.5 | 22.2 | 21.7 | 23.6 | 23.4 | 22.8 | 22.5 | 0.95 | 0.96 | 0.94 | 0.92 |
| L1 | 24.3 | 23.9 | 23.5 | 22.7 | 25.1 | 24.4 | 24.3 | 23.7 | 0.95 | 0.97 | 0.93 | 0.93 |
| L2 | 24.9 | 24.4 | 24.0 | 23.5 | 25.2 | 25.1 | 24.5 | 24.4 | 1.01 | 0.98 | 0.95 | 0.93 |
| L3 | 25.9 | 24.7* | 23.6 | 23.3 | 24.5 | 24.4 | 24.7 | 24.1 | 1.06 | 1.01 | 0.96 | 0.95 |
| L4 | 25.2 | 24.9 | 23.5 | 23.0 | 23.3 | 22.8 | 24.0 | 23.6 | 1.08 | 1.10 | 1.01 | 1.01 |

*$p<0.05$

was devised and from whom the Expert XL reference data were obtained.

The analysis of the data indicated a decrease of ~0.4 mm in average vertebral heights in older women ($p<0.05$). Bianco et al. [24] found a decrease of only 0.2 mm and Rea et al. [14] reported a larger decrease in the average vertebral heights (0.5 mm) in older women, but as in our study, they found no influence of age on the vertebral ratios ($p<0.05$). Bagur et al. [15] reported a decrease in vertebral heights and both the A/P and M/P ratios in older Argentinian women using MXA method; they suggested that even without any obvious vertebral fractures, "normal" women seem to have an average loss of 10–15 mm in the total height of their spine from youth to old age. However, the small decrease in our study may be due to small difference between the average age of the younger and older women [24]. On the other hand, in our study, the total spine $H_{avg}$ correlated fairly well with the stature ($r=0.47$, $p<0.05$), but no correlation was found between $H_{avg}$ and age ($p>0.05$). Bianco et al. [24] found a correlation between $H_{avg}$ and stature, as in our study, but in the study by Bagur et al. [15] the stature in two age groups was identical; so, no correlation was reported between the $H_{avg}$ of the spine and height of the subjects. Considering the difference of height between the two groups (mean 159 vs 154 cm, $p<0.05$) in our study, it can be suggested that the age differences reported may be attributed in part—or even entirely—to the increase in the total height of about 1 mm/ year [9] of women during last century and may not actually be a result of aging.

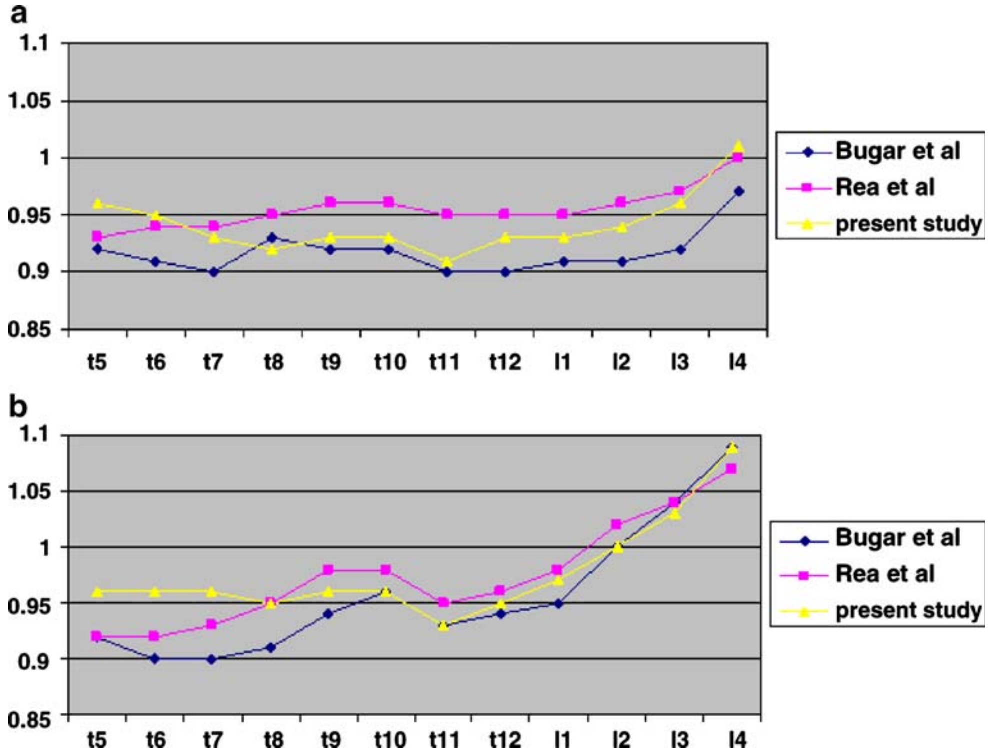
**Table 4** Average total heights (in millimeter) of the thoracic and lumbar vertebral bodies (T5–L4), thoracic vertebrae (T5–T12), and lumbar vertebrae (L1–L4) in the present study compared with the results reported by Rea et al. [14] and Bugar et al. [15]

| | Rea et al. | Bugar et al. | Present study | Δ1* | Δ2* |
|---|---|---|---|---|---|
| Total spine (height) | | | | | |
| Anterior | 276.2 | 250.2 | 245.8 | +26 | +4.4 |
| Middle | 276.8 | 239.4 | 236.8 | +40 | +2.6 |
| Posterior | 271.6 | 261.0 | 250.7 | +20.9 | +10.3 |
| Average | 271.9 | 249.9 | 244.4 | +27.5 | +5.5 |
| A/P ratio | 0.979 | 0.951 | 0.978 | +0.001 | −0.027 |
| M/P ratio | 0.954 | 0.915 | 0.944 | +0.01 | −0.029 |
| Thoracic spine | | | | | |
| Anterior | 158.7 | 147.2 | 146.6 | +12.1 | +0.6 |
| Middle | 174.4 | 145.2 | 143.1 | +31.3 | +2.1 |
| Posterior | 166.4 | 160.0 | 153.2 | +13.2 | +6.8 |
| Average | 166.5 | 150.8 | 147.6 | +18.9 | +3.2 |
| A/P ratio | 0.952 | 0.925 | 0.958 | 0.006 | 0.033 |
| M/P ratio | 0.947 | 0.915 | 0.935 | +0.012 | 0.020 |
| Lumbar spine | | | | | |
| Anterior | 108.4 | 102.8 | 99.7 | +8.7 | +3.1 |
| Middle | 102.3 | 94.2 | 93.8 | +8.5 | +0.4 |
| Posterior | 105.2 | 101.4 | 97.6 | +7.6 | +3.8 |
| Average | 105.3 | 99.4 | 97.0 | +8.3 | +2.4 |
| A/P ratio | 1.032 | 1.010 | 1.02 | +0.012 | 0.010 |
| M/P ratio | 0.973 | 0.925 | 0.960 | +0.048 | 0.035 |

*Difference between present study and Rea et al. [14] (Δ1), and Bugar et al. [15] (Δ2)

The vertebral heights in Iranian women average ~0.4 mm lower than the reference population consisting of American and European women ($p<0.05$), and 2–3 mm less than those reported by Rea et al. [14] ($p<0.05$). The difference with the data reported by Bagur et al. [15] is ~0.5 mm ($p<0.05$). Several studies have reported the difference between their MXA data with the reference values provided by the software designer [14, 15, 24], and are likely to be due to an overall difference in the height of

**Fig. 1** Comparisons of reference mean vertebral height ratio values from T5 to L4 derived from the present study (*filled triangle*), Rea et al. [14] (*filled square*), and Bugar et al. [15] (*filled diamond*). **a** Anterior/posterior ratio (A/P); **b** middle/posterior ratio (M/P)




the population [24] and because of racial differences [14] as well as the difference in height of the US and European women compared with our population [25]. Also, the higher stature of Argentinian women in the study by Bagur et al. [15], as compared with the subjects in our study (159±6 vs 157±5.5 cm, $p<0.05$), and racial differences between British women in the study by Rea et al. [14] (data on the stature not available), and our study group might have given rise to the different values obtained for the vertebral heights. Although this difference is adequately compensated for in the normalization procedure of the software [24], it is still essential that independent reference data be gathered for the specific study group, namely, Iranian women, due to the inaccuracy of the normalization procedure given in the software for our specific study group.

On the other hand, the A/P and M/P ratios were ~0.02 higher than the reference values ($p<0.05$). The difference with those given by Rea et al. [14] was 0.001 and 0.01 for the A/P ($p>0.05$) and M/P ($p<0.05$) ratios, respectively. The post normalization $Z$-score for both A/P and M/P ratios, in comparison with the three vertebral heights, were close to zero (+0.49, +0.34, respectively). It is suggestive of the accuracy of the normalization procedure for the vertebral ratios. The final results, as regards the A/P and M/P ratios, can be used for the investigation of vertebral fractures until independent reference data for our own study group are gathered. Until then, the significance of these findings for clinical use of the MXA method remains open to discussion.

In conclusion, this study suggests that reference data for MXA, like those for BMD, should be specific to the population. The normalization procedure used in the software is not accurate for differences of the vertebral heights attributable to the ethnic and environmental variations in Iranian women, and the reference values are thus not applicable to our population group. It follows that a separate study using a bigger sample size is required for the gathering of specific reference data for our population group.

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