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# Bone mineral density in healthy Syrian women measured by dual energyX-ray absorptiometry

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Abstract: Assessment of bone mineral density (BMD) using dual energy X-ray absorptiometry (DXA) technique is considered as a standard technique for diagnosing osteopenia and osteoporosis and evaluating the severity of such diseases. Numerous studies have demonstrated the necessity to establish an ethnic-specific reference data for Bone mineral density measurements. Such data are lacking for the Syrian population. The objectives of this study are (1) to establish BMD reference values in a group of healthy Syrian women using DXA technique, (2) to compare with values from other populations, (3) to study the prevalence of osteopenia and osteoporosis in Syrian women using the manufacturer reference values. A total of 951 healthy Syrian women aged 20-79 years participated in this study. Weight, height, and BMI have been determined. BMD measurements were performed using Lunar Prodigy Advance System (GE). The data were compared with those from other populations. The results have demonstrated the expected decline in BMD with age after peaking at 30-39 years old group. The peak values of the lumbar spine and femur neck were 1.16 (0.12), and 0.95 (0.13) g/cm$^2$, respectively. The results of the Syrian women were compared with those from other populations and the differences were presented. Osteopenia was diagnosed in 35.80% and 60.31% and osteoporosis in 6.23% and 2.72% in lumbar spine and femur neck, respectively, of women 50-59 years of age. These ratios increased to 36.84%, 68.42% and 23.68%, 13.10%, respectively, in the age group more than 59 years. BMD values of the Syrian women were determined for the first time. The results demonstrate the importance of establishing population-specific reference range for BMD values for an accurate assessment of Osteoporosis. High prevalence of osteopenia and osteoporosis was demonstrated in Syrian using the manufacturer reference values.

Key words: bone mineral density (BMD), dual-energy X-ray absorptiometry (DXA), osteoporosis, osteopenia, Syrian women

## Introduction

Osteoporosis is an important world-wide health issue, mainly among the post-menopausal women. In the UK 1 out of 3 women and 1 out of 12 men suffer from osteoporosis (Byers et al. 2001). Osteoporosis is characterized mainly by reduced BMD, deterioration of the micro-architectural structure of bone, and consequent an increased risk of fracture (Kanis 1997; Cooper et al. 1992). The

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World Health Organization (WHO) has defined osteoporosis through assessment the BMD measurements at several body regions, mainly lumbar spine and proximal femur based on DXA scan (WHO 1994). DXA is the most widely used technique for measuring BMD due to its good precision, short scan times, stable calibration, and exposure to very low doses of ionizing radiation (1 - 10 $\mu$Sv) (Steel et al. 2011) which is comparable to the average daily dose from natural background radiation (7$\mu$Sv) (Steel et al. 2011; Damilakis et al. 2010). This technique has considered by WHO as the technique of choice for assessing BMD. In 1994, WHO recommended a definition of osteoporosis based on BMD measurement of the lumbar spine, femur or forearm expressed as standard deviation (SD) called T-scores. This score is calculated by the difference between a patient's measured BMD and the mean BMD of healthy young adults and expressing the difference relative to the young adult population SD (WHO 1994). The WHO has defined osteoporosis as a BMD value more than 2.5 SD below the average value for a young healthy woman (T-score of <-2.5 SD). Osteopenia has defined as -1.0 to 2.5 SD, and, those with T-score values higher than −1 were classified as normal (Kanis et al. 1994). However, manufacturers use reference values based on western populations. Several studies conducted recently on BMD values showed that there are racial and ethnic important differences. Also, genetic, geographic, and socioeconomic characteristics are important factors in interpretation of BMD data (Maalouf et al. 2000; Mazess et al.1999). It has been demonstrated that BMD values in blacks are 8-12% higher than that in Caucasians, while, Asian women have lower BMD than Caucasians (Looker et al. 1995; Tobias et al. 1994). Moreover, published studies have demonstrated BMD differences in the Middle East and between Arab counterparts (Maalouf et al. 2000; Paker et al. 2005; Mahussain et al. 2006). These studies have demonstrated the necessity to establish a population-specific reference data for BMD measurements for each particular population for accurate interpretation of BMD measurements. The objectives of this study are (1) to establish BMD reference values for lumbar spine and femur neck, Femur total, and total body in healthy Syrian women using DXA technique, (2) to compare these values with those obtained in other populations, and, (3) to study the prevalence of osteoporosis and osteopenia in Syrian women using the manufacturer reference values.

## Materials and Methods

### Participants

The study participants were recruited by local advertisement and consisted of 951 healthy and physically active women aged 20 to 79 years living in Damascus city and surrounding areas. Damascus city is the capital of Syria with a diverse population representing most Syrians**.** The main exclusion criteria were pregnancy, history of fracture, thyroid, parathyroid, liver, intestinal and kidney diseases, malignancies, and any medication affecting bone mass or bone metabolism. The study protocol was approved by the scientific research and the ethical committee of the Atomic Energy Commission of Syria (AECS). Each participant provided informed consent prior to participation after a detailed explanation of the study protocol. This study was performed in accordance with guidelines prescribed by Helsinki Declaration of the

world Medical association. A special questionnaire was prepared for all participants to include personal data and all performed measurements. The participants arrived in the morning at the Human Nutrition Unit, health center, AECS. Brief clinical examination was performed prior to measurements by specialized medical doctors.

### Anthropometric measurements:

Body weight was measured using calibrated an electronic scale (Seca, Model 7671321004, Germany) and height was measured using a well-mounted stadiometer (Seca, Model 1721009, Germany). Participants were measured barefoot in light underwear. All measurements were done by the same person using the same equipment during morning hours. BMI was calculated as weight divided by height squared (kg/m$^2$).

### BMD measurements

BMD of lumbar spine (L1-L4), femur neck, femur total, and total Body of 951 Syrian women were measured using whole body DXA scan with Lunar Prodigy Advance System (analysis version: 13.20) manufactured by GE Healthcare. Daily quality control was carried out by measurement of a Lunar phantom in accordance with the manufacturer's instruction manual. At the time of the study, phantom measurements showed stable results. The results were expressed in g/cm$^2$. All measurements were performed by an experienced technologist under the supervision of an expert medical doctor at the Human Nutrition Unit, health center, AECS.

## Results

In total, 951 women met the inclusion criteria, and provided informed consent to participate in the study. The basic characteristics of the sample included in the current study are presented in the Table 1. The study group was divided into five age sub groups. The mean age, weight, height, and BMI (±SD) of the studied group were 43(±11), 73.8(±15.5) kg, 157.7(±5.6) cm, and 29.8(±6.3) kg, respectively. Table 2 shows the BMD SD) of the healthy Syrian women in the total body, lumbar spine (L1-L4), Femur neck, femur total grouped according to age. The peak of BMD values for these four measurement sites were 1.14(0.10), 1.16(0.12), 0.95(0.13), and 0.99(0.13) g/cm$^2$, respectively. The BMD value reached its peak in the age group of 30-39years for all measurement sites except for the femur total where the peak reached in the age group of 40-49 years. Table 3 shows

Table 1. Basic characteristics of the Syrian women according to age groups

| Age group n | Age (years) Mean±SD | Weight(kg) M±SD | Height(cm) M±SD | BMI(kg/m$^2$) M±SD |
|---|---|---|---|---|
| 20-29 (n=133) | 25±3.00 | 61.45±12.00 | 158.90±5.28 | 24.37±4.67 |
| 30-39 (n=216) | 35±3.00 | 70.91±14.29 | 158.98±5.44 | 27.96±5.57 |
| 40-49 (n=307) | 45±3.00 | 77.00±15.00 | 157.90±5.40 | 30.90±6.00 |
| 50-59 (n=257) | 54±3.00 | 78.67±15.25 | 156.20±5.35 | 32.20±6.04 |
| 60-79 (n=38) | 62±3.00 | 79.54±15.60 | 153.03±5.83 | 34.13±7.31 |
| All ages (n=951) | 43±11.00 | 73.80±15.50 | 157.70±5.60 | 29.80±6.30 |

M±SD: Mean±Standard Deviation

Table 2. BMD (g/cm$^2$) values of the measurement sites for the Syrian women according to age groups

| Age group (years) | n | Total body BMD(M±SD) | L1L4 BMD(M±SD) | Femur neck BMD(M±SD) | Femur total BMD(M±SD) |
|---|---|---|---|---|---|
| 20-29 | 133 | 1.11± 0.09 | 1.14 ± 0.11 | 0.93 ± 0.12 | 0.96 ± 0.12 |
| 30-39 | 216 | 1.14 ± 0.10 | 1.16 ± 0.12 | 0.95 ± 0.13 | 0.97 ± 0.17 |
| 40-49 | 307 | 1.14 ± 0.12 | 1.14 ± 0.12 | 0.93 ± 0.12 | 0.99 ± 0.13 |
| 50-59 | 257 | 1.08 ± 0.13 | 1.07 ± 0.12 | 0.87 ± 0.11 | 0.93 ± 0.13 |
| > 59 | 38 | 1.05 ± 0.12 | 1.01 ± 0.16 | 0.81 ± 0.11 | 0.87 ± 0.13 |
| All ages | 951 | 1.12 ± 0.12 | 1.12 ± 0.13 | 0.91 ± 1.12 | 0.96 ± 0.14 |

Table 3. Comparison of peak BMD in various studies in women

| Study | L1-L4 Peak BMD Age group | Mean±SD | Femur neck Peak BMD Age group | Mean±SD | Model/ Manufacturer |
|---|---|---|---|---|---|
| Current study(Syria) | 30-39 | 1.16±0.10 | 30-39 | 0.95±0.13 | Lunar Prodigy (GE) |
| Lebanon | 20-39 | 1.11±0.12 | 20-39 | 0.90±0.12 | Lunar Madison, WI |
| Kuwait | 40-49 | 1.15±0.15 | 40-49 | 0.96±0.11 | Lunar Prodigy (GE) |
| Morocco | 20-29 | 1.16± 0.12 | 20-29 | 1.03±0.12 | Lunar Prodigy (GE) |
| Qatar | 30-39 | 1.16± 0.12 | 40-49 | 0.97±0.13 | Lunar Madison, WI |
| Saudi | 31-40 | 1.16± 0.11 | 10-20 | 0.98±0.10 | Lunar Radiation Corp.,WI |
| Iran | 20-29 | 1.08± 0.09 | 20-29 | 0.91±0.13 | Norland XR-4L, Atkinson |
| Turkey | 30-39 | 1.19± 0.11 | 30-39 | 0.95±0.11 | Lunar Madison, WI |
| Greece | 30-35 | 1.04± 0.10 | 25-30 | 0.92±0.11 | N/A |
| Italy | 20-45 | 1.04± 0.11 | 20-29 | 0.86±0.12 | Hologic, waltham,Mass |
| India | 30-39 | 0.94±0.11 | 30-39 | 0.77±0.12 | Hologic 4500 US |
| Taiwan | 30-39 | 1.08±0.13 | 17-29 | 0.87±0.10 | XR36,Norland, Wisc |
| Beijing | 30-39 | 1.2±0.14 | 20-29 | 0.97±0.14 | Lunar Madison, WI |
| Japan (JPOS) | 20-40 | 1.05±0.11 | 15-19 | 0.85±0.10 | N/A |
| Caucasians | 30-39 | 1.21±0.12 | 25-29 | 0.86±0.12 | N/A |
| European/USA Data | 30-39 | 1.20±0.12 | 30-39 | 0.95±0.12 | Hologic, waltham,Mass |
| Canada (caMos) | 25-39 | 1.04±0.12 | 25-29 | 0.86±0.12 | Lunar Madison, WI |
| NHANES III | - | - | 20-29 | 0.86±0.12 | N/A |

BMD values (M±SD) of healthy Syrian women in the lumbar spine (L1-L4), and femur neck grouped according to age and the correlated results from other populations.

The T-score of the total body, lumbar spine (L1-L4), femur total, and femur neck were grouped according to age and the results are shown in the Table 4. The prevalence of osteopenia (T-score <-1SD) and osteoporotic (T-score<-2.5SD) in healthy Syrian women, according to age group, is shown in Table 5. Prevalence of osteopenia and osteoporotic was calculated using T- score from USA (Combined NHANES/Lunar) reference provided by the manufacturer. The results have indicated that lumbar spine (L1L4), total femur, and total body osteopenia, in women age 50-59 years, were very close (35.8% and 31.91%, 27.24%, respectively), but it was more prevalence in the femur neck (60.31%). These ratios were increased to 36.84%, 47.37%, 31.58%, and 68.42, respectively, in women age more that 59 years. However, the lumbar spine and to-

Table 4. T-score of the measurement sites (calculated from the reference data providing by the manufacturer) according to age groups

| Age group (years) | n | Total body T-score Mean±SD | L1L4 T-score Mean±SD | Femur total T-score Mean±SD | Femur neck T-score Mean±SD |
|---|---|---|---|---|---|
| 20-29 | 133 | -0.32±0.91 | -0.25±0.93 | -0.79±0.87 | -0.41±0.96 |
| 30-39 | 216 | 0.02±1.02 | 0.04±1.10 | -0.63±0.96 | -0.18±1.01 |
| 40-49 | 307 | 0.00±1.09 | -0.15±1.10 | -0.73±0.89 | -0.13±1.03 |
| 50-59 | 257 | -0.62±1.25 | -0.82±1.18 | -1.19±0.79 | -0.60±0.96 |
| > 59 | 38 | -0.89±139 | -1.37±1.42 | -1.64±0.78 | -1.06±1.05 |
| All ages | 951 | -0.24±1.15 | -0.35±1.18 | -0.88±0.91 | -0.35±1.03 |

Table 5. Prevalence of osteopenia and osteoporosis in the Syrian women according to measurements sites and age group

| Age group (years) | n | Measurements site | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | L1-L4 | | Total body | | Femur (neck) | | Femur (total) | |
| | | Osteopenia | Osteoporosis | Osteopenia | Osteoporosis | Osteopenia | Osteoporosis | Osteopenia | Osteoporosis |
| | | n (%) | n (%) | n (%) | n (%) | n (%) | n (%) | n (%) | n (%) |
| 20-29 | 133 | 23 (17.3) | 2 (1.5) | 26 (19.5) | - | 51 (38.3) | 1 (1.0) | 36 (27.1) | - |
| 30-39 | 216 | 32 (14.8) | 2 (1.0) | 30 (13.9) | - | 69 ( 31.9) | 4 1.85) | 40 (18.5) | 1 (0.5) |
| 40-49 | 307 | 62 (20.2) | 5 (1.6) | 49 (15.9) | 4 (1.3) | 113 (36.8) | 3 0.98) | 43 (14.0) | 1 0.3) |
| 50-59 | 257 | 92 (35.8) | 16 (6.2) | 70 (27.2) | 19 (7.4) | 155 (60.3) | 7 2.72) | 82 (31.9) | 5 (1.9) |
| >59 | 38 | 14 (36.8) | 9 (23.7) | 12 (31.6) | 5 (13.2) | 26 (68.4) | 5 13.10) | 18 (47.4) | 2 (13.2) |
| 20-79 | 951 | 223 (23.4) | 34 (3.6) | 187 (19.7) | 28 (2.9) | 414 (43.5) | 20 (2.16) | 219 (23.) | 9 (0.9) |

tal body osteoporosis were three times more than that of femur neck and total femur; these values were 6.23%, 7.39%, 2.72%, and 1.95%, respectively, in age 50-59 years. These ratios were increased to 23.68%, 13.16%, 13.10%, and 13.16%, respectively, in women age more that 59 years.

## Discussion

Osteoporosis is becoming a major health problem worldwide due mainly to increasing life expectancy. The magnitude of this disease is larger in the Middle East Region where the prevalence of low bone mass is higher than in western countries (Maalouf et al. 2007). The diagnosis of this disease is based mainly on the BMD and T-score identified by DXA scan (Kanis 1994; Marshall et al. 1999). However, many studies have indicated that the normal reference values provided by the manufacturers to define the T-score may not be representative of specific populations (Maalouf et al. 2007). These studies have demonstrated the need for establishing an ethnic-specific normative reference database for an accurate diagnosis of the osteoporosis. However, the differences were not only between ethnic groups, also, regional differences have been reported. In the Middle East Region several studies have been performed in an effort to determine the BMD and to compare it to that of Western populations. Reference ranges have been proposed for Lebanese, Saudi, Kuwait, Qatari, Moroccans, Turkish and Iranians women (Wehbe et al. 2003; Larijani 2007). Most of these studies have reported lower BMD than the reference established for the US/European populations. Such Studies of BMD reference data have never been done in Syria. In the current study, DXA scan was used to measure the BMD of lumbar spine (L1-L4), femur neck, femur total, and total body in 951 Syrian women aged 20-79 years. The BMD values of the Syrian women obtained in the current study were compared with those of the Lebanese (Maalouf et al. 2000), Kuwaiti (Mahussain et al. 2006), Moroccan (El-Maghraoui et al. 2006), Qatar (Hammoudeh et al. 2005), Saudi women (El-desouki 1995) for the Arab countries, and the values in some regional countries such as Iran (Hammoudeh et al. 2005), Turkey (Paker et al. 2005), Greece (Hadjidakis et al. 1997), and Italy (Pedrazzoni et al. 2003). Also, our data were compared with those from Asian countries from India (Panti 2010), Taiwan (Chan et al. 2004), Beijing (Yu et al. 1998), and Caucasians (Tobias et al. 1994). Data from European and USA (Panti 2010) were also included in the comparison. Our results have demonstrated that the Syrian women showed the same pattern of increasing the lumbar spine BMD up to age group of 30-39 years and declining later, that was described also for Lebanese, Qatari, Saudi, Turkish, Greek, Indians, Taiwan, Beijing, Caucasians and Europeans. However, The Moroccans, and the Iranians have showed that the BMD peak values were in the age group 20-29 years. The differences in the BMD peak values at maturity may be accounted for by differences in race and life style. Comparing different measurement sites, the BMD peak of the femur neck of Qatari, Saudi, Taiwan, Beijing, and Caucasians were reached in the age groups 40-49,10-20,17-29,20-29,25-29 years, respectively. However, the peak BMD of the femur neck was reached in the age group 30-39 years in the Syrian women. Similar results were reported for the Lebanese, Turkish, Indian, European and USA women. Various studies have showed that the age at which the

peak BMD values are attained is different among skeletal sites, occurring earlier in the femoral region than in the lumbar spine (Paker et al. 2005; El-Maghraoui et al. 2006; Mahussain et al. 2006).

In general, Syrian women have showed a lower BMD at the lumbar spine than the Caucasians, Beijing, USA, and Europeans. Compared with Lebanese, Turkey, Iranian, Greek, Italians, Indians and Taiwan women, Syrian women have showed higher BMD values. However, Syrian women demonstrated similar BMD values at the lumbar spine to that of Morocco, Qatar, Saudi, and Kuwait. The Syrian women have lower BMD at the femur neck than Morocco, but, higher values than Lebanese, Iranian, Greek, Italians, Indians, Taiwan, and Caucasians women. Similar BMD values at the femur neck of the Syrian women to that of Kuwait, Qatar, Saudi, Turkey, Beijing, and USA/ Europeans were detected in this study. Many factors might have contributed to low BMD seen, mainly, in the lumbar spine compared to the Caucasians, Beijing, USA, and Europeans; these are the sedentary life of the Syrian women (low physical activity), biological difference in the rate of bone loss, low exposure to sun shine, multiparity and lactation, low calcium intake, and influence of BMI. Another reason could be the effect of low vitamin D, where insufficiency or deficiency is common cases in the Middle East Region in general. Several studies have indicated that the genetic factors are very important contributor to peak bone mass. These factors account, sometimes, for as much as 80% of the variance in the bone peak value. Recent studies have proposed that polymorphism of the Vitamin D receptor gene has an important effect on BMD in women (Mishal 2001; El-Sunbaty et al.1996).

The prevalence of osteopenia and osteoporosis in the studied group was examined as well. The results of the current study revealed that in the age group 50-59 years 35.80% had osteopenia and 6.23% had osteoporosis as demonstrated by lumbar spine. However, in higher age group of more than 59 years 36.84% had osteopenia and 23.68% had osteoporosis. Similar results were reported in Qatari women were 30% and 5.7% of women in the age group 50-59 had osteopenia and osteoporosis, respectively (Hammoudeh et al. 2005). These ratios increased to 48% and 21% in the age group 60-69 years. Slightly higher prevalence was reported in Turkish women where 40%, 10% of women in age group 50-59 years and 45%, 21% in age group 60-69 had osteopenia and osteoporosis, respectively (Paker et al. 2005). Higher prevalence was reported in healthy Saudi women, where 66%, 28% of women had osteopenia and osteoporosis in age more than 50 years. Much lower prevalence was reported in Kuwaiti women (13.7%, 1.9% in the age group 50-59 and 9.3%, 4.7% in the age group 60-69 years) (Mahussain et al. 2006). In comparison, the prevalence of lumbar spine and femur osteoporosis was higher in the lumbar spine (11%) of Lebanese women and lower in the femur neck (2%) (Maalouf et al. 2000). This can be explained by the higher prevalence of obesity in Kuwaiti women relative to their Lebanese counterparts.

The main limitation of the current study exists in the part related to DXA comparing peak BMD values in women from different countries using different DEXA machines. The three dominant DXA manufacturers are Lunar, Hologic, and Norland. Although the DXA technology is similar for these manufacturers, the BMD results are different due to

different calibration standards, proprietary algorithms to calculate the BMD, and differences in the regions of interest (ROI). In 2015 Park and his team calculated the accuracy and precision of 36 DXA devices from three manufacturers Hologic, Lunar, and Osteosys using a ESP (semi-anthropomorphic (Park et al. 2015). Accuracy was assessed by comparing BMD ($g/cm^2$) values measured on each device with the actual value of the phantom. The BMD comparison in this study demonstrates that BMD results of the three different devices are significantly different between the three devices. Generally, Lunar scanners are more likely to overestimate the BMD values, Hologic scanners underestimate these values. These differences make it difficult to compare BMD measures from different countries. Several approaches were proposed in order to overcome such problem. So far, cross-calibration formulae for Lunar and Hologic devices have been developed (Genant et al. 1995; Hue et al. 1997). This is particularly useful for epidemiologic studies and therapeutic trials that deal with groups of patients (Reid et al. 2006). However, when we apply the cross-calibration equations derived from (Fan et al. 2010) study to convert the data obtained using Hologic machines in studies conducted in Italy, India, and European/USA studies to GE-Lunar (included in the current study for BMD comparison in different populations), we found that BMD GE-Lunar values, as expected, significantly greater than the Hologic BMD values as previously reported by many groups. However, as most of the DXA machines used in the various studies included in our work for BMD comparison were GE-Lunar, that makes our comparison relatively valid.

## Conclusions

This is the first study in Syria to provide a normative data of BMD at lumbar spine, femur neck, total femur, and total body in healthy Syrian women age 18-79 years old. The BMD values reached its peak 1.16(0.12), in the age group of 30-39 for all measurement sites except for the femur total where the peak 0.99±0.13 reached in the age group of 40-49 years. Healthy Syrian women have demonstrated lower BMD at the lumbar spine than the Caucasians, USA, and Europeans. Compared with Lebanese, Iranian, Greek, Italians, Indians and Taiwan women, Syrian women showed higher BMD values. However, Syrian women have demonstrated similar BMD values at the Lumbar spine to that of Morocco, Qatar, Saudi, Kuwait and Turkey. In the age group 50-59 years 35.80% had osteopenia and 6.23% had osteoporosis as demonstrated by T-score of lumbar spine. However in higher age group of more than 59 years 36.84% had osteopenia and 23.68% had osteoporosis. The results of this study indicate the importance of establishing population-specific reference range. High prevalence of osteopenia and osteoporosis was demonstrated in Syrian using the manufacturer reference values.

### Authors' contributions

MAB proposed the objectives of the paper, supervised the work, and the major contributor in writing the manuscript, KBH participated in performing the anthropometric measurements, collecting the participants data; statistical analysis and computing, KMH performed the DXA studies. All authors read and approved the final manuscript.

### Conflict of interest

The authors declare that have no conflict of interest to declare.

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