

# Effect of body mass index on quantitative ultrasound measurements of bone mineral density in Saudi women

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## ABSTRACT

Osteoporosis is a bone density associated disease that causes fading of the bone structure and function, which thereby makes the bone fragile. This fragile bone can be easily fractured as a result of mechanical forces, or events that would otherwise not cause a fracture if the bones were healthy. Most previous studies have been conducted on postmenopausal females. The few studies that have been conducted on a Saudi population have primarily focused on risk factors for osteoporosis in women > 60 years of age or who are postmenopausal. This study aimed to evaluate younger, premenopausal Saudi females, <59 years old to investigate the impact of body mass index (BMI) on bone mineral density (BMD) using a quantitative ultrasound (QUS) machine. Cross-sectional observational study of 100 Saudi women aged 19 to 58 years. Body mass index (BMI) was calculated from each participant's weight in kilograms divided by the square of her height in meters ( $\text{kg}/\text{m}^2$ ). The DMS PEGASUS SMART Bone Densitometer, Mauguio, France, was used for portable quantitative ultrasound (QUS) with a Caucasian ethnicity setting and measurement of the right calcaneus bone. The mean age of the participants was 29.62 year ( $\text{SD} \pm 10.25$ ), range (19 to 58 years). A total of 5% exhibited evidence of osteoporosis and 64% had normal broadband ultrasound attenuation (BUA). The average BMI was  $24.7268 \text{ kg}/\text{m}^2$  and average SOS was 1,390.28 m/s. Spearman's rho showed weak negative correlation between BMI and SOS ( $p = 0.001 \leq 0.05$  and  $r = -.331$ ) and fairly positive correlation between BUA and SOS ( $p = .000 \leq 0.05$  and  $r = .463$ ). Furthermore, none of the participants in the low and normal BMI category showed evidence of osteoporosis. A total of 6.9% of the participants in the overweight BMI category showed evidence of osteoporosis, and 17.6% of those in the obese BMI category had evidence of osteoporosis. In conclusion, low and high BMI were positively correlated with low BMD regardless of age. A BMD screening test using QUS should be considered as primary screening for BMD in pre- and postmenopausal females with low or high BMI, to prevent future development of osteoporosis. QUS should be used for primary screening because it is, portable, fast, efficient, user friendly, widely available and uses non-ionizing radiation.

**Keywords:** Body mass index (BMI), bone mineral density (BMD), osteopenia, osteoporosis, quantitative ultrasound (QUS), osteoporosis screening.

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## INTRODUCTION

Low bone density leads to osteoporosis, a silent disease that causes weakening of the bone structure and function, with resulting fragility fractures due to many factors. Fragility fractures, such as vertebral compression

fractures, occur as a consequence of mechanical forces or events that would not otherwise cause a fracture if the bones were healthy. Thereby, osteoporosis is diagnosed by measuring the bone mineral density.

Bone mineral density (BMD) criteria were summarized by the World Health Organization (WHO) (2003) in their Prevention and Management of Osteoporosis report which included epidemiologic data that described the normal distribution of BMD in a young healthy reference population. Among the various types of bone mineral density measurement tests available, dual-energy X-ray absorptiometry (DXA) is considered to be the most accurate method (Nelson et al., 2010) for measuring bone mineral density and thereby diagnosing osteoporosis. Several previous studies have compared the positive and negative attributes of non-DXA tests to DXA (Nelson et al., 2010). Today, the most commonly used non-DXA test in the United States is quantitative ultrasound (QUS) of the calcaneus bone (heel). The QUS is considered safe because it uses non-ionizing radiation and is portable, easy to use, and cheap. The operating principle behind QUS is based on measuring ultrasound waves through the bone using multiple parameters including broadband ultrasound attenuation (BUA), speed of sound (SOS), velocity of sound (VOS), quantitative ultrasound index (QUI), and stiffness. According to Nelson et al. (2010), the values of these parameters decline whenever low bone density is detected. There are many risk factors for developing low bone density and fractures, including female gender, older age, and a low BMI. These risk factors have been found to be the strongest predictors of low bone density.

Body mass index (BMI) is a measure that assesses nutritional status in adults and is calculated as a person's weight in kilograms divided by the square of the person's height in meters ( $\text{kg}/\text{m}^2$ ) (WHO: Obesity report, 2000).

The BMI is considered a strong predictor of osteoporotic fractures as reported in many studies. In 2014, Hoxha et al. (2014) reported a significant positive correlation between BMI and BMD in the femur neck and total hip. The UK National Clinical Guideline Centre (2012) recommended screening all women aged > 65 years and men aged > 75 years if a risk factor was present, for instance a low BMI ( $<18.5 \text{ kg}/\text{m}^2$ ) (National Clinical Guideline Centre, 2012). Fawzy et al. (2011) also concluded that advancing age and a lower BMI are important risk factors for the occurrence of a low BMD. Another study indicated that both weight and BMI are associated with BMD and found that overweight and obesity reduced the risk for osteoporosis (Salamat et al., 2013).

Some studies, such as that by Hendrijantini et al. (2016), reported a significant correlation between BMD and BMI in postmenopausal women. An interesting finding was the association between a higher body mass index and a higher bone mineral density. However, other studies have indicated that a correlation exists between a higher body mass index ( $> 35 \text{ kg}/\text{m}^2$ ) and lower bone mineral density (Oldroyd and Dubey, 2015; Mishra et al., 2016).

In Saudi Arabia, the Saudi Osteoporosis Society (SOS) guidelines recommend assessing bone mineral density

(BMD) for all Saudi females >60 years old using DXA (Al-Saleh et al., 2015).

Most of the published studies have been performed in postmenopausal females. The few studies that have been conducted in a Saudi population have mainly focused on risk factors for osteoporosis in women >60 years of age or who are postmenopausal. Therefore, this study aimed to include more young Saudi female (premenopausal) age <60 to evaluate the effect of body mass index (BMI) on bone mineral density (BMD) using a quantitative ultrasound (QUS) machine.

## MATERIALS AND METHODS

Cross-sectional observational study of 100 Saudi women aged between 19 and 58 years was conducted during osteoporosis awareness workshops held at Princess Nourah bint Abdulrahman University and Social Development Center in Riyadh. General information, including the participants' age, height, and weight, was collected and recorded on an information form for each subject. Body mass index (BMI) was calculated from each participant's weight in kilograms divided by the square of her height in meters ( $\text{kg}/\text{m}^2$ ). The DMS PEGASUS SMART Bone Densitometer, Maugeio, France, was used for portable quantitative ultrasound (QUS) with a Caucasian ethnicity setting and measurement of the right calcaneus bone.

Broadband ultrasound attenuation (BUA) and speed of sound (SOS) were recorded on each participant's printed report along with a line graph showing normal bone density. The BUA was reported in decibels per megahertz, and SOS was measured as meter per second. Figure 1 shows the relationship between BUA and bone density as printed on the report presented in Figure 2.

Broadband ultrasound attenuation (BUA = dB/MHz) were divided into four categories of normality of bone density, as shown in Figure 1. Bone mass density was classified as normal for BUA>70, below average if BUA was between 65 and 69.9, osteopenia if BUA was between 55 to 64.9, and osteoporosis for BUA<55.

Simple random sampling was applied by the authors, when collecting data. Saudi females aged <60 years were included.

This study was ethically approved by the Institutional Review Board at Princess Nourah bint Abdulrahman University, Riyadh (IRB Log Number: 18-0164). The IRB registration number with King Abdulaziz City for Science and Technology (KACST), Riyadh, Saudi Arabia, is H-01-R-059.

## Statistical analysis

In this study, SPSS 22.0 software was used to create the database and conduct the necessary statistical analysis. All dimension data conforming to a normal distribution was expressed as the mean  $\pm$  standard deviation. Kolmogorov-Smirnov's was used to test the normal distribution of BUA, BMI, SOS, and age. Nonparametric Spearman's rho was used to test the correlations between BMI and BUA, BMI, and SOS, and BUA and SOS. Pearson's Chi-Square test was used to analyze the association between BMI and BMD categories.

## RESULTS

The mean age of the participants was 29.62 year ( $\pm 10.2$ ), range (19 to 58 years). The BUA ranged between 40.54 and 91 dB/MHz, with a mean of 72.2 dB/MHz ( $\pm 8.6$ ) (5%

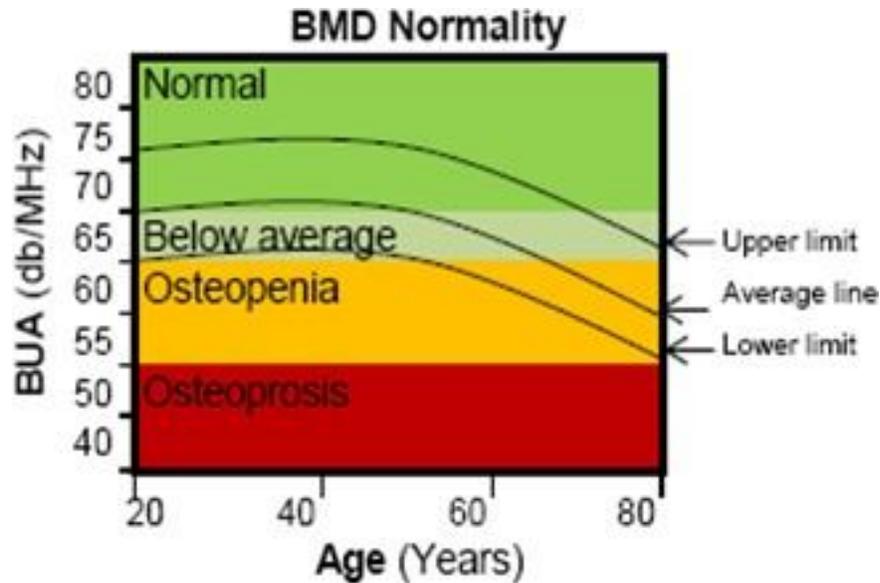


Figure 1. BUA and BMD normality curve (PEGASUS Smart Densitometer).

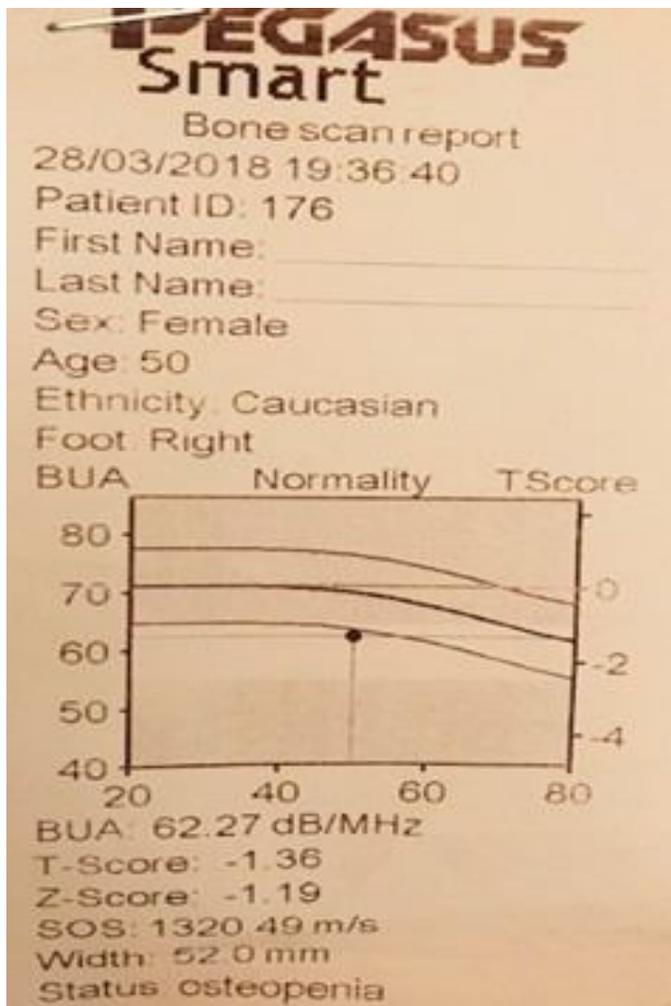


Figure 2. PEGASUS SMART portable QUS bone scan report.

exhibited evidence of osteoporosis, 64% had a normal BUA). The lowest BMI was 15.22 kg/m<sup>2</sup>, and the highest was 45.8 kg/m<sup>2</sup>, with a mean of 24.7 kg/m<sup>2</sup> ( $\pm 5.9$ ) (13% were underweight, and 41% had a normal BMI). The SOS range was 630.4 to 1,539.5 m/s, with an average of 1,390.28 m/s ( $\pm 114.30$ ) as shown in Table 1.

Table 2 shows that the variables BUA ( $p=0.024 < 0.05$ , 100 degrees of freedom), BMI ( $p=0.003 < 0.05$ ), SOS ( $p=0.000 < 0.05$ , 100 degrees of freedom) and age ( $p=0.000 < 0.05$ , 100 degrees of freedom) did not show a significantly normal distribution based on Kolmogorov-Smirnov's test.

Table 3 illustrates a significant (2-tailed) correlation between BMI and SOS ( $p = 0.001 \leq 0.05$  and  $r = -.331$ , weak negative correlation) and between BUA and SOS based on Spearman's rho ( $p = .000 \leq 0.05$  and  $r = .463$ , fairly positive correlation).

Table 4 indicates that none of the participants in the underweight BMI category ( $< 18.5$ ) had evidence of osteoporosis, and 53.8% had a normal BUA; none of the participants in the normal BMI category had evidence of osteoporosis, and 78% had a normal BUA. A total of 6.9% of the participants in the overweight BMI category had evidence of osteoporosis, and 58.6% had a normal BUA. A total of 17.6% of those in the obese BMI category had evidence of osteoporosis, and 47.1% had a normal BUA.

Table 5 shows the significant association between BMI and BUA ( $p = 0.046 \leq 0.05$ ) with 9 degrees of freedom based on the Pearson's chi-square analysis.

## DISCUSSION

As per BUA values, the BMD distribution was 64%

**Table 1.** BUA, BMI, SOS and age.

Variables	Mean $\pm$ SD	Minimum	Maximum	Categories	Percentages
Age	29.62 $\pm$ 10.250	19	58	-	-
BUA_dB/MHz	72.1935 $\pm$ 8.57293	40.54	90.82	Osteoporosis	5
				Osteopenia	15
				Below average	16
				Normal	64
BMI_kg/m <sup>2</sup>	24.7268 $\pm$ 5.93786	15.22	45.79	Underweight	13
				Normal	41
				Overweight	29
				Obese	17
SOS m/s	1390.28 $\pm$ 114.30	630.48	1539.47	-	-

**Table 2.** BMI categories \* BUA categories crosstabulation

Parameter	Kolmogorov-Smirnov		
	Statistic	df	Sig.
BUA - dB/MHz	.096	100	.024
BMI - kg/m <sup>2</sup>	.112	100	.003
SOS - m/s	.201	100	.000
Age - years	.251	100	.000

**Table 3.** BMI categories \* BUA categories crosstabulation.

	BMI and SOS	BUA and SOS
Correlation coefficient	-.331**	.463**
Sig. (2-tailed)	.001	.000
	100	100

**Table 4.** BMI Categories \* BUA Categories Crosstabulation

BMI_Categories		BUA_Categories				Total
		Osteoporosis	Osteopenia	Below average	Normal	
Underweight	f	0	4	2	7	13
	%	0.0%	30.8%	15.4%	53.8%	100.0%
Normal	f	0	6	3	32	41
	%	0.0%	14.6%	7.3%	78.0%	100.0%
Overweight	f	2	3	7	17	29
	%	6.9%	10.3%	24.1%	58.6%	100.0%
Obese	f	3	2	4	8	17
	%	17.6%	11.8%	23.5%	47.1%	100.0%

**Table 5.** Pearson Chi-square test of association between BMI\_CAT and BUA\_CAT.

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	17.148a	9	.046
No. of valid cases	100		

normal BMD, 16% below average BMD, 15% osteopenia and 5% osteoporosis. Although the below average BMD is considered at the lower normal range, individuals are still at risk of developing a low BMD in the presence of risk factors. According to the World Health Organization (WHO), obesity is classified as a BMI  $\geq 30.0$  kg/m<sup>2</sup>, underweight as a BMI  $< 18.5$  kg/m<sup>2</sup>, overweight as a BMI from 25 to 29.9 kg/m<sup>2</sup>, and normal as a BMI from 18.5 to 24.9 kg/m<sup>2</sup> (World Health Organization, 2000). Based on these definitions, 17% of participants were obese, 29% were overweight, 41% were normal weight and 13% were underweight.

While SOS had a fairly positive correlation with BMI, BUA was weakly correlated with BMI in this study. In fact, SOS and BUA reported from PEGASUS QUS showed lower reading level compared to a study reported by Sadat-Ali et al. (2010) which was conducted using Achilles Express, GE, to define Saudi women reference values upon which to base a diagnosis of low bone mass, using quantitative ultrasound portable scanner. For instance, according to Sadat Ali et al. (2010), the average BUA and SOS were  $114.4 \pm 12.1$  and  $1,547.32 \pm 39.1$ , respectively for healthy Saudi women aged 20-29 years. In this study, however, the BUA and SOS were  $77.5 \pm 4.3$  and  $1,431 \pm 38.8$ , respectively for the same age group. A possible explanation for the difference in results between this study and the study by Sadat-Ali et al. (2010) might be the difference QUS scanners used.

In this study, a total of 10% of all participants who were classified as positive for osteopenia and osteoporosis had a BMI  $\geq 25$  kg/m<sup>2</sup>. Furthermore, 11% were found in this study to be at risk for developing osteopenia and osteoporosis if they did not maintain their BMI within the normal range and they were thereby considered at risk for low BMD as suggested by previous studies. On the other hand, 10% of the participants, in this study, with a BMI  $\leq 24.9$  kg/m<sup>2</sup> had osteopenia, and 5% were not diagnosed with osteoporosis but were considered to be at risk (below average BMD) for getting the disease in the normal BMI group, between 18.5 and 24.9 kg/m<sup>2</sup>, 78% had normal BMD compared to BMI below and above this range, which shows that approximately 50% only were considered to have normal BMD.

In this study, 50% of low BMD was classified with high BMI  $\geq 25$  kg/m<sup>2</sup> which confirm with the findings by previous studies (Oommen et al., 2014). For instance, Watts et al. (2014) reported in his cohort study of osteoporosis, in 60,393 women aged  $\geq 55$  years in ten countries from three continents, that obesity is protective against hip fractures but is associated with

an increased risk of fractures of the ankle and lower leg. In contrast, 20% of diagnosed low BMD in our study were underweight. This result relates to findings from previous studies showing that increased weight increases bone health and vice versa (Kumar et al., 2016). De Melo et al. (2015) identified that one of the main risk factors for low lumbar and femoral BMD in Cross-sectional study of 109 postmenopausal women were low BMI. Another study by Zhao et al. (2008) exploring the clinical, epidemiologic, and patho-physiologic relation among obesity and osteoporosis showed that high BMI is correlated with high BMD and that low BMI causes bone loss. Furthermore, Palermo et al. (2016) summarized their review of 207 studies to illuminate that the relationship between BMI, BMD and risk of fractures to weight loss is generally associated with a decrease of mineral content and density.

Lee et al. (2010) summarized the risk factors for osteoporotic fracture on 9351 male and female Korean participants using QUS measurements of BMD for the radius and tibia, and they reported that the lower BMI were significantly associated with increased fracture risk.

Based on all mentioned studies we can say that women with either a low or high BMI, regardless of their age, can be considered at risk for developing low bone density, and should be encouraged to live a healthy life style and maintain their BMI within normal range.

The results from the current study are in agreement to those from mentioned before studies which showed that QUS parameters such as BUA and SOS can be used as effective, safe, and rapid measurements for evaluating bone mineral density status for all women with risk factors such as a low or high BMI.

### Significance of this study

This study shows that low BMD which can be led to osteoporosis also is frequent in younger women and that we should also include them in our awareness and screening programs to decrease their risk factors.

### Conclusions

Both low and high BMI are positively correlated with a low BMD, irrespective of age. A BMD screening test using QUS should be considered as primary screening in pre- and postmenopausal females with a low or high BMI to prevent the development of osteoporosis later in life. The

QUS modality is safe, uses non-ionizing radiation, portable, fast, efficient, user friendly and widely available. The QUS reference values are not applicable to measurements using machines from different vendors, for that; it is highly recommended that the vendors and researchers should develop normative reference values for each device based on the predominant ethnicity.

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This research was ethically approved by the Institutional Review Board at Princess Nourah bint Abdulrahman University, Riyadh (IRB Log Number: 18-0164). The IRB registration number with King Abdulaziz City for Science and Technology (KACST), Riyadh, Saudi Arabia, is H-01-R-059.

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