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Age-dependent changes in bone mineral density for males and females aged 10-80 years

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Abstract.
BACKGROUND: One of the most accurate and highly reproducible techniques is dual- energy x-ray absorptiometry (DXA). DXA device used to measure BMD, BMC, T-score, Z-score, and consequently used to measure fat mass (FM) and lean mass (LM) for different body sites such as arms, ribs, thoracic spine, lumbar spine, pelvis, legs and whole body. DXA technique is widely used in clinical application researches like diagnosing and treating osteoporosis in elderly men and women with different diseases and assessment of skeleton status.
METHODS: One hundred and seventy-six males and females participated in the current study consisting of 48 males and 128 females were evaluated by Dual Energy X-ray Absorptiometry (DXA)**.**
RESULTS: The estimated correlation coefficients values were as follows: total BMD depending on segmental BMD of arms, legs were fitted with correlation coefficient of ($r=0.92$) and ($r=0.91$) respectively; also it were fitted with ($r=0.85$), ($r=0.84$), ($r=0.73$), ($r=0.70$), and ($r=0.65$) for head, pelvis, ribs, thoracic spine and lumber spine respectively; $p<0.0001$.
CONCLUSION: The mean total bone mineral density BMD of the total body for both genders shows highly significant ;(p-value = 0.0001) through the ages (20-29). The same results are shown in the ages of (60-69) years with a significant relationship between males and females; ($p= 0.01$). All the other groups (10-19), (30-39), (40-49), (50-59) and (70-80) years showed no significant relationship between both genders, where all mean total BMD amounts were small in female subgroups; $p>0.01$.
KEYWORDS: Dual energy x-ray absorptiometry, bone mineral content, bone mineral density, T-score, Z-score.

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INTRODUCTION

Body composition densitometry is a useful method for measuring and detecting of bone status through measuring bone mineral content (BMC), bone mineral density (BMD), and diagnosing osteoporosis in addition to knowing the influence of bone metabolism.[1,2] The last few decades show several methods which have been used to measure the bone mineral density (BMD) like quantitative ultrasound, DXA and computed tomography.[3-7] One of the most accurate and highly reproducible techniques is dual-energy x-ray absorptiometry (DXA). DXA device is used to measure BMD, BMC, T-score, Z-score, and also used to measure fat mass (FM) and lean mass (LM) for different body sites such as arms, ribs, thoracic spine, lumbar spine, pelvis, legs, and whole body. DXA technique is widely used in clinical application researches like diagnosing and treating osteoporosis in elderly men and women with different diseases to determine the bone quality and skeleton status. The condition of patients with low bone density which followed up before and after treatment can also be observed. For these reasons, DXA is gaining international acceptance as a body-composition reference method.[3]

Osteoporosis causes weakness in the bone by decreasing bone mineral density (BMD) and bone strength. It is called the silent disease because having no symptoms until a fracture occurs in the bone. Women after menopause are exposed to osteoporosis because of decreasing in estrogen hormone levels which responsible for calcium balance in the body. European studies show fractures have reached 3.79 million, and over 300 million individuals are already suffering from osteoporosis in post- menopause ages.[3] Other studies show that there are more than 44 million people in America diagnosed with osteoporosis in the USA, 55% of the population over age 52 years, which affects the role in medical services and support for the injured, and about 30% of postmenopausal women In the USA are suffering from osteoporosis.[2-4]

The correlation between the total and segmental bone mineral density (BMD) in a wide range of ages was calculated. The prediction equations of the total BMD based on the segmental part, the distribution of BMD for both sexes, and the model of correlation regarding the total BMD with the segmental sites were also studied and discussed. Furthermore, the assessment of the linear regression between total and segmental bone mineral density during ages (10-70) years and more were also performed.

MATERIALS AND METHODS

The study included the participation of 176 persons; 48 male and 128 females aged (10-80) years from the local community of the city of Mosul in Iraq. Ethical permission was obtained in the College of Medicine, Nineveh University by the scientific section.

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The research is conducted as a propriety study at the DXA laboratory in the Medical Physics Unit of the Physiology Department in Medical College at Nineveh University in Iraq. Exclusion criteria from the study protocol were: rheumatic bone disease, history of rickets or osteomalacia, congenital liver and kidney diseases, and corticosteroid therapy for more than 6 months.

The scanner is an x-ray source uses two energy levels of 40 and 70 keV by using DXA machine (Dual Energy X-ray Absorptiometry) type STRATOS densitometer from DMS group, France.[1-2, 5-6] The scanning process takes (10-15) minutes in the whole body scan. The participants are asked to remove all metal accessories during the scanning.[5] Anthropometric data like height, weight, and body mass index (BMI) were calculated for all participants. The body weight (kg) was measured by using a digital scale while the height (m) was scaled by using a stadiometer. The body mass index (BMI) was calculated using the following equation:[2-3, 7]

$$BMI = \frac{Weight}{(Height)^2} \qquad (kg/m^2) \qquad \ldots\ldots\ldots\ldots (1)$$

DXA machine measures the following values: bone mineral content (BMC), bone mineral density (BMD), fat mass (FM), and lean mass (LM).[3] The scanner provides data about the whole body and segmental parts (head, ribs, spine, pelvis, arms, and legs).[8-9] The T-score and Z-score classified as in Table 1:

Table 1. T-score and Z-score criteria[6,10-11]

Status	Criteria
Normal	T-score at -1 and above
Osteopenia (low bone mass)	T-score between -1 and -2.5
Osteoporosis	T-score at or below -2.5

where T-score and Z-score are calculated by using the Equations 2 and 3 as follows:[6]

$$T\ score = \frac{aBMD_{patient} - aBMD_{young\ adult\ mean}}{SD_{young\ adult\ mean}} \qquad \ldots\ldots\ldots (2)$$

$$Z\ score = \frac{aBMD_{patient} - aBMD_{age-ethnicity-matched\ adult\ mean}}{SD_{age-ethnicity-matched\ adult\ mean}} \qquad \ldots\ldots (3)$$

STATISTICAL ANALYSIS

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The data provided by the DXA machine were analyzed using the program SPSS (Statistical Package for Social Sciences) version 19. Descriptive statistics including frequencies, proportions, and means ± SD were calculated for all relevant variables. Linear regression and its coefficients, correlations between data values were also calculated. The differences were considered to be significant at the level $P<0.05$. The associations between each BMD variable (i.e., Arms, pelvis, legs, and total) were modeled using linear regression analysis.

RESULTS

Descriptive statistics of the subjects according to their anthropometric measurements are shown in Table 2. The mean (age ± SD) of the participant group was (50.32±17.73) years consisting of (37.81±17.03) years for males and (55.13±15.55) years for females. The mean (height± SD) was (1.60±0.10) m, (1.74±0.05) m for males and (1.56±0.08) m for females, while the mean (weight ± SD) was (75.56 ±15.79) kg, (75.48±13.78) kg for males and (75.59±16.55) kg for females, Finally, the body mass index (BMI±SD) appeared as (29.60 ± 6.89) kg/m^2, (24.80±4.33) kg/m^2 for males and (31.44±6.81) kg/m^2 for females.

Table 2. Descriptive characteristics of the participants (N=176)

	Minimum	Maximum	Mean	Std. Deviation
Age (year)	16.00	80.00	50.32	17.73
Height (m.)	1.30	1.83	1.60	0.10
Weight (kg)	44	141	75.56	15.79
BMI (kg/m^2)	15.92	56.48	29.60	6.89

Table 3 shows the body mass index (BMI) distribution according to gender for all studied groups as well as the percentages for every subgroup.

Table 3. BMI distribution among each subgroup

BMI Classes	Male		Female	
	N=48	No. (%)	N=128	No. (%)

Normal	28	(60.9%)	18	(39.1%)
Overweight	12	(23.1%)	40	(76.9%)
Obese	8	(10.3%)	70	(89.7%)

Figure 1 explains the distribution of the age-related the mean total bone mineral content (BMC) for the whole body according to age groups (each 10 years category) between both genders.

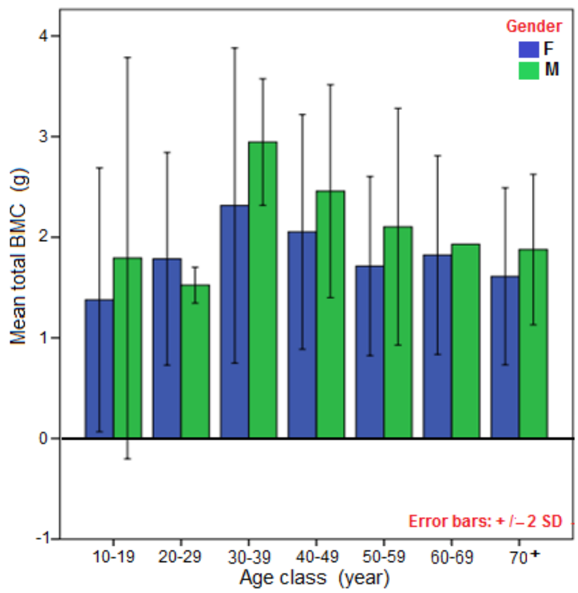

Figure 1. Graphical plot of the mean total BMC distribution for both genders

The results recorded in Table 4 explain the values of the mean bone mineral content (BMC ± SD) in the organs, arms, ribs, thoracic spine, the lumbar spine, pelvis, legs, and head, as well as the total body for both genders; male and female.

Table 4. Mean bone mineral content (BMC ± SD) in different organs

Organ	Mean bone mineral content (BMC ± SD (kg)		
	Both genders	Male	Female
Arms	0.25±0.07	0.27± 0.11	0.23±0.07

Ribs	0.30±0.09	0.32±0.12	0.29 ±0.09
Thoracic spine	0.12±0.05	0.13±0.05	0.11±0.08
Lumbar spine	0.05±0.05	0.09±0.11	0.04±0.03
Pelvis	0.25±0.07	0.26±0.09	0.25±0.06
Legs	0.71±0.16	0.80±0.20	0.70±0.15
Head	0.39±0.10	0.43±0.10	0.38±0.09
Total body	1.84±0.57	2.21±0.66	1.78±0.53

However, the distribution of bone mineral density (BMD± SD) of the of the participants for the whole or total body according to age category for both genders at different period of age (each 10 years interval) can be represented by a graphical plot as in Figure 2, and their values are given in Table 5.

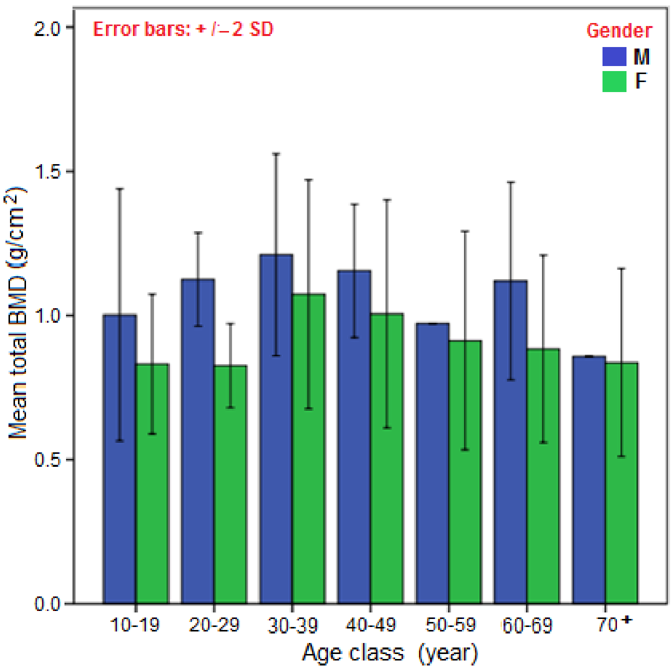

Figure 2. Graphical plot of age-dependent mean total bone density (BMD±SD) distribution for both genders.

Table 5. Age-dependent mean total bone mineral density (BMD±SD) for both genders.

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Age period (year)	Mean total bone mineral density (BMD ± SD) (g/cm^2)	
	Male	Female
10-19	1.02±0.21	0.83±0.12
20-29	1.12±0.08	0.82±0.07
30-39	1.21±0.17	1.07±0.19
40-49	1.15±0.11	1.01±0.19
50-59	0.97±0.01	0.91±0.18
60-69	1.11±0.17	0.88±0.16
70-80	0.85±0.02	0.83±0.16

The mean BMC of the total body reviled a higher content at the age period (20-29) years in females than that in males. Accordingly, it is found that the mean BMC of the total body at the age period categories (10-19), (30-39), (40-49), (50-59), (60-69), and (70-80) years are higher in males as it is clear in Figure (1). On the other hand, the mean BMD of the total body for all considered age periods (10-80) years appeared higher in males than that in females as shown in Figure 2.

According to body mass index (BMI) classification, the mean T-score of the total body shows that in all subgroups the amount of a healthy, overweight, and obese was high in males compared to female ones. Noticing Figure 3, it is shown that according to the BMI distribution, the participants of the healthy subgroup is lying in a class of osteopenia (-2.0) for females versus of (-1.51) for males, whereas for the overweight subgroup lies in the class of osteopenia (-1.35) for females group and for males it belongs to a class of normal (-0.83). lastly, the mean T-score of the total body in the obese subgroup returns to a class of osteopenia (-1.06) for females and to a class of normal (0.25) for males.

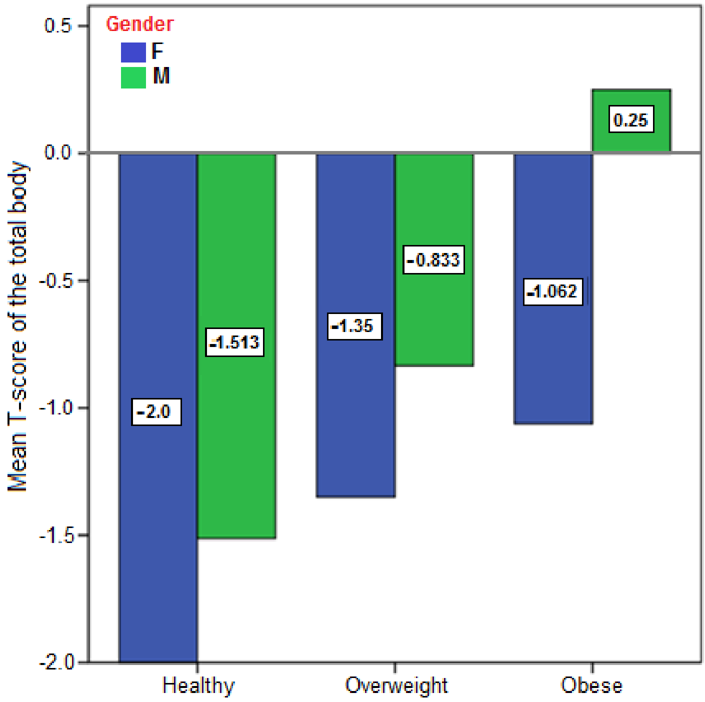

Figure 3. The mean T-score distribution among the participants according to the body mass index (BMI)

Figure 4. shows the graphical plot of the T-score of the total body as a function of age groups for both genders male and female. It was found that the T-score of the total body is belonging to a class of osteopenia for both male and female groups aged (10–20) years with -1.33 and -1.33 respectively. It is also found the T-score lies in osteopenia class (-1.03, -1.50) and (-2.0, -2.05) for both males and females in the subgroups aged (20-29) and (70+) years of respectively.

For subgroups aged (30-39) and (40-49) years, the measured T-score belonged to a normal class with values (0.75, 0.17) and (-0.33, -0.38) for both males and females respectively. On the other hand, the subgroup aged (50-59) years showed two statuses; a normal class for males groups with value -0.33 and osteopenia class for females with value -1.34. The results have shown a variation in the values of T-score for the group aged (60-69) years between osteoporosis class of -4.0 in males and osteopenia class of -1.58 in females as shown in figure (4).

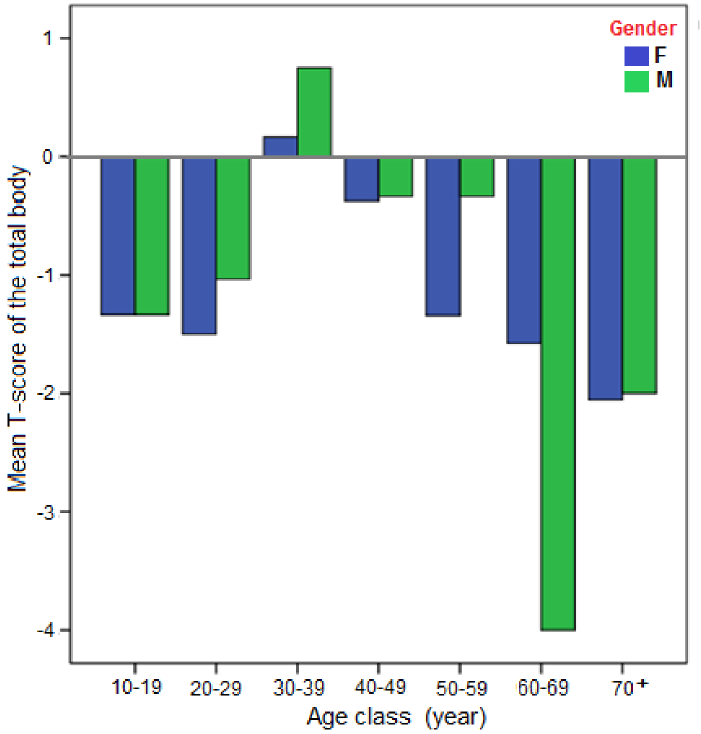

Figure 4. The mean T-score for male and female age groups.

A scattered plot and fitted regression lines between both total and segmental bone mineral density (BMD) in the arms are depicted in Figure 5; p<0.0001. Figures 6 and 7 also show the scattered plot and fitted regression lines between both total and segmental bone mineral density (BMD) in pelvis and legs; p<0.0001. The total BMD as a function of the correlation between BMD of the total and total T-score is given in Figure 8.

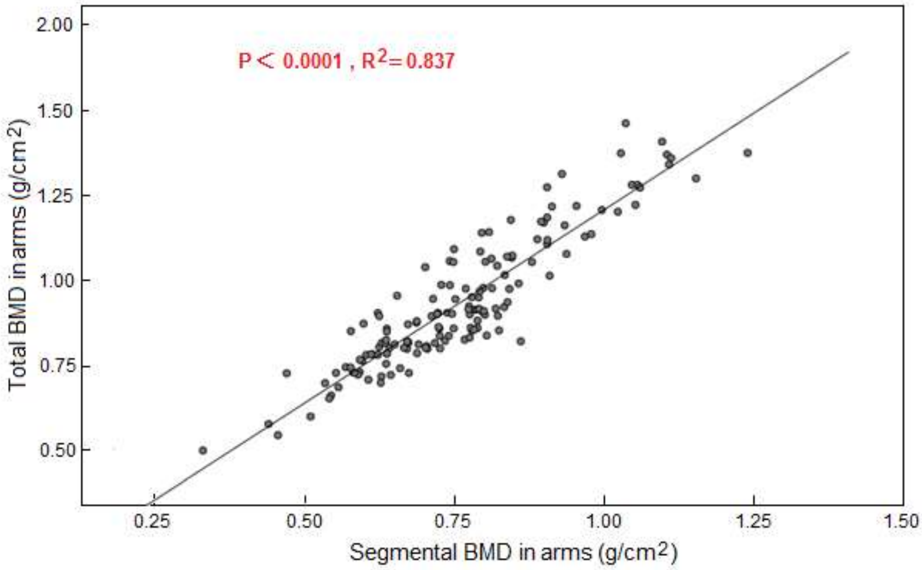

Figure 5. Correlation between BMD of the total and segmental arms.

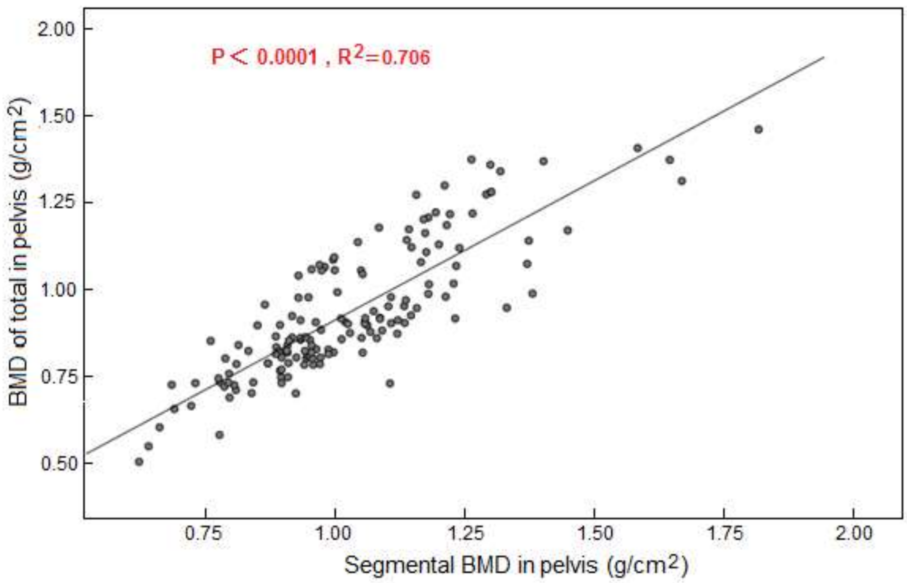

Figure 6. Correlation between BMD of the total and segmental pelvis

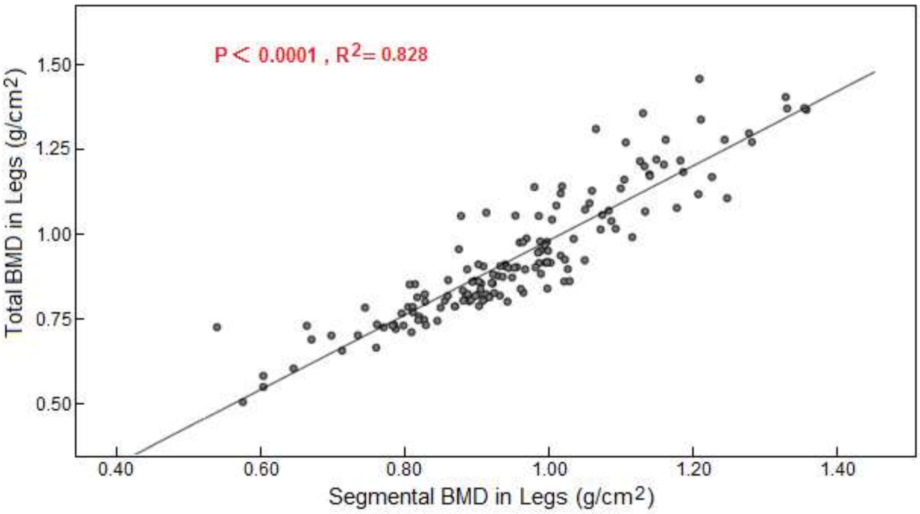

Figure 7. Correlation between BMD of the total and segmental legs.

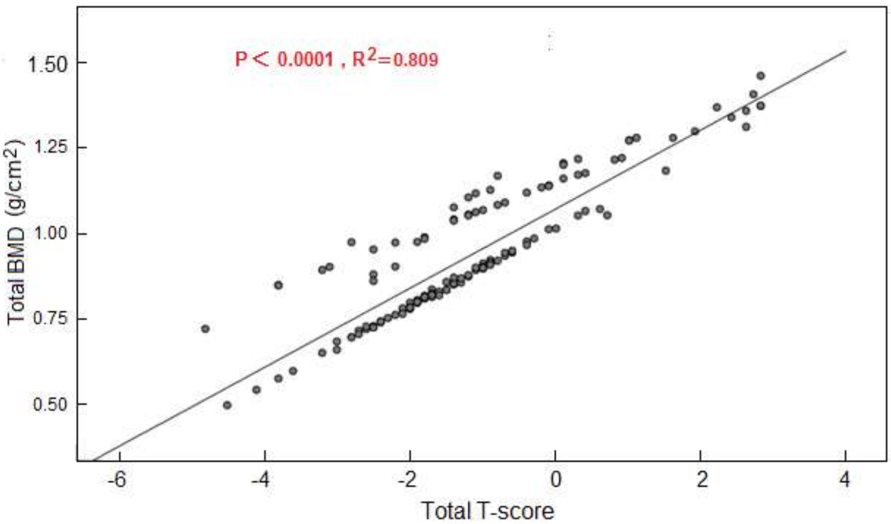

Figure 8. Correlation between total BMD and total T-score.

In other words, the values of the estimated correlation coefficients (in descending form) were as follows: total BMD depending on segmental BMD fitted with a correlation coefficients r=0.92 and r=0.91 for the arms and legs, then followed by correlation coefficients r=0.85, r=0.84, r=0.73, r=0.70, and r=0.65 for the head, pelvis, ribs, thoracic spine and lumbar spine respectively as shown from Figures (5-8); p<0.0001.

Extensive correlation and regression analysis have been used to assess total bone mineral density estimated with segments part of the body. The equations presented in Table 6 can be used to estimate different body segments to yield the corresponding estimated total BMD. These prediction equations are developed using independent variables: BMD head, BMD arms, BMD ribs, BMD thoracic spine, BMD lumbar spine, BMD pelvis, and BMD legs to determine the total BMD. On the other hand, the values of the determination coefficient (R^2) for all prediction equations showed that the independent variables mentioned above might explain at least 71%, 83%, 53%, 49%, 42%, 70% and 82% of the variability in each predicted value of the total BMD respectively as shown in Table 6.

Table 6. The prediction equations for each segmental part of the body

Body Segment BMD	r	R^2	p-value	Prediction equations Total BMD
arms	0.92	0.83	0.0001	= 0.057+ 1.15× (BMD arms)
ribs	0.73	0.53	0.0001	= 0.27+ 0.91× (BMD ribs)
thoracic spine	0.70	0.49	0.0001	= 0.29+ 0.56 ×(BMD spine)
lumber spine	0.65	0.42	0.0001	= 0.43+ 0.40×(BMD lumber spine)
pelvis	0.84	0.70	0.0001	= 0.08+ 0.82×(BMD the pelvis)
legs	0.91	0.82	0.0001	= -0.12+ 1.09×(BMD legs)
head	0.85	0.71	0.0001	= 0.24 + 0.41×(BMD head)

Table 6 shows estimated correlation coefficients (r), determination coefficients (R^2), p- value and prediction equations for each predictors using the following formula:[12]

$$Dependent\ variable = constant + B_1 \times (independent\ variable\ "segment\ part")$$

and can be formulated as:

$$Y = B_o + B_1 . X \qquad \ldots\ldots\ldots..(4)$$

where Y represents the value of the variable being predicted, B_o is the y-interception, B_1 is the slope of the straight line, and X is the value of the independent variable (segment part) which already known.

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DISCUSSION

The study provides new insight into a group of males and females of the Iraqi population regarding their bone mineral content (BMC), bone mineral density(BMD), T-score, and Z-score. Previous studies used techniques like quantitative ultrasound, x-ray radiography, and invasive quantitative computed tomography QCT-scan.[13-15] In the present study, we have used the modern dual-energy X-ray absorptiometry (DXA) technique to analyze segmental and total body composition, and also to show differences in the body composition according to the age for both genders; males and females. Whatever, it is useful to use the DXA technique by applying a small dose of X-ray, which provides highly accurate measurement of bone status of segmental and total human body composition.[16]

The mean total bone mineral content (BMC) of the body composition in both genders has achieved great importance since it was highly significant and more by 39% ($p<0.001$) for females subgroups in the age period (20-29) years. This increment is due to the lower and limitation of the males' numbers that participated in the studied samples. In contrast, the results show that the mean total BMC of the body is also highly significant for age period (60-69) years, and it is greater in males subgroups rather than females ones by an amount 41%; $p<0.0001$. Once again, high statistical significance has emerged at ages groups (30-39), (40-49) years, where the mean BMC were bigger in the subgroups of males compared with females by 28% and 22% respectively; $p<0.001$.

With regard to age groups (10-19), (50-59), and (70-80) years, although the mean BMC was greater in males than females by 9% and 11% respectively, the statistical results did not show any significance during the comparison between both genders. Thus, it is found that the result is in a good agreement with that concluded by Oddom et al.[17], who mentioned that the life for a lifetime was associated with a reduction in the rate of bone mineral content (BMC) loss at all skeletal sites among participants aged 50 and older.

The mean total bone mineral density (BMD) of the total body for both genders shows a highly significant relationship between males and females through age period (20-29) year with increases of 26% ($p= 0.0001$) over the female subgroup which due to the low participation number of males in the studied sample. The same results of significant relationship also appear in the group aged (60-69) years where the amount of mean total BMD is greater in the male subgroup by 20 %; ($p= 0.01$). The lower in bone density indices of overage women are consistent with previously published studies.[3,17] However, the rest groups aged (10-19), (30-39), (40-49), (50-59) and (70-80) years showed no significant relationship between both genders since all the mean total BMD amounts have fewer values in female subgroups by 17%, 11%, 13%, 6%, and 2% respectively. This figure matches the conclusion of Hou Yl et al.[15] who proved that the rapid loss of bone mineral density which occurs between both sexes over the age of 60

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years becomes an important factor in increasing the incidence of the femur and lumbar fractures.

Throughout the advanced calculation in our study, the T-score of the total body at the age period (20-29) year showed a statistically significant relationship between males and females; (p=0.001) with a certain increase in the male over female subgroups. Accordingly, the female subgroup appeared it lies in a class of osteopenia of (T-score= -1.63) while the male subgroup returns to a normal healthy case of (T-score=-0.72). All the other groups represented by the periods (10-19),(30-39), and (60-69) years showed no significant increase in T-score for the male subgroup. Though the increase in T-score for the male subgroups there is no statistical significance be shown by the age groups (40-49),(50-59), and (70-80) years one which confirms the fact that the bone loss is a direct effect for menopause.[19] The lower bone status indices of post-menopausal women are consistent with previous studies.[20-22]

The results in-depth analysis of the Z-score of the whole body showed that it is high in males in all studied age groups compared to the female ones, and there is no significant between them; p>0.05. Accordingly, using the Body Mass Index (BMI) classification and consequently the mean T-score and Z-score of the total body the results were low. In a healthy subgroup both T-score and Z-score of the mean total body shows that the results are not statistically significant with low values in females than male ones ; p>0.05. In the overweight subgroup it is seen that T-score is not statistically significant and low valued in females; p>0.05, While Z-score is highly significant but also low valued in females ; p<0.0001. In the same context, both T and Z- scores during the obese subgroup have no statistically significant but it is high in males; p>0.05.

CONCLUSION

The mean total bone mineral density BMD of the total body showed highly significant between males and females; (p=0.0001) through the ages (20-29) years. The same results appeared in ages (60-69) years with a significant relationship between both genders; (p= 0.01). All the other considered groups aged (10-19), (30-39), (40-49), (50-59), and (70-80) years have shown no significant relationship between males and females, where the mean total BMD for all studied cases was low in the female subgroups ; p>0.01. From the results obtained above, we can generally conclude that the bone mineral density in males was higher than the proportions found in females for all specified age periods. The results are scientifically consistent with the that presented by Alswat.[23] These results may be attributed to several reasons, one of which is the social traditions and restrictions of the population during their lifetime (such as type and form of clothing and housing ..etc) that may reduce the amount of sunlight reaching the body skin,[24]. This in turn causes a deficiency of vitamin D in females, that gained from the sunlight exposure. Another reason is the restricted physical exercise as a consequence of social and religious barriers may reduce or prevent the females from practicing daily sporting activity causing a loss in bone mineral density. which negatively affects the metabolism of bone and minimize the bone formation within the body.[25] Finally, the lack of estrogen hormone plays an important role in the development of osteoporosis in both sexes when detected in women during a menopause period compared to men.[26]

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