Association between Obesity and Osteoporosis

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ABSTRACT

Background: Persons with high body mass index (BMI); in particular those with BMI at the range of obesity (≥ 30 Kg/M2) are protected from osteoporosis to some extent. Osteoporosis is a multi-factorial disorder responsible for significant morbidities and mortalities, essentially in post-menopausal women.

Objective: To evaluate the relationship between the body mass index and some other risk factors with osteoporosis and to define the cutoff point of body mass index at which the protective effect against osteoporosis/osteopenia will be defined.

Methods: A case-control and correlation study. It was conducted at the Rheumatology Outpatient Clinic and the Dual Energy X-ray Absorptiometry unit of Al-Jumhury Teaching Hospital in Nov.1st, 2011 through June 1st, 2012. Three hundreds and thirteen postmenopausal female patients whose ages ranged between (45-90) years including 100 with a body mass index of (18.5-24.9) as a control and 213 patients with a body mass index of ≥ 25 Kg/m^2. The cases were randomly enrolled in the study. The patients and controls were subjected to clinical assessment, anthropometric measurements of length, weight, body mass index, the necessary related biochemical tests, and the Dual Energy X-ray Absorptiometry (DXA) examination for the measurement of bone mineral density. Osteomalacia and secondary causes of osteopenia and osteoporosis were excluded. The physical activities, socioeconomic status, educational level and previous history of fracture were also recorded.

Results: The data of this study proved that there is a decrease in the percentage of osteoporosis as the body mass index increase with a high significant difference (P-value= 0.0001) as compared to that with normal body mass index patients. The body mass index of 25 Kg/m^2 was defined as the cutoff point below which the incidence of osteoporosis will increase. The sedentary lifestyle with low physical activities, low educational level, history of previous fractures and low socioeconomic status were notice to be risk factors for the development of osteoporosis.

Conclusion: The body mass index at a level of ≥ 25 Kg/m^2 has a protective effect on the bone mass, so that the percentage of osteoporosis/osteopenia clearly declines at such level.

Keywords: Body mass index, Dual-energy X-ray, Absorptiometry, Obesity, Osteopenia, Osteoporosis.

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Osteoporosis is a common health problem in Iraq but unfortunately, the real prevalence and socioeconomic burden of the disease are underestimated. Osteoporosis is characterized by a reduction in bone mass. It is typically defined in an individual with a decline in the bone mineral density (BMD) and 'T-score' of ≤ −2.5 according to Dual Energy X-ray absorptiometry (DXA) examination[1].

An inverse relationship between the osteoporosis and high body mass index (BMI), especially in those in the range of obesity is a well-known fact. According to WHO definition, the obesity is defined as those having a body mass index ≥ 30 kg/m² as it is commonly used to measure the degree of obesity; primarily because it is easy to calculate[2]. The relationship between the osteoporosis and obesity are a complex one, and the precise underlying cause(s) for this relation is a matter of continuous dispute; however, the interaction between the genetic and environmental components is the major

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explanation for this relation[2]. It is generally accepted that a larger body mass imposes a greater mechanical loading on the bone and that the bone mass increases to accommodate the greater load. Some studies proved this relationship and found that a high BMI is associated with a higher bone mass, and vice versa[3-5].

Postmenopausal women have their estrogen resource from the adiposities and through the presence of estrogen, osteoclasts will inhibit bone resorption. Postmenopausal women with increasing BMI will have more estrogen production, which will result in an increase in bone mass through the inhibition of bone resorption[6].

Lastly, the similarities between obesity and osteoporosis could be due to the pathophysiologic linkage[7].

The aim of this study is to evaluate the relationship between the body mass index and some other risk factors with osteoporosis and to define the cutoff point of BMI at which the protect effect against osteoporosis begins.

Methods

The present study had the approval of the regional research committee of Mosul Health Administration, and the Scientific Research Committee of the College of Medicine, University of Mosul - Iraq. This study was performed in the period Nov.1st, 2011 through June 1st, 2012 in the Rheumatology Outpatient Department at Ibn Sina Teaching Hospital and Dual Energy X-ray Absorptiometry unit at Al-Jumhury Teaching Hospital in Mosul city.

Three hundred and thirteen (313) postmenopausal women with ages between (45-90) years were randomly enrolled in this case-control and correlation study after their consents had been taken into consideration. The patients, including the controls, were consulting the Rheumatology Outpatient Clinic of Ibn Sina Teaching Hospital complaining of varieties of musculoskeletal problems not necessary to be related to osteoporosis. The patients were divided into two groups according to the results of their body mass index. A group consists of a hundred (100) postmenopausal women with BMI 18.5-24.9 Kg/M^2 (a control group) and a second group (patients) consists of (213) postmenopausal women with BMI ≥ 25, and three subgroups: overweight, obese and morbid obese (The Practical Guide Identification, Evaluation, and Treatment of Overweight and Obesity in Adults)[8], (Table 1).

Table 1: The body mass index and the nutritional status.

BMI	Nutritional (weight) status
Below 18.5	Underweight*
18.5 – 24.9	Normal weight
25 – 29.9	Pre-obese (overweight)
30 – 39.9	Obese (class I and II)
Above 40	Morbid obese (class III)

*This group was excluded from the study.

Inclusion criteria: Postmenopausal females whose ages range between (45-90) years.

Exclusion criteria: Patients with the following conditions were excluded from the study: Underweight (BMI < 18.5), smokers, pre-menopausal women, patients on steroid for more than 3 months, patients with disability for more than 3 months, and patients with osteomalacia, autoimmune diseases like rheumatoid arthritis, recent incidental fractures caused by high-impact trauma such as car and motor vehicle accidents.

The studied groups were subjected to clinical assessment, anthropometric measurement, laboratory tests, and bone mineral density (BMD) assessment.

The clinical assessment was performed in Rheumatology Outpatient Clinic through a direct face to face interview with the patients by investigator. A special questionnaire form was used to record the patient's age, present and previous medications, the education level of the patient and her husband, physical activity of the patient, her marital status, the history of fracture, and any disease or condition that may consider as a secondary cause of osteoporosis.

The majority (276) of our patients was above 50 years of age and only 37 out of total 313 patients were aged between 45-50 years (below 50). All women in the study sample were at menopause. We select these age groups because the most typical age for menopause is between the ages of 40 and 61 years as studies suggest[9,10].

The potential effect of physical activities was also taken into consideration and their activities were recorded and classified according to the following:

1- Active: At least 30 minutes of continuous activity 6 times /week.

2- Moderate: At least 30 minutes of continuous activity 3 times /week.

3- Mild: At least 30 minutes of continuous activity 1 time /week.

4- Sedentary: None/week.

To evaluate the effect of educational level of the patients and their husbands as a reflection of their socioeconomic status on osteoporosis, patients were divided into two groups:

1- Group one includes; the illiterate and primary school level education.

2- Group two includes; the secondary school and higher level education.

Furthermore, the patients had been divided into those with a history of previous fracture and those without fracture to study the relationship between fractures history and the percentage of osteoporosis among them.

The anthropometric parameters (weight, height, and BMI) were measured during the first visit. A calibrated anthropometric scale with a stadiometer (Seca; made in Germany) was used to record weight and height of barefooted (no shoes) and light clothing patients. The BMI was calculated using a digital scale (calculator) according to the following equation: Weight in kilograms (Kg)/(Height)^2 in (M).

Laboratory tests: included the measurement of serum alkaline phosphatase, serum calcium, and serum phosphorus. Other specific individualized tests were indicated only in cases of suspected secondary causes. These tests were performed at Ibn Sina Teaching Hospital laboratories.

The assessment of bone mineral density (BMD) was performed in the DXA unit of Al-Jumhury Teaching Hospital in Mosul city, through a Dual-energy X-ray absorptiometry (DXA) [*DXA- machine (Lunar DPX). HOLOGEC, Denmark 2009-2010*]. An anterior-posterior (AP) scanning of the spinal vertebrae was the technique used in this test. The BMD is based on the T-scoring test, and according to this test, a T-score of -1.0 or above is normal bone density. A T-score between -1.0 and -2.5 means osteopenia. A T-score of -2.5 or below is a diagnosis of osteoporosis.

Data had been processed and analyzed using the software of Statistical Package for Social Science (SPSS) version 17.0 for windows. The data mean and standard deviation (SD) were considered. Paired t-test and two sample t-test were used to compare the results of various parameters among the studied groups. Linear regression analysis (Person Correlation Coefficients) (r) was performed for finding the degree of association between different parameters. Some values expressed as mean ±SD and P value of < 0.05 was considered to be statistically significant. For each potential risk factor, we calculated the odds ratio as an estimate of the relative risk of osteoporosis. To determine whether the odds ratio were significantly different from

one another, we calculated the 95% confidence intervals.

Results

A total of 313 postmenopausal females were enrolled in this study. We compared the age of patients of the studied groups according to their BMI.

The age-range of the control group (who has BMI<25) which represents 100 patients included within the total of 313 patients was 45 to 86 years, with the mean± SD (58.9±10.10). The age-range and mean of other subgroups, (Table 2).

The results of the comparison between cases subgroups (BMI ≥ 25) and control group (BMI ≤ 25) indicate that there were no statistically significant differences between the two groups regarding the ages and their mean with standard deviation (mean ±SD). Also, there was no such differences between cases subgroups (overweight, obese and morbid obese) regarding the ages and their mean and standard deviation (mean ±SD), (Table 2).

Patients with osteoporotic value (according to their T-score results) were more commonly seen in those with lower BMI and the vice versa with a statistically significant difference between them (p-value=0.0001), (Table 3).

The group with low BMI had a large number of patients (83 of patients with BMI (18.5-24.9) and a high percentage of osteoporosis or osteopenia with T-score ≤ -1.6, whilst that with high-value BMI (25 to 40 $^{+}$) had a lower number of patients and a low percentage of osteoporosis or osteopenia with T-score ≤ - 1.6 in each subgroups, (Table 4).

In the present study, it was demonstrated that there is a decrease in the number of osteoporotic patient with increasing BMI, the correlation shows a highly significant difference between them with a (P-value 0.0001), (Figure 1).

Table 2: The age of the studied population according to BMI.

BMI	Age (years)			
	No. (%)	Mean±SD [a]	Minimum	Maximum
18.5-24.9 (control)	100 (31.9)	58.9±10.10	45	86
25-29.9 (overweight)	49 (15.7)	59.1±10.60	45	90
30-39.9 (obese)	110 (35.1)	58.3±8.74	45	83
40 + (morbid obese)	54 (17.3)	59.6±8.08	47	77
Total (patients and control)	**313 (100)**	**58.8±9.33**	**45**	**90**

[a] No significant differences between mean age groups by applying ANOVA test for more than two means.

Table 3: Distribution of the study population according to BMI and DXA analysis.

Bone density	BMI				Total No. (%)	P-value [b]
	Normal No. (%)	Over weight No. (%)	Obese No. (%)	Morbid obesity No. (%)		
Normal (> -1)	7(7.0)	20(40.8)	42(38.2)	31(57.4)	100(31.9)	0.000
Osteopenia (-1 to > -2.5)	33(33.0)	16(32.7)	44(40.0)	20(37.0)	113(36.1)	
Osteoporosis (≤ -2.5)	60(60.0)	13(26.5)	24(21.8)	3(5.6)	100(31.9)	
Total	**100**	**49**	**110**	**54**	**313(100.0)**	---
Mean ± SD[a]	-2.57±1.1	-1.43±1.8	-1.37±1.4	-0.85±1.3	---	0.000

[a]ANOVA test for more than two means was used.
[b] Chi-square test was used.

Table 4: The bone mineral density of the study groups according to BMI (Data expressed as a number of patients and percentage).

BMI	Patients with T-score (≤ -1.6) (n=183)[1]		Patients with T-Score (> -1) (n=100)		Odd`s Ratio	95% C.I	P-value
	No.	%	No.	%			
40 +*	19	10.4	31	31.0	---	---	---
30-39.9	27	14.8	20	20.0	9.2	3.86; 22.02	0.001
25-29.9	54	29.5	42	42.0	8.8	3.35; 23.03	0.001
18.5-24.9 (control)	83	45.3	7	7.0	19.4	7.41; 50.50	0.001

*Reference group (the group with the lowest percentage of osteoporosis or osteopenia).
[1] This T- score includes all cases with definite osteoporosis (T-score of ≤ -2.5) and 83 patients with osteopenia and T- score ≤ -1.6), the remaining 30 patients with mild or borderline osteopenia (T-scores -1 to -1.5) were not included in this table and the subsequent tables to avoid controversial results.

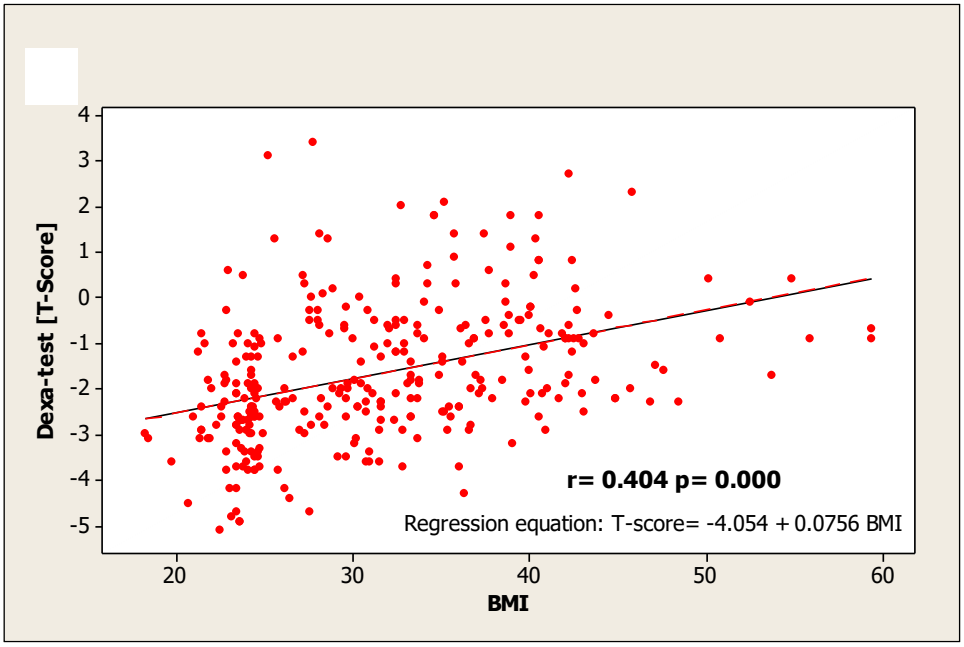

Figure 1: Correlation between BMI and DXA results in the study sample.

To evaluate the risk factor of physical activity, our patients were divided into two groups; patients with sedentary lifestyle group and patients who are the physically active. The percentages of patients with osteoporosis or osteopenia with T-score ≤ -1.6) were more common among patients with the sedentary lifestyle (149 vs. 34), although there were no statistically significant difference between the two groups (P-value 0.152), (Table 5).

An important observation in the current study for assessing the effects of education level on the development of osteoporosis/osteopenia was that the percentage of patients with osteoporosis/ osteopenia with T-score ≤ -1.6) was more in the illiterate and primary school education group than in the secondary school and high education group, although there were no statistically significant differences between the two groups (p-value 0.252), (Table 6).

The percentage of patients with osteoporosis and osteopenia with T-score ≤ - 1.6 in whom their husbands were illiterate or primary school education level were more than those who have high educated husbands with a statistically significant difference between them (P-value 0.041), (Table 7).

The percentage of patients with osteoporosis or osteopenia with T- score ≤ -1.6 was more among those with the history of fracture than those with no such history with a statistically significant difference between them (P-value 0.003), (Table 8).

Table 5: The effect of physical activity on the development of osteoporosis or osteopenia in patients with BMD T-score (≤ -1.6).

Physical activity	Patients with T-score (≤ -1.6) (n=183)		Normal T-Score (> -1) (n=100)		Odd`s Ratio	95% C.I	P-value
	No.	%	No.	%			
Physically active (30 min. of cont. activity 6 times/wk.)	34	18.6	12	12.0	1.67	0.82; 3.40	0.152
Sedentary* (30 min. of cont. activity 1 time/wk. and none/wk.)	149	81.4	88	88.0			

* Including low physically active > 30 minutes 1-3 times daily/week.

Table 6: Level of women`s education and osteoporosis/osteopenia in patients with BMD T-score (≤ -1.6).

Education	Patients with T-score (≤ -1.6) (n=183)		Normal T-Score (> -1) (n=100)		Odd`s Ratio	95% C.I	P-value
	No.	%	No.	%			
Secondary school and higher	**88**	**48.1**	41	41.0	1.33	0.81; 2.18	0.252
Illiterate and primary school	**95**	**51.9**	59	59.0			

Table 7: The effect of husband's education on the development of osteoporosis/osteopenia with BMD T-score ≤ -1.6.

Education of husband	Patients with T-score (≤ -1.6)		Normal T-Score (> -1)		Odd`s Ratio	95% C.I	P-value
	No.	%	No.	%			
Secondary school and higher	69	37.7	23	25.0	1.79	1.02; 3.16	0.041
Illiterate and primary school	114	62.3	69	75.0			

Table 8: History of fractures and relation with osteoporosis/osteopenia in patients with BMD T-score (≤ -1.6).

History of fractures	Patients with T-score (≤ -1.6) (n=183)		Normal T- Score (> -1) (n=100)		Odd`s Ratio	95% C.I	P-value
	No.	%	No.	%			
No	32	17.5	5	5.0	4.03	1.52; 10.69	0.003
Yes	151	82.5	95	95.0			

Discussion

This study was a case-control study done to evaluate the relationship between body mass index (measured according to the WHO classification) and other risk factors for osteoporosis/osteopenia in postmenopausal women by measuring bone mineral density (BMD) depending on T-score, using the Dual Energy X-ray Absorptiometry (DXA) instrument.

Exclusion criteria in our study take in consideration factors reported to be responsible for the reduction of bone density in patients diagnosed as osteoporosis, including low BMI[11], Smoking, inactivity[12], and corticosteroid therapy[13].

However, the effects of these factors, with the exception of BMI, are still controversial. From our results the various groups were matched according to the patient's age, this may abolish the effect of age on the results of the study as the increasing age is a risk factor for osteoporosis, and one of the major cause of decreased in the bone mineral density in the general population (WHO, 2007)[14].

This study proved that there is a decrease in osteoporosis/osteopenia as the BMI increases with a high significant difference. This could be attributed to the mechanical loading of increasing body weight, increase in the level of the adipocyte in adipose tissue is considered as a good source of estrogen that protects the bone in the postmenopausal period. There is an association of fat mass with the secretion of bone-active hormones from the pancreatic β-cell[7].

A decrease in number and percentage of osteoporosis/osteopenia with T-score ≤ -1.6 according to the DXA results beginning at a cutoff BMI of 25 Kg/m^2 below which the number and percentage of osteoporosis will increase was noticed in the present study. For this reason the BMI of 25 was considered as a cutoff point in this study. This is in total agreement with the results that were obtained in a meta-analysis study, which included 44,757 females with recommendations in the Scottish Intercollegiate Guidelines. Those individuals with a low BMI (< 20 kg/m^2) are at risk of fracture and should be encouraged to gain weight to maintain BMI levels at 20-25 kg/m^2[15].

The results of the present study matched with the observation of asthmatics patients on steroids treatment[16]. They indicate that the increasing body mass index particularly at the range of obesity level has a positive effect on BMD probably by maintaining higher levels of estrogen during menopause, whilst a low body weight is negatively correlated with the peak bone mass and the fracture risk as compared with the high adiposity which is considered a protective factor against both hip and vertebral fractures[16].

On the other hand, the results of some other studies e.g. a study performed by (Jay J Cao) found that there was a decrease in bone mass with obesity due to increased marrow adipogenesis at the expense of osteoblastogenesis, and increased osteoclastogenesis, with reduced calcium absorption, which is associated with high fat intake[17].

To evaluate the development of osteoporosis and or osteopenia in relation

to the type of physical activity, the patients in this study divided into two groups. A group with sedentary lifestyle, or low physical activity (>30 minute for 1-3 times daily/week), and the physically active group, including patients with at least 30 minutes of continuous activity 6 times/week and/or moderately active patients, with at least 30 minutes of continuous activity 3 times/week.

From these results, we are able to find that the osteoporosis/osteopenia is seen more in the sedentary lifestyle group, although there were no statistically significant differences between the two groups. A similar finding was obtained by Khawlah Al-Muhanna et al who confirmed that lack of physical activity is thought to be one of the common risk factors for osteoporosis among Saudi women aged more than 40 years[18].

The protective effect of physical activity found in the present study was also in agreement with Mamji MF and coauthors[19]. They pointed out that a physically active lifestyle has been shown as a protective factor.

Other kinds of activity like swimming and weight lifting have been shown to have a protective factor in Iranian and Pakistani women [19].

The same results were found by Dontas IA and coauthors [20] who demonstrate that moderate load such as walks and cooper promote an increase in the bone minerals of the postmenopausal women and that a physically active lifestyle beginning from childhood and continuing throughout life, is important for maintaining a healthy bone. The physical activity, which is performed, transmits loads to the bone through muscle pull and gravitational force during a weight-bearing activity.

The increase of gravitational force upon bone in a weight-bearing position, strength-training exercises performed on foot are considered more effective at stimulating bone formation than machine-based exercises performed in the seated position.

On the other hand, the results of the present study were in disagreement with the study performed by Nordström et al[21]; they evaluated the effect of physical activity on bone accrual, osteoporosis and fracture prevention. They concluded that in postmenopausal women, no relationship between physical activity and BMD has been observed.

It seems that, in some cases, the physical activity might diminish BMD, as a loss in sites that are exposed to mechanical loading. These results might be related to the differences in study design, limitation, variation in the numbers of study subjects, and the differences in types of lifestyle wither sedentary or active patients[21], while the present study pointed out the role of physical activity in the building of healthy bone and increase BMD.

Measurements of socio-economic status and its influences on the people health, depends on many factors such as personal education, family educational status, the economic status of the person in a society that determine health status and access to health care, and the income which is strongly correlated to health status and access to health care[22].

Therefore, the effects of some of these factors were evaluated in this study. We found that the distribution of osteoporosis/osteopenia was more common among patients with low educational level with no statistically significant difference, although, the odds ratio was high and this may be due to a limited number of the sample taken in the present study.

To evaluate the influence of the educational level on osteoporosis/osteopenia; our patients were divided into two groups: one includes the illiterate and or the primary school educated patients, and the other includes patients with secondary school and higher education. We found that 51.9% out of 183 of osteoporotic/osteopenic patients were illiterate or had finished the primary school; on the other hand, 59.0% out of 100

patients with normal T score were illiterate or had finished the primary school. On the other hand, 48.1% out of 183 osteoporotic/osteopenic patients were among the higher education group in comparison with 41.0% out of 100 patients with normal T score among the same group.

We can say that these results were due to the effect of education on lifestyle, nutrition, and economic status.

The other possibility is the effect of economic status on education level as the people grow in wealthy families have more chance of continuing their education and they have better nutrition, and probably their health status during childhood affect their bone mass.

A study shows that a higher level of education was associated with significantly higher BMD at the whole body, lumbar spine, and hip sites with lower prevalence of osteoporosis, and there was a significant relationship between the education level of women and osteoporosis/osteopenia. Just like our study, another study found that osteoporosis was more frequent in postmenopausal women with low education [19].

On the other hand, the result of the present study is not matched what Davoud Shojaeizadeh et al had pointed[23]. They assessed the effect of educational intervention on the prevention of osteoporosis on 100 volunteers receiving or holding an educational class, they found that the education cannot merely change people's attitude and cannot motivate them to adopt a certain behavior. They also showed that after passing four months of attending educational class, calcium consumption has got a downward trend, and concluded that this may be attributed to many other factors that may be considered.

One of the explanations for this reduction attributed to some socio-economic issues in the society. Therefore, they are also at risk for osteoporosis.

Davoud Shojaeizadeh, et al [23] study is nothing to do with education level, their study seems to be concerned with a short spell of training only, and for this fact, we believe it was not in a line of our results. Ho et al in 2005[24] show that in part of Asia, individuals with a lower level of education usually have high levels of physical activities due to engagement in manual labor. They also tended to have higher intakes of vegetables and plant protein due to limited income and availability of animal foods and they stated that individuals with better education and income usually consume more foods from animal sources, and have less physical activities, due to their luxurious lifestyle. In these settings, higher education might not be associated with better health outcomes and this was in disagreement with the present study.

Mehmood Riaz et al [25, 26] showed that knowledge about osteoporosis did not improve lifestyle or prevent habits that may cause osteoporosis, which was in disagreement with the present study. This study showed that the percentage of patients with osteoporosis and their husbands were illiterate were more common than those ladies who have highly educated husbands with a statistically significant difference between them, this was in agreement with A Keramat et al[27], as they found a significant relationship between husbands' education level and osteoporosis. They found that low education of husbands is a risk factor for osteoporosis in both Iranian and Indian women.

We noticed that 17.5% out of 183 osteoporotic/osteopenic patients had no history of the previous fracture in comparison with only 5.0% out of 100 patients with normal T-score who had such history.

On the other hand, 82.5% out of 183 osteoporotic/osteopenic patients had a history of fracture in comparison with 95.0% of those with normal T-score value had a history of fractures, and there was a statistically significant difference between the two groups. Many studies showed the high correlation between osteoporosis as a

risk factor and the percentage of hip, vertebral, and forearm fractures.

Furthermore, Mamji MF et al [19] showed that, family history of osteoporosis and previous history of fractures on trivial trauma as a significant risk factor for patients with hip fractures, and that women with family history of osteoporosis may have a genetic predisposition to osteoporosis with low bone mass.

In summary, we found that; obesity, has a protective effect against osteoporosis/osteopenia, due to the positive effect of mechanical loading on the bone mineral density (BMD), sedentary lifestyle, low education level, improper house conditioning, and the history of previous fracture may be considered as risk factors for osteoporosis.

In addition, we also found that the BMI value of 25 was considered as a cutoff point below it the percentage of osteoporosis/osteopenia start to increase.

In conclusion: The percentage of osteoporosis/osteopenia decreases with the increment of body mass index. Obesity may have a protective effect against osteoporosis/osteopenia but we do not recommend or advice for gaining extra weight because of its association with many adverse effects on the health and income of the community. BMI value of 25 considers as a cutoff point below it the percentage of osteoporosis start to increase. Physically active lifestyle reduce osteoporosis/osteopenia by increasing the bone mass.

Recommendations: Bone mineral density (BMD) measurement should be considered in patients at high risk for osteoporosis such as postmenopausal women, especially those with low BMI, or those who had a history of osteoporotic fracture. We advise to avoid the overuse or unnecessary use of the steroid unless if it is highly indicated and in the lowest possible doses. The knowledge of the relationship between BMI and osteoporosis is of great importance, because it may lead us to develop a new therapeutic intervention to prevent both obesity and osteoporosis.

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