

Bone Mineral Density and Body Mass Index: The Practicable Interaction Between Bone Fragility and Obesity Interaction

Maryam Inayat¹, Zuneera Akram², Syed Ahmed Hussain³, Usman Ghani Farooqi⁴, Sobia Akhter⁵, Mobeen Islam⁶, Safoora Tariq¹, Muzammil Hussain²

¹Department of Pharmacy Practices, Faculty of Pharmacy, Baqai Medical University, Karachi, Pakistan

²Department of Pharmacology, Faculty of Pharmacy, Baqai Medical University, Karachi, Pakistan

³Professor, Clinical Pharmacy, AGA Academy, Calgary, Canada.

⁴Lecturer, Baqai Institute of Health Management Sciences, Baqai Medical University, Karachi, Pakistan

⁵Deputy Chief Pharmacist, Fatima Hospital, Baqai Medical University

⁶Department of Pharmacognosy, Faculty of Pharmacy, Baqai Medical University, Karachi, Pakistan

Email: dr.zunaira@baqai.edu.pk

DOI: 10.47750/pnr.2022.13.S06.456

Abstract

Background: Previous findings have shown that the body mass index (BMI) is related positively to bone mineral density (BMD). In patients with low BMI (<18.5 kg/m²), the levels of BMD have usually been decreased and the T-values have been low. The goal of the study is to assess weight-BMI-BMD relationships among 743 healthy people from the Karachi Gulshan district.

Methodology: The research comprised a population of 743 people classified into four BMI classes. The BMD measurement in all the study participants was done by using a Sonost 3000 (Ultrasound Bone Densitometer) from Osteosys CO. Ltd. Korea.

Results: The findings of BMI and BMD correlation indicated that osteopenia was occur more in underweight individuals than the overweight and obese, while osteoporosis occurred more in those who were obese in the comparison under & overweight individuals.

Conclusion: The study of the associations between BMI and BMD in both male and female participants revealed a strong positive association showed by Pearson's correlation analysis.

INTRODUCTION

Obesity and osteoporosis are two of the most severe illnesses that are strictly linked to a higher global incidence of both mortality and morbidity rate [1-5]. Several studies suggest that obesity involves a preventive influence against osteoporosis. However, new surveys have found that the risk factors for diminished bone density and fractures could be obesity and therefore body mass [6-8].

Obesity may be defined by an excessive or disproportionate volume of body fat complex disorder. This discrepancy increases the risk of multiple illnesses, including diabetes, cardiac failure, and hypertension.

The WHO emphasized, that more than 1.9 billion people in 2014 were overweight and over 600 million were obese. In 2014, roughly 13 percent of adults in the world (15% of females and 11% of males) were obese. Furthermore, between 1980 and 2014 the global obesity rate on than doubled. This energy discrepancy between calories expended and calories burnt will contribute to several possible reasons. Increased consumption of high-fat energy-dense food and decreased physical activity as a result of lifestyle changes such as sedentary work, increased use of automatic transport, and increasing urbanization are among these possible factors [9].

Obesity expenses are measured at 147 billion US dollars to almost 210 billion US dollars per year in the United States [10-11]. Employers had an average expense of approximately 4.3 billion in absenteeism [12] and reduced productivity at work for

employers [13]. What about Europe? A healthcare cost of up to € 10.4 billion was reported and a proportional financial burden of between 0.09% and 0.61% of the gross domestic product of each country [14].

The skeletal condition of osteoporosis can be described as impaired bone strength, which raises the likelihood of fracture. Bone strength represents the integration of bone density and bone consistency of two major characteristics. The most frequent cause of fracture is osteoporosis, and every year it accounts for about 1.5 million fractures in the U.S. [15-16]. Bone mineral density (BMD) measurement is used to identify this bone condition. Osteoporosis is a disease according to the WHO criteria in which BMD sits 2.5 or less than standard deviations for young people with stable conditions (a t-score of 2.5 SD) [17]. Because of the rise in the median age, the prevalence of osteoporosis and related factor rates is expected to increase considerably in the future 16. By 2020, osteoporosis could influence around 14 million people older than 50 and a low bone density could affect another 47 million 17. The country of origin or ethnicity is of critical significance, and the largest danger recorded to European Americans [18-20]. In comparison, more than 500,000 hospital admissions, over 2.6 million doctor appointments, more than 800,000 emergency department admissions, and about 180,000 people are enrolled in the United States per year, and the expense is projected to rise from 100 percent to 2040 to around 200 percent by 2040 [21].

Obesity has traditionally been associated as a preventive factor with bone health [22,23]. Adipose tissue, however, represents an estimate of less than 40% of the overall body weight, which suggests the mechanical load associated with increased fat mass may not be adequate to cause this beneficial effect on bone tissue [24]. Latest trials have also been carried out to reassess whether or not obese people have an elevated risk for some forms of anatomical zone fractures [25]. As the Body Mass Index (BMI) and age are increasing globally, the likelihood of osteoporosis in this population has never been more important to consider [26].

As the number of studies that have focused on the contribution made by body composition to BMD is limited, we investigated the relative contribution of BMI to BMD in healthy individuals.

METHOD

Study design and population

There was a cross-sectional analysis under Dr. Saleem Ahmed Rajput, which obtained retrospective details after receiving permission from the Doctor at the Muneefa Cardiac and General Clinic, Karachi, Pakistan. The criteria for informed concern in this retrospective analysis were waived because there was no direct communication with the subject. There was no involvement or treatment during the study, so there was no harm to the participants in the test. To identify the subject, the subject ID number was used and the subject names/identity remained confidential and was not published in a particular manner before or after this database analysis. The subject information was also kept secret.

In the course of this research, health histories were analyzed of 743 (age range 20-90) stable men and women who had spontaneously agreed to take BMD steps for their general medical check-ups during their visits to the hospital. Sampling was performed to capture the data using a consecutive process.

Exclusion criteria

Participants of or using osteoporosis, oral contraception, or hormone replacement treatment have not been permitted to be part of this study. Those who suffered from bone disease history, tumors, severe hepatic and renal diseases, or parathyroid disorder were also excluded. The research even omitted pregnant and lactating mothers.

Collection of data:

Data were reported depending on gender and age (years), height and weight, BMI status, and food intake (Vegetarian, Semi-vegetarian, non-vegetarian diet). The data were also based on the status of alcohol consumption and smoking, exercise level, fracture history, and other co-morbidities present or not. The bone screening measures have been carried out with Osteosys CO. Ltd. (Sonost 3000 Ultrasound Bone Densitometer). Korea, in general, has health checkups. The peripheral radial bone BQI values and T scores have been collected.

Data entry and analysis.

For data processing, we used Microsoft Excel® and the Social Science Methodological Kit 21 (SPSS Inc., Chicago, IL, USA). All statistical test results are considered significant if the p-value was less than 0.05 [27].

Bone mineral density status

Bone status analysis was classified into three groups using a WHO classification based on T score:

Normal BMD (T score ≥ -1),

Osteopenia (T score -1 and -2.5), and

osteoporosis (T score < -2.5) [28-29].

Categories of body mass index

On-site measurements of weight, height, and BMI were taken, and BMI was measured using the ratio of body mass to the square of weight (kg)/ [height(m)]² [30]. Categories follow WHO standards:

Underweight (<18.5 kg/m²),

Healthy weight (18.5 – 24.9 kg/m²),

Overweight (25.0–29.9 kg/m²), and

Obese (30.0 kg/m²–above) [31].

RESULTS

Results show that 743 individuals of age 53.14 ± 32.65 were analyzed and grouped into four BMI status-based classes. There were 363 females (48.86% with mean age 52.19 ± 32.49) and 380 males (51.13% with mean age 54.09 ± 33.97) in the sample.

		<i>Table 1: Gender specified BMI (Kg/m²)</i>					Total
			Underweight	Healthy Weight	Over Weight	Obese	
Gender	Male	Count	47	117	86	70	380
		Expected Count	54.7	164.2	90.5	70.6	380.0
	Female	Count	60	144	91	68	363
		Expected Count	52.3	156.8	86.5	67.4	363.0
Total		Count	107	321	177	138	743
		Expected Count	107.0	321.0	177.0	138.0	743.0

Gender specified BMI (Kg/m²) Percentages

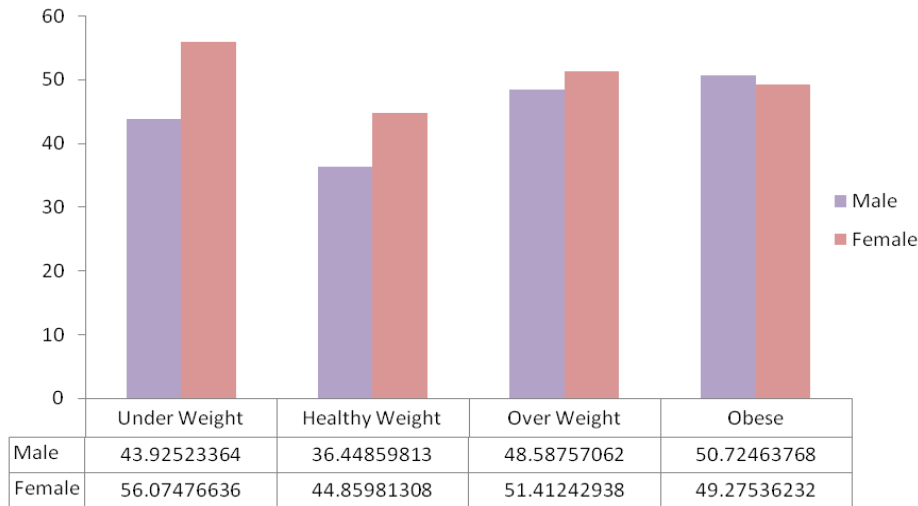


Figure 1: Gender specified percentages of BMI (Kg/m²)

TABLE 2: Baseline characteristics							
Variable	Total population		Females		Males		P-value
Demographic characteristics, Mean ± SEM							
Age, Y	53.14±32.65		52.19±32.49		54.09±33.97		0.914
Lifestyle characteristics, n (%)							
Non- Smokers	574	77.25 %	331	57.66 %	243	42.33 %	0.000
Smokers	169	22.74 %	32	18.93 %	137	81.06 %	
No Alcohol consumption	732	98.52%	358	48.91%	374	51.09%	0.531
Alcohol consumption Present	11	1.48%	5	45.45%	6	54.54%	
No Exercise	452	60.83%	236	52.21%	216	47.79%	0.014
Exercise Present	291	39.16%	127	43.64%	164	56.36%	
Vegetarian Diet	146	19.65%	64	43.84%	82	56.16%	0.032
Semi-Vegetarian Diet	428	57.60%	211	49.30%	217	50.70%	
Non-Vegetarian Diet	169	22.75%	88	52.07%	81	47.93%	
Fracture History	46	6.19%	14	30.43%	32	69.56%	0.039
No Fracture History	697	93.80%	349	50.07%	348	49.93%	

Co morbidities	209	28.13%	102	48.80%	107	51.20%	0.526
No Co morbidities	534	71.87%	261	48.88%	273	51.12%	

Gender specified baseline feature:

The baseline feature in Table 1 demonstrates the trends of the gender-stratified population of the study. In contrast to earlier research, BMI shows that females are more likely to be underweight, healthy weight, or overweight than males, whereas males are more likely to be obese (Table 1, Figure 1).

Males consumed more alcohol and smoked more cigarettes than females. Physical activity registered to females was significantly lower than to males. Intakes of non-vegetarian food and semi-vegetarian food were found to be higher in females than in males, suggesting that the vegetarian diet was higher for males. The presence of co-morbidities and fractures revealed that males suffer the most from co-morbidities than females. (Table 2)

The majority of the research participants were between the ages of 20 and 39 years and had a BMI of 16.45% underweight, 42.52 % healthy weight, 24.57% overweight, and 16.45% obese, with 35% of persons having a BMD in the osteopenia spectrum (Table 3). The majority of people in the age range 40-59 years had a normal BMI and BMD. 27.33% of individuals in the age range 40-59 had osteoporosis, whereas 17.98% had osteopenia (Table 3). About 33% of 60-79-year-olds were osteopenic, whereas 19.54% had osteoporosis. Approximately 20.69% of this group's members were overweight, while 19.54% were obese. The majority of people in the 80-year-old age group had normal BMD and were obese.

Variable		Table 3: Relationship between BMI and BMD with Age, (n)					p-value
		Age	20-39	40-59	60-79	80 & above	
BMI	Under Weight	Count	77	17	9	4	0.095
		Expected Count	67.4	20.0	12.5	7.1	
	Healthy Weight	Count	199	64	43	15	
		Expected Count	202.2	60.1	37.6	21.2	
	Overweight	Count	115	30	18	14	
		Expected Count	111.5	33.1	20.7	11.7	
	Obese	Count	77	28	17	16	
		Expected Count	86.9	25.8	16.2	9.1	
BMD	Normal	Count	231	76	41	20	0.149
		Expected Count	231.8	68.8	43.1	24.3	
	Osteopenia	Count	163	38	29	14	
		Expected Count	153.7	45.6	28.6	16.1	
	Osteoporosis	Count	74	25	17	15	
		Expected Count	82.5	24.5	15.3	8.6	

Obesity is often seen as beneficial to bone health since the mechanical stresses imposed by body weight have been shown to improve the structure of bones, while also serving as a risk factor for a variety of other chronic diseases. While body mass has a beneficial effect on bone formation, it is unknown if the mass gained as a consequence of obesity or excessive fat accumulation is beneficial to the bone. The pathophysiological connection between fat and bone is complicated and continues to be a subject of investigation [32].

In table 4, osteopenia was more likely to occur in underweight persons than in overweight or obese individuals. BMI was related to BMD in this research, which revealed substantial findings. Additionally, obese individuals were more likely to develop osteoporosis than those who were overweight or had a normal BMI ($p < 0.000$) (Table 4). This demonstrates that the indices used in this research are positively associated with BMD, which corresponds to a study previously published in 2019 by Bierhals and coworkers [30].

Variable		Table 4: Relationship between BMI and BMD					
		BMD	Normal	Osteopenia	Osteoporosis	Total	p-value
BMI (Kg/m ²)	Under Weight	Count	35	70	2	107	0.000
		Expected Count	53.0	35.1	18.9	107.0	
	Healthy Weight	Count	242	57	22	321	
		Expected Count	159.0	105.4	56.6	321.0	
	Overweight	Count	55	79	43	177	
		Expected Count	87.7	58.1	31.2	177.0	
	Obese	Count	36	38	64	138	
		Expected Count	68.3	45.3	24.3	138.0	

DISCUSSION:

Bodyweight, smoking, alcohol, physical activity, and diet have been proven to affect bone mineral density (BMD) directly or indirectly. Of these, bodyweight is perhaps best known to affect BMD. However, there is some debate as to whether lean body mass (LBM) or fat mass (FM), the two components of body weight, most determines BMD.

Bodyweight impacts both bone turnover and bone density and is, therefore, an important risk factor for vertebral and hip fractures, ranking in importance alongside that of age. The effect of body weight is probably contributed to by both fat mass and lean mass.

Previous studies suggested a positive relationship between body mass index (BMI) and bone mineral density (BMD) levels. Generally, patients with low BMI (<18.5 kg/m²) have reduced BMD levels and, thus, low T-scores; hence, they are categorized as osteopenic or osteoporotic. In this study, correlations between BMI and BMD T-scores were significantly directly proportional although the correlation strength varied between the strong and moderate, which means that an increase in BMI could result in increased BMD T-scores, and vice versa. Previous studies concluded that when BMI increases, BMD levels will also increase, which further supports our findings [33-34]. Moreover, other studies explained that such a relationship exists because heavy body weight could result in bone remodeling to compensate for the heavy mechanical load [35- 36].

Age was shown to be an independent predictor of BMI and BMD in this research. BMD declines with age, while BMI rises, and the 80-year-old age group was determined to be obese. Due to ethnic or cultural variations, age-related changes in body composition may vary across groups. As a result, it is critical to understand the separate effects of BMI on BMD to design an osteoporosis prevention plan for young men and women.

BMD and BMI were influenced by many additional variables such as hereditary factors, and female hormone status is thought to be significant. In addition, numerous medical disorders, such as thyroid illness, parathyroid disease, liver disease, rheumatoid arthritis, hypertension (37), diabetes(38), and different medications including steroids and anticonvulsants are also known to impact BMD, either directly or indirectly. These variables, however, are not readily changeable. Therefore, we were interested in those variables that can be changed such as weight, smoking, alcohol, physical activity, and food habit. Of these variables, we examined BMI and BMD components and link them with modifiable factors. It was found that nutrition, physical activity, and smoking are strongly linked to obesity and affect bone health. These variables are possibly changeable, and intervention studies targeting this risk category of the study group are required.

CONCLUSION

Results from the study suggest that BMI and BMD have a positive correlation, which does not vary according to age, sex, or ethnicity. A rise of 10 units of BMI will shift an individual from osteoporotic to average levels of BMD, e.g., from normal to

obese BMI. Results in a recent study of Pakistani indicate a protective, cross-sectional correlation between obesity and osteoporosis.

REFERENCES

1. Greco EA, Lenzi A, Migliaccio S. The obesity of bone. *Ther Adv Endocrinol Metab* 6 (6): 273–286. doi: 10.1177/2042018815611004. PMID: 26623005. PMID: PMC4647134
2. Kado DM, Huang MH, Karlamangla AS, Barrett-Connor E, Greendale GA. Hyperkyphotic posture predicts mortality in older community-dwelling men and women: a prospective study. *Journal of the American Geriatrics Society*. 2004 Oct;52(10):1662-7. doi: 10.1111/j.1532-5415.2004.52458.x. PMID: 15450042
3. Rössner S. Obesity: the disease of the twenty-first century. *International journal of obesity*. 2002 Dec;26(4):S2-4. doi: 10.1038/sj.ijo.0802209. PMID: 12457290
4. Hu FB. Overweight and obesity in women: health risks and consequences. *Journal of women's health*. 2003; 12(2):163-72. doi: 10.1089/154099903321576565. PMID: 12737715
5. Consultation WHO. Obesity: preventing and managing the global epidemic. World Health Organization technical report series. 2000; 894: 1-253. PMID: 11234459
6. Greco EA, Fornari R, Rossi F, Santiemma V, Prossomariti G, Annoscia C, Aversa A, Brama M, Marini M, Donini LM, Spera G. Is obesity protective for osteoporosis? Evaluation of bone mineral density in individuals with high body mass index. *International journal of clinical practice*. 2010 May;64(6):817-20. doi: 10.1111/j.1742-1241.2009.02301.x. PMID: 2051895
7. Kim KC, Shin DH, Lee SY, Im JA, Lee DC. Relation between obesity and bone mineral density and vertebral fractures in Korean postmenopausal women. *Yonsei medical journal*. 2010; 51(6): 857-63. doi: 10.3349/ymj.2010.51.6.857. PMID: 20879051. PMID: PMC2995981
8. Compston JE, Flahive J, Hosmer DW, Watts NB, Siris ES, Silverman S, Saag KG, Roux C, Rossini M, Pfeilschifter J, Nieves JW. Relationship of weight, height, and body mass index with fracture risk at different sites in postmenopausal women: the Global Longitudinal study of Osteoporosis in Women (GLOW). *Journal of Bone and Mineral Research*. 2014 Feb;29(2):487-93. doi: 10.1002/jbmr.2051. PMID: 23873741. PMID: PMC4878680
9. Ibrahim S, Akram Z, Noreen A, Baig MT, Sheikh S, Huma A, Jabeen A, Lodhi M, Khan SA, Hudda A, Shahid U. Overweight and Obesity Prevalence and Predictors in People Living in Karachi. *Journal of Pharmaceutical Research International*. 2021; 194-202. DOI: 10.9734/JPRI/2021/v33i31B31708
10. Cawley J, Meyerhoefer C. The medical care costs of obesity: an instrumental variables approach. *Journal of health economics*. 2012; 31(1): 219-30. doi: 10.1016/j.jhealeco.2011.10.003. PMID: 22094013
11. Finkelstein EA, Trogdon JG, Cohen JW, Dietz W. Annual Medical Spending Attributable To Obesity: Payer-And Service-Specific Estimates: Amid calls for health reform, real cost savings are more likely to be achieved through reducing obesity and related risk factors. *Health affairs*. 2009;28(Suppl1):w822-31. doi: 10.1377/hlthaff.28.5.w822. PMID: 19635784
12. Cawley J, Rizzo JA, Haas K. Occupation-specific absenteeism costs associated with obesity and morbid obesity. *Journal of Occupational and Environmental Medicine*. 2007; 49(12):1317-24. doi: 10.1097/JOM.0b013e31815b56a0. PMID: 18231079
13. Gates DM, Succop P, Brehm BJ, Gillespie GL, Sommers BD. Obesity and presenteeism: the impact of body mass index on workplace productivity. *Journal of occupational and environmental medicine*. 2008; 1:39-45. doi: 10.1097/JOM.0b013e31815d8db2. PMID: 18188080
14. Müller-Riemenschneider F, Reinhold T, Berghöfer A, Willich SN. Health-economic burden of obesity in Europe. *European journal of epidemiology*. 2008 Aug;23(8):499-509. doi: 10.1007/s10654-008-9239-1. PMID: 18509729
15. WHO Study Group. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis. Report of a WHO Study Group. *World Health Organ. Tech. Rep. Ser.*. 1994;843:1-29. PMID: 7941614
16. Cooper C, Campion G, Melton L. Hip fractures in the elderly: a world-wide projection. *Osteoporosis international*. 1992; 2(6):285-9. doi: 10.1007/BF01623184. PMID: 1421796
17. Shuler FD, Conjeski J, Kendall D, Salava J. Understanding the burden of osteoporosis and use of the World Health Organization FRAX. *Orthopedics*. 2012 Sep 1;35(9):798-805. doi: 10.3928/01477447-20120822-12. PMID: 22955392
18. Elffors I, Allander E, Kanis JA, Gullberg B, Johnell O, Dequeker J, Dilsen G, Gennari C, Vaz AL, Lyritis G, Mazzuoli GF. The variable incidence of hip fracture in southern Europe: the MEDOS Study. *Osteoporosis international*. 1994 Sep;4(5):253-63. DOI: 10.1007/BF01623349. PMID: 7812073
19. Kanis JA, Johnell O, De Laet C, Jonsson B, Oden A, Ogelsby AK. International variations in hip fracture probabilities: implications for risk assessment. *Journal of bone and mineral research*. 2002 Jul;17(7):1237-44. DOI: 10.1359/jbmr.2002.17.7.1237. PMID: 12096837
20. Thomas PA. Racial and ethnic differences in osteoporosis. *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*. 2007; 15:26-30. DOI: 10.5435/00124635-200700001-00008. PMID: 17766786
21. US Department of Health and Human Services. Bone health and osteoporosis: a report of the Surgeon General. Rockville, MD: US Department of Health and Human Services, Office of the Surgeon General. 2004 Oct 14;87. PMID: 20945569
22. Reid IR. Fat and bone. *Archives of Biochemistry and Biophysics*. 2010; 503:20–27. DOI: 10.1016/j.abb.2010.06.027. PMID: 20599663.
23. Guh DP, Zhang W, Bansback N, Amarsi Z, Birmingham CL, Anis AH. The incidence of co-morbidities related to obesity and overweight: a systematic review and meta-analysis. *BMC public health*. 2009 Dec;9(1):1-20. https://doi.org/10.1186/1471-2458-9-88. PMID: 19320986. PMID: PMC2667420
24. Zhao LJ, Jiang H, Papasian CJ, Maulik D, Drees B, Hamilton J, Deng HW. Correlation of obesity and osteoporosis: effect of fat mass on the determination of osteoporosis. *Journal of bone and mineral research*. 2008 Jan;23(1):17-29. https://doi.org/10.1359/jbmr.070813. PMID: 17784844. PMID: PMC2663586
25. Compston J (2013) Obesity and bone. *Current Osteoporosis Reports* 11:30–35. https://doi.org/10.1007/s11914-012-0127-y. PMID: 23288547
26. Nielson CM, Srikanth P, Orwoll ES. Obesity and fracture in men and women: an epidemiologic perspective. *Journal of Bone and Mineral Research*. 2012 Jan;27(1):1-0. https://doi.org/10.1002/jbmr.1486.
27. Puspitadewi SR, Wulandari P, Kusdhany LS, Masulili SL, Iskandar HB, Auerkari EI. Relationship of Age, Body Mass Index, Bone Density, and Menopause Duration with Alveolar Bone Resorption in Postmenopausal Women. *Pesquisa Brasileira em Odontopediatria e Clínica Integrada*. 2019 Oct 31;19. https://doi.org/10.4034/PBOCI.2019.191.92.
28. Kanis JA. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. *Osteoporosis international*. 1994; 4(6):368-81. DOI: 10.1007/BF01622200. PMID: 7696835
29. Blake GM, Fogelman I. The role of DXA bone density scans in the diagnosis and treatment of osteoporosis. *Postgraduate medical journal*. 2007 Aug 1;83(982):509-17. https://dx.doi.org/10.1136/pgmj.2007.057505. PMID: 17675543. PMID: PMC2600106
30. Bierhals IO, dos Santos Vaz J, Bielemann RM, de Mola CL, Barros FC, Gonçalves H, Wehrmeister FC, Assunção MC. Associations between body mass index, body composition and bone density in young adults: findings from a southern Brazilian cohort. *BMC musculoskeletal disorders*. 2019

Dec;20(1):1-0. doi.org/10.1186/s12891-019-2656-3 PMID: 31288773. PMCID: PMC6617655

31. World Health Organization. Obesity: preventing and managing the global epidemic. 2000.
32. Cao JJ. Effects of obesity on bone metabolism. *Journal of orthopaedic surgery and research*. 2011 Dec;6(1):1-7. doi.org/10.1186/1749-799X-6-30. PMID: 21676245. PMCID: PMC3141563
33. Kirchengast S, Peterson B, Hauser G, Knogler W. Zur Bedeutung des Gewichtsstatus für die Knochendichte bei Betagten und Hochbetagten. *Zeitschrift für Gerontologie und Geriatrie*. 2001 Aug;34(4):313-8. doi.org/10.1007/s003910170055. PMID: 11584716.
34. Doğan A, Nakipoğlu-Yüzer GF, Yıldızgören MT, Özgirgin N. Is age or the body mass index (BMI) more determinant of the bone mineral density (BMD) in geriatric women and men?. *Archives of gerontology and geriatrics*. 2010 Nov 1;51(3):338-41. doi.org/10.1016/j.archger.2010.01.015. PMID: 20202698
35. Kang D, Liu Z, Wang Y, Zhang H, Feng X, Cao W, Wang P. Relationship of body composition with bone mineral density in northern Chinese men by body mass index levels. *Journal of Endocrinological Investigation*. 2014; 37(4):359–367. doi.org/10.1007/s40618-013-0037-6. PMID: 24477947
36. Wee J, Sng BY, Shen L, Lim CT, Singh G, Das De S. The relationship between body mass index and physical activity levels in relation to bone mineral density in premenopausal and postmenopausal women. *Archives of osteoporosis*. 2013 Dec;8(1):1-8. doi: 10.1007/s11657-013-0162-z. PMID: 24281832
37. Akram Z, Perveen R, Siddiqi HS, Hussain M, Imam S, Abrar H, Mahmood SM. Pharmacological basis for the antihypertensive activity of *Grewia asiatica* fruit extract. *Pakistan Journal of Pharmaceutical Sciences*. 2021 Jul 1;34(4):1429-37.
38. Ibrahim S, Naqvi S, Perveen R, Abrar H, Akram Z, Tabassum H, Sheikh S. Hepatoprotective and antidiabetic effect of *Guaiacum officinale* in diabetes induced male albino wistar rats. *Pakistan Journal of Pharmaceutical Sciences*. 2019 Sep 1;32(5 (Supplementary)):2251-6.