Short Communication

The Relationship Between Particulate Matter and Body Mass Index in Osteoporosis

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ABSTRACT

A strong relationship is observed between air pollution and a higher risk of being overweight or obese, reduced bone mineral density (BMD), and an increased likelihood of osteoporosis. This study aimed to examine the relationship between suspended particles and body mass index (BMI) in patients with osteoporosis and osteopenia. Data on particulate matter (PM) collected by the Abadan Environmental Protection Department from February 1, 2022, to August 22, 2023, were utilized in Abadan City, Iran. Demographic information, along with the BMD and T-scores of the patient's left femur and lumbar spine (L1-L4), as well as the BMI of patients with osteoporosis, osteopenia, and those with normal bone density, were obtained from the files of individuals referred to the nuclear medicine center. In this study, out of 431 individuals referred to the density measurement center, 383(88.9%) were women and 48(11.1%) were men. The participants mean BMI was 28.78±5.45, indicating that it was elevated across all three groups (normal, osteopenia, and osteoporosis). The mean concentrations of PM2.5 and PM10 on the days of admission of the study participants were 95.51±126.05 and 188.62±181.11, respectively. The Pearson correlation analysis between PM10, PM2.5, and BMI revealed no significant relationships. In this study, the average BMI among the groups (osteopenia, osteoporosis, and normal BMD) was above the normal range, and no significant correlation was observed between PM and BMI.

Keywords: Osteoporosis, Obesity, Air pollution

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Introduction

Obesity and osteoporosis have become major global health problems with their increasing prevalence in recent decades. The interaction between obesity and bone metabolism is complex and not fully understood. Obese individuals are at a higher risk of certain fractures [1]. As we age, the bone marrow undergoes significant changes, resulting in an increase in fat cells and a decrease in the function of osteoblasts (osteoblasts synthesize and secrete organic compounds of the bone matrix, causing bone formation), which leads to osteoporosis. In addition, osteoclast activity (which plays a role in the destruction of bone matrix, bone resorption, and bone tissue remodeling) is heightened during this process. In addition, secondary causes of osteoporosis, such as glucocorticoids, diabetes, and immobility, are associated with the development of bone marrow obesity [2].

Studies have shown a strong relationship between air pollution, particularly particulate matter (PM), and the risk of becoming overweight or obese at various life stages. However, comprehensive research on this topic is lacking. Further studies are required to determine the specific components of PM, the duration of exposure, the range of safe dosage, and the effectiveness of interventions and measures to prevent obesity [3]. Exposure to PM_{10} and $PM_{2.5}$ has been shown to increase the risk of obesity by 10 $\mu g/m^3$ [4]. Oxidative stress and the inflammatory response are considered the most important mechanisms involved in PM-induced obesity. Increased blood lipid levels as a risk factor accelerate the effects of PM on obesity. PM affects these functions and also causes the onset and progression of metabolic syndrome [4]. Ambient air pollution may contribute to lower bone mineral density (BMD) and increased osteoporosis risk [5]. Air pollution can lead to vitamin D deficiency, which can cause bone damage and increase the risk of osteoporosis. Understanding these mechanisms can inform environmental policies and reduce health-related costs by preventing fragility fractures [6]. Studies have indicated that air pollution can lead to inflammation and oxidative stress, both of which contribute to bone disorders. Polycyclic aromatic hydrocarbons, found in PM, serve as endocrine disruptors that interfere with bone metabolism [5]. Clear evidence links air pollution, specifically PM, to obesity risk across all life stages. Multilevel interventions are necessary for global obesity prevention. Further research on specific PM components, exposure periods, and interventions is required [3].

Abadan, one of the cities of Khuzestan Province in southwest Iran, is exposed to industrial pollutants due to its industrial nature, and, due to its proximity to countries with active dust sources, it is also exposed to annual dust storms [7].

Considering that no study has investigated the relationship between air pollution and body mass index (BMI) in patients with osteoporosis in Abadan City, Iran, and that Abadan and many cities worldwide are exposed to air pollution, this study aimed to investigate the relationship between suspended particles and BMI in patients with osteoporosis and osteopenia.

Methods

PM mass concentration measurement

PM_{10} and $PM_{2.5}$ were collected by the Abadan Environmental Protection Department from February 1, 2022, until August 22, 2023. Meteorological information for Abadan (relative humidity, air temperature, wind speed, dew point, and air pressure) was retrieved from the Iran Meteorological Organization's website from January 21, 2022, to August 22, 2023. There were some days during the study period when PM data were unavailable. PM concentration levels were used to determine the air quality index. The met one beta attenuation monitor measured particle mass concentration. To estimate PM_{10} and $PM_{2.5}$ levels, aerosol optical depth (AOD) was used data collected from Giovanni, a daily temporal resolution and 1° spatial resolution dataset available on NASA's website. AOD data are frequently used in studies to determine the concentration of PM in the tropospheric region [8, 9].

Participants

The files of individuals referred to the nuclear medicine center were used to collect demographic data and measurements of BMI, BMD, bone mineral content, Z-score, and T-score for the left femur and lumbar spine. This data has been collected from individuals with osteoporosis and osteopenia, as well as from those with normal BMD. The relationship between PM and BMI (obese and overweight, normal and underweight) in people with osteoporosis and osteopenia and normal BMD is investigated. The inclusion criteria included people with osteoporosis and osteopenia, and normal people referred to Abadan Nuclear Medicine Center from February 1, 2022, until August 22, 2023, and information about their BMI is available in their records. The T-score was obtained from the files of individuals referring to the bone densitometry department at the nuclear medicine center. The participants in this study are categorized as follows: T-scores between -1 and -2.5 indicate osteopenia (decreased bone density); a T-score below -2.5 indicates osteoporosis, while a T-score above -1 signifies normal BMD. Dual-energy X-ray absorptiometry is a common method used to measure BMD using X-rays to determine BMD.

The BMI is calculated by dividing an individual's weight by the square of their height. Based on the calculated BMI, a person can be classified as underweight (BMI<18.5 kg/m^2), normal-weight (BMI between 18.5 and 24.9 kg/m^2), overweight (BMI between 25 and 29.9 kg/m^2), or obese (BMI≥30 kg/m^2) [10].

Statistical analysis method

The data was summarized using mean, standard deviation, and frequency distribution. The normality of continuous variables was evaluated using the Shapiro-Wilk test. Differences between groups were compared using analysis of variance with the post-hoc Tukey test. To examine the association between categorical variables, we used the chi-square test. To evaluate the relationship between two continuous variables, Pearson's correlation coefficient was utilized. All statistical analyses were conducted using IBM SPSS software, version 16.0 with a significance level of 0.05.

Results

In this study, 431 people (with osteopenia, osteoporosis, and normal BMD) had their femurs and spine examined, of which 383 (88.9%) were women, and 48 (11.1%) were men. In all three groups (with osteopenia, osteoporosis, and normal BMD), the frequency of women was higher than men. The mean age of the study participants was 58.15±10.48 years, and the highest mean age was observed in patients with osteoporosis (Table 1).

The mean total BMI in the study participants was 28.78±5.45, higher than normal in all three groups (with osteopenia, osteoporosis, and normal BMD). The mean concentrations of $PM_{2.5}$ and PM_{10} on the days of admission of the study participants were 95.51±126.05 and 188.62±181.11, respectively (Table 1), which is in the unhealthy air range according to the air quality index (AQI).

The mean PM_{10} and $PM_{2.5}$ concentrations on the days of visit for all three groups (with osteopenia, osteoporosis, and normal BMD) were examined. The relationship between the mean PM_{10} concentrations on the days of visit of all three groups was not significant (for lumbar and femoral BMD groups, P=0.597 and P=0.441, respectively). Also, the relationship between the mean $PM_{2.5}$ concentrations on the days of the visit of all three groups was not significant (for lumbar and femoral BMD groups, P=0.459, P=0.357, respectively) (Table 1). The relationship between the mean BMI concentration in all three groups studied (with Osteopenia, osteoporosis, and normal BMD) was significant (P=0.001) (Table 1).

Table 2 presents the Pearson's correlation between $PM_{2.5}$, PM_{10}, and BMI in all three groups (osteopenia, osteoporosis, and normal BMD, based on femoral BMD). No significant relationship was observed between $PM_{2.5}$ and BMI in all three groups (osteopenia [P=0.839], osteoporosis [P=0.133], and normal BMD [P=0.329]). Also, no significant relationship was observed between PM_{10} and BMI (osteopenia [P=0.821], osteoporosis [P=0.154], and normal BMD [P=0.258]).

Table 3 presents the Pearson correlation between PM_{10}, $PM_{2.5}$, and BMI in all three groups (osteopenia, osteoporosis, and normal BMD, which were grouped based on lumbar BMD). In these groups, no significant relationship was observed between $PM_{2.5}$ and BMI (osteopenia [P=0.149], osteoporosis [P=0.452] and normal BMD [P=0.919]). Also, no significant relationship was observed between PM_{10} and BMI (osteopenia [P=0.146], osteoporosis [P=0.404], and normal BMD [P=0.741]).

Discussion

In this study, referrals to the bone densitometry department of the nuclear medicine center in Abadan City, southwest Iran, were examined. The referrals were categorized into three groups based on their BMD: with osteopenia, osteoporosis, and normal BMD. Most people in all three groups were female and had a higher weight than normal. The mean concentration of PM_{10} and $PM_{2.5}$ in all three groups at different BMI levels was examined, and no significant relationship was observed. Pearson correlation between PM_{10}, $PM_{2.5}$, and BMI was also examined, and no significant relationship was observed.

According to a systematic review by An et al. in 2018, 16 studies reporting associations between air pollution and body weight status were analyzed. The results showed that 44% of the associations had a positive correlation, 44% reported no correlation, and 12% had a negative correlation. These associations vary based on factors, such as sex, age, and pollutant type. The studies hypothesized three possible pathways: Chronic comorbidities, increased oxidative stress and inflammation, and insufficient physical activity [11].

Table 1. Demographic characteristics of participants

Variables		Mean±SD/No. (%)							P	
	Total (n=431)	Normal BMD		Osteopenia		Osteoporosis				
		Femur Group (n=189)	Lumbar Spine Group (n=197)	Femur Group (n=199)	Lumbar Spine Group (n=145)	Femur Group (n=43)	Lumbar Spine Group (n=89)		Femur Group	Lumbar Spine Group
Age (y)	58.15±10.48	55.68±10.54[b, c]	56.78±10.51[c]	58.77±9.90[a, c]	58.17±10.98	66.09±8.53[a, b]	61.13±8.98[a]		<0.001[¥]	0.005[¥]
Sex: Female	383(88.9)	164(42.8)	169(44.1)	182 (47.5)	128(33.4)	37(9.7)	86(22.5)		0.282[¶]	0.025[¶]
Sex: Male	48(11.1)	25(52.1)	28(58.3)	17 (35.4)	17(35.4)	6(12.5)	3(6.3)			
BMI (kg/m^2)	28.78±5.45	30.51±5.74[b, c]	29.98±5.84[b, c]	27.75±4.73[a]	28.51±4.90[a, c]	25.93 ± 4.88[a]	25.57±4.65[a, b]		<0.001[¥]	<0.001[¥]
BMD-component[*]	0.0±1.0	0.77±0.77[b, c]	0.77±0.89[b, c]	-0.39±0.52[a, c]	- 0.34±0.31[a, c]	-1.59±0.60[a, b]	- 1.14±0.39[a, b]		<0.001[¥]	<0.001[¥]
$PM_{2.5}$ (μg/m³)	95.50±126.54	99.28±115.41	100.04±125.27	97.55±136.81	98.44±138.08	69.41±118.54	80.69±105.87		0.357[¥]	0.459[¥]
PM_{10} (μg/m³)	188.62±181.11	187.49±156.54	193.23±176.80	196.40±202.16	193.04±199.58	157.54±179.33	171.21±158.39		0.441[¥]	0.597[¥]

JRH

Abbreviations: BMI: Body mass index; PM: Particulate matter; BMD: Bone mineral density.

[¥]conducted from one-way analysis of variance with Tukey post-hoc; [a, b, c] results of the Tukey post-hoc test, indicating a significant difference with the normal, osteopenia, and osteoporosis groups, respectively; [¶]chi-square test; [*]latent factors identified through principal component analysis (PCA).

Table 2. The correlation between PM and BMI in femur group

Femur					
Variables			$PM_{2.5}$	PM_{10}	BMI
Normal BMD	$PM_{2.5}$ (n=189)	Pearson correlation	1	0.890**	-0.071
		Sig. (two-tailed)		0	0.329
	PM_{10} (n=189)	Pearson correlation	0.890**	1	-0.083
		Sig. (two-tailed)	0		0.258
	BMI (n=189)	Pearson correlation	-0.071	-0.083	1
		Sig. (two-tailed)	0.329	0.258	
Osteopenia	$PM_{2.5}$ (n=199)	Pearson correlation	1	0.998**	-0.015
		Sig. (two-tailed)		0	0.839
	PM_{10} (n=199)	Pearson Correlation	0.998**	1	-0.016
		Sig. (two-tailed)	0		0.821
	BMI (n=199)	Pearson correlation	-0.015	-0.016	1
		Sig. (two-tailed)	0.839	0.821	
Osteoporosis	$PM_{2.5}$ (n=43)	Pearson correlation	1	0.995**	-0.233
		Sig. (two-tailed)		0	0.133
	PM_{10} (n=43)	Pearson correlation	0.995**	1	-0.221
		Sig. (two-tailed)	0		0.154
	BMI (n=43)	Pearson correlation	-0.233	-0.221	1
		Sig. (two-tailed)	0.133	0.154	

Abbreviations: BMI: Body mass index; PM: Particulate matter; BMD: Bone mineral density.

**Correlation is significant at the 0.01 level (two-tailed).

According to a study by White et al. no statistically significant correlation is observed between weight change and fine PM over 16 years. This implies that exposure to air pollution has not been found to cause weight gain in African-American adult women [12]. In a study by Li et al. the annual mean $PM_{2.5}$ was not associated with obesity [13].

Liu et al. suggested that long-term exposure to fine PM (PM1, $PM_{2.5}$, and PM_{10}) is associated with obesity, with $PM_{2.5}$ having the strongest correlation. The study found that even rural residents exposed to lower pollution concentrations had a higher risk of obesity. The risk of obesity increased with a 3-year average of exposure to ambient air pollution [14].

A study conducted by Bowe et al. revealed that $PM_{2.5}$ air pollution is associated with obesity and weight gain in a predominantly male population in the United States. Considering $PM_{2.5}$'s impact on obesity is crucial to epidemiological research. Further research on other groups can help us better understand the relationship between $PM_{2.5}$ and obesity [15]. A study conducted by Furlong in 2020 revealed that the associations of NOX, NO_2, $PM_{2.5}$, and PM_{10} with BMI were stronger among individuals with a higher BMI polygenic risk score at the time of enrollment, but not at follow-up. This study was conducted on a large, prospective cohort and found that air pollution was associated with several measures of obesity at both enrollment and follow-up [16].

Table 3. The correlation between PM and BMI in lumbar spine group

Lumbar Spine					
Variables			$PM_{2.5}$	PM_{10}	BMI
Normal BMD	$PM_{2.5}$ (n=197)	Pearson correlation	1	0.939**	-0.007
		Sig. (two-tailed)		0	0.919
	PM_{10} (n=197)	Pearson correlation	0.939**	1	-0.024
		Sig. (two-tailed)	0		0.741
	BMI (n=197)	Pearson correlation	-0.007	-0.024	1
		Sig. (two-tailed)	0.919	0.741	
Osteopenia	$PM_{2.5}$ (n=145)	Pearson correlation	1	0.967**	-0.120
		Sig. (two-tailed)		0	0.149
	PM_{10} (n=145)	Pearson correlation	0.967**	1	-0.121
		Sig. (two-tailed)	0		0.146
	BMI (n=145)	Pearson correlation	-0.120	-0.121	1
		Sig. (two-tailed)	0.149	0.146	
Osteoporosis	$PM_{2.5}$ (n=89)	Pearson correlation	1	0.996**	-0.081
		Sig. (two-tailed)		0	0.452
	PM_{10} (n=89)	Pearson correlation	0.996**	1	-0.090
		Sig. (two-tailed)	0		0.404
	BMI (n=89)	Pearson correlation	-0.081	-0.090	1
		Sig. (two-tailed)	0.452	0.404	

Abbreviations: BMI: Body mass index; PM: Particulate matter; BMD: Bone mineral density. JRH

**Correlation is significant at the 0.01 level (two-tailed).

According to a study conducted by Liu et al. in 2020, long-term exposure to ambient air pollutants, particularly PM_{10}, may increase the risk of obesity in rural Chinese adults. The study found that this association was particularly significant among elderly individuals, women, people with low education and income, and those with unhealthy lifestyles [17].

A connection may exist between air pollution, low vitamin D levels, and obesity. This connection suggests that air pollution may contribute to vitamin D deficiency. This could lead to a harmful cycle involving low vitamin D levels, air pollution, and obesity, which could negatively impact cardio-metabolic health [18]. A 2022 study by Kim et al. found that lower serum vitamin D levels and a higher risk of deficiency were significantly associated with annual average concentrations of PM_{10}, nitrogen dioxide (NO_2), and carbon monoxide (CO). Women with obesity were more vulnerable to this effect, while men did not show the same pattern [19].

Studies have shown a direct positive relationship between the AQI and the BMI score. For every one-unit increase in AQI, the BMI score increases by 0.031. Air pollution, particularly CO, negatively impacts body weight [20].

Among the limitations of this study was the lack of clarity about PM concentrations on some days of the year. Another limitation of this study was the small number of patients with osteoporosis during the study period, which affects the results.

The results of various studies worldwide regarding the relationship between PM and BMI are contradictory. These differences may be due to variations in sample size, exposure period, study conditions, and geographic location. Studies on the relationship between PM and

BMI in patients with osteoporosis and osteopenia are insufficient; therefore, more studies are recommended for these patients.

Conclusion

In this study, women were more frequently referred to the bone density measurement department than men (with osteopenia, osteoporosis, and normal BMD). The highest mean age was observed in patients with osteoporosis. The mean BMI in all three groups was above normal, and most individuals in all three groups had higher-than-normal weights. No significant relationship was observed between the mean concentration of PM_{10} and $PM_{2.5}$ on the days of visit for all three groups with different BMI levels. In the future, it would be beneficial to conduct studies with a larger sample size and differentiate between days with and without air pollution concerning osteoporosis-related parameters.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Abadan University of Medical Sciences, Abadan, Iran (Code: IR.ABADANUMS.REC.1402.054).

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Authors' contributions

Conceptualization and investigation: Esmat Radmanesh and Seyed Mohammad Mohammadi; Formal analysis: Naser Kamyari; Writing the original draft: Esmat Radmanesh; Methodology: Seyed Mohammad Mohammadi, Heidar Maleki, Gholamreza Goudarzi, Seyed Amin Hossaini Motlagh and Esmat Radmanesh; Data collection: Mohammad Lotfi, Heidar Maleki, Sheyda Ghasemi and Fatemeh Shojaei Moghaddam; Review, editing and final approval: All authors.

Conflict of interest

The author declared no conflicts of interest.

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