Immunopathologia Persa
http www.immunopathol.com
DOI:10.34172/ipp.2022.29296

Investigation of the level of agreement between bone mineral density and trabecular bone score regarding gender, age and body mass index

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Received 25 Sep. 2021
Accepted 14 July 2023
Published online 5 Dec. 2023

Keywords: Densitometry, Trabecular bone score, Bone mineral density, Body mass index

Abstract

Introduction: Increasing and maintaining bone density can play a role in preventing osteoporosis, as changes in the trabecular bone score (TBS) and bone mineral density (BMD) affect bone density, especially in the spine.
Objectives: The present study aimed to determine the level of agreement between TBS and BMD in patients with osteoporosis and also to investigate the relationship between these two indices with body mass index (BMI).
Patients and Methods: Data were collected from 843 patients, referred to the densitometry department of Resalat hospital. BMD and TBS were measured in the subjects to determine the risk of osteoporosis. The results of BMD were measured based on T-score level. The patients' individual and clinical characteristics were also recorded and factors influencing the prognosis of density changes were evaluated. Moreover, the effect of BMI was investigated in this study.
Results: The mean age of patients was 55.5 years. The kappa coefficient and Spearman's correlation coefficient of BMD and TBS were 0.004 and -0.015, respectively. There was a significant correlation between BMI and BMD in men. The kappa coefficient gradually increased from normal bone density to osteoporosis. There was a significant negative correlation between BMI and BMD, while a significant positive correlation between height and BMD in women was existed. On the other hand, a significant negative correlation between weight and BMD was detected accordingly.
Conclusion: According to the results of our study, there is no agreement between BMD and TBS.

Citation: Rajaei A, Kamkar I, Farsad F. Investigation of the level of agreement between bone mineral density and trabecular bone score regarding gender, age and body mass index. Immunopathol Persa. 2024;x(x):e29296. DOI:10.34172/ipp.2022.29296.

Introduction

Osteoporosis is a skeletal disease characterized by skeletal stiffness, increased fragility and hypersensitivity to fractures due to compromised bone strength and abnormalities in the bone micro-architecture (1). The quality of the skeleton is related to bone remodeling. Osteoblasts and osteoclasts have a role in bone remodeling. They play these roles by some proteins and cytokines (2-4). These cytokines have different roles such as tumor necrosis factor-α (TNF-α) and interleukin-6 that have suppressing effects on osteoblast or interleukin-17 that has a significant role in bone destruction (4,5). Although fractures may occur in different parts of the skeletal system, they are more common in the vertebrae, femur and distal forearm. Evidence suggests that osteoporosis accounts for more than 8.9 million fractures annually worldwide (i.e., one fracture every three seconds) and is speculated to increase over the next few decades (6,7).

A bone mineral density (BMD) test measures the value of calcium and other types of minerals in the bone. Various factors, including gender, age, weight, height and body mass index (BMI), affect BMD and the risk of osteoporotic fracture. Prior to the incidence of a fracture, osteoporosis can be diagnosed by non-mineral bone measurements (8). Therefore, increasing and maintaining bone density can play a role in preventing osteoporosis. The National Institutes of Health (NIH) has reported that increased impairment of BMD, involving both bone density and quality, makes a person prone to bone fractures. As

Key point

Trabecular bone score (TBS) and bone mineral density (BMD) are two methods for assessment of bone quality. In this study, we assessed the level of agreement between TBS and BMD on 843 patients with osteoporosis. Our study showed no agreement between TBS and BMD (kappa coefficient = 0.004).

mentioned earlier, BMD is a major predictor of future bone fractures (9-11). Following the speed and accuracy of BMD measurement, it is being increasingly conducted as an adjunct in the prevention, treatment and prognosis of bone loss. Osteoporosis can be defined by measuring the bone density alone (12). To determine the prevalence of osteoporosis, a reliable normal range for each study population seems to be mandatory. Generally, trabecular bone score (TBS), as a textural index evaluating pixel gray level variations in the lumbar spine providing an indirect index of trabecular microarchitecture, can provide information about the bone microarchitecture and skeletal system, which cannot be obtained by standard BMD measurement (13). Although TBS does not provide a direct measurement of the bone microarchitecture, it represents the three-dimensional (3D) characteristics of the bones, such as trabecular number, trabecular separation and connectivity density. TBS is normally calculated by micro-tomography (14,15). It is determined based on its strong positive correlation with the trabecular bone volume relative to the volume of the studied tissue. Low-TBS indicates a fracture-susceptible microarchitecture. There is evidence that TBS can distinguish between two three-dimensional (3D) microstructure with the same bone density, however it is appropriate for to differentiate trabecular characteristics (16). TBS is generally obtained by re-analyzing of lumbar spine anteroposterior view on dual-energy X-ray absorptiometry images. This method allows direct comparison with BMD, which can be conducted with the available datasets. The correlation of TBS and BMD has a significant importance, in which their strongly correlation results in the use of one of the TBS and BMD. Additionally, several studies have reported that, vertebral fracture diagnosis is significantly increased by the combination of TBS and BMD compared with BMD alone (17,18).

Objectives

The present study aimed to determine the coefficient of agreement between TBS and BMD indices to diagnose osteoporosis in a group of patients, referred to a densitometry clinic.

Patients and Methods

Study design

This descriptive retrospective study was conducted on 843 patients, referred to the Resalat hospital during 2017-2018 in Tehran, Iran. The analysis was carried out, based on the guidelines announced by the World Health Organization (WHO). The method of sampling was census and the data of all eligible patients were included. Inclusion criteria were the patients aged more than 18 years undergone both BMD and TBS in the period of 2017-2018 and had legible file. Exclusion criteria were the patients who undergone one of the BMD or TBS and had illegible data. All the data were employed to examine the presence of osteoporosis and to determine differences between these two indices. The results of BMD were measured based on T-score level. The patients' individual and clinical characteristics were recorded, and factors influencing the prognosis of density changes were evaluated.

Statistical analysis

The collected data were analyzed by Statistical Package for the Social Sciences (SPSS) version 25. Data are presented as mean, standard deviation, median, range, frequency and percentage. Kolmogorov-Smirnov test was employed to determine the normal distribution of variables. One-way analysis of variance (ANOVA) was conducted to compare quantitative variables (i.e., age, height, weight and BMI) between the three groups, while the chi-square test was conducted for evaluating qualitative variables (i.e., gender). Moreover, Spearman's correlation coefficient and the kappa coefficient were measured to examine the agreement between BMD and TBS indices. All data analysis were performed in SPSS version 25. *P* value of less than 0.05 was considered statistically significant.

Results

Table 1 presents the demographic characteristics of 843 patients, according to gender. The mean age of the patients was 55.5 years (range; 40-65 years). Overall, 104 (12.3%) participants were male and 739 (87.7%) were female. The mean BMI was 28.68 ± 4.75 kg/m^2 (range: 15.92-47.67 kg/m^2).

Table 1. Demographic data of patients participating in the project based on sex

Variable	Mean ± SD	Median (Range)
Male (n=104)		
Age	52 ± 5	53 (40, 63)
BMI	26.99 ± 3.47	27.08 (17.44, 38.1)
Height	171.6 ± 5.12	171 (158, 180)
Weight	79.63 ± 11.97	79 (51, 118)
BMD	-1.31 ± 0.87	-1.25 (-3.6, 1)
TBS	1.32 ± 0.16	1.35 (0, 1.51)
Female (n=739)		
Age	55 ± 5	56 (45, 65)
BMI	28.91 ± 4.86	28.67 (15.92, 47.67)
Height	157.56 ± 5.61	157 (142, 180)
Weight	71.71 ± 12.23	70 (42, 116)
BMD	-1.21 ± 1.19	-1.2 (-4.8, 2.3)
TBS	1.33 ± 0.1	1.33 (0.92, 1.59)
Total (n=843)		
Age	55 ± 5	55 (40, 65)
BMI	28.68 ± 4.75	28.44 (15.92, 47.67)
Height	159.29 ± 7.22	158 (142, 180)
Weight	72.69 ± 12.47	72 (42, 118)
BMD	-1.22 ± 1.16	-1.2 (-4.8, 2.3)
TBS	1.33 ± 0.11	1.33 (0, 1.59)

The subjects were assessed regarding osteoporosis, based on BMD and TBS, which were employed to classify the subjects into three groups. According to the TBS method, patients with TBS scores <1.2, 1.2-1.35 and >1.35 were included in the fully degraded micro-architecture (FDM), partially degraded micro-architecture (PDM) and normal micro-architecture (NM) groups, respectively. Moreover, the participants were divided into three groups, based on the BMD scores. According to BMD, patients with T-scores ≤-2.5, -2.5 to -1 and >-1 were classified in the osteoporosis, low-bone mass (LBM) and normal groups, respectively. According to the BMD scores, 44.6% of patients were normal, while 40.2% had LBM and 15.3% had osteoporosis. In contrast, based on TBS, 44.5% of patients were classified as NM-TBS, 45.8% as PDM-TBS and the rest as FDM-TBS. The mean TBS and BMD were 1.33±0.11 and -1.22 ± 1.16, respectively. The mean total height of patients was 159.29 ± 7.22 cm (range from 142 to 180) and the mean weight was 72.69 ± 12.47 kg (rang from 42 to 118). In addition, the patients' mean BMI was 28.68 ± 4.75 kg/m^2 with a range of 15.92 to 47.67 kg/m^2. The mentioned parameters are specified by gender in Table 1.

We compared the results of the two diagnostic indices in subjects participating in the study (Table 2). The results showed 172 (45.7%) patients were normal, according to both indices. In contrast, there were four (3.1%) patients with severe osteoporosis, based on BMD, who were classified in the FDM-TBS group. However, these diagnostic indices did not produce similar results for some patients. Overall, 42 (11.2%) subjects were categorized in the FDM-TBS group and classified as normal, based on BMD. On the other hand, 61 (47.7%) of cases were in the severe stage of osteoporosis based on BMD, while they were classified as normal, according to TBS. According to the correlations, these findings were not positive.

As shown in Table 2, no agreement between the results of the two indices was detected. To confirm this finding, in addition to the correlation coefficient, the kappa coefficient was calculated. Spearman's correlation coefficient of the two indices was equal to -0.015. In fact, there was no correlation between two indices, which shows that both TBS and BMD should be used for fracture risk assessment. It may be due to the age of participants because correlation between TBS and BMD reduces by aging (9). The kappa coefficient was measured to be 0.004, indicating no level of agreement between the two indices (P = 0.87).

We investigated the association between contextual variables and BMD subgroups (Table 3).

In all three subgroups, most of the subjects were female, while the difference was statistically significant regarding gender (P = 0.011). The mean age difference between the three groups was statistically significant (P<0.001; ANOVA test). The patients with osteoporosis group comprised the oldest group (57±4 years). Considering the mean height, normal subjects (159.8±7.07 cm) were significantly different from the osteoporosis (157.05±6.2 cm) and LBM (159.56±7.61 cm) groups. With regard

Table 2. Comparison of BMD and TBS diagnostic tests for patients participating in the project

		BMD			Spearman's correlation coefficient (*P* value)	Kappa coefficient (*P* value)
		Normal	Low Bone Mass	Osteoporosis		
TBS	NM	172 (45.7%)	142 (41.9%)	61 (47.7%)	0.015 (0.658)	0.004 (0.878)
	PDM	162 (43.1%)	161 (47.5%)	63 (49.2%)		
	FDM	42 (11.2%)	36 (10.6%)	4 (3.1%)		

Table 3. Investigation of contextual variables in BMD subgroups

		BMD			*P* value	Pairwise comparison
		Normal (1)	Low Bone Mass (2)	Osteoporosis (3)		
Gender	Male	40 (10.6%)	55 (16.2%)	9 (7.0%)	0.011*	
	Female	336 (89.4%)	284 (83.8%)	119 (93.0%)		
Age	Mean ± SD	53 ± 5	55 ± 5	57 ± 4	<0.001**	All
	Median (range)	53 (40, 65)	56 (41, 65)	58 (48, 65)		
Height	Mean ± SD	159.8 ± 7.07	159.56 ± 7.61	157.05 ± 6.2	0.001**	All except 1,2
	Median (range)	159 (142, 180)	158 (142, 179)	156 (145, 180)		
Weight	Mean ± SD	71.85 ± 11.45	71.93 ± 12.47	77.16 ± 14.33	<0.001**	All except 1,2
	Median (range)	70.5 (44, 115)	71 (42, 106)	76 (48, 118)		
BMI	Mean ± SD	28.18 ± 4.42	28.26 ± 4.61	31.24 ± 5.27	<0.001**	(1,3) (2,3)
	Median (range)	27.97 (15.92, 47.26)	28.03 (17.44, 41.58)	30.83 (20.7, 47.67)		

* *P* value is based on chi-square test.

** *P* value is based on ANOVA (In all the above analysis multiple comparison correction have done with Bonferroni method).

to weight, the results showed the greatest weight in the osteoporosis group. Based on the results, normal subjects (71.85±11.45 kg) were significantly different from the osteoporosis (77.16±14.33 kg) and LBM (71.93±12.47 kg) groups in terms of the mean weight. Finally, BMI-related comparisons were made.

The association between contextual variables and TBS subgroups is presented in Table 4. In all three groups, most participants were female, since the difference was not significant. BMI-related comparisons were conducted. As shown in Table 4, the results were similar to those obtained for height and weight.

Table 5 presents the descriptive statistics and the correlation between BMD and TBS in different BMI subgroups. An increase in BMI was associated with a higher BMD score, however is associated with a lower TBS score. Pearson's correlation coefficient of BMD and TBS decreased with increasing BMI.

In Table 6, osteoporosis based on BMD was compared with fully degraded microarchitecture based on TBS in participants. Comparisons were performed in terms of age, height, weight and BMI, which showed a significant difference regarding age, BMI and height. Patients with osteoporosis-BMD were older; additionally those with FDM-TBS were taller. Moreover, osteoporosis-BMD patients had a higher BMI values ($P=0.02$).

In men, a negative correlation between BMI and BMD was found(r=-0.254, $P=0.009$), while a positive relationship between BMI and TBS was existed (r=0.011, $P=0.91$) too. Moreover a positive relationship between height and BMD (r=0.103, $P=0.297$), and also the height and TBS (r=0.045, $P=0.65$) were detected. On the other

Table 4. Investigation of contextual variables in TBS subgroups

		TBS			*P* value
		NM	PDM	FDM	
Gender	Male	52 (13.9%)	40 (10.4%)	12 (14.6%)	0.272
	Female	323 (86.1%)	346 (89.6%)	70 (85.4%)	
Age	Mean (SD)	54 ± 5	55 ± 5	54 ± 5	0.422
	Median (range)	55 (41,65)	55 (42, 65)	55 (40, 65)	
Height	Mean (SD)	159.37 ± 7.4	158.55 ± 10.6	160.67 ± 7.77	0.131
	Median (range)	159 (142,180)	158 (0, 180)	160 (145, 180)	
Weight	Mean (SD)	72.61 ± 12.07	72.66 ± 12.88	73.19 ± 12.41	0.928
	Median (range)	71 (42,116)	72 (46, 118)	73 (42, 99)	
BMI	Mean (SD)	28.63 ± 4.68	28.79 ± 4.89	28.33 ± 4.44	>0.999
	Median (range)	28.4 (15.92,47.67)	28.57 (19.2, 47.67)	27.91 (19.05, 39.66)	

Table 5. Contextual variables in TBS subgroups

		Number (%)	BMD, Mean ± SD	TBS, Mean ± SD	Pearson Correlation (TBS Vs. BMD)
BMI	<18.5	3 (0.4%)	-1.23 ± 1.33	1.38 ± 0.04	0.999 (P<0.001)
	18.5 - 24.90	186 (22.1%)	-1.1 ± 1.04	1.32 ± 0.14	0.019 (P=0.57)
	25 - 29.9	353 (41.9%)	-1.13 ± 1.04	1.33 ± 0.1	-0.07 (P=0.878)
	30 - 34.9	213 (25.3%)	-1.24 ± 1.31	1.33 ± 0.1	-0.049 (P=0.907)
	+35	88 (10.4%)	-1.8 ± 1.31	1.32 ± 0.09	0.083 (P=0.399)

Table 6. Contextual variables in some categories

	TBS FDM		BMD osteoporosis		*P* value
	Mean ± SD	Median (range)	Mean ± SD	Median (range)	
Age	54 ± 5	55 (40, 65)	57 ± 4	58 (48, 65)	<0.001
Height	160.67 ± 7.77	160 (145, 180)	157.07 ± 6.28	156 (145, 180)	<0.001
Weight	73.19 ± 12.41	73 (42, 99)	76.87 ± 14.36	76 (48, 118)	0.059
BMI	28.16 ± 3.76	27.64 (20.24, 36.63)	31.19 ± 4.94	30.85 (20.78, 47.67)	0.02
Gender					
Male	12 (14.6%)		9 (7.3%)		0.102
Female	70 (85.4%)		115(92.7%)		

hand, a negative relationship between weight and BMD (r = -0.175, *P* = 0.076) was seen too. Furthermore, a positive relationship between weight and TBS was found (r = 0.02, *P* = 0.842).

In women, a negative relationship between BMI and BMD was found (r = -0.167, *P*<0.001), while there was a positive relationship between BMI and TBS (r = 0.01, *P* = 0.785). We also detected a positive relationship between height and BMD (r = 0.123, *P* = 0.001), whereas a negative relationship was observed between height and TBS (r = -0.022, *P* = 0.542). Likewise, a negative relationship between weight and BMD (r = -0.114, *P* = 0.002) was detected. Accordingly we found a positive relationship between weight and TBS (r = 0.001, *P* = 0.97). The slopes diagram for relationship between BMI and BMD in women is seen in Figures 1A to 1D.

Discussion

The present study aimed to determine the coefficient of agreement between TBS and BMD in the diagnosis of osteoporosis in a group of patients referred to a densitometry department. For this purpose, the demographic data of 843 patients were examined. According to the BMD score, 44.6% of patients were normal, while 40.2% had LBM and osteoporosis. In contrast, according to TBS, 44.5% and 45.8% of patients were classified in the NM-TBS and PDM-TBS groups respectively, while the remaining patients were included in the FDM-TBS group. In the present study, the osteoporosis group was found to be older. Height was also investigated in this study. The results showed, the mean height of patients with osteoporosis was significantly shorter than of normal subjects and those with LBM. In other words, normal subjects were the tallest group. Moreover, regarding weight, patients with osteoporosis were found to be heavier. The mean weight of normal subjects was less than the osteoporosis group. Additionally, 45.7% of the patients had a normal bone density in both tests. In contrast, 3.1% of the patients with severe osteoporosis were classified in the BMD and FDM-TBS groups. However, these two diagnostic indices did not produce similar results for some patients. Ripamonti et al in a retrospective study of the patients who had undergone consecutive BMD measurements of the lumbar spine, found that TBS had a relatively higher predictive power than BMD, but it was not independent of it. TBS has been conducted to predict spine fragility fractures as a non-osteoporosis subgroup (19). Correlation between TBS and BMI is controversially positive and is affected by age and weight.

In the study by Bazzocchi et al (20), values for both indices were reported to be similar for male (0.555) and female (0.655). The correlation between BMD and TBS

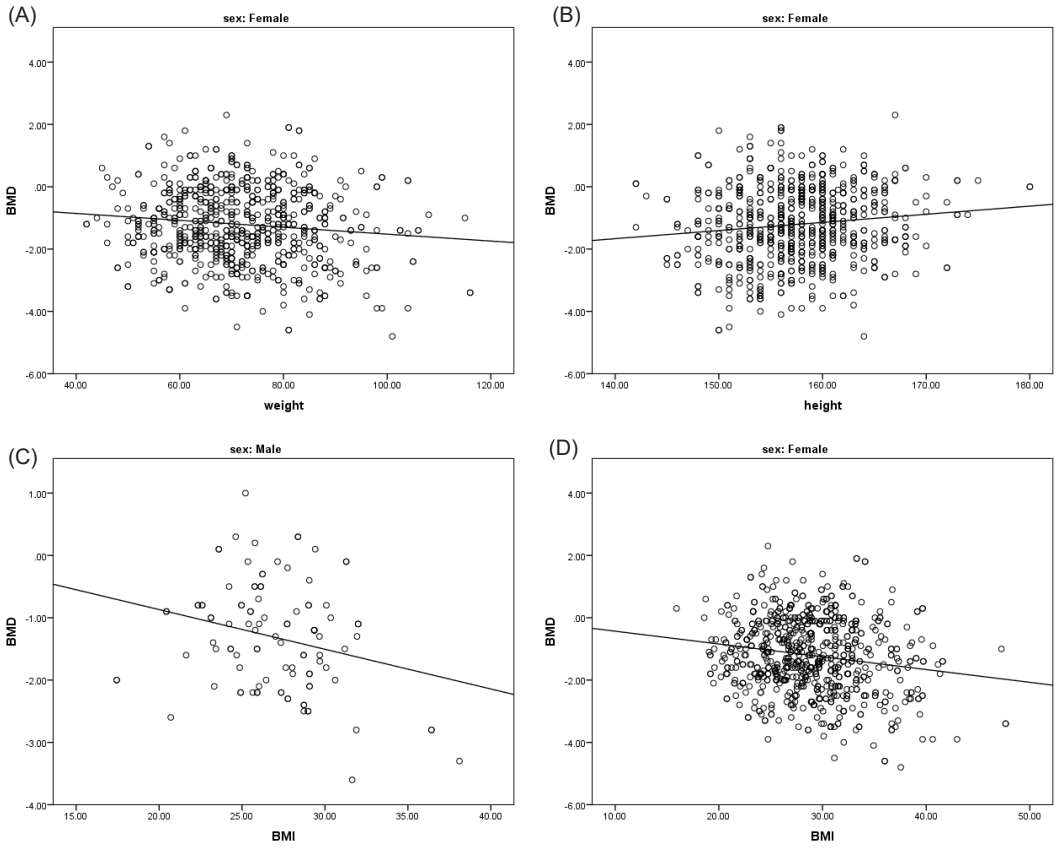

Figure 1. (A) The diagram slopes for relationship between weight and BMD in women. **(B)** The diagram slopes for relationship between height and BMD in women. **(C).** The diagram slopes for relationship between BMI and BMD in men. **(D)** The diagram slopes for relationship between BMI and BMD in women

is somewhat related to the BMI in which Langsetmo et al (21) reported, an increase in BMI was associated with a lower correlation between BMD and TBS. In a study conducted on Italian people, no correlation was found between BMI and TBS, which was consistent with our results (21). In another study, a positive correlation between BMI and TBS was reported (22). In contrast, in a meta-analysis, McCloskey et al showed a weak negative correlation between BMD and TBS (23). Therefore, it can be concluded that, no strong evidence about positive correlation of the BMD and TBS was existed; hence, BMD is stronger index to assess osteoporosis.

Rabier et al found that TBS and BMD were not significantly different indices. Nevertheless, the combined employing of these indices showed a greater predictive power than their independent use for future fractures (17). Conversely, in another study, Winzenrieth et al found that TBS had a higher predictive power than BMD (24).

The present study also we showed an increase in BMI was correlated with a higher BMD score; however, regarding TBS, increasing in BMI was correlated with lower TBS score. In a study on 548 patients, a positive relationship between TBS and LS-BMD was detected, which decreased with age. Besides, the significance of correlation varies depending on BMI, as Pearson's correlation coefficient of BMD and TBS decreased by increasing BMI (8).

Cheng et al reported, TBS was significantly related to age in the age group of 50-59 years. Moreover, TBS was measured in postmenopausal women (for <10 years) during their study (1). In the current study, a negative relationship between BMI and BMD in women was shown, while the relationship between BMI and TBS was positive. Moreover, a negative relationship between weight and BMD was seen, whereas the relationship between weight and TBS was positive. These results are similar in some cases and different with some other studies in comparison with the study conducted by Kim et al (25). Kim et al found a significant correlation between BMI and TBS in both male and female participants. The correlation coefficient gradually increased from the normal group to the osteoporosis group. Moreover, a significant positive correlation between height and TBS in women was observed, while a significant negative correlation between weight and TBS in men was detected. Although BMI increases the BMD score, it seems to have a negative impact on bone quality (25).

Conclusion

BMD and TBS have no significant correlation between them, since the two indices are almost independent of each other. Therefore, both BMD and trabecular bone should be used for fracture risk assessment.

Limitations of the study

This study was single center. Therefore, multicenter studies were recommended.

Authors' contribution

Conceptualization: Alireza Rajaei, Faraneh Farsad and Ideh Kamkar.
Data curation: Alireza Rajaei
Formal analysis: Alireza Rajaei and Ideh Kamkar.
Funding acquisition: Ideh Kamkar.
Investigation: Alireza Rajaei
Methodology: Ideh Kamkar.
Project administration: Alireza Rajaei, Faraneh Farsad and Ideh Kamkar.
Resources: Ideh Kamkar.
Software: Alireza Rajaei
Supervision: Alireza Rajaei
Validation: Alireza Rajaei, Faraneh Farsad and Ideh Kamkar.
Visualization: Ideh Kamkar.
Writing–original draft: Ideh Kamkar.
Writing–review & editing: Alireza Rajaei, Faraneh Farsad and IK.

Conflict of interest

The authors declare no conflict of interest.

Ethical issues

The research followed the tenets of the Declaration of Helsinki. The Ethics Committee of Shahid Beheshti university of medical sciences approved this study. (Ethical code#IR.SBMU.MSP.REC.1398.882). Accordingly, written informed consent was taken from all participants before any intervention. This study was extracted from M.D., thesis of Ideh Kamkar at this university (Thesis #2785). Besides, ethical issues, including plagiarism, data fabrication and double publication, have been completely observed by the authors.

Funding/Support

This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

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