Evaluation of bone mineral loss in patients with chronic traumatic spinal cord injury in Iran

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Objectives: We described the associations between demographic and injury-related factors on bone mineral density (BMD) of the spine and the hip among adult patients with chronic spinal cord injury (SCI).

Design: BMD in spinal and femoral bone sites were assessed. Multivariate analysis was performed to evaluate the relationship between anthropometric and injury-related factors with BMD. Serum level and amount of dietary intake of calcium, phosphor, and 25-hydroxy vitamin D were measured.

Setting: A referral tertiary rehabilitation center in Iran.

Participants: Patients with SCI who had no previous history of endocrine disorders and were not on specific medications entered the investigation. Those with non-traumatic SCI, pregnant, or with substance dependency were excluded as well.

Interventions: No interventions were applied.

Main study outcome measures: Dual X-ray absorptiometry was performed to estimate BMD. Body mass index was positively associated with higher femoral ($P < 0.01$, $r = 0.56$) and hip ($P < 0.0001$, $r = 0.82$) BMD only in female participants. The high prevalence of vitamin D deficiency (60%) was noticeable.

Results: Older male patients revealed lower BMD only in spinal vertebrae ($P < 0.02$, $r = -0.21$). A significant higher BMD loss in lumbar vertebrae in male patients with complete spinal cord lesion ($P < 0.009$) was detected. Spinal reduction of BMD was more severe when the level of injury was above T6 ($P < 0.02$).

Conclusion: Along with the clarification of age, gender, post injury duration, and the other factors' effect on the BMD in the SCI patients, here we have also shown the noticeable prevalence of the 25-hydroxy vitamin D deficiency in these patients which needs attention.

Keywords: Spinal cord injury, Vitamin D, Bone mineral density, Osteoporosis

Introduction

Severe reduction of bone density has been detected in patients with spinal cord injury (SCI). Decreased bone mineral density (BMD) is a known consequence of spinal injury.¹ Osteoporosis is a known complication of long-term SCI which manifests with pathological fractures in these patients especially in lower extremities.²⁻⁴ Many factors are proposed as predictors in

BMD loss in patients with SCI including demographic features² such as age,⁵ sex, body weight, and body mass index (BMI).⁶ Many studies have evaluated the effects of these factors on BMD in patients with SCI, but many controversies still exist.²⁻⁶ Studies show that all patients with SCI show mostly osteopenia or osteoporosis of the hip, but BMD values in the rest of the body are more stable and the reduction of BMD which occurs in the spinal vertebrae in these patients is not large.^{7,8} It seems that the factors predicting bone loss in spinal vertebra and long bones are rather different.

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The high bone turnover rate after the SCI can last for 1–2 years,⁹ which leads to rapid bone loss. Patients with tetraplegia and paraplegia were previously compared, and no significant difference in BMD has been reported.^{3,5,9} The level of injury appears to influence vertebral BMD¹⁰ but the existence of such an effect on long bones remains unclear. Generally, it seems that various factors affect BMD in vertebrae and long bone sites, and further investigations are required to determine these triggers.

Injury-related factors have shown controversial effects on BMD^{5,6,11–13} and the correlation of these variables with long bones' mineral density still needs further investigation. Factors including time since injury, completeness, and the level of injury have been proposed, which have shown some controversial effects. Although these studies evaluated a number of factors, a combined consideration of these factors could help to predict bone loss in SCI patients.^{5,6,11–13}

Therefore, the purpose of this study was to assess BMD of hip and vertebral sites in Iranian patients with chronic SCI according to age, sex, demographic and injury-related factors, and some intake of specific nutrients to determine their effects on BMD in these patients.

Methods

Subjects

Patients with chronic SCI who were referred to Brain and Spinal Injury Research center (BASIR) were invited to participate in this cross-sectional study and written consent was obtained from each participant before enrollment. All participants were healthy and lived with their families. All female patients older than 55-years-old were excluded to omit the bias effect of menopausally induced osteoporosis. Exclusion criteria were pregnancy, lactation, any rehabilitation therapy, amputation, and non-traumatic SCI etiology. Patients with a history of diabetes, cancer, endocrine disease, acute infection, use of specific medications such as glucocorticoid, hormones, thyroid hormones, or nutritional supplements, and smoking or alcohol consumption were also excluded. The study was approved by the research ethics committee of Tehran University of Medical Sciences.

Anthropometric measures

All measurements were conducted by the same investigator. Body weight was measured using a digital wheel-chair scale. Body height was obtained by measuring the supine length, and BMI was calculated as body weight (in kilograms) divided by height (in meters) squared.

Clinical measurements

All study participants were medically stable upon inclusion into the study. Patients' demographic features such as sex, age, weight, height, supplement and drug intakes, time since injury, location, and completeness of injury were assessed by using a questionnaire in an interview by an experienced investigator.

Dietary intake

Dietary intakes of the patients were assessed by standard 3-day food records and a food frequency questionnaire validated by the nutrition group of the BASIR.¹⁴

Neurological assessment

The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI), which is an examination used to determine the motor and the sensory impairment, and the severity of an SCI was used and the related American Spinal Injury Association (ASIA) score was estimated.^{14,15} In this classification, patients are classified into five groups as follows: (A) Complete; no motor or sensory function is preserved in the sacral segments S4–S5, (B) Incomplete; sensory but not motor function is preserved below the neurological level and includes the sacral segments S4–S5. (C) Incomplete; motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade <3. (D) Incomplete; motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more. (E) motor and sensory function are normal. The level of spinal injury was also determined by using imaging facilities such as magnetic resonance imaging. Patients with non-traumatic SCI were excluded. Completeness was classified as either complete (no sensory or motor function preserved in the sacral segments (S4–S5)) or incomplete (variable motor function preserved below the neurological level of injury).^{14,15}

Laboratory measurements

Blood samples were taken to assess serum level of total calcium (ionized plus albumin attached), phosphorus, and 25-hydroxy vitamin D in Endocrinology and Metabolism Research Institute. Normal level of phosphorus was considered as 2.5–4.5 mg/dl and normal range of calcium level was 8.5–10.5 mg/dl. Serum 25-hydroxy vitamin D levels were assessed by a competitive protein-binding assay and the normal range was considered as 30.0–74.0 ng/ml.

BMD measurements

Dual-energy X-ray absorptiometry which is the proposed method to assess BMD¹⁶ was used. Calibration of bone densitometer Lunar DPXMD device (Lunar Corporation, Madison, WI, USA) was performed weekly by using appropriate phantoms. The precision error for BMD measurements was 2–3 in the femoral and 1–1.5 in the lumbar regions. All scans were performed according to the manufacturer's guidelines. *T*-scores and *Z*-scores of the femur neck, the trochanters, the intertrochanteric zone, and also the lumbar vertebra (L1–L4) were investigated. In patients with spinal implant, the involved lumbar vertebrae were excluded and the mean bone density of non-involved vertebrae was entered into the analysis. An assessment of the femur BMD was conducted by using the abovementioned three points (neck, trochanters, and intertrochanteric zone), which seemed to be adequate as an indicator of long bones. We also measured the total hip BMD. According to World Health Organization/Osteoporosis foundations¹⁷ diagnostic categories, we defined osteoporosis as BMD *T*-score $\leq -2.5SD$, osteopenia as $-2.5SD < T\text{-score} \leq -1SD$, and BMD *T*-score $> -1SD$ young adult mean was considered as normal.

Analysis

All statistical analyses were performed using SPSS 18.0 (SPSS, Inc., Chicago, IL, USA). We report results by expressing percentages, mean $\pm$ 95% confidence interval, and the proper comparison of means using *t*-test and one-way analysis of variances (ANOVA). Pearson's correlation was used to investigate correlations between variables along with linear regression and univariate models. $P < 0.05$ was considered statistically significant. The data related to the intakes of calcium, phosphor, and vitamin D data were analyzed using Nutritionist IV 3.5.3. (N-Squared Computing, Salem, OR, USA) modified for Iranian foods.¹⁸

The differences of vitamin D, calcium, and phosphor intake amount and serum levels between those with paraplegia and tetraplegia and those with complete and incomplete injuries were determined by independent *t*-tests. Multivariate analysis with observed power using α (0.05) was performed to evaluate the relationship between gender, completeness of injury, and ASIA score with femoral and spinal BMD.

Results

Patients' demographic features along with their daily dietary intake and the serum levels of calcium, phosphor, and 25-hydroxy vitamin D are shown in Table 1. Sex distribution of participants was 116 male (78.4%) and 32 female (21.6%). Mean BMI was 23.71 in the male group in which 64.7% had normal BMI (BMI < 25), 28.1% were overweight (BMI: 25–30), and 7.2% were obese (BMI > 30) according to WHO classification. The female group, with a mean BMI of 25.14, consisted of 57.6% with normal BMI, 37.2% overweight, and 5.2% obese.

Total mean *T*-score in lumbar vertebrae was -0.05 ± 1.99 . For each patient, every lumbar vertebrae BMD (L1–L4) was measured which included a total number of 592 entries for 148 patients in whom 108 vertebrae were excluded because of implant placement. Mean BMD of intact vertebrae with no implant was considered as lumbar vertebrae's total BMD and entered into analysis. No implant was administered in 78 patients. Female patients showed higher BMD in femoral neck, trochanter, intertrochanteric zone, and total hip (*P* values for *T*-scores: 0.030, < 0.0001 , 0.006, and 0.001 with $r = 0.18$, 0.37, 0.23, and 0.27, respectively) but no significant association between sex and lumbar vertebrae's BMD could be detected (Table 2).

Factors triggering BMD in patients with SCI are shown in Table 3. A positive relationship between BMI and femur neck, trochanter, and intertrochanteric zone

Table 1 Demographic features, serum level, and dietary intake of calcium, phosphor, and 25-hydroxy vitamin D in patients with SCI

Parameter	Female (<i>n</i> = 32)		Male (<i>n</i> = 116)	
	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
Age (years)	42.80 $\pm$ 4.81	36–54	51.00 $\pm$ 12.89	14–73
Weight (kg)	61.16 $\pm$ 12.67	41–98	70.79 $\pm$ 14.48	41–115
Height (cm)	156.21 $\pm$ 5.77	145–166	172.37 $\pm$ 7.17	155–188
BMI (kg/m ²)	25.14 $\pm$ 5.63	17.7–43.56	23.71 $\pm$ 4.034	17.07–36.30
Calcium level (mg/dl)	8.928 $\pm$ 0.551	8–10	9.506 $\pm$ 5.885	7.2–10.6
Phosphor level (mg/dl)	3.875 $\pm$ 0.385	2.99–4.67	3.772 $\pm$ 0.408	2.99–4.6
25-Hydroxy vitamin D (μ g/dl)	54.70 $\pm$ 113.52	7.5–595	40.90 $\pm$ 53.06	6.40–343.10
Dietary calcium (mg)	565.7 $\pm$ 270.6	244–1178	835.3 $\pm$ 755	106–5910
Dietary phosphor (mg)	1061.6 $\pm$ 656.9	386–2560	1174.9 $\pm$ 709.88	160–4272
Dietary vitamin D (μ g)	0.84 $\pm$ 1.23	0–3	1.26 $\pm$ 2.21	0–16

BMI, body mass index; SCI, spinal cord injury.

Table 2 Femoral and lumbar vertebrae BMD in patients with SCI

Measurement site	Female (<i>n</i> = 32)				Male (<i>n</i> = 116)				P value
	<i>T</i> -score		<i>Z</i> -score		<i>T</i> -score		<i>Z</i> -score		
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	
Femur neck	−1.335 ± 1.971*	−6.20–4.50	−1.092 ± 1.959*	−6.0–4.90	−1.943 ± 1.069*	−4.40–1.10	−1.527 ± 1.093*	−3.60–1.50	0.030*
Femur trochanter	−0.940 ± 1.155*	−2.60–1.60	−0.863 ± 1.132*	−2.60–1.60	−1.876 ± 0.879*	−4.0–0.9	−1.688 ± 0.891*	−3.80–1.20	0.000*
Femur intertrochanteric zone	−1.433 ± 1.258*	−3.70–2.10	−1.366 ± 1.227*	−3.50–2.20	−2.075 ± 1.029*	−4.30–0.50	−1.999 ± 1.046*	−4.30–0.60	0.006 [#]
Total hip	−1.42 ± 1.25*	−3.50–2.40	−1.30 ± 1.20*	−3.00–2.50	−2.13 ± 0.95*	−4.10–0.20	−1.99 ± 0.983*	−4.20–0.4	0.001 [#]
Lumbar vertebra	0.63 ± 1.636	−2.7–4.0	0.86 ± 1.52	−1.40–4.20	−0.219 ± 2.042	−5.25–7.10	0.45 ± 3.06	−3.90–4.40	0.054

BMD, bone mineral density; SCI, spinal cord injury.

*Significant difference between male and female groups by independent-test at the level of $P < 0.05$.[#]Significant difference between male and female groups by independent-test at the level of $P < 0.01$.

(Female patients had higher BMD only in femoral bone sites.)

T- and Z-scores was detected only in female patients (P : 0.01, 0.019, 0.001, 0.003, 0.013, and <0.0001 , respectively), but there was no significant relationship between BMI and spinal vertebra BMD. The correlation between BMI and total hip BMD in female patients was also significant ($P < 0.0001$) (Table 3).

There was also no significant correlation between age and female BMD, but older male patients had lower T-score in lumbar vertebrae bone density ($P < 0.02$, $r = -0.21$), while this relationship with spinal Z-score of BMD remained non-significant ($P = 0.08$). We also detected a negative relationship between age and femoral neck BMD Z-score only in male participants (Table 3).

Post injury duration had no significant association with bone density T- and Z-scores of femoral neck, trochanter, intertrochanteric zone, and total hip (Table 3).

SCI was complete in 77% of patients and incomplete in 23%. Male patients with complete SCI had lower BMD in lumbar vertebra T- and Z-score (P : 0.009 and 0.02, respectively), but femoral and total hip BMD revealed no statistically significant difference between these two groups. The most common type of ASIA score in our center was type A (no motor or sensory function is preserved in the sacral segments S4–S5). We also detected lower bone density in intertrochanteric zone of femur in patients with ASIA type D ($P = 0.005$), but no other relationship between ASIA score and other bones' density was found.

Patients' age, weight, and BMI showed no significant correlation with serum calcium and phosphor levels. Mean calcium intake was 565.7 ± 270 mg/day in the female group and 835.3 ± 755 mg/day in the male patients with SCI. No supplemental intake existed. As almost all patients were bedridden or unable to walk, sun exposure was considered as "very low" for all patients. Mean serum calcium and inorganic phosphor levels showed no statistically significant relationship with age,

weight, height, BMI, femoral, and lumbar vertebrae T- and Z-scores of BMD. However, there was a negative correlation between serum 25-hydroxy vitamin D level and lumbar vertebrae Z-score (P : 0.04, $r = -0.18$). There was also no association between completeness of injury and serum calcium and phosphor level. Renal function, which was interpreted by creatinine clearance, was normal in all the patients.

Serum levels of calcium, phosphor, and 25-hydroxy vitamin D had also no difference between patients with different ASIA score. The level of injury correlated significantly with the serum levels of calcium, phosphor, and 25-hydroxy vitamin D as the higher calcium level was in patients with injury at level T5 (P : 0.04), the highest phosphor level was at level of T6 (P : 0.006), and the highest 25-hydroxy vitamin D was detected at the injury level of C4 (P : 0.027). Post injury duration had no effect on serum calcium, phosphor, and 25-hydroxy vitamin D level. Low levels of 25-hydroxy vitamin D were detected in 64.7% (lower than 30 ng/ml) (Table 4). This investigation was performed on patients with SCI at their primary referral visits when no medical and rehabilitation treatments were applied yet. Of course, most of these patients went through some medical therapies after gathering required items for this study.

Discussion

Most patients with SCI experience bone mineral reduction due to inability to move. Decreased motility and accompanying muscle atrophy lead to reduced bone mineral.^{2,3} Studies show that most patients with SCI show osteopenia or osteoporosis at weight-bearing bones while bone demineralization in lumbar spine remains lower.^{2,3,19} Our study revealed the same result as reduction of BMD was more severe in femoral bone sites. Previously, the level of injury was proposed as an effective factor in bone loss in patients with SCI.¹⁰

Table 3 Factors triggering BMD in patients with SCI (numbers presenting P values (*r*))

		Femur neck		Femur trochanter		Femur intertrochanteric zone		Total hip		Lumbar vertebra	
Variable		T-score	Z-score	T-score	Z-score	T-score	Z-score	T-score	Z-score	T-score	Z-score
Age	Male	0.10	0.025 (<i>r</i> = -0.20)	0.75	0.10	0.24	0.37	0.33	0.10	0.022 (<i>r</i> = -0.21)	0.08
	Female	0.43		0.70	0.62	0.85	0.74	0.73	0.72		0.69
BMI	Male	0.44	0.18	0.75	0.73	0.20	0.08	0.23	0.12	0.49	0.65
	Female	0.014*	0.009**	0.016*	0.008**	0.0001**	0.0001**	0.0001**	0.0001**	0.39	0.29
		(<i>r</i> = 0.56)	(<i>r</i> = 0.59)	(<i>r</i> = 0.55)	(<i>r</i> = 0.60)	(<i>r</i> = 0.75)	(<i>r</i> = 0.79)	(<i>r</i> = 0.82)	(<i>r</i> = 0.87)		
Injury completeness	Male	0.44	0.76	0.74	0.89	0.40	0.77	0.45	0.96	0.009**	0.029*
	Female	0.65	0.68	0.78	0.79	0.31	0.29	0.69	0.70	0.83	0.82
Post injury duration	Male	0.58	0.33	0.69	0.34	0.93	0.49	0.96	0.34	0.06	0.12
	Female	0.33	0.40	0.77	0.72	0.80	0.06	0.18	0.21	0.19	0.11

BMD, bone mineral density; BMI, body mass index; SCI, spinal cord injury.

P value stands for ANOVA test for SCI severity and gender association with BMD and for linear regression for BMI, age, and post injury duration's correlation with bone density.

*Correlation is significant at the 0.05 level.

**Correlation is significant at the 0.01 level.

Our data support the fact of higher reduction of BMD when the level of injury is above T6 (*P*: 0.029). Some studies have revealed no specific BMD difference between patients with paraplegia and tetraplegia,^{3,5,11–13,20,21} whereas other studies have shown more severe BMD reduction in cases with injury level above T6,^{10,22} which is in line with our results. We propose that the occurrence of autonomic dysreflexia is one of the factors causing higher bone loss in patients with higher injury level. Although autonomic dysreflexia has been reported even when the lesion level was below T8,^{23,24} it seems that it may occur more frequently as a clinical sequelae in patients with SCI above thoracic level 6 (T6). The BMD reduction in spinal vertebrae in male patients with tetraplegia and complete injury was also significantly lower (*P*: 0.01 and 0.03 for spinal *T*- and *Z*-scores, respectively), but no such a relationship could be detected in femoral bone sites.

According to our results, BMI is positively related with femoral and total hip BMD in female patients with SCI (Table 3). Some studies have reported a positive association between BMD and body weight,⁶ and a positive relationship between BMI and sublesional BMD in individuals with SCI was previously reported,¹⁰ which is in agreement with our results. A protective effect of weight on paralyzed lower limbs has been claimed⁴ and our results have revealed higher femoral BMD in female patients with higher body weight. Generally, it seems that higher BMI can decrease bone mineral loss in patients with SCI and it seems this effect is more significant in female individuals.

Previously, no significant association between age and BMD in patients with SCI could be detected,^{9,16} but our

study shows a negative effect of age only on spinal vertebrae *T*-score of BMD (*P*: 0.02, *r* = -0.21) and no such influence could be found on femoral bones. The negative effect of age on lumbar vertebrae's BMD was stronger than femur bone sites. Although this study is a cross-sectional evaluation which does not follow BMD of patients through time, it seems that higher age is more closely associated with the loss of BMD in spinal vertebra. Post injury duration is one of the factors affecting BMD, with controversial results reported in previous investigations.^{3,11–13,19–21,25} Our findings show that post injury duration has no effect on sublesional femoral BMD which is in line with Shojaei *et al.*¹⁹ However, while Reiter *et al.*¹² revealed a positive association between post injury duration and spinal BMD, our data revealed no such correlation. However, studies do support the finding that reduction of bone density slows down over time after SCI.²⁵

Completeness of SCI is another factor which is assumed to have some effects on BMD, but recent investigations have so far yielded conflicting results. Some studies have found no effect of completeness of injury on BMD,⁹ whereas some have shown a negative correlation.²⁶ Our results show a significantly higher BMD loss in lumbar vertebrae in male patients with complete spinal cord lesion in comparison with incomplete injuries. Patients with complete SCIs have no sensory or motor function in the sacral segment, while incomplete lesions show some preserved motor functions, which prevent the massive bone loss in lumbar vertebrae. This protective effect cannot be described in femoral bones.

Calcium and phosphor serum levels undergo some changes due to bone turn over, which is rapid in acute

Table 4 Serum calcium, phosphor, and 25-hydroxy vitamin D levels in patients with chronic traumatic SCI

		Calcium level	Phosphor level	25-hydroxy vitamin D level
Low	Male	31 (26.7%)	2 (1.7%)	74 (63.8%)
	Female	8 (25%)	0 (0%)	21 (65.6%)
Normal	Male	84 (72.4%)	112 (96.6%)	30 (25.9%)
	Female	24 (75%)	30 (93.8%)	7 (21.9%)
High	Male	1 (0.9%)	2 (1.7%)	12 (10.3%)
	Female	0 (0%)	2 (6.3%)	4 (12.5%)

SCI, spinal cord injury.

Normal range of total calcium level: 8.5–10.5 mg/dl. Normal range of phosphor level: 2.5–4.5 mg/dl. Normal range of 25-hydroxy vitamin D: 30.0–74.0 ng/ml.

Frequencies are represented as the number of patients (percentage).

phase of SCI^{27,28} and is stabilized through time. We only recruited patients with chronic, traumatic SCI, in order to omit the acute phase effect on serum calcium and phosphor level. No relationship between BMD, age, weight, BMI, and post injury duration with calcium, phosphor, and 25-hydroxy vitamin D levels could be found, but taller patients had significantly higher 25-hydroxy vitamin D ($P < 0.008$, $r = -0.27$). No previous effect of height on 25-hydroxy vitamin D level has been reported but the determination of the exact association needs further investigation, with studies matching other effective factors on the serum level of 25-hydroxy vitamin D.

It has been shown that vitamin D deficiency is common among patients with SCI.^{29–31} Zhou *et al.*³¹ reported that serum 25-hydroxy vitamin D and calcium levels are significantly lower in men with SCI compared with healthy controls. Our study revealed low 25-hydroxy vitamin D levels (lower than 30 ng/ml) in about 63.8% (n : 74) of males and 65.6% (n : 21) of females with SCI (Table 4), which is in line with previous investigations showing higher frequency of vitamin D deficiency in individuals with SCI. Total calcium level is shown to be decreased in SCI patients due to altered vitamin D metabolism or inadequate intake.^{29,31} Our study showed that 72.4% (n : 84) of males and 75% (n : 24) of females with SCI had normal calcium level and most patients had normal phosphor level. Different dietary intakes may explain the difference. The very high prevalence of vitamin D deficiency in patients with SCI has been reported frequently.^{29,31–33} Some studies showed a greater drop of 25-hydroxy vitamin D in individuals with incomplete injury compared with complete lesions.³⁰ The lower level of 25-hydroxy vitamin D in patients with paraplegia versus individuals with tetraplegia was reported as well.³³ We detected significantly higher vitamin D levels in individuals with incomplete SCI ($P < 0.01$), which is in controversy with these studies.^{32,33} As the factors influencing 25-hydroxy vitamin D levels are numerous (such as sun exposure rate and intake of supplemental vitamin D and fortified foods with vitamin D), the comparison of our results with previous published

data is impossible. Fortification of foods with vitamin D is not common in our country and none of the participants in our study had supplemental intake of vitamin D which can be an important factor affecting the 25-hydroxy vitamin D level and causing such a discrepancy with the findings from the previous studies. By considering the fact that many SCI patients in Iran have low accessibility to medical centers and thus receive inadequate calcium and vitamin D supplements, regular food is their only access to these vital materials. Our data represents a high frequency of vitamin D deficiency in Iranian spinal cord injured individuals which needs attention.

Study limitations

There are some limitations that should be considered when examining the results of this study prior to applying its results in people with SCI. One of them is using a cross-sectional design to evaluate the association of bone loss to injury-related variables. Although a large number of participants were included in the study, the present sample was still fairly small and limited our ability to distinguish slight differences between the groups.

Conclusion

This is the first published study of a population based in Iran to assess BMD in patients with chronic SCI according to demographic, dietary, and injury-related factors. Our study revealed that reduction of BMD was more severe in femoral bone sites and higher reduction of lumbar BMD was shown when the level of injury is above T6. We detected a significantly higher vitamin D deficiency in individuals with SCI. Fortification of foods with vitamin D is not common in our country and none of the participants in our study received vitamin D supplements. This study has clarified the effect of various factors such as age, post injury duration, sex, BMI, etc. on BMD in patients with SCI. Moreover, the high prevalence of vitamin D deficiency in these patients is noticeable and requires attention.

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Disclaimer statements

Contributors ANJ helped recruit the subjects and data collection. HS contributed to the design of the study and was responsible for collecting data and for editing the manuscript. SL contributed in Data analysis, interpreting data, writing and editing the manuscript.

Conflicts of interest To the best of our knowledge, no conflict of interest, financial or other, exists.

Ethics approval The study was approved by the research ethics committee of Tehran University of medical sciences.

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