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Research Article

The effect of bone mineral density on development of Schmorl's nodes in young patients

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ABSTRACT

Objective: The aim of this study was to detect the relationship between the development of Schmorl's nodes (SNs) and bone mineral density (BMD) in young patients.

Methods: Computerized tomography (CT) images of the thoracolumbar vertebral column were retrospectively examined by two experienced radiologists for SNs. The diagnostic criterion for SN was defined as a node size larger than one-third but not more than two-thirds of the relevant vertebral endplate. Considering the eligibility criteria, a total of 74 individuals (60 males and 14 females; mean age: 24.3 years; age range: 18-40 years) with SN at the thoracolumbar vertebrae were included in the patient group, and a total of 38 age- and gender-matched individuals (30 males and 8 females; mean age: 25 years) with no evidence of SN were included in the control group. All these individuals were younger than 40 years. In the patient group, SNs were assessed in terms of the distribution of the thoracolumbar vertebrae, the location of the upper and lower endplates, and the total number of lesions. In all individuals included in the study, BMD was measured from the axial CT sections by quantitative CT and then compared between the two groups.

Results: The distribution of age and gender was comparable between the two groups (p=0.438). A total of 208 SNs were identified in the patient group. Of these, 92 (44%) were located at the thoracic vertebrae and 116 (56%) at the lumbar vertebrae. The mean BMD was 131.6 g/cm3 in the patient group and 140.7 g/cm3 in the control group (p=0.03). There was no significant relationship between the total number of SNs per patient and the mean BMD (p=0.156).

Conclusion: Evidence from this study revealed that low BMD may be a predisposing factor for the development of SNs in patients younger than 40 years.

Level of Evidence: Level III, Diagnostic Study

The herniation of an intervertebral disc in a superior or inferior direction within the adjacent corpus vertebrae is referred to as a Schmorl's node (SN) (1). The incidence of SN was reported to be between 38% and 76% in two studies with a mean age of 50 years and to involve the lower thoracic and lumbar regions more frequently, based on the fact that these regions carry the highest proportion of load on the axial skeleton (2, 3).

Various theories have been introduced to explain the pathogenesis of SN. As the annulus fibrosus of the intervertebral disc is still healthy and intact in young patients, the disc herniations in these patients tend not to take the form of the classical horizontal disc herniation, as seen in older patients (4). Though posterolateral herniations are common in older patients, only few studies have shown that the higher-level herniations are strongly related to age. In case of a trauma that exerts an axial force, herniation occurs toward the corpus vertebrae through micro-fractures developing in the weak points within the end plates (5).

The conditions that cause a weakening of the vertebral endplates include the primary and secondary bone dysplasia, neoplasms such as multiple myeloma and metastases, hyperparathyroidism, osteoporosis, osteomalacia, and disc infections (6).

Magnetic resonance imaging (MRI) is the ideal imaging for the diagnosis of SN, although a direct X-ray may also indicate SN in the late stage after calcification occurs around the node. In a direct X-ray, SNs appear as lucent

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lesions with regular borders, surrounded by a sclerotic appearance localized to the vertebral endplate. In addition to identifying SN, MRI also facilitates the differentiation between the acute and chronic cases; the increased bone marrow signal intensity in the T2A sequences may help identify the acute cases requiring treatment (7, 8). In the presence of non-acute SNs, there is generally no edema seen in the adjacent bone marrow.

The diagnosis of SN and other spinal pathologies by multi-detector computed tomography (MDCT) has become more common in recent years. Kayan et al. reported that they detected SN with an accuracy of 87% by MDCT (9).

A quantitative computerized tomography (qCT) is the only method that can provide volumetric bone mineral density (BMD) values in g/cm^3 separately for the cortex and trabecular bone. The qCT offers the additional advantage of providing axial images. Depending on the age and disease severity, it is obvious that the bone losses at the cortical and trabecular bone levels are not the same; therefore, it is important that the values obtained from each anatomical site have only a minimal effect on each other. The qCT allows the evaluation of the trabecular and cortical bones separately, and it might also be applied to the spinal vertebral column and peripheral appendicular skeletal system.

It is generally evaluated based on the bone density at the trabecular bone level within the consecutive trabecular bone structures between thoracic vertebrae 12 and lumbar vertebrae 4 (T12 and L4).

The relationship between the formation of SN and BMD has not been investigated in young patients. We hypothesized that BMD is a clinically important indicator in young patients with SN. This study investigated the relationship between the development of SN and BMD in the vertebral column.

Materials and Methods

The radiological imaging archive of our hospital, covering the period of 2011 to 2015, was retrieved to analyze the CT images of the thoracolumbar vertebral columns obtained through a 64- and 16-channel multi-slice CT (MSCT) device (Brilliance, Philips Medical Systems, Eindhoven, Netherlands) or the thoracoabdominal CT images involving the thoracic and lumbar vertebrae. The images were evaluated by two radiologists with 4 and 2 years of experience. The criterion for the SN diagnosis was to have a node larger than one-third but smaller than two-thirds of the endplate, depending on the consensus between the two radiologists. The distribution of the thoracolumbar vertebrae, the location of the upper and lower endplates, and the total number of SNs were evaluated in detail (Figure 1, 2).

A previous study performed at our department showed that the intra- and inter-observer coefficients of variation (CV) of the BMD measurements via qCT were satisfactory for such an analysis. The intra- and inter-observer CV were 5.1 and 5.9, respectively (10).

All cases were selected from the individuals younger than 40 years. For the patient group, the presence of a node in the same plane in both the sagittal and coronal sections indicated SN. The patient group included 74 patients who were diagnosed with one or more SN in the thoracolumbar vertebral columns by CT and were randomly selected from the archive. The control group included 38 cases with a similar distribu-

HIGHLIGHTS

- In the literature, there is no study investigating the relationship between SN and bone mineral density in young patients.
- In this study, only patients under 40 years of age were included in the study to obtain a homogeneous patient population.
- The results of this study indicated that the BMDs of patients with SNs were significantly lower than those of the control group.
- The finding of lower BMD in those with SN might contribute to understanding the pathogenesis of SN and its significance in clinical issues.

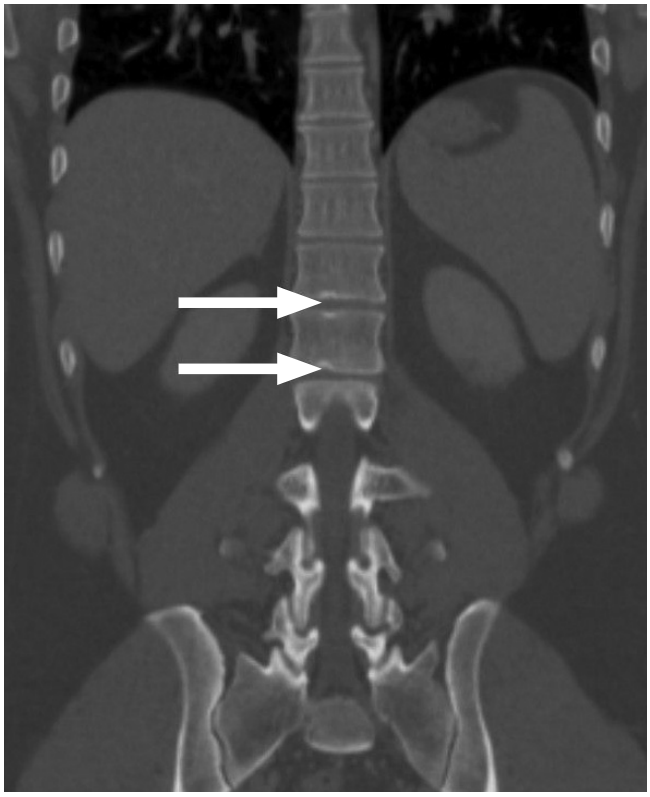

Figure 1. Coronal reformat CT image showing the SNs at thoracic 12 and lumbar 1 vertebrae of a 31-year-old male patient

CT: computerized tomography; SNs: Schmorl's nodes

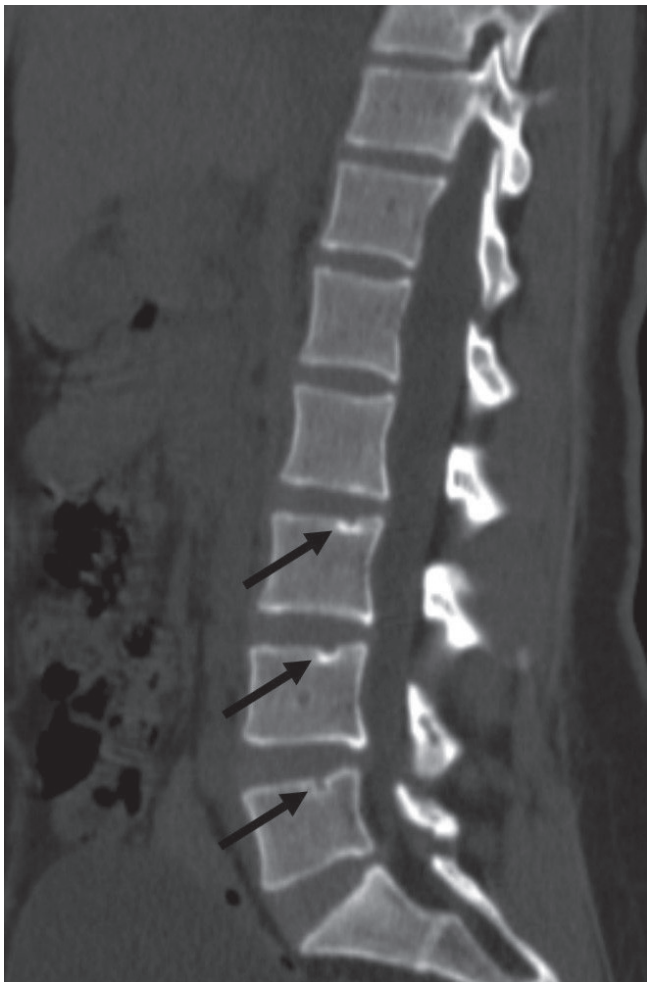

Figure 2. Sagittal reformat CT image showing the SNs at lumbar 3, 4, and 5 vertebrae of a 23-year-old female patient

CT: computerized tomography; SNs: Schmorl's nodes

tion of age and gender but without an SN being detected in the CT images. The spinal column CT scanning parameters were as follows: 120 kVp, 120 mA, beam pitch of 0.688, and slice thickness of 0.75 mm. The axial scans were reconstructed with 1.0-mm slice thickness and 0.75-mm reconstruction increment to obtain the sagittal plane images.

Approval for the study was obtained from the Ethics Committee of Dokuz Eylül University, School of Medicine (approval number: 1829-GOA 2014/38-02).

Patients with a congenital vertebral abnormality, bone metabolism disorder, infection in the vertebral column, fracture, tumor, and a history of vertebral column surgery for any reason were excluded from the study.

Age, gender, and the presence and number of SNs were recorded for all participants. BMD was measured from the CT images obtained from the axial plane by using the qCT software at a Philips workstation (Philips Extended Brilliance Workspace V3.5.0.2254). The qCT measurements included the volumetric measurements of 1-cm cross-section thickness, ensuring that the bone volume was not lower than 2.5 cm^3. The region of interests (ROIs) in the spine were placed in the trabecular bone of each corpus vertebrae at the T12-L5 level, and the BMD measurements were obtained in a blinded manner by a radiologist with 4 years of experience.

The findings of the three previous studies were utilized to calculate the positive effects of the contrast agent on BMD in the CT images obtained by using an intravenous contrast agent (11-13). To eliminate the effects of the contrast agent, we used the formula developed in these studies through linear regression analysis. The BMD values, which were calculated from the CT images obtained by using an intravenous contrast agent, were revised using the following formula:

$$BMD_{qCT\ without\ contrast} = \left(0.91 \times BMD_{qCT\ with\ contrast}\right) - 0.31$$

The trabecular BMD (mg/cm^3) was measured by the phantomless qCT technique. An ROI of approximately 2.5 cm^3 (with a thickness of 1 cm and an area of 2.5 cm^3) was drawn by using a hands-free tracing tool and was located in the trabecular bone of the corpus vertebrae. During the BMD measurement, the ROI was placed in the central part of the vertebral corpus; the posterior venous plexus, degenerative sclerotic areas, and SNs were not included in the ROI to increase the accuracy of the measurements. The measured total volume was about 2.5 cm^3. We used the standard qCT BMD protocol by measuring the number of fat and muscle areas on the same slice for calibration according to the guidelines set by the manufacturer (Figure 3).

Statistical analysis

The statistical analysis was carried out using the Statistical Package for Social Sciences version 15.0 program (SPSS Inc., Chicago, IL, USA). The descriptive statistics were presented as mean±standard deviation for the continuous variables and as percentages for the categorical variables. A Kolmogorov–Smirnov test was used to assess the distribution of the continuous variables. All variables except the total number of SNs were normally distributed ($p>0.05$). The p values <0.05 were considered statistically significant. The normally distributed variables were analyzed using the independent samples *t* test; others were evaluated with the Mann–Whitney U test. A chi-square test was used to compare the distribution of gender. Finally, the Pearson and Spearman correlation tests were used to evaluate the correlation between various variables.

Results

The patient group included 74 patients, 14 (18.9%) women and 60 (81%) men; and the control group included 8 (21%) women and 30 (78.9%) men. The mean ages of the patient and control groups were 24.3 and 25.0 years, respectively. The

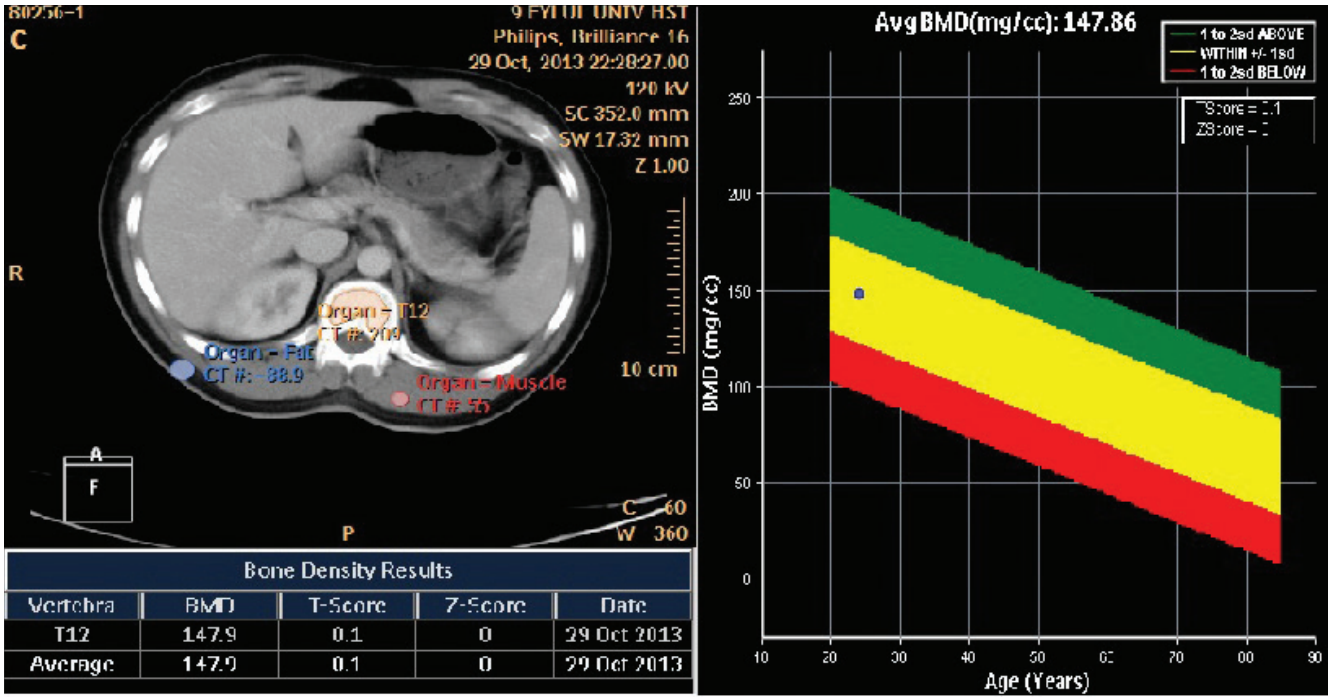

Figure 3. BMD measurements (T12 vertebrae level)
BMD: bone mineral density

Table 1. Demographic characteristics of the patient and control groups

	Patients (n=74)	Controls (n=38)	p
Age (years)*	24.3	25.0	>0.05**
Female/male	14/60	8/30	>0.05***
Presence of SN	+	–	
Mean BMD (mg/cm^3)	131.6	140.7	0.003**

BMD: bone mineral density; SN: Schmorl's node
Values expressed as *mean, **Mann-Whitney U test, and ***Chi-square test

distribution of age and gender was not significantly different between the two groups (p=0.438) (Table 1). The BMD measurements were done using a contrast thoracoabdominal CT for 47 patients and a contrast-free thoracolumbar CT for 27 patients. In the control group, the measurements were done using a contrast thoracoabdominal CT for 25 participants and a contrast-free thoracolumbar CT for 13 participants.

A total of 208 SNs were found in 74 patients. Of the total, 92 (44%) SNs were in the thoracic vertebrae and 116 (56%) were in the lumbar vertebrae. Of the total, 144 SNs (69.3%) were localized in the superior endplate of the thoracic and lumbar levels.

In the thoracic vertebrae, the SNs were more frequently present on the T12 vertebrae, and the frequency of SN gradually increased from T8 (9%) to T12 (21%). The superior and inferior endplates in the thoracic vertebrae were affected by 79% of the SNs. In 34% of SNs, the superior endplates were affected. In the lumbar vertebrae, the SNs were predominantly located in the L1 (25%) and L3 vertebrae (29%). The superior and inferior endplates in the lumbar vertebrae were affected by 82% of the SNs, which was more frequently seen in the superior endplate (45%).

Moreover, 1 SN was found in 10 patients, 2 SNs were found in 23 patients, 3 SNs were found in 25 patients, and 4 or more SNs were found in 16 patients.

As the trabecular bone is affected earlier and to a greater degree than the cortical bone, qCT is likely to detect the low bone mass earlier in the spine than the other BMD measurements. In this study, the trabecular BMD was based on. The mean BMDs in the patient and control groups were 131.6 g/cm^3 and 140.7 g/cm^3, respectively; the difference between the two groups was statistically significant (p=0.03) (Table 1).

A significant negative correlation was found between the mean BMD and age in the patient group (p=0.001; r=−0.323).

The mean number of SNs in the male and female patients were 3.5±2.9 and 2.9±1.5, respectively; no significant difference was found between the two genders regarding the total number of SNs (p>0.05). No significant relationship was found between patients' total number of SNs and the mean BMD (p=0.156).

Discussion

The results of this study indicated that the BMDs of patients with SNs were significantly lower than those of the control

group. As bone fracture strength is linearly correlated with the mineral content, low BMD might be a predisposing factor in the etiopathogenesis of SNs.

Only the participants younger than 40 years were included to achieve a homogeneous study population. A younger study group is an objective strength of this study because most of the previous studies included elderly patients. Rather than investigating the factors causing SN, this study focused on the potential relationship between the formation of SN and BMD. Similar to previous studies, the BMD measurements were done by using a phantom-free standard qCT protocol and by obtaining the fat and muscle measurements for calibration from the same section (14). To increase the measurement accuracy, the volumetric measurement method was preferred over the single-section measurement approach. The significant difference between the BMD measurements of the patient and control groups supports the potential role of BMD in the development of SN. Therefore, it is important to evaluate BMD in young patients with SN.

Previous studies investigated BMD in patients with spinal problems such as spondylolisthesis, intervertebral disc degeneration, and osteoarthritis. However, they did not address BMD in young patients with SNs. Besides, several previous studies measured BMD using dual X-ray absorptiometry (DXA). One of the strengths of this study is the use of qCT for BMD measurement. DXA is an established standard for BMD and is commonly used in the clinical setting for monitoring bone strength (10, 14). However, DXA has some disadvantages because of its projectional nature; aortic calcifications and osteoarthritis may cause an artificial elevation of BMD in the anteroposterior measurements in DXA. On the other hand, qCT provides an accurate volumetric determination of BMD in the trabecular bone. The qCT measurement is affected less by confounding factors such as osteophyte and subchondral sclerosis. Therefore, qCT was used in this study as a newer method to measure the distribution of BMD at different spine levels.

SNs were first described by the pathologist Christian Schmorl in 1927 as a herniation of the nucleus pulposus through the cartilaginous and bony endplate into the vertebral body (15). Previous studies have found SN to be significantly associated with the presence and severity of lumbar disc degeneration in general (16-18). Lumbar disc degeneration has been associated with low back pain, which is one of the most common disabling conditions in the world (19).

The vertebral endplate becomes narrower and its vascularity decreases with aging. During maturation, an avascular layer consisting of hyaline cartilage is formed within the vertebral endplate. The amount of water and proteoglycan in the disc decreases with age; therefore, the rate of disc degeneration and SN increases with age. In a study of 320 patients, Moustarhfir et al. found that the incidence of SN was significantly lower in those younger than 40 years (20). In a study investigating the thoracolumbar vertebra of 70 individuals who died as a result of motorcycle accidents, Fahey et al. identified SN in 40% of all cases and reported a strong correlation between acute trauma and the formation of SN (21). During a motorcycle accident, the inverted position of the head results in an overload on the axial skeleton. Interestingly, in a study comparing gymnasts and the general population, the frequency of SN was 71% and 44%, respectively (22).

SNs are more common in men compared to women (2). In this study, the number of male patients was 4 times more than that of female patients (Male/Female=60/14). However, in patients with SN, the mean number of SNs did not differ significantly between the two genders ($p>0.05$).

Several theories have been proposed to explain the pathogenesis of SN. The conditions that result in the weakness of the vertebral endplate have been reported to cause SN. The main reasons behind the weakness in the vertebral endplate include the primary and secondary bone dysplasia, neoplasms such as multiple myeloma and metastases, hyperparathyroidism, osteoporosis, osteomalacia, and disc infections (6). Patients with known metabolic or bone disorders were excluded from this study.

The detection of SN in patients younger than 40 years may allow predicting future vertebral degeneration and related diseases. Providing appropriate treatment plans before the development of vertebral sequelae is clinically relevant. Patients suffering from symptomatic SNs, who were not relieved by the conservative therapy (analgesics, bed rest, and bracing), may benefit from percutaneous vertebroplasty.

This study has some limitations. First, the retrospective nature of the study stands as a significant limitation. The patients included in the study were selected based on the investigations and the anamnesis results available in the hospital database. As our study was a retrospective study, some of the relevant data about the patients (i.e., the type of occupation, ethnicity, physical activity, and body mass index) could not be evaluated. Secondly, data on the congenital etiology of SNs in our patients could not be evaluated. Prospective studies involving a larger patient population may allow a better understanding of the contributing factors.

In conclusion, this study indicates that when compared to healthy controls, patients younger than 40 years with SN in the thoracolumbar vertebrae had significantly lower BMD than those without SN. The finding of lower BMD in those with SN might contribute to understanding the pathogenesis of SN and its significance in clinical issues such as back pain and related disabilities.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of Dokuz Ey-

lül University, School of Medicine (approval number: 1829-GOA 2014/38-02).

Informed Consent: Written informed consent was obtained from the patients.

Author Contributions: Concept - Ö.G., N.S.G.; Design - Ö.G., N.S.G.; Supervision - N.S.G., A.B.; Resources - Ö.G., U.Ö.; Materials - Ö.G., U.Ö.; Data Collection and/or Processing - Ö.G., N.S.G., U.Ö.; Analysis and/or Interpretation - Ö.G., N.S.G., A.B.; Literature Search - Ö.G.; Writing Manuscript - Ö.G.; Critical Review - N.S.G., A.B.

Conflict of Interest: The authors have no conflicts of interest to declare.

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