Low Back Pain, Somatic Dysfunction, and Segmental Bone Mineral Density T-Score Variation in the Lumbar Spine

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Context: Identifying objective measures that correlate with somatic dysfunction palpatory findings will aid in establishing clinical relevance of the findings and provide outcome measures for future studies.

Objective: To investigate the association of altered segmental lumbar vertebral mechanics (ie, somatic dysfunction) as assessed by palpation with bone mineral density (BMD) T-score variability in participants, some with chronic low back pain (CLBP) and others without low back pain (LBP).

Methods: Individuals with CLBP and individuals without LBP were examined by 2 blinded examiners for the presence or absence of paraspinal tissue texture abnormalities, vertebral rotational asymmetry, anterior motion restriction, and tenderness from L1 to L4. All participants then received a dual-energy x-ray absorptiometry scan of the lumbar spine. Bone mineral density T scores were compared between the CLBP and non-LBP groups.

Results: Sixty-three individuals (16 CLBP, 47 non-LBP) participated in the study. Lumbar segments with perceivable rotational asymmetry had higher mean BMD T scores (95% confidence interval [95% CI]) than lumbar segments with no asymmetry (0.5 [0.4-0.7] vs -0.2 [-0.6 to 0.2], respectively; P=.002). Additionally, lumbar segments with anterior motion restriction had higher mean BMD T scores (95% CI) than lumbar segments with no motion restriction (0.6 [0.4-0.7] vs 0.1 [-0.2 to 0.3], respectively; P=.03). Participants with CLBP demonstrated higher regional mean lumbar BMD T scores (95% CI) than those without CLBP (0.9 [0.6-1.1] vs 0.3 [0.2-0.5], respectively; P<.001). After accounting for sex and body mass index, vertebral segments with rotational asymmetry (in non-LBP participants only) and vertebral segments with motion restriction had higher mean BMD T scores than vertebral segments with no asymmetry or motion restriction.

Conclusion: Participants with CLBP had significantly higher lumbar BMD than participants without LBP. The presence of rotational asymmetry or motion restriction was associated with elevated BMD at the affected vertebrae.

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Individual physical examination maneuvers should be sensitive and specific and have a positive predictive value. Ideally, the physical findings should also relate to objective measures whenever possible. The physical findings associated with somatic dysfunction include tenderness, tissue texture abnormalities, positional asymmetry, and/or alterations in the articular range of motion.1-3 Because these findings are assumed to indicate impaired or altered functioning of the skeletal, arthrodial, or myofascial structures, they should correlate with objective measurable findings consistent with biomechanical dysfunction. Potential objective tests that may correlate with somatic dysfunction physical findings include magnetic resonance imaging and computed tomography. These tests are interesting in that abnormalities are frequently found in asymptomatic patients.4-11

Dual-energy x-ray absorptiometry (DXA), also known as bone densitometry, is potentially a lower-cost option for establishing an objective measure. Bone mineral density (BMD) changes with altered mechanics, allowing for maximum strength along the lines of gravitational force and, thus, should respond to the altered biomechanics from somatic dysfunction. Pathologic changes occur when altered gravitational or mechanical forces are applied over a long period, resulting in bone being laid down to make the affected structures stronger. Gradually, sclerosis, bony outgrowths (ie, osteophytes), or both appear. These changes are the hallmark of degenerative osteoarthritis and manifest as increased BMD when evaluated by DXA.12-15 In the lumbar spine, osteoarthritis exhibits local pathologic increases in BMD secondary to the formation...
of osteophytes and bony sclerosis. Though many people with osteoarthritis are asymptomatic, chronic low back pain (CLBP) is associated with degenerative changes, such as endplate abnormalities and facet (ie, zygapophyseal joint) degeneration, as well as clinically reduced gross range of motion.

The present pilot study investigated the association between somatic dysfunction, as diagnosed by physical examination, and lumbar BMD T scores in participants with CLBP and participants without low back pain (LBP). Given the initial assumption that vertebral somatic dysfunction represents locally altered vertebral biomechanics, the investigators hypothesized that individual vertebral segments that manifested somatic dysfunction would demonstrate altered BMD in relation to unaffected vertebrae. Additionally, the investigators hypothesized that participants with more somatic dysfunction in the lumbar region, particularly those with CLBP, would demonstrate a change in overall lumbar BMD when compared to participants with less total somatic dysfunction.

Methods

Participants

Healthy volunteers aged 20 to 40 years were recruited from the local community of Kirksville, Missouri. This age range was chosen because these individuals were less likely than older individuals to have radiologic findings of degenerative joint disease that could affect BMD measures. Participants were recruited regardless of LBP history. Study exclusion criteria were the presence of any condition that would alter the lumbar bony anatomy (eg, lumbar or low thoracic vertebral fractures or surgery; known congenital vertebral abnormalities of the lumbar spine, such as spina bifida). Pregnant or potentially pregnant volunteers and those having had manual treatment of the spine within 8 weeks of the initial musculoskeletal examination were also excluded.

Participants completed a medical history questionnaire. Based on their answers, they were identified as belonging to the CLBP or non-LBP group. Participants in the CLBP group had pain in the lumbar region for a minimum of 5 days a week for at least 3 months. The non-LBP group included participants with no self-reported history of LBP in the last 3 months or only occasional nonpersistent LBP not exceeding twice a week. Participants with low pain levels who did not meet CLBP criteria were excluded.

All aspects of the study protocol were approved by the institutional review board of A.T. Still University in Kirksville, Missouri. Informed signed consent was obtained from each participant prior to examination.

Palpatory Diagnosis of Somatic Dysfunction

The different elements of somatic dysfunction (ie, tissue texture abnormalities, rotational asymmetry, motion restriction, tenderness) were assessed separately for each lumbar vertebra in each participant. Participants received a focused musculoskeletal examination of lumbar vertebrae L1 to L4 by 2 osteopathic physician examiners (K.T.S., B.F.D.). The L5 vertebra was not evaluated due to the high incidence of occult anatomic abnormalities associated with this vertebral segment. The locations of spinous processes of L1 to L4 were marked by drawing a horizontal line in black, water-soluble ink across the vertical midpoint. The spinous process locations were identified using the following anatomic landmarks:

- Identification of T12 by its smaller spinous process size to verify the location of L1
- Identification of the twelfth ribs and their attachment site at T12 to identify L1
- Identification of the iliac crests, approximately at the height of the L4/L5 interspace (ie, Tuffier line)
- Location of the sacral base and L5 to identify the L4 spinous process

Participants were evaluated in the prone position by the 2 blinded examiners using 4 common osteopathic palpatory assessments (paraspinal tissue texture abnormalities, vertebral rotational asymmetry, anterior springing motion restriction, and spinous process tenderness) to determine the presence of somatic dysfunction. The 2 osteopathic physicians who participated as examiners in the present study established the interobserver reliability of these 4 tests prior to this study. Details of this reliability training were discussed at length in a previous publication.

Any inconsistencies in examiner findings were reevaluated by both examiners until consensus was reached regarding the presence or absence of the somatic dysfunction finding. This method of establishing consensus allowed the examiners to continually improve interobserver reliability and is discussed in a previous publication.

The 4 assessments of somatic dysfunction were evaluated from L1 to L4 as follows:

- Tissue texture abnormalities—The pads of the examiner’s fingers contacted the subcutaneous tissue overlying the right and left inferior facet joints of each vertebra of the participant. Presence of tissue texture abnormalities was evaluated individually for right and left facet areas based on the presence of localized edema, tissue tension, or fibrotic changes in the subcutaneous tissue.
- Static rotational asymmetry of the transverse processes—Static positional asymmetry of each vertebra of the participant was assessed by the examiner by palpating for the posterior prominence of the right vs the left transverse process. Both palpatory and visual assessments were used to determine which prominence was more posterior. No motion testing was performed. Posterior prominence of the right transverse process was recorded as right vertebral rotation,
and posterior prominence of the left transverse process was recorded as left vertebral rotation.1,2,3,10

- **Anterior springing motion restriction**—Anterior force was applied with the examiner’s thumb or hypothenar eminence on the spinous process of each vertebra of the participant to determine its resistance to springing. This test, which is meant to assess sagittal motion, was performed 1 to 3 times as needed for each participant to assess motion. Resistance to anterior motion was noted in relation to the other vertebrae.29

- **Spinous process tenderness**—Anterior force was applied directly to the individual spinous processes with the examiner’s thumb. A total pressure of 4 kg/cm² was used, based on the 1990 American College of Rheumatology criteria for defining a significant tenderpoint in diagnosing fibromyalgia.33 To mimic the clinical setting, a dolorimeter was not used. Calibration of the applied force was performed prior to each participant examination by repeatedly applying pressure on an 11-lb (5-kg) food scale (model 3870; Taylor Precision Products, Oak Brook, Illinois) with the thumb until intraobserver reliability was obtained for the application of 4 kg/cm² of pressure. For both examiners this pressure was enough to blanch the thumb nail but not enough to cause discomfort in the examiner’s thumb.29 Participants verbally indicated when the applied pressure elicited a sensation of pain or tenderness.

### DXA Scan Evaluation of Bone Mineral Density

Participants received a BMD analysis of the lumbar spine from L1 to L4 with a DXA scanner (model 4500C; Hologic Inc, Bedford, Massachusetts) 1 to 2 weeks after the focused musculoskeletal examination. The precision error of the DXA scanner had significantly higher mean segmental BMD T scores (95% confidence interval [CI]) than lumbar segments with no asymmetry (0.5 [0.4-0.7] vs -0.2 [-0.6 to 0.2], respectively; P=.002) (Table 2). A similar pattern in BMD T scores (95% CI) was observed for lumbar segments with motion restriction compared to lumbar segments with no motion restriction (0.6 [0.4-0.7] vs 0.1 [-0.2 to 0.3], respectively; P=.03). There was no significant relationship between tissue texture abnormalities and BMD T scores or between tenderness and BMD T scores. Participants with CLBP had higher mean lumbar BMD T scores (95% CI) overall for the L1-L4 region than participants with no LBP (0.9 [0.6-1.1] vs 0.3 [0.2-0.5], respectively; P<.001).

To further clarify the effect of palpatory findings and group (ie, CLBP or non-LBP participants) on BMD, the combined relationship of palpatory findings and group with segmental lumbar BMD T scores was examined (Figure). There was a statistically significant interaction of group and tissue texture abnormalities (P=.03, Figure A). Vertebral segments with

### Statistical Analyses

The CLBP participants and non-LBP participants were compared on demographic variables using the Fisher exact test (for sex) and Mann-Whitney test (for age and body mass index [BMI]). To test whether the presence or absence of each of the 4 elements of somatic dysfunction (ie, tissue texture abnormalities, rotational asymmetry, motion restriction, tenderness) were associated with BMD T scores for the same vertebral segment, generalized linear mixed models were fit to the data using restricted maximum likelihood estimation. Each participant contributed 4 separate vertebral measurements of somatic dysfunction and BMD to each analysis. The participants were treated as random effects to account for the dependence of the 4 vertebral measurements of somatic dysfunction and BMD for the L1-L4 vertebrae obtained from each participant. Additional generalized linear mixed models included group (CLBP or non-LBP), sex, and BMI to test for the effects of these characteristics on the association of somatic dysfunction with BMD T score. The model assumptions, including normal distribution of errors, were verified. Statistical significance was set at α=.05. Statistical analyses were conducted using SAS 9.2 software (SAS Institute Inc, Cary, North Carolina).

### Results

Sixty-three individuals participated in the present study: 16 (25%) had CLBP and 47 (75%) had no LBP. The present study occurred over 3.5 months and included 8 separate palpatory sessions with 2 to 19 participants evaluated during each session. There were no statistically significant differences between CLBP participants and non-LBP participants for sex, age, or BMI (Table 1).

Lumbar segments with perceivable rotational asymmetry had significantly higher mean segmental BMD T scores (95% confidence interval [CI]) than lumbar segments with no asymmetry (0.5 [0.4-0.7] vs -0.2 [-0.6 to 0.2], respectively; P=.002) (Table 2). A similar pattern in BMD T scores (95% CI) was observed for lumbar segments with motion restriction compared to lumbar segments with no motion restriction (0.6 [0.4-0.7] vs 0.1 [-0.2 to 0.3], respectively; P=.03). There was no significant relationship between tissue texture abnormalities and BMD T scores or between tenderness and BMD T scores. Participants with CLBP had higher mean lumbar BMD T scores (95% CI) overall for the L1-L4 region than participants with no LBP (0.9 [0.6-1.1] vs 0.3 [0.2-0.5], respectively; P<.001).

Table 1. Association of Somatic Dysfunction With Bone Mineral Density T Score: Characteristics of Participants (N=63)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All Subjects</th>
<th>CLBP (n=16)</th>
<th>Non-LBP (n=47)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, Men, No. (%)</td>
<td>15 (24)</td>
<td>6 (38)</td>
<td>9 (19)</td>
<td>.18</td>
</tr>
<tr>
<td>Age, Mean (SD), y</td>
<td>29.7 (6.4)</td>
<td>29.4 (6.6)</td>
<td>29.9 (6.3)</td>
<td>.88</td>
</tr>
<tr>
<td>BMI, Mean (SD)</td>
<td>26.1 (4.9)</td>
<td>26.3 (4.2)</td>
<td>26.0 (5.2)</td>
<td>.60</td>
</tr>
</tbody>
</table>

* P values are for comparisons of chronic low back pain (CLBP) subjects with non-low back pain (LBP) subjects using the Fisher exact test (for sex) and the Mann-Whitney test (for age and body mass index [BMI]).
Table 2. Relationship of Presence or Absence of Somatic Dysfunction With Bone Mineral Density T Score

<table>
<thead>
<tr>
<th>Somatic Dysfunction Assessment</th>
<th>Somatic Dysfunction, BMD T score, Mean (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tissue Texture Abnormalities □</td>
<td>0.5 (0.3-0.6) 0.2 (-0.3-0.7)</td>
<td>.26</td>
</tr>
<tr>
<td>◷ n</td>
<td>235</td>
<td></td>
</tr>
<tr>
<td>Rotational Asymmetry □</td>
<td>0.5 (0.4-0.7) -0.2 (-0.6-0.2)</td>
<td>.002</td>
</tr>
<tr>
<td>◷ n</td>
<td>227</td>
<td></td>
</tr>
<tr>
<td>Motion Restriction □</td>
<td>0.6 (0.4-0.7) 0.1 (-0.2-0.3)</td>
<td>.03</td>
</tr>
<tr>
<td>◷ n</td>
<td>192</td>
<td></td>
</tr>
<tr>
<td>Tenderness □</td>
<td>0.7 (0.4-0.9) 0.4 (0.2-0.5)</td>
<td>.09</td>
</tr>
<tr>
<td>◷ n</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>◷ n</td>
<td>190</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BMD, bone mineral density; CI, confidence interval; n, number of vertebral segments (4 per subject) with or without particular somatic dysfunction.

Comment

The present pilot study examined the association of objective lumbar vertebral BMD variation to somatic dysfunction physical findings. Lumbar vertebral segments that demonstrated somatic dysfunction findings associated with biomechanical dysfunction (ie, positional asymmetry and motion restriction) had higher BMD T scores than segments with no biomechanical dysfunction. These findings were independent of the participant’s back pain. Additionally, participants with CLBP had higher overall mean lumbar BMD T scores than participants with no LBP. The literature was reviewed for possible biomechanical and physiologic mechanisms that could explain these findings.

One area of the literature review concerned the effect of osteoarthritis on BMD. Pathogenesis of lumbar osteoarthritis is a complex process involving chemical and mechanical changes in subchondral bone, leading to destruction of the cartilage, thickening of the subchondral plate, formation of osteophytes, and deformation of the joint structure.17,18,34,37

The thickening of the subchondral plate is due to bony sclerosis stemming from subchondral micro-fractures. These microfractures stimulate locally increased bone turnover, which leads to increased number and decreased separation of the trabeculae.18,34,35 While the new bone is hypomineralized, the overall increased trabeculae volume leads to an increased BMD reading on DXA scans. The increased number and volume of trabeculae also result in increased stiffness of the bone, thus impairing its ability to act as a shock absorber for the overlying cartilage.18,35 The bony and cartilaginous changes in the joint surface affect the mechanical loading and motion of the involved joints.17,24,38-40

Degeneration of different structures, such as intervertebral disks, vertebral endplate, and facets, appears to have different effects on segmental vertebral motion. Fujiwara et al38 associated subchondral sclerosis with decreased sagittal motion (ie, flexion and extension) and decreased rotation of cadaveric lumbar specimens, though the researchers reported that the presence of osteophytes seemed to have no effect on segmental motion. In live subjects, degenerative disk changes tend to increase regional sagittal motion in the lower grades of degeneration and decrease motion in the higher grades of degeneration.39,41,42

The present study specifically assessed a passively induced anterior translatory motion produced by springing anteriorly on each spinous process, which is not the same motion produced by the active lumbar extension that is used in most segmental vertebral motion studies.39,41,42 Though disk degeneration is expected to begin in the late teens to early twenties, as evidenced by MRI studies,43 our study population was not expected to exhibit the higher grades of degeneration that could account for the loss of anterior translatory motion. It is possible that the translatory motion testing used in the present study is more easily influenced by degeneration and, thus, is a more sensitive test than gross range of motion. Radiographic
arthrodial changes. Specific sites of osteoarthritis, such as the knees or hands, have been found to correlate with whole-body increases in BMD.15,16,21,37,46-52

The present study’s finding that participants with CLBP had higher regional mean lumbar BMD T scores than those with no LBP supports the idea that elevated BMD may be a systemic process. However, this finding may simply indicate that correlation, particularly by MRI, of the sagittal motion assessment used in this study is warranted.

Many asymptomatic individuals have degenerative findings. Individuals with pain generally have more severe endplate and facet degeneration and more severe disk findings than do individuals without pain.8,10,22-26,44,45 However, degenerative arthritis appears to be more systemic than only local arthrodial changes. Specific sites of osteoarthritis, such as the knees or hands, have been found to correlate with whole-body increases in BMD.15,16,21,37,46-52

The present study’s finding that participants with CLBP had higher regional mean lumbar BMD T scores than those with no LBP supports the idea that elevated BMD may be a systemic process. However, this finding may simply indicate that

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**Figure.** Relationship of presence or absence of somatic dysfunction—(A) tissue texture abnormalities, (B) rotational asymmetry, (C) motion restriction, (D) tenderness—and chronic low back pain (CLBP) with bone mineral density (BMD) T scores. P values for the interaction of presence of somatic dysfunction and group (ie, CLBP or non-LBP) are the following: (A) P=.03, (B) P=.01, (C) P=.65, and (D) P=.70. Squares indicate mean BMD T scores for participants with CLBP. Circles indicate mean BMD T scores for participants without LBP. Bars indicate 95% confidence interval (95% CI) for the mean BMD T scores. The n and % represent the number and percentage of vertebral segments with or without somatic dysfunction within a group (ie, CLBP or non-LBP).
the CLBP participants had more somatic dysfunction than the non-LBP participants, as previously reported in a separate publication.53

Another potential explanation of the BMD findings of the present study can be seen in the altered biomechanics, BMD changes, and degenerative changes observed in vertebral segments adjacent to lumbar fusions or rod placement in both human and animal models.54-57 The biomechanical changes secondary to surgical fusion or rod placement can manifest as locally altered segmental motion or reduced gross range of motion of the spine.55,58-62 These changes may be responsible for local early degenerative changes in those vertebral segments adjacent to lumbar fusions.50,62,63

Lee and Langrana64 evaluated the biomechanical effects of various types of spinal fusions on excised cadaveric human lumbar spines. They found that all types of spinal fusions altered the local mechanical loading of the unfused vertebral segments, resulting in profound changes in the biomechanics of the facet joints and intervertebral disks.

A flattening or proximal shift of lumbar lordosis in humans is associated with early degenerative changes, spinal stenosis, and LBP.65,66 In sheep, flattening of the normal lumbar curve secondary to a kyphotic posterolateral lumbar fusion of L3 to L5 resulted in significantly more degenerative changes in vertebral segments above the fusion than when the lumbar vertebrae were fused in the in situ lordotic configuration.63

Loss of segmental BMD has been found as an early change occurring after lumbar fusions. Bogdanoff et al67 found that 3 to 6 months postsurgery, significant decreases in segmental vertebral BMD of L2 and L3 occurred adjacent to an L4 to S1 spinal fusion. Lipscomb et al68 found that this BMD decrease occurred over 7 months, but BMD appeared to recover and exceed initial loss by 1-year postsurgery. The increase in BMD in the adjacent vertebral segments correlates with the appearance of other structural changes, such as spinal osteophytes. Spinal osteophytes result in measurement artifacts on BMD scans but not true increases in localized vertebral body BMD.69 In animal models, removal of the hardware and restoration of normal motion resulted in restoration of normal BMD.54

Limitations

The present study has several limitations in addition to the small sample size. Palpatory assessments are inherently subjective. Because the osteopathic physician examiners in the present study underwent stringent training to establish interobserver reliability for the assessment tests,29 as well as continued training during the study by reaching consensus for each participant when examiners’ findings differed,30 the study findings may not be reproducible by examiners who have not undergone the same stringent training. Therefore, the data require conservative interpretation until more individuals have been assessed by a larger cohort of examiners.

Another limitation of this study was the use of palpatory assessment coupled with verbal cues from study participants to determine tenderness. Dolorimeters are often used in research to objectively palpate the palpatory pressure needed to elicit tenderness. However, we chose not to use this tool so that results would be more equivalent to the clinical setting. In addition, preliminary interobserver reliability training, supported by previous studies,30,70 indicated that this study’s palpatory assessment of tenderness had the highest level of reproducibility of the 4 assessment tests.29 Moreover, we used a pressure calibration before each participant examination to ensure intraobserver reliability.

A final limitation of the present study involves the accuracy of identification of L1 to L4. Though the examiners used 4 palpatory landmarks to ensure correct identification of these lumbar segments, no objective verification, such as ultrasonography, was used. Furthermore, 1 of the landmarks, the Tuffier line (ie, intercrestal line), which is generally used to find the L4/L5 interspace, has been found to correspond with the body of L4 in men and the body of L5 in women.72 This gender variation was not considered in the present study.

Future research should be directed to objectively verify the accuracy of the palpatory methods used in the present study and to collect broader demographic data to evaluate factors that could underlie the relationship of somatic dysfunction and BMD. If this correlation continues to be found and if it is unrelated to population characteristics, then longitudinal studies evaluating changes in BMD over time should be performed to determine if somatic dysfunction predicts the development of osteoarthritis.

Conclusion

The present study demonstrated several findings that have important implications in clinical practice. Somatic dysfunction findings of positional asymmetry and motion restriction were associated with objective, measurable BMD elevations in affected vertebrae. Though the examiners in the present study underwent stringent interobserver reliability training, the palpatory assessments used in the study are commonly taught at osteopathic medical schools throughout the United States and, thus, are skills available to all osteopathic physicians. Given that the purpose of osteopathic manipulative treatment is to normalize somatic dysfunction, segmental vertebral BMD may be an objective measure for assessing the long-term physiologic effects of osteopathic manipulative treatment.

The present study also found that participants with CLBP had significantly higher mean regional lumbar BMD than participants without LBP. We have discussed possible biomechanical and physiologic mechanisms for the findings of the present study. However, because observed differences in BMD were small, the discussion is inherently speculative without additional research. Further studies are warranted to assess the reproducibility of our findings and to clarify the nature of the observed BMD changes.
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References


