The Persistence of Lumbar Somatic Dysfunction and Its Association With Bone Mineral Density

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Context: Clinically meaningful somatic dysfunction, if left untreated, should persist over time and be associated with objective measurable findings.

Objective: To investigate the persistence of lumbar somatic dysfunction over 8 weeks and the association of that persistence with lumbar bone mineral density (BMD) T scores.

Methods: Individuals were assessed at 0, 4, and 8 weeks for the presence and severity of paraspinal tissue texture abnormalities (TTA), vertebral rotational asymmetry, anterior motion restriction, and tenderness from L1 to L4. Participants underwent dual-energy x-ray absorptiometry of the lumbar spine at 0 and 8 weeks. Persistent somatic dysfunction findings from all 3 examinations were compared with BMD T scores obtained at 8 weeks and to changes in the BMD T scores from 0 to 8 weeks.

Results: Forty-eight individuals (38 women [79%] and 10 men [21%]) participated in the study. The mean (standard deviation [SD]) age was 30.1 (6.4) years (range, 20.0-40.8 years), and the mean (SD) body mass index was 26.3 (5.2). The percentage of vertebrae with persistent somatic dysfunction varied by vertebral level and ranged from 44% to 83% for TTA, 63% to 79% for rotational asymmetry, 10% to 56% for motion restriction, and 2% to 10% for tenderness. Vertebral segments with persistent motion restriction had higher mean BMD T scores (95% confidence interval [CI]) than those without persistent motion restriction (0.6 [0.4 to 0.8] vs 0.2 [0.1 to 0.4], respectively; $P=.02$). There was a significant increase in the vertebral BMD T scores for those vertebrae that demonstrated persistent TTA ($P=.02$) and for those vertebrae that demonstrated persistent moderate/severe TTA ($P=.02$). A significant difference was found in the initial to final vertebral BMD T-score change between vertebrae that demonstrated persistent tenderness and those that did not (mean [95% CI] change, −0.2 [−0.4 to 0.1] vs 0.1 [0.0 to 0.1], respectively; $P=.04$).

Conclusion: A persistence of predominantly left lumbar rotation was observed. Persistent vertebral motion restriction was shown to have an association with final lumbar BMD T scores, and persistent TTA and tenderness were associated with changes in the BMD T scores over 8 weeks.

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Somatic dysfunction is diagnosed by the presence of 1 or more of the TART criteria: tissue texture abnormalities (TTA), asymmetry, restricted range of motion, or tenderness.[1] Clinically meaningful somatic dysfunction, if left untreated, should persist over time. Research has primarily focused on the persistence of the individual TART criteria or elements of somatic dysfunction. For instance, the persistence of tenderness and range of motion restriction has been studied throughout manual medicine disciplines,[2-5] and the persistence of vertebral sidebending and rotation has been demonstrated in scoliosis research.[6,7] Additionally, most studies[2-8] assessing the presence of somatic dysfunction elements have used objective measures, such as radiography, dolorimeters, and stiffness measuring devices. Somatic dysfunction findings detected by palpation should demonstrate levels of persistence similar to those detected by objective measures, but no palpation studies, to our knowledge, have measured these levels.

Dual-energy x-ray absorptiometry (DXA), also known as bone densitometry, is a low-cost, objective measure for monitoring changes in bone mineral density (BMD) over time. Lumbar BMD responds to gravitational loading and biomechanics[9-11] and thus may respond to the altered biomechanics that result from somatic dysfunction. In adults, the resorptive period of bone turnover lasts about 30 days.[11] Therefore, changes in BMD due to somatic dysfunction may be measured approximately 1 month after persistent somatic dysfunction occurs.

The purpose of the current line of research was to examine the relationship between somatic dysfunction and BMD. The first portion of the current study, published in 2011, compared the presence of lumbar somatic dysfunction found with palpatory examination to the vertebral BMD T scores as measured by DXA.[12] Additionally, a high frequency of left lumbar rotation was identified,[13] which was consistent with the common compensatory pattern of somatic dysfunction identified by Zink and Lawson.[14] The current study followed up 48 of the original 63 study participants over 8 weeks to assess the persistence of lumbar somatic dysfunction at 3 palpatory examinations and the association of that persistence with lumbar BMD T scores. Moderate/severe somatic dysfunction was expected to have greater persistence than mild somatic dysfunction and greater impact on BMD T scores.

Methods

Participants

As part of a larger study,[12,13,15] participants aged 20 to 40 years were recruited by means of e-mail and flyers between June and October 2001 from the 8-county region around A.T. Still University-Kirksville College of Osteopathic Medicine in Missouri. Participants were recruited without regard to low back pain (LBP) symptoms, but once enrolled they were placed into 1 of 2 groups—those with chronic LBP or those without chronic LBP—on the basis of whether LBP symptoms were present. In the current study, chronic LBP was defined as pain in the small of the back for a minimum of 5 days per week for at least 3 months. Those who reported no LBP or who reported occasional nonpersistent LBP that occurred 2 or fewer days per week were classified as having no LBP. Participants who had LBP 3 or more days per week but who did not meet the chronic LBP criteria were excluded from the study.

Before enrollment, potential participants were screened via telephone and then again in person to determine eligibility. Potential participants were excluded from the study if they had any conditions that would prohibit them from lying prone for 30 minutes or that could potentially alter the lumbar bony anatomy, such as congenital vertebral anomalies (eg, spina bifida), previous lumbar or low thoracic vertebral fractures, or previous surgical procedures. Participants who were pregnant or those who had received spinal manipulation within 8 weeks of the initial examination were also excluded. Participants agreed to not receive spinal manipu-

lation for the duration of their participation in the study (8-10 weeks).

All aspects of the study protocol were approved by the A.T. Still University-Kirksville Institutional Review Board, and all participants provided informed consent before study enrollment. The current study was completed before clinical trial registration requirements were standard.

Somatic Dysfunction Determination

While in the prone position, each participant received a palpatory examination of vertebral levels L1 through L4 that assessed for the presence and severity of the 4 elements of somatic dysfunction: TTA, static rotational asymmetry of the transverse processes, anterior springing motion restriction, and tenderness. Vertebral level L5 was not examined because of the high frequency of associated occult congenital anomalies.[16] The procedures for these examinations have been described in detail in previously published LBP, BMD, and somatic dysfunction studies.[12,13] Each participant was examined separately by 2 of 3 trained examiners (K.T.S., B.F.D., and E.J.S.), and a consensus of the findings was used for analysis. The consensus process and interobserver reliability of the findings have also been described in detail in previous publications.[12,13,15,17] Examiners were blinded to the participant's LBP history. *Table 1* summarizes the palpatory examination protocols for each of the somatic dysfunction elements in the order that they were performed and the severity scale for each element. The participants received additional identical palpatory examinations at 4 and 8 weeks after the initial examination.

Bone Mineral Density Determination

All participants underwent DXA within 1 to 2 weeks of the initial palpatory examination and within 1 to 2 weeks of the final palpatory examination. Like the palpatory examinations, these tests covered vertebral levels L1 through L4 only, and vertebral level L5 was not examined because of the high frequency of occult congenital anomalies that can affect the BMD measurement. The DXA was performed at the Northeast Regional Medical Center in Kirksville, Missouri, using a Hologic 4500C Model (Hologic Inc). The individual vertebral BMD T scores for each of the vertebral levels were obtained, and the mean of the vertebral BMD T scores was used as a measure of overall BMD of the lumbar region (regional BMD T score).

Persistence of Somatic Dysfunction

Participants were examined for multiple classifications of persistent somatic dysfunction to determine whether persistent somatic dysfunction was related to BMD T scores (*Table 2*). Nonspecific somatic dysfunction was defined as the presence of any somatic dysfunction element. Specific somatic dysfunction was defined as the presence of a specified element of somatic dysfunction (ie, TTA, rotational asymmetry, motion restriction, or tenderness). Regional somatic dysfunction was defined as somatic dysfunction found anywhere from L1 to L4. Vertebral somatic dysfunction was defined as somatic dysfunction found at the vertebral level. For each classification, persistent somatic dysfunction was defined as a specified somatic dysfunction finding being present at all 3 palpatory examinations (0, 4, and 8 weeks). For example, persistent vertebral TTA was defined as TTA being present at all 3 palpatory examinations at the same vertebral level. The same participant could have had some vertebral levels with persistent vertebral TTA and other vertebral levels without persistent vertebral TTA. Similarly, persistent moderate/severe somatic dysfunction was defined as a specified somatic dysfunction finding having a severity score of 3 at all 3 palpatory examinations.

Statistical Analyses

The frequency of occurrence of nonspecific and specific regional and vertebral somatic dysfunction was calculated as the number of palpatory examinations (0, 1, 2, or 3) during which the specified somatic dysfunction element was present. Frequencies of persistent nonspecific and specific vertebral somatic dysfunction and persistent moderate/severe specific vertebral somatic dysfunction were

Table 1.
Palpatory Examination Protocols in the Assessment of Study Participants

Palpatory Examination	Assessment Protocol	Indication of Positive Finding	Severity Scale
Tissue texture changes	Assessed by palpating subcutaneous tissues with pads of fingers directly posterior to inferior articular facets of L1-L4.	Localized edema and/or fibrotic changes, rated separately for right and left inferior articular facets of each vertebra.	1=No texture changes 2=Mild texture changes 3=Moderate/severe texture changes
Static rotational asymmetry	Assessed with simultaneous placement of thumbs on the transverse processes of L1-L4. Anterior pressure was applied until transverse processes could be palpated. No motion testing performed.	On the basis of static positioning of transverse processes of each vertebra. Direction of rotation defined by whether right or left transverse process demonstrated prominence.	1=No rotation 2=Mild rotation 3=Moderate/severe rotation
Resistance to anterior springing	Localized extension induced by springing anteriorly with hypothenar eminence on spinous processes of L1-L4. Each examiner could spring anteriorly as many as 3 times.	Resistance encountered to anterior springing, compared with vertebral segment above or below.	1=No motion restriction 2=Mild motion restriction 3=Moderate/severe motion restriction
Tenderness	Applied localized anterior thumb pressure directly over the spinous processes of L1-L4.	Subject verbalized response to development of tenderness as elicited by anterior thumb pressure.	1=No tenderness with as much as 4 kg/cm^2 pressure 2=Tenderness with 2-4 kg/cm^2 pressure 3=Tenderness with $<$2 kg/cm^2 pressure

Source: Reprinted from Snider KT et al.[13]

assessed for each vertebral level. Generalized linear mixed models were fit to the data using maximum likelihood estimation with the participants treated as random effects to test whether persistent somatic dysfunction findings were associated with both final BMD T scores and changes in BMD T scores from initial to final DXA. Statistical significance was set at α=.05. Analyses were conducted using SAS software, version 9.3 (SAS Institute Inc).

Results

Forty-eight individuals (38 women [79%] and 10 men [21%]) participated in the current study. The mean (SD) age was 30.1 (6.4) years (range, 20.0-40.8 years), and the mean (SD) body mass index (BMI) was 26.3 (5.2). Because only 2 participants (4%) had chronic LBP, the effect of chronic LBP was not analyzed further, and the data from these participants were combined with the data from participants without LBP. During the study, 144 separate palpatory examinations were performed (48 participants $\times$ 3 palpatory examinations). At least 1 element of somatic dysfunction was detected in the lumbar region (persistent regional nonspecific somatic dysfunction) in all 48 participants (100%). Persistent regional specific somatic dysfunction was detected as follows: 47 participants (98%) had right, left, or bilateral TTA, 47 (98%) had right or left rotational asymmetry, 46 (96%) had motion restriction, and 9 (19%)

Table 2.
Categories of Persistent Somatic Dysfunction in Study Participants

Category of Persistent Somatic Dysfunction[a]	Definition
Nonspecific regional	Any somatic dysfunction finding for any vertebra (L1-L4)
Specific regional	The same somatic dysfunction element found for any vertebra (L1-L4)
Nonspecific vertebral	Any somatic dysfunction finding at the same vertebra
Specific vertebral	The same somatic dysfunction element found at the same vertebra, regardless of sidedness

[a] Somatic dysfunction was considered persistent if the participant had the defined somatic dysfunction findings at all 3 palpatory examinations (0, 4, and 8 weeks).

had tenderness. Tenderness demonstrated the highest degree of variability among the somatic dysfunction elements, with no tenderness found in 96 of the 144 palpatory examinations (67%).

For each set of palpatory examinations (0, 4, and 8 weeks), 192 lumbar vertebral segments were evaluated (48 participants × 4 lumbar segments). The frequency of positive findings for each somatic dysfunction element is presented in *Figure 1*. The frequency of persistent somatic dysfunction elements (ie, those found at all 3 palpatory examinations) for each vertebral level is presented in *Table 3*. Persistent TTA was most common at L1 (83%) and least common at L4 (44%). Persistent rotational asymmetry was predominantly to the left side

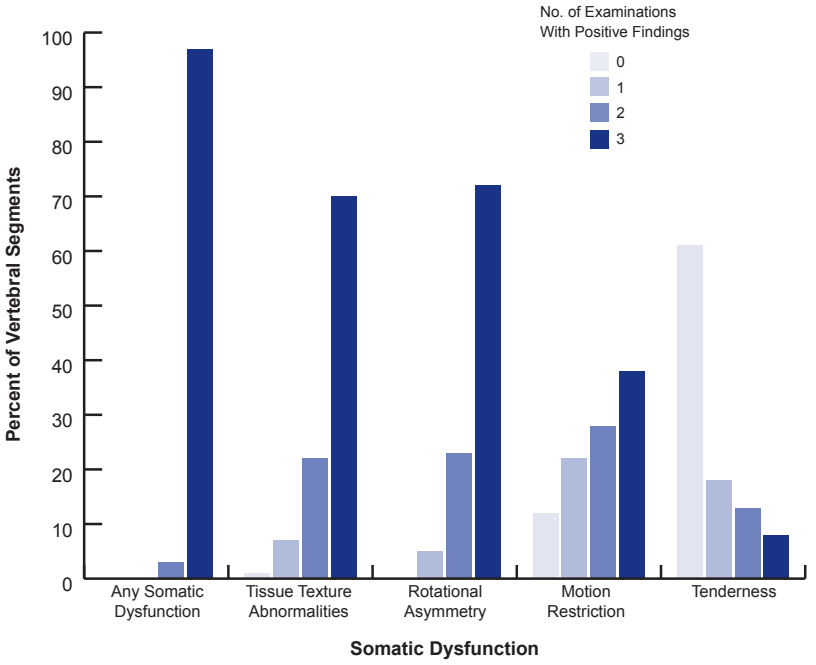

Figure 1.
Lumbar vertebral segments with positive nonspecific and specific vertebral somatic dysfunction findings present at 0, 1, 2, or 3 palpatory examinations (N=192).

Table 3.
Frequency of Persistent Nonspecific and Specific Vertebral Somatic Dysfunction by Vertebral Level in Study Participants (N=48)

Persistent Somatic Dysfunction Element[a]	Positive Findings by Vertebral Level, No. (%)			
	L1	L2	L3	L4
Any Somatic Dysfunction	46 (96)	48 (100)	46 (96)	47 (98)
Tissue Texture Abnormalities				
Any	40 (83)	39 (81)	35 (73)	21 (44)
Right only	5 (10)	4 (8)	3 (6)	0
Left only	11 (23)	13 (27)	24 (50)	19 (40)
Bilateral	21 (44)	19 (40)	5 (10)	0
Rotational Asymmetry				
Any	30 (63)	38 (79)	37 (77)	33 (69)
Right	2 (4)	1 (2)	1 (2)	0
Left	25 (52)	33 (69)	33 (69)	32 (67)
Motion Restriction	19 (40)	27 (56)	21 (44)	5 (10)
Tenderness	1 (2)	3 (6)	6 (13)	5 (10)

[a] Somatic dysfunction was considered persistent if the participant had the defined somatic dysfunction findings at all 3 palpatory examinations (0, 4, and 8 weeks).

compared with the right side (52%-69% vs 0%-4%) at all vertebral levels.

The frequency of moderate/severe specific vertebral somatic dysfunction findings (ie, present at 0, 1, 2, or 3 palpatory examinations) is presented in *Figure 2*. The frequency of persistent moderate/severe specific vertebral somatic dysfunction findings for each vertebral level is presented in *Table 4*. No participants demonstrated persistent moderate/severe vertebral tenderness, and less than 25% demonstrated persistent moderate/severe TTA, rotational asymmetry, or motion restriction.

Persistent regional tenderness (the regional somatic dysfunction element with the highest degree of variability) was not significantly related to the final regional BMD T score; the mean (95% confidence interval [CI]) regional BMD T score was 0.7 (0.9 to 1.3) for participants with persistent regional tenderness vs 0.3 (0.0 to 0.6) for participants without persistent regional tenderness ($P=.25$). There was insufficient variability among participants to examine the association of persistent regional TTA, rotational asymmetry, or motion restriction with the final regional BMD T score. The association of persistent nonspecific and specific vertebral somatic dysfunction and persistent moderate/severe specific vertebral somatic dysfunction with the final vertebral BMD T score is presented in *Table 5*. Vertebrae demonstrating persistent motion restriction had significantly higher final vertebral BMD T scores than those that did not ($P=.02$). No other significant relationships of persistent specific vertebral somatic dysfunction and the final BMD T scores were observed.

The mean (95% CI) change from the initial to final vertebral BMD T scores was 0.1 (−0.0 to 0.1), with a range of −1.2 to 1.7. There was no significant difference

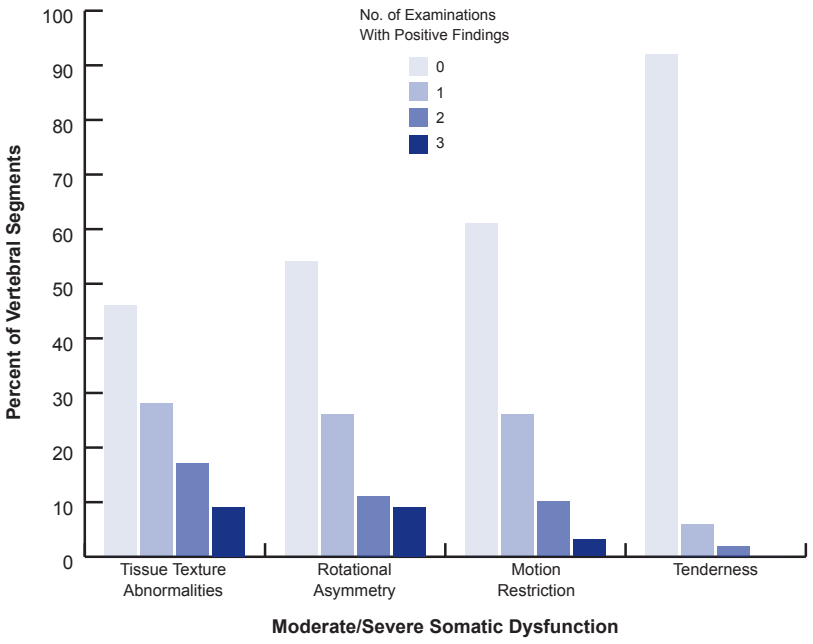

Figure 2.
Lumbar vertebral segments with positive moderate/severe specific vertebral somatic dysfunction findings present at 0, 1, 2, or 3 palpatory examinations (N=192).

between the initial and final vertebral BMD T scores (*P*=.06). The mean (95% CI) change from the initial to final regional BMD T scores was 0.1 (−0.0 to 0.1), with a range of −0.6 to 0.4. There was no significant difference between the initial and final regional BMD T scores (*P*=.10). Persistent regional tenderness was not significantly related to changes from the initial to final regional BMD T scores; the mean (95% CI) regional BMD T-score change was −0.1 (−0.2 to 0.1) for participants with persistent regional tenderness vs 0.1 (0.0 to 0.2) for participants without persistent regional tenderness (*P*=.09). There was insufficient variability among participants to examine the association of persistent regional TTA, rotational asymmetry, or motion restriction to changes from the initial to final regional BMD T scores.

The association of persistent nonspecific and specific vertebral somatic dysfunction and persistent moderate/severe specific vertebral somatic dysfunction with changes from the initial to final vertebral BMD T scores is presented in *Table 6*. There was no significant difference in changes from the initial to final vertebral BMD T scores between vertebrae that demonstrated persistent TTA, rotational asymmetry, or motion restriction and those that did not (*P*=.17, .79, and .44, respectively). There was a significant difference in changes from the initial to final vertebral BMD T scores between vertebrae that demonstrated persistent tenderness and those that did not; the mean (95% CI) BMD T-score change was −0.2 (−0.4 to 0.1) vs 0.1 (0.0 to 0.1), respectively (*P*=.04). There was a significant increase in the vertebral BMD T scores for those vertebrae that did not have persistent tenderness (mean [95% CI] BMD T-score change, 0.1 [0.0 to 0.1]; *P*=.02), whereas those vertebrae that had persistent tenderness did not demonstrate a significant change in vertebral BMD T scores (mean [95% CI] BMD T-score change, −0.2 [−0.4 to 0.1]; *P*=.15).

There was a significant increase in the vertebral BMD T scores for those vertebrae that demonstrated persistent TTA (mean [95% CI] BMD T-score change, 0.1 [0.0 to 0.2]; *P*=.02), whereas those vertebrae that did not have persistent TTA did not demonstrate a significant change in vertebral BMD T scores (mean [95% CI] BMD T-score change, −0.0 [−0.1 to 0.1]; *P*=.85). Additionally, there was a significant increase in the vertebral BMD

Table 4.
Frequency of Persistent Moderate/Severe Specific Vertebral Somatic Dysfunction by Vertebral Level in Study Participants (N=48)

Persistent Somatic Dysfunction Element[a]	Positive Findings by Vertebral Level, No. (%)			
	L1	L2	L3	L4
Tissue Texture Abnormalities				
Any	10 (21)	7 (15)	0	0
Right only	0	0	0	0
Left only	2 (4)	1 (2)	0	0
Bilateral	8 (17)	6 (13)	0	0
Rotational Asymmetry				
Any	3 (6)	2 (4)	7 (15)	5 (10)
Right	0	1 (2)	0	0
Left	2 (4)	1 (2)	7 (15)	5 (10)
Motion Restriction	0	4 (8)	1 (2)	0
Tenderness	0	0	0	0

[a] Somatic dysfunction was considered persistent if the participant had the defined somatic dysfunction findings at all 3 palpatory examinations (0, 4, and 8 weeks).

T scores for those vertebrae that demonstrated persistent left TTA (mean [95% CI] BMD T-score change, 0.1 [0.0 to 0.2]; $P=.05$). There was no significant difference in the changes from the initial to final vertebral BMD T scores between vertebrae that demonstrated persistent moderate/severe TTA, rotational asymmetry, or motion restriction and those that did not ($P=.07$, .19, and .79, respectively). However, there was a significant increase in the vertebral BMD T scores for those vertebrae that demonstrated persistent moderate/severe TTA (mean [95% CI] BMD T-score change, 0.3 [0.0 to 0.5]; $P=.02$), whereas those vertebrae that did not have persistent moderate/severe TTA did not demonstrate a significant change in vertebral BMD T scores (mean [95% CI] BMD T-score change, 0.0 [−0.0 to 0.1]; $P=.22$).

Comment

The current study assessed the persistence of lumbar somatic dysfunction over 8 weeks and the association of that persistence with lumbar BMD T scores. Although the study population was a primarily asymptomatic group, specific patterns of persistent somatic dysfunction were observed. Persistent left lumbar rotational asymmetry occurred 10 to 30 times more often than persistent right rotational asymmetry. Left lumbar rotation is consistent with the common compensatory pattern defined by Zink and Lawson,[14] who reported that asymptomatic individuals frequently have common patterns of asymmetry throughout the body, including right pelvic rotation and left lumbar rotation. This pattern is also consistent with the most common lumbar scoliosis pattern, T12-L4 convex left, which is accompanied by left lumbar rotation.[18] Shaw et al[19] also noted a predominance of left lumbar rotational asymmetry in an assessment of 12 asymptomatic osteopathic medical students. In their study,[19] the rotational asymmetry was identified independently by means of both palpation and ultrasonography. In the previously published portion of the current study,[13] we found that participants with and without chronic LBP

Table 5.
Association of Persistent Nonspecific and Specific Vertebral Somatic Dysfunction With Final Vertebral Bone Mineral Density T Score in Study Participants

Somatic Dysfunction Element	BMD T Score, Mean (95% CI)		*P* Value[a]
	Persistent Somatic Dysfunction	No Persistent Somatic Dysfunction	
Any Somatic Dysfunction	0.3 (0.2 to 0.5)	1.1 (0.2 to 2.0)	.09
Tissue Texture Abnormalities			
Any	0.4 (0.2 to 0.5)	0.4 (0.1 to 0.6)	.97
Right only	0.2 (−0.4 to −0.7)	0.4 (0.1 to 0.6)	.47[b]
Left only	0.3 (0.0 to 0.5)	-	
Bilateral	0.6 (0.2 to 0.9)	-	
Moderate/severe	0.5 (0.0 to 1.0)	0.4 (0.2 to 0.5)	.61
Rotational Asymmetry			
Any	0.4 (0.3 to 0.6)	0.2 (−0.0 to 0.5)	.25
Right	−0.2 (−1.1 to 0.8)	0.3 (0.1 to 0.6)	.47[c]
Left	0.4 (0.2 to 0.6)	-	
Moderate/severe	0.4 (−0.1 to 0.8)	0.4 (0.2 to 0.5)	.97
Motion Restriction			
Any	0.6 (0.4 to 0.8)	0.2 (0.1 to 0.4)	.02
Moderate/severe	0.7 (−0.2 to 1.6)	0.4 (0.2 to 0.5)	.48
Tenderness			
Any	0.5 (−0.0 to 1.0)	0.4 (0.2 to 0.5)	.70
Moderate/severe	NA[d]	0.4 (0.2 to 0.5)	NA[d]

[a] Between-group *P* value from generalized linear mixed model testing for the association of persistent nonspecific and specific vertebral somatic dysfunction with final vertebral bone mineral density (BMD) T score. This analysis determined whether final BMD T score was different between vertebrae with persistent somatic dysfunction and vertebrae without persistent somatic dysfunction.
[b] Comparison of right only vs left only vs bilateral vs no persistent tissue texture abnormalities.
[c] Comparison of right vs left vs no persistent rotational asymmetry.
[d] Not available (NA). Insufficient data available for analysis.

Abbreviation: CI, confidence interval.

demonstrated a greater incidence of left rotational asymmetry than right rotational asymmetry. In addition, both groups had a significantly higher frequency of left moderate/severe rotational asymmetry than right moderate/severe asymmetry ($P<.001$). A small percentage of the persistent left rotational asymmetry seen in the current study was moderate/severe. This low percentage of moderate/severe findings is likely a result of the inclusion of a low number of chronic LBP participants (ie, 2) who were followed up over the 8 weeks of the study, so the persistence of the somatic dysfunction could not be compared between groups.

Few studies have been performed that have assessed the persistence of vertebral somatic dysfunction over time. Motion restriction as assessed in the current study is also known as spinal stiffness or posterior-to-anterior

Table 6.
Association of Persistent Nonspecific and Specific Vertebral Somatic Dysfunction With Changes[a] in Vertebral Bone Mineral Density T Scores in Study Participants

Somatic Dysfunction Element	BMD T-Score Change				
	Persistent Somatic Dysfunction		No Persistent Somatic Dysfunction		
	Mean (95% CI)	*P* Value[b]	Mean (95% CI)	*P* Value[b]	*P* Value[c]
Any Somatic Dysfunction	0.1 (−0.0 to 0.1)	.07	0.1 (−0.3 to 0.5)	.72	.95
Tissue Texture Abnormalities					
Any	0.1 (0.0 to 0.2)	.02	−0.0 (−0.1 to 0.1)	.85	.17
Right only	−0.1 (−0.3 to 0.2)	.58	0.0 (−0.1 to 0.1)	.53	.55[d]
Left only	0.1 (0.0 to 0.2)	.05	-		
Bilateral	0.1 (−0.1 to 0.2)	.42	-		
Moderate/severe	0.3 (0.0 to 0.5)	.02	0.0 (−0.0 to 0.1)	.22	.07
Rotational Asymmetry					
Any	0.1 (−0.0 to 0.1)	.08	0.0 (−0.1 to 0.2)	.45	.79
Right	−0.1 (−0.6 to 0.3)	.52	0.1 (−0.0 to 0.2)	.15	.61[e]
Left	0.1 (−0.0 to 0.1)	.16	-		
Moderate/severe	0.2 (−0.0 to 0.4)	.07	0.0 (−0.0 to 0.1)	.16	.19
Motion Restriction					
Any	0.1 (−0.0 to 0.2)	.08	0.0 (−0.0 to 0.1)	.33	.44
Moderate/severe	0.0 (−0.4 to 0.4)	.98	0.1 (−0.0 to 0.1)	.06	.79
Tenderness					
Any	−0.2 (−0.4 to 0.1)	.15	0.1 (0.0 to 0.1)	.02	.04
Moderate/severe	NA[f]	NA[f]	0.1 (−0.0 to 0.1)	.06	NA[f]

[a] From 0 to 8 weeks.
[b] Within-group *P* value from generalized linear mixed model testing for changes from initial to final vertebral bone mineral density (BMD) T scores for those vertebrae with and without persistent somatic dysfunction. This analysis determined whether there was significant change in BMD T scores for vertebrae with persistent somatic dysfunction and for vertebrae without persistent somatic dysfunction.
[c] Between-group *P* value from generalized linear mixed model testing for the association of persistent somatic dysfunction with change from initial to final vertebral BMD T score. This analysis determined whether the change in BMD T score was different between vertebrae with persistent somatic dysfunction and vertebrae without persistent somatic dysfunction.
[d] Comparison of right only vs left only vs bilateral vs no persistent tissue texture abnormalities.
[e] Comparison of right vs left vs no persistent rotational asymmetry.
[f] Not available (NA). Insufficient data available for analysis.

Abbreviation: CI, confidence interval.

spinal stiffness[20] and is commonly used as part of clinical assessment in physical therapy, chiropractic, and osteopathic manipulative medicine.[21] Latimer et al[8] assessed motion restriction over time by using a stiffness testing device in participants with LBP and without LBP. Over an average of 22 days, they found that stiffness stayed relatively constant in participants without LBP, but stiffness decreased as pain decreased in the LBP participants. Spinal motion restriction is multifactoral and is affected by the thickness of overlying tissues,[21] the participant's respiratory cycle,[22] the tension of the supporting structures such as the muscles and ribs,[23] and the range of motion of the vertebral elements.[24] Lee et al[21] noted a decrease in motion restriction at L4 in asymptomatic individuals who had a greater iliac crest skinfold thickness, a measurement probably proportional to the depth of the tissue overlying the spinous processes. (The average BMI in the Lee et al[21] study was 23.8, whereas ours was 26.3.) Owens et al[20] noted that the spinous processes of L4 and L5 were more difficult to palpate because of a greater depth of overlying tissues in their study participants. Greater tissue depth may be the reason that 10% of L4 vertebrae in the current study demonstrated persistent motion restriction, compared with 40% or more of L1-L3 vertebrae that had persistent motion restriction.

Although a small percentage of the persistent motion restriction seen in the current study was graded as moderate/severe, motion restriction was the only persistent somatic dysfunction element to show an association with the final vertebral BMD T score. Disk deformation commonly occurs with scoliotic curvatures, with osteophytes occurring more frequently on the concave side of the curve and disk herniations occurring more frequently on the convex side.[25] Persistence of lumbar group curves, such as those seen in scoliosis, is associated with a loss of the lumbar lordosis and reduced extension range of motion.[25] Lumbar degenerative joint disease and lumbar degenerative disk disease most commonly occur at the L4-L5 and L5-S1 levels.[26,27] Degenerative disk disease, which typically precedes degenerative joint disease, alters the mechanical loading of intervertebral disks and the facet joints[27,28] and may lead to changes in passive range of motion. The osteophytes, along with the endplate sclerosis that occurs in spinal degenerative joint disease, affect BMD values as measured with DXA.[29,30] Therefore, elevated BMD—as was seen with persistent motion restriction—may represent early degenerative changes.

In the previously reported data,[12] the presence of both rotational asymmetry and motion restriction were found to be related to the initial vertebral BMD T scores. When the association of persistent somatic dysfunction with the final BMD T scores in the current study was assessed, only persistent vertebral motion restriction was associated with the final vertebral BMD T scores. Persistent vertebral tenderness and moderate/severe vertebral TTA were associated with changes from the initial to the final BMD T scores. Because the occurrence of persistent tenderness and moderate/severe TTA in the participants was fairly low, the current study should be repeated with a larger sample size to determine the reproducibility of this finding.

Limitations

One of the major limitations of the current study was the small sample size, which may have contributed to the lack of persistent moderate/severe somatic dysfunction. As stated previously, the significant relationship between increasing BMD T score and lack of persistent tenderness was probably a result of the small sample size and the absence of moderate/severe tenderness. A small number (15 of 192) of vertebral segments demonstrated persistent tenderness. Therefore, these findings may differ in a study with a larger sample size. On the basis of data in studies by Snider et al[13] and Licciardone and Kearns,[31] the lack of persistent moderate/severe somatic dysfunction in the current study was probably a result of the small number of participants with chronic LBP. Because of this limitation, we performed a follow-up persistence study that specifically recruited participants with chronic LBP. Another major limitation of the current study was the lack of objec-

tive verification of vertebral level during palpation. A few years after conducting the current study, we conducted another study using lumbar radiographs to assess the accuracy of the palpatory method used in the current study. The accuracy was determined to be 67% to 78% for these investigators.[32] The accuracy was also affected by participant BMI and the presence of anatomic anomalies, such as the absence of the 12th ribs. Review of the DXA images from the current study revealed 5 participants without visible 12th ribs. Within the scope of the current study, inaccurate localization may affect both the frequency of persistence of somatic dysfunction and its association to lumbar BMD T scores. Future studies should verify the location of the anatomic structures to ensure accurate correlation.

Conclusion

The current study assessed the persistence of lumbar somatic dysfunction over 8 weeks and the association of that persistence with lumbar BMD T scores. Although the study population was primarily asymptomatic, common patterns of somatic dysfunction persisted over the 8-week study. The persistence of predominantly left lumbar rotation was consistent with Zink and Lawson's common compensatory pattern of somatic dysfunctions. However, the rotational asymmetry was not related to either the final BMD T scores or changes in BMD T scores over time. Persistent vertebral motion restriction was shown to have an association with the final lumbar BMD T scores, and persistent TTA and tenderness were associated with changes in BMD T scores over 8 weeks. The next step of the current research is to assess the persistence of somatic dysfunction in chronic LBP participants and to investigate the association between somatic dysfunction and degenerative changes in the lumbar spine.

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