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ORIGINAL CONTRIBUTION

Confirmatory Factor Analysis in Osteopathic Medicine: Fascial and Spinal Motion Restrictions as Correlates of Muscle Spasticity in Children With Cerebral Palsy

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Context: While numerous measures are available to assist physicians in assessing patients with cerebral palsy, there is a paucity of instruments that capture data relevant to osteopathic assessment. The lack of such tools limits the reach of research in key osteopathic indicators.

Methods: A structured objective form designed to assist osteopathic physicians in the evaluation of fascial restriction, restriction of spinal motion, and muscle spasticity was developed for use during osteopathic musculoskeletal structural examinations. Data were collected as part of a larger study investigating the effects of osteopathic manipulative treatment versus acupuncture in children with cerebral palsy. In the present study, confirmatory factor analysis was used to examine the relationships between fascial and spinal motion restrictions in addition to spasticity.

Results: In 57 children with spastic cerebral palsy, latent factors for fascial restrictions and spinal motion restriction fit the data well and both factors were correlated with a visual analog scale rating of the child's muscle spasticity.

Conclusions: These findings provide preliminary evidence for the factorial and concurrent validity of fascial and spinal motion restrictions, demonstrating the benefits of an instrument for assessing the results of osteopathic musculoskeletal structural examinations.

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With incidence rates of up to 2.5 per 1000 live births in the United States and other developed nations, cerebral palsy is the most frequent cause of childhood disability.[1] In the majority of children with cerebral palsy, the disability's most dominant feature is muscle spasticity. Children with spastic cerebral palsy have limited motor function and may need specialized medical care and services throughout their lives. It is estimated that lifetime healthcare costs for cerebral palsy are $503,000, making it second in cost only to truncus arteriosus.[2] Because conventional treatment for cerebral palsy is often limited in its success for improving motor function, parents are constantly alert for new treatment options that may improve their children's abilities to live more independently.

Osteopathic manipulative treatment (OMT) is one integrative treatment to which parents have turned to reduce their children's symptoms.[3,4] The osteopathic medical profession has a long history of a special focus on the treatment of children dating back to the late 19th and early 20th centuries when the field of pediatrics was in its infancy.[5] Osteopathic literature addressing the treatment of children first appeared in 1939 with the work of William Garner Sutherland, DO,[6] on the craniosacral mechanism. The most prolific contributor to the literature on pediatric care using the osteopathic approach is Viola Frymann, DO.[7] Other early contributors include Margaret W. Barnes, DO,[8] who addressed using OMT for infants, and Beryl Arbuckle, DO,[9] who specifically evaluated the craniosacral mechanism in brain-injured children, especially those with cerebral palsy.

A necessary component of osteopathic evaluation is the musculoskeletal structural examination. As outlined by Kappler and colleagues,[10] three key components of the structural examination involve inspection, motion testing, and palpation of the neuromusculoskeletal system. This examination helps osteopathic physicians identify somatic dysfunction and viscerosomatic changes, which can then be treated using OMT. Kelso and Townsend[11] also emphasized the importance of these three components, as did Dinnar and coauthors[12] and Beal.[13] In fact, Kelso[14] developed guidelines for designing osteopathic protocols and recording the findings of a structural examination.

Fascial restrictions and motion restriction of the spine are important elements of an osteopathic musculoskeletal structural examination. In the present study, we hypothesized that indicators for these kinds of restrictions would be represented as latent constructs in a sample of children with spastic cerebral palsy, and that they would be correlated with one other—as well as with an objective rating of muscle spasticity. *Latent*

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factors, or *constructs*, refer to underlying characteristics of an organism that cannot be observed directly.[15] Instead, latent factors are inferred from more than one observed or manifest variable.[15] For example, depression cannot be observed directly; it can only be inferred from patient behavior and self-report.

Methods

Inclusion criteria were diagnosis of cerebral palsy with spasticity as a predominate feature, prior diagnosis by a pediatric neurologist, less than 12 years of age, and completion of baseline assessment and informed consent forms. Exclusion criteria were recent interventions, such as injections with botulinum toxin type A within 4 months of study enrollment. As noted, all individuals for whom baseline assessments were completed and informed consent were received were included in the study regardless of their participation in and completion of study protocols in the larger OMT versus acupuncture investigation. Approximately 40 subjects completed both studies. Approval for this study was obtained from the institutional review board at the University of Arizona in Tucson.

Data were taken from the baseline assessments in the larger study. Children were recruited from local clinics, where the diagnosis of spastic cerebral palsy was made by a pediatric neurologist.[16] On study enrollment,[16-18] subjects received an extensive battery of measures designed to evaluate impairment, functioning, and well being. The parent and, where appropriate, the child signed informed consent forms.

Osteopathic objective physical findings (ie, somatic dysfunction) were collected and included:

- asymmetry (eg, one shoulder sitting higher than the other)
- differences in range of motion (eg, one ankle with greater dorsiflex than the other)
- tissue texture abnormalities of anatomic structures (eg, boggy edematous tissue texture of an acute sprained ankle versus the ropey, fibrotic texture of a chronic postural strain of paraspinal musculature)

Although osteopathic examiners process the results of musculoskeletal structural examinations somewhat differently as a result of their own physiology, training, and clinical experience, we sought to reduce the effects of this bias by having only one osteopathic physician (K.W.) complete all baseline subject assessments. The two variables analyzed in the current study were fascial restrictions and restriction of spinal motion. Findings were recorded on an original form (*Appendix*) that included a 100 mm visual analog scale to be used by the examiner to rate the severity of subject muscle spasticity.

Validity refers to how adequately a test or instrument measures what it purports to measure. There are several types of validity including construct validity and predictive validity. *Construct validity* refers to the degree to which an underlying hypothesized dimension is represented or confirmed by empirical data. *Concurrent validity* refers to the relationship of a measure to an external criterion.[19] (Alternative terms for these two concepts are *factorial validity* and *predictive validity*, respectively.) In this study, construct validity was used to assess the structure and interrelationships of the osteopathic findings. Concurrent validity was assessed by the correlation between several osteopathic latent factors and an external criterion—a rating of the child's muscle spasticity on a visual analog scale.

We specified latent factors for fascial restrictions and restriction of motion in the spine. As noted, we hypothesized that these two factors would correlate with muscle spasticity. Children with greater restrictions in these factors were expected to have higher levels of impairment as reflected by examiner ratings of muscle spasticity.

The fascia are sheets of connective tissue that wrap around every muscle group and internal organ and are continuous and contiguous from head to toe. The four primary fascia in the transverse plane are the tentorium cerebelli, cervicothoracic junction, abdominal diaphragm, and the pelvic diaphragm. Blood, lymphatic vessels, and nerve fibers pierce through and are held in place by the fascia. According to osteopathic theory, restrictions or twists in the fascia can have localized or distant effects on tissue health by changing local levels of oxygenation, nutrition, detoxification, and neuronal activity. The four fascial planes act as transverse baffles in the closed-fluid system of the human body. If they move in synchrony, a fluid wave can pass through the system with minimal disturbance; when out of synchronization, the same fluid wave produces complex patterns of disturbance. This action, in turn, disturbs the milieu of the cell and the homeostasis of the organism, affecting basic functionality. The osteopathic structural examination assesses the presence and severity of restriction in the four transverse diaphragms. We hypothesized that all fascial restrictions in the study population could be explained by a single underlying factor.

An osteopathic physician (K.W.) recorded somatic dysfunctions of the spine (eg, higher shoulder, sacrum, gait) on the new assessment form (*Appendix*), noting fascial and spinal restriction on a numbered four-point scale, with severity ratings ranging from 0, absent, to 3, severe. Functionally, the spine is divided into three regions: cervical, thoracic, and lumbar. These regions are further divided into seven subregions based on the anatomic changes in the spinal curves. The cervical spine has two subregions, an upper (C1-C2) and a lower (C3-C7); thoracic, an upper (T1-T4), middle (T5-T8), and lower (T9-T12); and lumbar, an upper (L1-L3) and a lower (L4-L5). As with fascial restrictions, we hypothesized that spinal restrictions were related and could be explained by a single underlying factor of spinal motion restriction. In addition to the structural assessment, the examiner (K.W.) used a visual analog scale to rate the severity of each child's muscle spasticity compared to all other patients with this diagnosis encountered during approximately 15 years of clinical experience.

We hypothesized that the latent factors of restriction in the fascial planes and in the spine would covary and that each of these would be correlated with the examiner-assigned rating for muscle spasticity.

We entered data into a Microsoft Access 2000 for Windows database (Microsoft Corporation, Redmond, Wash). Statistical analysis was conducted using SPSS statistical software (version 11.0 for Windows; SPSS Inc, Chicago, Ill)[20] and EQS structural equation modeling software (version 6.1 for Windows; Multivariate Software, Inc, Encino, Calif).[21] The few instances of missing data were imputed using multiple regression techniques.

We used confirmatory factor analysis to examine the underlying structure of the osteopathic indicators.[21] In this type of analysis, researchers specify the factors a priori (ie, osteopathic findings and the degree of spasticity) and then confirm whether a relationship between the theorized factors does in fact exist. The fit of the theorized model is compared to actual data.

Robust maximum likelihood estimation was used. Model fit statistics reported here are the Satorra-Bentler scaled χ^2 statistic, comparative fit index (CFI), and root mean square error of approximation (RMSEA). The χ^2 test assesses the size of the discrepancy between the original sample covariance and the proposed model. Statistically significant results from χ^2 analysis indicate that the proposed model is significantly different from the data. That is, the a priori model does not explain the actual data well. The CFI compares the proposed model to a null model with values that range from 0 to 1. A CFI higher than 0.95 indicates a good fit between the proposed model and the data. A RMSEA is a measure of misfit by degrees of freedom. Values below 0.10 are considered acceptable; below 0.05, good. Values that are over 0.10 are considered a poor fit. Fit indices are complimentary, the χ^2 is sensitive to sample size, the CFI is not as sensitive to sample size, and the RMSEA makes adjustments for the number of model parameters. With a sample size of 57 and an alpha (α) level of .05 powered at 80%, a model with 10 path coefficients had sufficient power to detect a large effect size (0.35).

Results

Fifty-seven children with mild to severe spastic cerebral palsy were enrolled in a study to assess the effects of OMT or acupuncture on impairment and functioning. Using the Gross Motor Functional Classification System, half of the children were classified as level I-III, and half were classified as level IV-V.[22] The mean (SD) average age of subjects was 6.2 (3.0) years. Of these subjects, 41 (72%) were boys; 16 (28%), girls. Twenty-seven (47%) were Hispanic; 25 (44%), white; 3 (5%), Asian; 1 (2%), African-American; and 1 (2%), Native American—a reflection of the population in Tucson, Ariz.

On average, the children had moderate fascial and spinal motion restrictions (*Table 1*). The average (mean [SD]) rating of severity of muscle spasticity was 61 (25) on the 100 mm visual analog scale. None of the indicators showed significant skewing though four of the spinal motion indicators demonstrated moderate, positive kurtosis.

Confirmatory factor analysis was used to examine the factorial structure of the osteopathic indicators. A single factor model was executed for four indicators of fascial restriction (*Table 2*). The Satorra-Bentler χ^2_2 for this proposed model was 2.19 (P=.33). Fit statistics indicated a good model fit (CFI=0.996, RMSEA=0.03).

In addition, a single factor model was executed for seven indicators of restriction of motion in the cervical, thoracic, and lumbar spine (Satorra-Bentler χ^2_{14}=22.83, P=.08, CFI=0.73, RMSEA=0.11). The upper cervical, upper thoracic, and lower thoracic subregions were significant indicators for the factor. The middle thoracic subregion had the next highest factor loading and was retained to facilitate factor identification. The lower cervical and both lumbar spinal indicators did not load significantly on the factor. A model including the upper cervical spine and all three thoracic spine subregions (*Table 2*) provided a better fit to the data (Satorra-Bentler χ^2_2=.38, P=.83, CFI=1.00, RMSEA=0.0). The χ^2_{12} difference between the two models was 22.45 ($P<.05$).

We used confirmatory factor analysis to test the relationship between the two latent osteopathic factors, and one external criterion—the global rating of muscle spasticity (*Figure*). The correlation between the latent factors of fascial and spinal restriction was 0.51. The pathway from fascial restriction to muscle spasticity was 0.58 and the pathway from spinal restriction to muscle spasticity was 0.22. These two paths were not significantly different (χ^2_1=0.87, $P>.05$). The final model accounted for 51% of the variance (Satorra-Bentler χ^2_{25}=32.17, P=.15, CFI=0.92, RMSEA=0.07). The fit of the proposed model was reasonable.

We collected data for subjects' left and right sides for many indicators, including the spine. Analyses were executed using indicators from the left and right sides of the spine as well as the side with the most severe spasticity. Because the results were nearly identical for subjects' left and right sides, we have reported the outcomes for the left side only . No model showed evidence of multivariate nonnormality.

Comment

Few assessment tools have been designed to measure concepts specific to osteopathic medicine, and the absence of these instruments has hampered osteopathic research.[23] As part of a randomized treatment outcomes study, we collected data from osteopathic musculoskeletal structural examinations. This study design allowed us to investigate the construct and

Table 1
Fascial and Spinal Motion Restrictions in Children With Spastic Cerebral Palsy: Means, Standard Deviations, and Item Intercorrelations for Osteopathic Structural Examination Findings (N=57)*

Restriction Type	1	2	3	4	5	6	7	8	9	10	11	12
■ **Fascial**												
□ Tentorium cerebelli	1.00											
□ Cervicothoracic junction	0.39	1.00										
□ Abdominal diaphragm	0.18	0.15	1.00									
□ Pelvic diaphragm	0.44	0.41	0.39	1.00								
■ **Spinal Motion**												
□ Upper cervical (C1-C2)	0.05	0.23	0.27	0.40	1.00							
□ Lower cervical (C3-C7)	0.20	-0.08	...	-0.06	-0.11	1.00						
□ Upper thoracic (T1-T4)	0.32	0.22	0.10	0.18	0.32	0.25	1.00					
□ Middle thoracic (T5-T8)	0.16	0.39	0.10	0.16	0.09	-0.04	0.24	1.00				
□ Lower thoracic (T9-T12)	0.10	0.08	0.16	0.15	0.30	0.15	0.47	0.25	1.00			
□ Upper lumbar (L1-L3)	0.03	-0.05	-0.03	0.09	0.26	0.23	-0.05	-0.13	0.05	1.00		
□ Lower lumbar (L4-L5)	0.17	0.12	0.15	0.16	0.19	0.03	0.21	-0.16	0.16	0.10	1.00	
■ **Muscle Spasticity Severity**	0.44	0.23	0.44	0.51	0.31	0.15	0.36	0.26	0.25	0.08	0.21	1.00
■ **Mean (SD)**	3.26 (.55)	2.88 (.66)	3.00 (.54)	2.91 (.69)	1.89 (.99)	1.77 (.89)	2.05 (1.04)	2.00 (.98)	1.98 (1.03)	1.88 (.98)	2.14 (1.11)	61.05 (24.57)

* Correlation coefficient of 0.26 is statistically significant at an α (alpha) level of .05.

concurrent validity of several osteopathic factors. We found evidence for both the factorial validity and construct validity of fascial and spinal motion restriction factors.

Empirical outcomes studies in osteopathic medicine generally use standard outcomes measures to evaluate the effects of OMT.[24-33] This is as it should be, because OMT—like all other medical interventions—must show a positive impact on patient complaints (eg, reduced pain, functional improvement). While these studies examine the measurable effects of OMT, they were not designed to study the theoretical mechanisms behind the potency of this treatment modality. In order to investigate osteopathic principles and practice empirically, data measuring these concepts are required. There are a few examples in osteopathic medicine and the most notable is the groundbreaking instrument designed by Sleszynski and colleagues.[34] Other examples in the literature include work by Rivera-Martinez and coinvestigators[35] and Walko and Janouschek.[36]

In the present study, we collected data from osteopathic musculoskeletal structural examinations to analyze relationships among several osteopathic factors. A quantitative dataset such as this one has the potential to allow researchers to measure and test core theories of the discipline. Our purpose in this analysis was to examine empirically the construct, or factorial validity, of several osteopathic factors and the relationships between them.

The fascial indicators were clearly represented by a single latent factor in a sample of children with spastic cerebral palsy. Fascial restrictions were expressed uniformly by one or more

Table 2
Fascial and Spinal Motion Restrictions in Children With Spastic Cerebral Palsy: Measurement Models by Restriction Type

Restriction Type	Factor Loading	Regression Coefficient*
■ **Fascial**		
□ Tentorium cerebelli	0.56	0.11
□ Cervicothoracic junction	0.53	0.11
□ Abdominal diaphragm	0.43	0.10
□ Pelvic diaphragm	0.80	0.10
■ **Spinal Motion**		
□ Upper cervical (C1-C2)	0.42†	0.16
□ Lower cervical (C3-C7)	0.23	0.15
□ Upper thoracic (T1-T4)	0.76†	0.14
□ Middle thoracic (T5-T8)	0.29	0.16
□ Lower thoracic (T9-T12)	0.64†	0.13
□ Upper lumbar (L1-L3)	0.06	0.16
□ Lower lumbar (L4-L5)	0.25	0.16

* Standard error
† $P<.05$

of the four fascia. Spinal motion restriction was also represented by one factor. We tested a spinal motion restriction factor with indicators for the seven subregions of the spine. In this sample, three of the seven subregions were significant

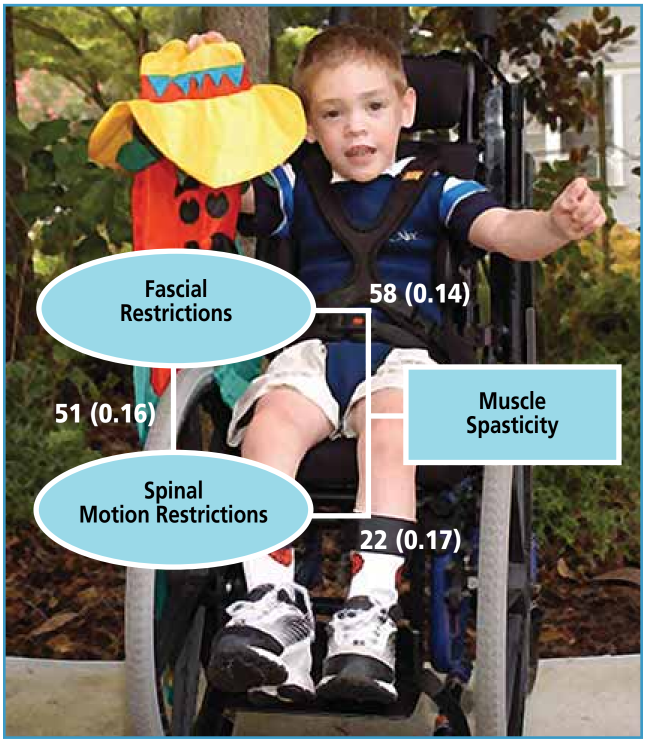

Figure. *Relationship between osteopathic factors and muscle spasticity. Null model χ^2_{36}=130.59; Satorra-Bentler scaled model χ^2_{25}=32.17 (P=.15); comparative fit index=0.92; root mean square error of approximation=0.07. Numbers shown in parentheses are standard errors.*

indicators of the factor: upper cervical restriction, and upper and lower thoracic spine restriction.

The correlation between the fascial and spinal restriction factors was 0.51, accounting for 26% of the variance between them. This estimate is in line with two core osteopathic principles: (1) the body is a whole, and (2) structure and function are interrelated. Thus, a problem in the spine is often associated with a problem in the fascia and vice versa.

We assessed concurrent validity by correlating osteopathic physical findings to an objective rating of muscle spasticity on a visual analog scale. The path coefficients between the osteopathic factors of fascial restriction and spinal motion restriction and the examiner's severity rating of muscle spasticity provide support for concurrent validity. One promising result of this investigation is that these indicators are correlated with an external measure of impairment.

I11 Our analysis was limited to children with mild to severe spastic cerebral palsy. Furthermore, a sample size of 57 is quite small for a confirmatory factor analysis, and the study had the power to detect only large effect sizes. Analysis was limited to factorial and concurrent validity. For these reasons, our findings should be tested in other, larger samples. Finally, our study design mandated the use of only one osteopathic examiner, limiting the generalizability of our findings.

However, we have replicated the factorial analyses in a second study designed to investigate similar factors in young children with recurrent ear infections (M.F.D., unpublished data, 2002). While the sample size in both studies was small, the results from our otitis media study also provide evidence for the factorial validity of the fascial and spinal motion restriction factors.

Quantifiable process and outcomes measures are useful in every field of research, and OMT is no exception. Data from an instrument designed for use during osteopathic musculoskeletal structural examinations have allowed us to investigate the factorial validity of several osteopathic concepts and the relationships between them. Such findings facilitate osteopathic medical research, provide the potential to explore the mechanisms by which OMT works, and are necessary for the evaluation of the principles and practice of osteopathic medicine.

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(continued)

Appendix

A structured objective form designed by the authors to assist osteopathic physicians in the evaluation of fascial restriction, restriction of spinal motion, and muscle spasticity. This form was developed for clinician use during musculoskeletal structural examinations. In the present study, the authors used the form to record results of structural examinations for 57 children with mild to severe spastic cerebral palsy. Based on these data, the authors found that indicators of fascial and spinal restriction predict an external measure of impairment, muscle spasticity. ***Abbreviation****: UG, urogenital. Form has been altered for graphic enhancement only.*

Indicate level of restriction present.

	Absent	Mild	Moderate	Severe
Fascial Restrictions				
A. Tentorium cerebelli	0	1	2	3
B. Cervicothoracic junction	0	1	2	3
C. Abdominal diaphragm	0	1	2	3
D. Pelvic (UG) diaphragm	0	1	2	3
Cervical Spine				
A. Upper (C0-C2) motion restricted	0	1	2	3
B. Lower (C3-C7) motion restricted	0	1	2	3
Thoracic Spine				
A. Upper (T1-T4) motion restricted	0	1	2	3
B. Middle (T5-T8) motion restricted	0	1	2	3
C. Lower (T9-T12) motion restricted	0	1	2	3
Lumbar Spine				
A. Upper (L1-L3) motion restricted	0	1	2	3
B. Lower (L4-L5) motion restricted	0	1	2	3

How severe is the child's spasticity today, compared to all spastic children?
(Place an "X" on the line.)

Low ____________________|____________________ **High**