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ORIGINAL CONTRIBUTION

Kinematic Measures to Objectify Head and Neck Motions in Palpatory Diagnosis: A Pilot Study

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Context: Physicians typically combine the use of palpation and objective measures, as evidence-based medicine dictates, to improve patient diagnosis and care. Practitioners also use palpatory examination in manual medicine to diagnose musculoskeletal impairment; however, there are no commonly accepted objective measures to complement palpatory findings.

Objective: To evaluate coupled vertebral motion as a parameter to complement palpatory findings from a standard clinical diagnostic test of cervical function.

Methods: Two examiners performed a blind screening of volunteer subjects for the presence of palpable symmetry or asymmetry in motions of the head and neck. In cases of interexaminer agreement, subjects then participated in kinematic assessment of cervical motion patterns. Neck angles were recorded, plotted, and evaluated for amounts of vertebral coupling.

Results: Interexaminer agreement was reached with 18 of the 34 subjects screened. Seven subjects with symmetric responses constituted the control group. Experimental subjects consisted of an asymmetric-asymptomatic (pain-free) group (n=6) and an asymmetric-symptomatic (pain) group (n=5). Control subjects exhibited the smallest average linear slope (−0.32) for the least amount of coupled motion. The average linear slopes for asymmetric subjects was −0.42 (asymptomatic) and −0.50 (symptomatic). Data analysis revealed that statistically significant differences among groups will be detected with a larger sample size.

Conclusions: Objective, kinematic parameters can be generated, measured, and evaluated relative to palpatory findings of musculoskeletal impairment by identifying trends in ratios of cervical lateral flexion and axial rotation.

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The current global impact of musculoskeletal disease is staggering. Data from the World Health Organization and the Bone and Joint Decade 2000-2010 indicate that musculoskeletal disease—the most frequent cause of human impairment, functional limitation, and disability throughout the world—is on the rise.[1] Longer life expectancies and, in turn, increased morbidity and disability have likely contributed to the condition's growing prevalence. Neck impairment in particular is a commonly reported musculoskeletal disorder affecting 70% of individuals at some time in their lives.[2,3] As a result, a significant proportion of manual medicine practice is devoted to the care of neck problems.[4]

Musculoskeletal dysfunction—such as neck impairment—can be evaluated using palpatory examination. However, even though such diagnostic tests are standard, palpatory findings may differ depending on practitioners' skill levels and experience.[5] In addition, most practitioners' orientation toward the application of knowledge rather than the creation of it has contributed to a shortage of scientific research that confirms the validity of palpatory techniques.[6] This lack of an evidence base no doubt affects students' understanding and desire to learn these diagnostic methods.

In evaluating the musculoskeletal system, much attention is given to vertebral flexion and rotation. Although these movements are typically described as occurring separately because of the complexity of their motions, they are naturally coupled. Vertebral coupling, along with range of motion, is well documented experimentally.[7-14] However, little attention has been given to the clinical relationship between this coupled motion and palpable signs of cervical dysfunction. Currently, there are no published, scientifically accepted objective measures to complement the subjective palpatory findings of cervical function.[15-19]

The current pilot study evaluates the kinematic parameter of coupled motion. We sought to determine if it is possible to relate this parameter to the palpatory findings of a standard clinical diagnostic test of cervical function (ie, lateral flexion). We believe the current study, in addition to establishing objective correlates of palpatory diagnosis, will also help broaden the understanding of spinal biomechanics, expand practi-

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tioners' knowledge base on the role of palpation in the diagnosis of musculoskeletal impairment, and permit new insight into teaching and training venues for manipulation techniques, particularly those specific to osteopathic medicine.

Methods

All methods and procedures were reviewed and approved by the Committee for Research Involving Human Subjects at Michigan State University (MSU) in East Lansing.

Examiner Training

Before initiating the screening sessions, two osteopathic physicians—the examiners in the current pilot study—trained together to develop consensus on diagnostic criteria. The lead examiner (William L. Johnston, DO) was an instructor and trainer in osteopathic manipulative medicine (OMM) who had 60 years of experience in osteopathic clinical manual medicine. The second examiner (M. Shannon Arnsberger, DO) had 5 years of experience as an osteopathic physician and regularly used manual medicine in her private practice.

Examiner training consisted of evaluating approximately 15 individuals—who did not participate in the present study—in lateral flexion of the head and neck region, specifically to determine whether motions were symmetric or asymmetric. Diagnoses were determined by integrating the following three critical assessments,[12,20-22] which were the accepted diagnostic criteria in the current study:

- a visual evaluation of the magnitude and symmetry of head and neck motion range
- a palpatory assessment for the quality of motion (eg, smoothness, palpable resistance) occurring during lateral flexion
- tissue resistance as subjects reached the end of joint motion range

Diagnostic Screening

Subjects were volunteers who responded to advertisements posted around the MSU campus and at the MSU OMM clinic between January 2003 and June 2003. The examiners performed a blind screening of subjects for the presence of palpable symmetry or asymmetry in response to a lateral flexion motion test. The examiners gave subjects a thorough description of the procedures that were going to be performed for the screening. Subjects sat on a stool with their arms crossed in front of their chests while the examiner stood behind the subject to initiate and guide the motions.

For right lateral flexion, the examiner's right hand was lightly formed to the vertex of the subject's head, fingers to the left and palm to the right, while his left hand rested lightly on the posterior upper-thoracic region (*Figure 1*). Lateral flexions started with the subject's head in a neutral position (ie, head and eyes facing forward). The examiner asked the subject to close his or her eyes and permit the introduction and guidance of the movements. The examiner moved the head and neck by

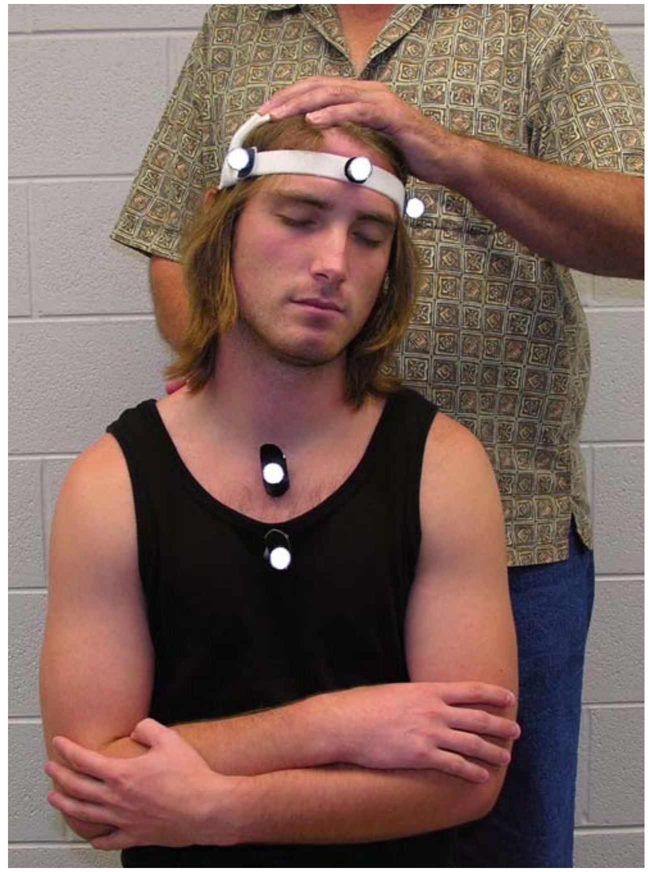

Figure 1. *An example of the diagnostic and kinematic test procedures, including position of examiner's hand and location of reflective markers.* (Photograph by Tamara Reid Bush, PhD)

guiding the ear toward the ipsilateral shoulder until a palpable sense of end-of-range was achieved. Motions were performed at a speed relative to the subject's own motion behavior to acquire palpatory information from the responding tissue.[21,22] The head and neck were then guided back to a neutral position, the left and right hand placement was switched, and motion to the opposite side followed.

Head and neck motion is complex, consisting of combined physiologic behaviors (ie, coupled motions) that occur as a result of vertebral geometry, connecting soft tissues, and the curvatures of the region.[21,23] Because of this coupling, the response of the entire cervical region during this diagnostic motion was evaluated—not merely the responses of individual vertebrae.[22] The passive lateral flexion diagnostic test, which elicits both lateral and axial rotations, was also chosen for the current study because it is a regularly practiced procedure, common to osteopathic medicine, chiropractic, physical therapy, and other manipulative and body-based disciplines.[20-22] Also, previous studies[24,25] indicate that this movement produces the most dependable within-subject diagnostic uniformity.

Each examiner documented subject assessments relative to the specific assessment criteria. The examiners then made final overall categorizations of either "symmetric" or "asymmetric" for each subject. Subjects who reported pain in the head or neck region were also classified as "symptomatic." When the examiners concluded their diagnoses, a third person (T.R.B.) collected and reviewed the written records to determine whether there was interexaminer agreement. Subject classification was based on the concurrence of the examiners' findings. In cases where the examiners' findings were not in agreement, subjects were not included in the remainder of the study.

Kinematic Testing Methods

When interexaminer agreement occurred during the screening, subjects were asked to return for the kinematic test, which occurred within 4 days of the initial screening. On the day of the kinematic test, an examiner (W.L.J.) performed an additional palpatory assessment of lateral flexion to confirm screening results. In the event that the screening and confirmation palpatory assessments differed, subjects still participated in the kinematic test, but this change was noted in our records. Data analysis was performed both with and without those subjects' results.

The same examiner then directed and performed the kinematic test motions. The protocol was identical to the diagnostic screening protocol with the exception that subject motions were video-recorded, as described below under "Data Collection and Analysis." Each cycle consisted of movement first directed to the right, then to the left, and finally back to the neutral position. Examiners paused slightly to adjust hand placement for movement to the opposite direction when the subjects head was back in the neutral position. Two trials, consisting of three cycles each, were performed for each patient. Both sets of data were used in the development of summary data. Trials were separated by 1 to 3 minutes and lasted approximately 35 seconds each.

Data Collection and Analysis

Head and neck kinematic data were collected by a five-camera Qualisys 3-dimensional video-based measurement system (Qualisys; Gothenburg, Sweden). The five cameras were positioned to record movements of retro-reflective targets affixed to the subjects. To reduce any motion of the targets relative to the head, subjects wore a custom-fitted headband, which had three reflective targets positioned on the temples: one frontal and two lateral (*Figure 1*). This headband was developed and tested in preliminary investigations. Anterior reflective targets were also applied at the sternal notch and the midsternum. A posterior reflective target was applied to the spinous process of thoracic segment 6 (T6) to account for any possible thoracic motion occurring during the test. To reduce target motion relative to the body, subjects wore snug-fitting clothing and, when possible, targets were attached directly to the skin. Data were recorded at a rate of 12 Hz.

Data analysis was performed in 2006. Dynamic target data were identified and tracked using Qualisys Track Manager software (Qualisys; Gothenburg, Sweden). Computations were then made to determine head motion relative to the thorax. Richards[26] showed the Qualisys system to be accurate within 1 mm and 1.5 degrees of target position. Whittle and Walker[27] reported various computation sequences and corresponding errors specific to the head and neck. Therefore, to reduce error in the current pilot study, we followed Whittle and Walker's recommendations[27] and computed data in the following sequence: (1) lateral flexion, (2) axial rotation, and (3) forward flexion/extension.

Each subject's angular head and neck data were plotted on individual graphs with lateral flexions on the x-axis and rotations along the y-axis. Plotting these angles on individual graphs and determining the slope values of the data sets quantified specific relationships between the two angles. These slopes represented ratios of rotation to lateral flexion, thus establishing the target parameter used to quantify the amounts of cervical vertebral coupling. Finally, these slopes were averaged across subjects and inspected for trends related to clinical diagnoses.

An initial assessment of the data demonstrated lack of homogeneity of variances and departure from normality. Thus, the standard analysis of variance (ANOVA) was not applicable, and nonparametric testing was used. The Kruskal-Wallis nonparametric one-way ANOVA was performed and a 95% confidence interval (α=.05) was established.

Results

Of the 34 subjects who received palpatory screening, interexaminer agreement was reached with 18 subjects (53%): 10 men and 8 women. Seven subjects who had symmetric responses to right and left lateral cervical flexion constituted the control group (symmetric-asymptomatic). The second group consisted of 6 pain-free subjects with an asymmetric response to lateral cervical flexion (asymmetric-asymptomatic). The third group, which comprised 5 subjects, likewise demonstrated motion asymmetry but reported pain in the head and neck region at the time of the screening (asymmetric-symptomatic). No subjects were identified as symmetric-symptomatic. *Figure 2* provides an overview of subject enrollment. The average age of subjects in the present study was 32.6 years.

Results indicate that the control group had the smallest mean linear slope (-0.32), indicating less rotation during lateral flexion (*Table*). The mean linear slope for asymmetric-asymptomatic subjects was -0.42, and the mean for asymmetric-symptomatic subjects was -0.50. The Kruskal-Wallis test did not indicate significant differences among the three study groups. However, an exploratory statistical analysis of our data indicated that increasing the sample size of each diagnostic group to 30 subjects would likely yield statistical significance. That is, given the observed between-group data reported here, 30 subjects per group would yield a power of

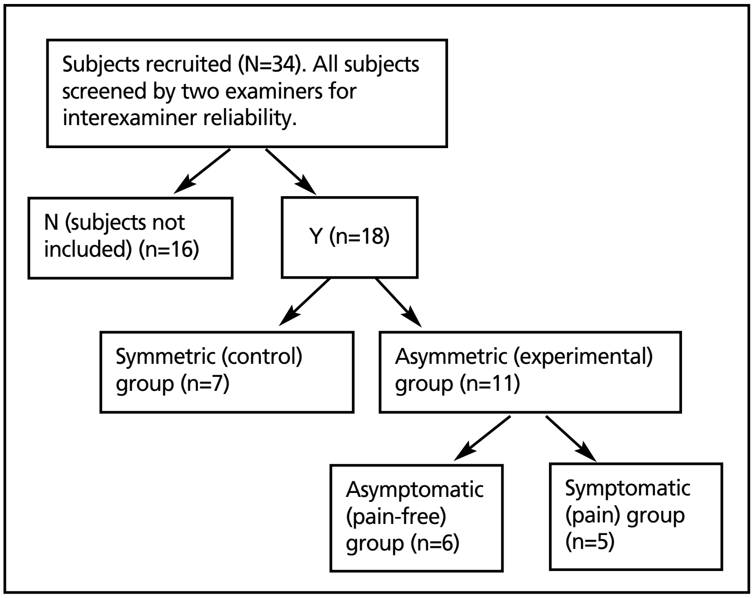

Figure 2. *Methodology flowchart. Subjects were volunteers from Michigan State University (MSU) and from MSU osteopathic manipulative medicine clinic iin East Lansing. Kinematic testing was performed (n=18), and slope data was calculated for each group (ie, symmetric control group and both asymmetric groups) using a video-based system.*

Table
Complete Coupled Motion Data: Linear Slopes Between Lateral Flexion and Rotation for All Subjects (n=18)*

Subject No.	Symmetric-Asymptomatic Subjects (n=7) Linear Slope Trial 1	Trial 2
1	−0.20	−0.16
2	−0.37	−0.39
3	−0.02	−0.005
4	−0.39	−0.31
5	−0.33	−0.42
6	−0.38	−0.33
7	−0.59	−0.59
Mean (SD),* −0.32 (0.18)		
	Asymmetric-Asymptomatic Subjects (n=6)	
8	−0.55	−0.52
9	−0.30	−0.30
10	−0.52	−0.50
11	−0.30	−0.26
12	−0.42	−0.42
13	−0.48	−0.48
Mean (SD),* −0.42 (0.10)		
	Asymmetric-Symptomatic Subjects (n=5)	
14	−0.52	−0.52
15	−1.53	−1.26
16	−0.41	−0.41
17	−0.08	−0.003
18	−0.14	−0.14
Mean (SD),* −0.50 (0.51)		

* Mean (SD) calculated using data from both trials.

80% to detect differences at a significance level of α=.05.

Figure 3 provides plots of the primary and secondary motions for a single subject and single trial. *Figure 4* presents graphic comparisons between a symmetric-asymptomatic subject and an asymmetric-asymptomatic subject. These graphs typify results from each subject group and indicate that symmetric subjects demonstrated less rotation with greater ranges of lateral flexion (ie, flatter slopes) than asymmetric subjects.

On the day of the kinematic test, the palpatory diagnosis differed for 7 subjects. Four subjects experienced a diagnosis change (symmetric vs asymmetric) during the interval between the initial palpatory diagnosis and the confirmation diagnosis. Three subjects reported diminished symptoms on the day of the kinematic test. To reflect these changes, subjects who did not fall into their original categories were removed from the analysis and new average slopes were computed. Thus, the reconfigured data included only subjects with palpatory assessments at the time of the kinematic test that matched their initial diagnostic assessment. Evaluating these selected data indicated the following slope values: −0.37 for the symmetric-asymptomatic group (n=5), −0.43 for the asymmetric-asymptomatic group (n=4), and −0.09 for the asymmetric-symptomatic group (n=2). Results indicated that trends for both pain-free groups—asymmetric and symmetric—were consistent with the data from the entire group. In other words, a larger slope value was demonstrated for the asymmetric group compared with the symmetric group.

Discussion

Kinematic results from our initial palpatory screening indicate a trend for control subjects to exhibit less coupled rotation with the primary lateral flexion motion of the head and neck as compared with both groups of experimental subjects. That is, subjects exhibiting symmetry during palpation (control group) demonstrated smaller amounts of axial rotation and thus smaller slope values when performing a standard diagnostic motion test than all asymmetric subjects regardless of symptom status. The results of this pilot study support basic observations: symmetric subjects move more efficiently (ie, they are less affected by the secondary motion of rotation).

The research presented in the current study is a foundational activity, as the kinematic factor of coupled motion has not been previously reported in association with cervical

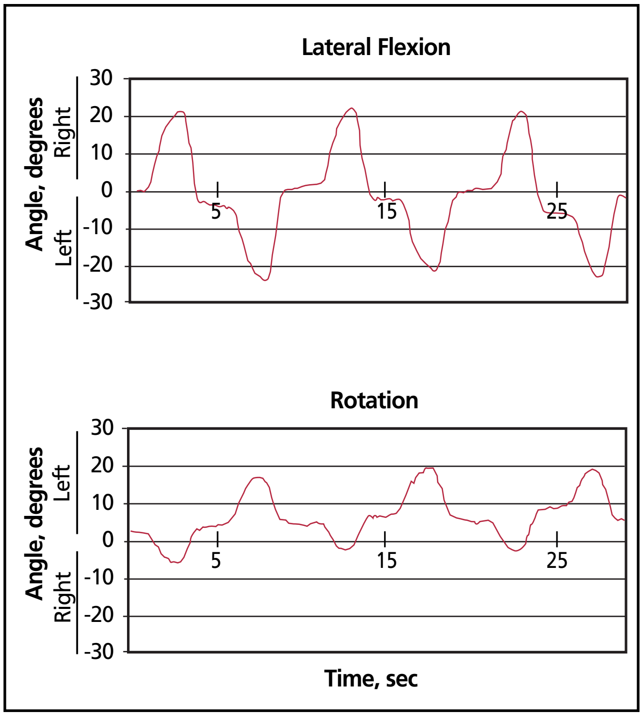

Figure 3. *Plots of primary and secondary head angles during a single trial for a single subject.*

impairment. With the increased global call for evidence-based medicine,[28] it is clear that additional research is necessary before a "gold standard" for objective evaluation can be associated with cervical dysfunction. However, the current pilot study demonstrates the potential for the kinematic profile of coupled motion to serve as an objective measure.

The asymmetric-symptomatic group had the smallest sample size and also the largest variation in slope values. However, this variation is not surprising because many things may alter a motion profile, including the pain and restriction that can accompany somatic dysfunction. A larger group of symptomatic subjects is recommended for future investigations. For research in which an unprecedented attempt to link a palpatory diagnosis to a biomechanical measure is made, special attention is required to determine appropriate sample size.

Interexaminer Reliability

Our diagnostic screening protocol incorporated tests by two examiners in order to address concerns associated with interexaminer reliability. However, for the purposes of the current pilot study, we also attempted to limit the amount of repetitive diagnostic palpation to avoid any risk of unintentional therapeutic effects from our study protocol. Thus, the number of examiners and trials was kept to a minimum.

Few interexaminer studies provide reliable conclusions,[29] while others provide less positive or questionable outcomes.[30] What is apparent, however, is that studies in manual medicine that address interexaminer reliability would benefit from the use of objective markers.[5,16-19,31-36]

Objective markers—such as values for coupled vertebral motion—may improve consistency across examiners, particularly those just learning the skill. Palpatory diagnosis is taught by direct, shared experience between instructors and students. This training process allows students to develop diagnostic psychomotor skills and clinical rationales to accurately assess palpable findings. However, motion and tissue texture cues used in palpatory diagnoses relate to complex motor behaviors that are typically evaluated in a subjective manner. Therefore, objective information, coupled with other advances in palpatory training,[37] can provide students with additional information to aid in skill development. Students can be exposed to didactic sessions of palpatory diagnosis and can confirm diagnoses with the kinematic test. Over time, the consistent use of such didactic sessions may help improve consistency among clinicians who practice the various forms of manual medicine.[28,38]

Diagnostic Assessment

In our study protocol, the interval between diagnostic screening and kinematic testing provided an opportunity for changes to occur in some subjects' movement patterns. Originally, the reason for this interval was logistic, related to the amount of time needed to compare the results of the diagnostic screening and perform the kinematic procedures. Based on the results of the current pilot study, interexaminer reliability studies should include same-day diagnoses and kinematic testing.

However, the fact that several subjects' diagnostic grouping changed between the initial and the confirmatory palpatory screenings is not as surprising as it is revealing about the difficulty related to generating reliable analytic techniques involving palpatory protocols. These changes may have resulted from a variety of factors. For example, subjects in pain on the day of the initial screening may have taken medication or other steps to reduce or relieve the pain before the confirmation assessment. Also, any injury or strenuous or unusual physical activity between the initial screening and the kinematic test day could have prompted changes in screening status.

Without objective tools to corroborate a clinical diagnosis based on palpatory findings, it will never be known whether such changes represent adaptive differences in subjects' movement behaviors or differences in examiners' judgements. For more accurate assessments of subjects' self-reported pain, studies should use a standardized pain rating scale as well as details regarding the etiology of their pain (eg, congenital abnormality, injury, surgery, bone pathology).

Clinical Utility

Reference data such as blood pressure values, respiratory rates, blood cell counts, urinalysis, chemical panels, and lipid

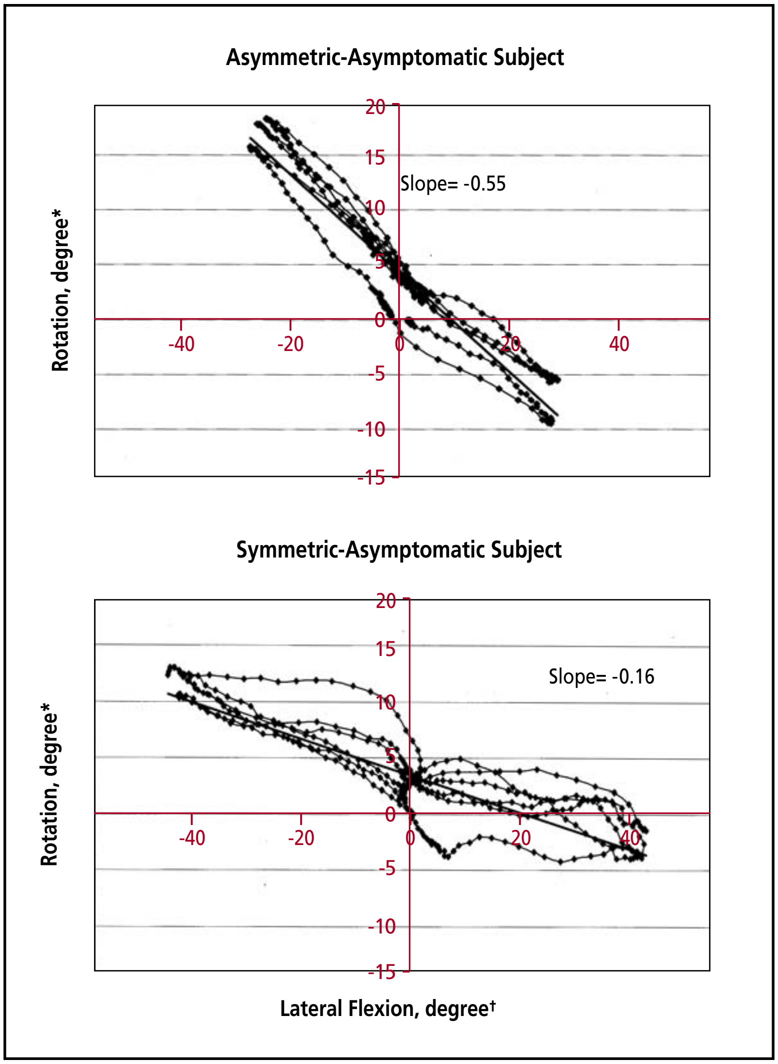

Figure 4. *Motion data for an asymmetric-asymptomatic subject and a symmetric-asymptomatic subject performing three cycles of lateral flexion. Each cycle consists of a movement from the neutral position to the right, then to the left, and finally a return to neutral. Note the flatter best-fit line (indicating less rotation during lateral flexion) for the symmetric subject compared with that of the asymmetric subject. *The amount of rotation occurring during lateral flexion. A positive sign indicates rotation to the left; a negative sign indicates rotation to the right. †The largest negative number is the endpoint of left lateral flexion, while the largest positive number is the endpoint of right lateral flexion.*

profiles are common in medicine and provide objective information to assist clinicians in making diagnoses. For example, physicians will subjectively assess patients' heart sounds. However, before arriving at a diagnosis, physicians will also establish objective parameters of heart health (eg, blood pressure, heart rate). The subjective assessment will then be combined with the objective data to arrive at a diagnosis.

The results of the current pilot investigation attempt to establish objective correlates for the subjective assessments of palpatory diagnosis, just as heart sounds and blood pressure are correlated. Once objective palpatory markers are established (in this case, parameters for coupled vertebral motions), they can be used in various areas of medicine.[38] *Figure 5* denotes several areas where an objective measure can be incorporated.

Coupled Vertebral Motion

Group assignments in the current study were determined based on clinical signs of cervical function and impairment as well as symptom status. The data suggest that coupled motions parallel differences between these subject groups (ie, increasing slope with increasing impairment). The variation in ratios we observed for coupled cervical motions relative to palpable findings and diagnostic categories can be attributed to numerous factors. Among these factors are the possibility of local sensory alteration, hyperirritability, changes in tissue texture, and changes in local circulatory patterns. In turn, such "compromised internal environments" affect normal motor function, mechanical properties of muscle, muscle loading factors, force feedback from muscles and tendons, and velocity feedback from spindle receptors. These structural and physiologic factors clearly signal a neural basis for vertebral function and dysfunction, thus affecting the reflex control of motion. Because this control is used to coordinate agonist and antagonist muscular activity to produce smooth and effective motions, diagnoses of functional asymmetry and variation in coupled motion may indicate adaptive motor patterns (functional irregularities) in response to altered reflex function when symmetry no longer exists.

Conclusions

A thorough understanding of palpatory methods now requires a solid link with evidence-based data. Only with the use of objective markers can practioners of manual medicine broaden the scientific understanding of palpatory techniques. Likewise, such tools will allow us to improve our ability to describe accurately musculoskeletal motor behaviors. Further, we believe that with continued study, additional evidence-based data for palpatory assessments will provide a tangible basis for clinical judgments, promote diagnostic consistency, permit new insight into manual medicine teaching strategies, aid in disease monitoring, and define new treatment approaches.

The preliminary data presented here indicate that objective, kinematic parameters can be generated, measured, and

- Support for teaching and training medical students and possible use of real-time display of the objective measure while learning palpatory diagnostic techniques
- Tools to assess interexaminer repeatability and reliability
- Ability to document treatment progress and efficacy and modify treatment if patient is not progressing
- Quantitative data for insurance companies to support the need for treatment
- Guidelines developed from an objective data set and slope ranges associated with levels of impairment allow possible intervention before pain ensues

Figure 5. *Potential benefits of established objective measures related to manual medicine.*

evaluated relative to palpatory findings of musculoskeletal impairment by identifying trends for coupled cervical vertebral motion—specifically differences in ratios of cervical lateral flexion and axial rotation. Findings from the current pilot investigation are being incorporated into the study protocols of upcoming research projects. We predict that larger sample sizes will statistically link objective measures to palpatory clinical diagnoses. Once the parameter of coupled motion has been statistically linked to palpatory evaluation, future studies can address matters of interexaminer reliability, subject sample size, and the effects of repeated palpatory examinations on subjects.

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A Tribute

We thank all of our collaborators, particularly the students and clinicians who helped with data collection and analysis.

We also thank William L. Johnston, DO, for his participation in this study and for his enduring inspiration. This experiment was Bill's final scientific effort—he died shortly after the completion of the data collection.

Throughout his career, Bill endeavored to understand and report relationships between clinical experiences and a theoretical basis for osteopathic manual medicine. In doing so, he attracted a variety of collaborators to the truest spirit of the scientific method. Together, Bill and his co-researchers sought to acquire new knowledge, amend and integrate existing knowledge, embrace objectivity, and work to assess differences between fact and belief.

For the current pilot study, Bill collaborated with an engineer (T.R.B.) and an anatomist (J.V.) to better understand physiologic correlates of palpable clinical signs of musculoskeletal function and dysfunction detected during clinical motion tests. His enthusiasm for this research was contagious, especially for those who shared his love of human-movement phenomena and biomechanics.

We are most fortunate to have worked with Bill. Our efforts, which were always a challenge, ended with great reward, but, for us, their most enduring significance will always be the pleasure of Bill's company, the opportunity to share our search for an objective basis for manual medicine, and Bill's inspiration to continue our work.

Editor's Note: Dr Johnston, a former member of the Editorial Advisory Board for *JAOA—The Journal of the American Osteopathic Association*, died June 10, 2003. He published numerous studies in the *JAOA* throughout his 60 years in practice. A list of these studies accompanied a *JAOA* editorial by AOA Editor in Chief Gilbert E. D'Alonzo, Jr, DO (available at: http://www.jaoa.org/cgi/reprint/103/8/357).