Use of the SMART Balance Master to Quantify the Effects of Osteopathic Manipulative Treatment in Patients With Dizziness

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Context: Dizziness is the third most common complaint among outpatients and the most common complaint in patients aged 75 years or older. It can be incapacitating for patients, affecting both productivity and quality of life.

Objective: To evaluate the effect of osteopathic manipulative treatment (OMT) for spinal somatic dysfunction in patients with dizziness lasting longer than 3 months.

Design: A prospective clinical cohort study that took place in 2011.

Setting: Department of Physical Therapy laboratory at the Western University of Health Sciences College of Osteopathic Medicine in Pomona, California.

Patients: Sixteen participants (2 male, 14 female; mean [range] age, 49 [13-75] years) with dizziness lasting at least 3 months (mean duration of symptoms, 84 months) and spinal somatic dysfunction, but no history of known stroke or brain disease, were recruited from the local community and evaluated for postural balance control before, immediately after, and 1 week after OMT.

Intervention: Four osteopathic physicians board certified in neuromusculoskeletal medicine/osteopathic manipulative medicine provided OMT, including muscle energy; high-velocity, low-amplitude; counterstrain; myofascial release; balanced ligamentous release; and cranial OMT techniques.

Main Outcome Measures: Outcomes were assessed with the SMART Balance Master (NeuroCom), a validated instrument that provides graphic and quantitative analyses of sway and balance, and the Dizziness Handicap Inventory (DHI), a self-assessment inventory designed to assess precipitating physical factors associated with dizziness and functional and emotional consequences of vestibular disease.

Results: Paired *t* tests, performed to assess changes in mean composite scores for all challenge tests, revealed that balance was significantly improved both immediately and 1 week after OMT (both $P<.001$), with no significant difference between immediate and 1-week post-OMT scores ($P=.20$). The DHI scores, both total and subscale, improved significantly after OMT ($P<.001$), and changes in composite and DHI scores were correlated with each other ($P=.047$).

Conclusion: Osteopathic manipulative treatment for spinal somatic dysfunction improved balance in patients with dizziness lasting at least 3 months.

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Dizziness is a commonly encountered complaint in the clinical setting and is frequently experienced by elderly patients.[1,2] Patients may describe it in a variety of ways, including a sensation of imbalance or unsteadiness. Dizziness can result from many conditions and is typically classified into 4 main groups: vertigo, disequilibrium without vertigo, presyncope, and psychophysiological dizziness.[3] Vertigo is typically diagnosed in patients experiencing a spinning sensation while their bodies remain stationary with respect to the earth or their surroundings. Vertigo is categorized as peripheral or central in origin. Central vertigo results from a problem with the central nervous system (ie, ischemic or hemorrhagic insult to the cerebellum or brainstem), and peripheral vertigo results from dysfunction of the vestibular system and cranial nerve VIII; a common example of the latter is benign paroxysmal positional vertigo (BPPV). From 20% to 30% of the general population is affected by vertigo, and the estimated lifetime prevalence for BPPV is 2.4%.[4] Vertigo can have a significant effect on productivity and quality of life. It can be incapacitating; approximately 86% of patients with vertigo experience an interruption of daily activities and lost days at work, and older patients with vertigo have an increased incidence of falls and depression.[5,6]

Cervical spine mechanoreceptors and muscle spindles transmit afferent input to both vestibular and cervical proprioceptive systems. Therefore, conditions that affect the cervical spine may cause or contribute to vertigo. The mechanoreceptors of the joint capsules associated with the cervical facet joints are in fact thought to be important in proprioception.[7] Similarly, the spinovestibular tract connects the muscle spindles of cervical spine intrinsic muscles with the vestibular nuclei and plays an important role in maintaining balance.[8,9] This may explain why whiplash and injury of cervical spine soft-tissue structures may cause vertigo and impaired postural stability and sensorimotor control.[10] These mechanisms are also thought to account for the altered balance seen in patients with chronic neck pain and atrophy of the suboccipital muscles.[11-13]

Somatic dysfunction is defined as impaired or altered function of the body's skeletal, arthrodial, and myofascial structures and related vascular, lymphatic, and neural elements.[14] These structures are innervated by the central nervous system, and their function is influenced by the excitatory and inhibitory input from these nerves. As just mentioned, the connections between the spinovestibular tract and cervical spine muscle spindles are important in maintaining balance and sensorimotor control; thus, injury of cervical spine myofascial tissues may alter balance. In addition, injury of tissues or other peripheral somatic structures can increase afferent input into the spinal cord. If this input is maintained, it can ultimately lead to sensitization of spinal interneurons, loss of inhibitory interneurons, and formation of new excitatory synapses within the spinal cord. This facilitation or alteration of spinal excitability can in turn maintain somatic dysfunction, including changes in tissue texture, tenderness, and asymmetry of arthrodial and myofascial structures.[15]

Although it seems that injury of cervical spine myofascial structures can affect balance, the incidence of spinal somatic dysfunction in those with dizziness or vertigo is not known, to our knowledge. Studies,[16,17] however, have found somatic dysfunction in patients with vertigo. These studies also showed improvement in somatic dysfunction with osteopathic manipulative treatment (OMT), for both subjective and objective outcome criteria (assessed with the Dizziness Handicap Inventory [DHI] and computerized dynamic posturography, respectively). The chiropractic literature has also supported the idea that spinal manipulation may help in managing vertigo.[19,20] In fact, the authors of a systematic review evaluating the effect of chiropractic care in patients with nonmusculoskeletal conditions concluded that patients with vertigo accompanied by neck pain, cervical spine dysfunction, or both seem to benefit from spinal manipulation.[20]

The objective of the present study was to evaluate the effect of OMT for spinal somatic dysfunction in patients with dizziness lasting longer than 3 months by using the SMART Balance Master (NeuroCom), a validated instrument for measuring balance. We recruited patients who had experienced dizziness for more than 3 months, because Imai et al reported that the mean spontaneous remission time in untreated BPPV is 39 days for posterior and 16 days for horizontal canal BPPV.[21] Therefore, improvement in dizziness was more likely due to response to OMT than to spontaneous remission.

Materials and Methods

The present prospective clinical cohort study was approved by the institutional review board and sponsored by the departments of neuromusculoskeletal medicine/osteopathic manipulative medicine, physical therapy, and physical medicine and rehabilitation at the Western University of Health Sciences College of Osteopathic Medicine of the Pacific in Pomona, California.

Setting

All enrolled participants were evaluated and treated in the laboratory of the Department of Physical Therapy at Western University of Health Sciences.

Patients

A power analysis using the DHI data obtained from a pilot study on OMT and vertigo[16] determined that 16 patients were required to obtain 99% power at an α level of .05 (2-sided). Recruitment occurred in a sequential manner until a total of 16 eligible candidates completed participation in the study. Participants were recruited from the local university community by flyer and e-mail. No financial compensation was provided for participation in the study, but evaluation and OMT were provided at no cost. There was no control group; all patients received OMT.

Patients of all ages were eligible to participate in the study. Inclusion criteria were somatic dysfunction and symptoms of dizziness lasting at least 3 months. For safety reasons, all enrolled patients were required to have a driver bring them to and from the clinic. Exclusion criteria included peripheral neuropathy and central nervous system disease, such as a history of stroke, multiple sclerosis, traumatic brain injury, or tumor. Patients were also excluded if they had received OMT, other manual medicine treatment, or vestibular rehabilitation therapy within the past 3 months. Study participation and its risks and benefits were discussed with all patients before enrollment, and all patients (and parents or legal custodians for those younger than 18 years) were required to sign informed consent and patient bill of rights forms.

Measurements

Balance was measured with the SMART Balance Master, a validated instrument for this purpose[22-24] that performs computerized dynamic posturography to assess quantitatively the sensory and motor components of postural control, demonstrating impairments and determining the effectiveness of strategies for treating patients with balance disorders.[25,26] It provides graphic and quantitative analyses of sway and balance through responses to a sensory organization test (SOT). The SOT uses 6 conditions to challenge the sensory system (*Table 1*), systematically eliminating sight, spatial orientation, and platform levelness; 3 trials are performed for each condition to reduce error and increase accuracy, and participants are challenged to remain standing for all trials (*Figure 1*). The force plate measures changes in center-of-foot pressure and generates sway tracings and an equilibrium score. Examples of sway tracings and SOT data collected from a study participant are shown in *Figure 2*. The SOT was performed before, immediately after, and 1 week after OMT (*Figure 3*).

The SOT equilibrium scores are based on data showing that 12.5° is the mean sway for adults aged 18 to 64 years.[27-29] In other words, the average adult can sway 12.5° anterior to posterior without loss of balance. An

Table 1.
Conditions Used in the Sensory Organization Test Performed to Evaluate Balance on the SMART Balance Master

Condition	Visual Surroundings	Surface
1	Eyes open	Fixed
2	Eyes closed	Fixed
3	Moving visual surroundings	Fixed
4	Eyes open	Movable
5	Eyes closed	Movable
6	Moving visual surroundings	Movable

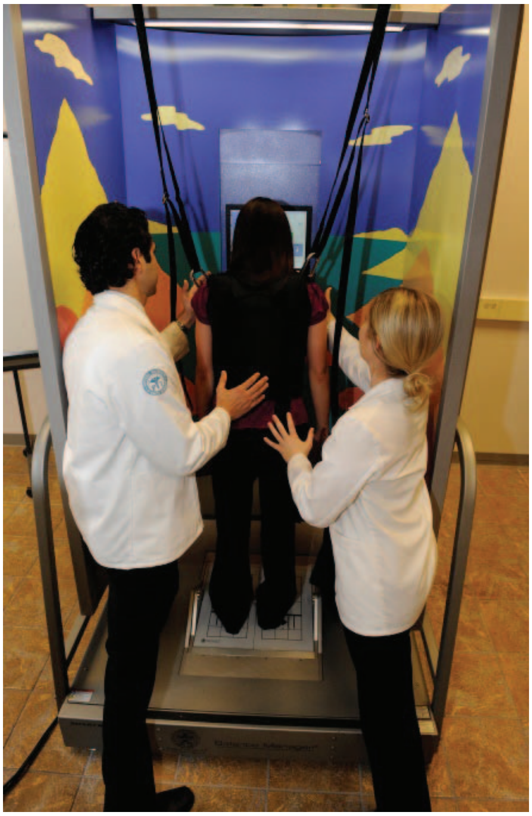

Figure 1.
SMART Balance Master (NeuroCom) being used to measure the effect of osteopathic manipulative treatment in patients with dizziness. The SMART Balance Master is a validated instrument that provides graphic and quantitative analyses of sway and balance.

equilibrium score is calculated by comparing the angular difference between maximum anterior-to-posterior center of gravity displacement with the theoretical maximum displacement of 12.5°. Each individual trial has a score reported as an inverse percentage between 0% and 100%, with higher scores indicating more stability. A participant with a score of 100% would display no motion, whereas a score of 0% indicates a fall. The composite score (CS) is the mean for all trials across the 6 conditions. It can be used as a global marker of balance and postural control.[30,31] Moreover, a change in the CS of more than 2 standard deviations, or more than 8 points, is considered clinically significant and can be used when evaluating the impact of an intervention on balance and postural control.[24] We calculated CSs for our participants before, immediately after, and 1 week after OMT.

In addition to the balance measurements obtained with the SMART Balance Master, the DHI was also used to evaluate for subjective symptoms of dizziness and improvement after OMT. A self-assessment inventory, the DHI, is used to assess the physical factors associated with vertigo, as well as the functional and emotional consequences of vestibular disorders.[32] It is helpful in quantifying the level of disability that a person with vertigo experiences, and it comprises 25 questions that are grouped into 3 subscales: physical (7 questions), functional (9 questions), and emotional (9 questions). Respondents may answer "yes" (4 points), "no" (0 points), or "sometimes" (2 points), for a total possible score of 100 points; persons with higher scores typically experience greater impairment and handicap secondary to vertigo. Scores from 61 to 100 signify severe vertigo and a high risk of falling; scores from 31 to 60, moderate vertigo; and scores from 0 to 30, mild or no vertigo.[30]

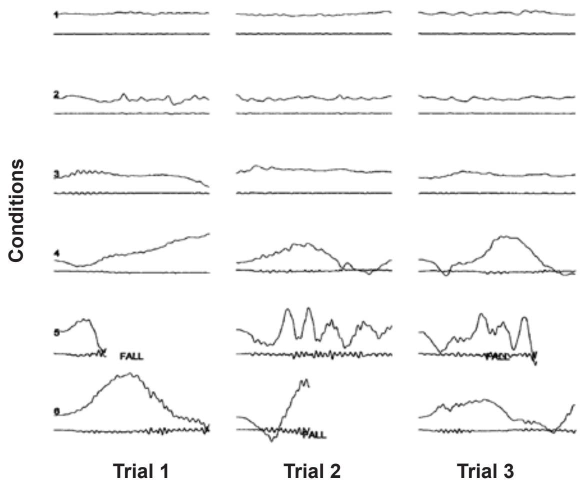

Figure 2.
Sensory organization test data. Sway tracings are shown for each of the 6 conditions, and each condition had 3 trials. The upper line represents the study participant's sway direction and amplitude (up represents anterior; down represents posterior); lower line, shear forces produced as the participant shifts from an ankle to a hip strategy for balance. The x-axis represents the duration in seconds (total tracing duration, 20 seconds), and the y-axis represents the amplitude in increments of 5°. Conditions 1, 2, and 3 are fairly level with little variability in amplitude. Condition 4 has increased variability in amplitude, and in conditions 5 and 6, variability in sway increases enough to cause the participant to fall.

The DHI is one of the most widely used self-assessment questionnaires for disability associated with vertigo and dizziness. It is a validated inventory with both high internal consistency (α=89) and test-retest reliability, and its results correlate with functional balance performance.[32,33] It is also useful in clinical management and decision making and has been used to assess the efficacy of various treatments for vertigo, including vestibular rehabilitation.[34] In the current study, the DHI was administered before and 1 week after OMT.

Evaluation

The osteopathic structural examination in each participant included evaluation for cranial, cervical, thoracic, costal, lumbar, sacral, and upper- and lower-extremity somatic dysfunction. Patients were initially screened by an osteopathic medical student for cervical somatic dysfunction to identify patients who met the inclusion criterion of somatic dysfunction. Specific areas or joints within all body regions (including the occipitoatlantal, atlantoaxial, and sacroiliac joints and the vertebrae [C2 through C7, T1 through T4, and T12 through L5]) were assessed for restricted motion, tenderness, and changes in tissue texture by 1 of 4 faculty members who are American Osteopathic Association board certified in neuromusculoskeletal medicine/osteopathic manipulative medicine (including M.A.S.).

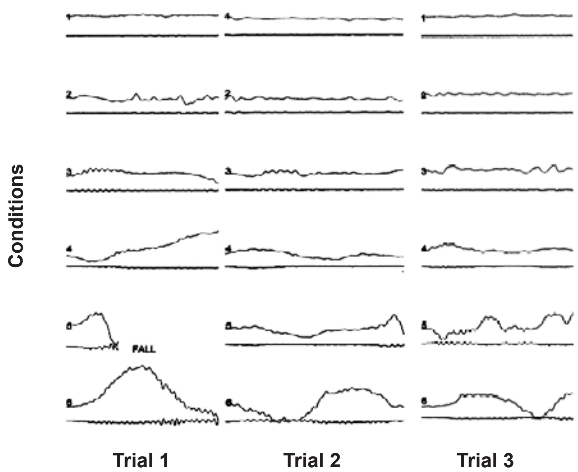

Figure 3.
Sensory organization test data before and after osteopathic manipulative treatment (OMT). Sway tracings for each of the 6 conditions were obtained before, immediately after, and 1 week after OMT. The upper line represents the study participant's sway direction and amplitude (up represents anterior; down, posterior), and the lower line represents the shear forces produced as the participant shifts from an ankle to a hip strategy for balance. The x-axis represents the duration in seconds (total tracing duration, 20 seconds), and the y-axis, the amplitude in increments of 5°. For conditions 5 and 6, variability in sway decreased immediately and 1 week after OMT, resulting in no fall.

Table 2.
Osteopathic Manipulative Treatment Techniques Used in 16 Patients with Dizziness[15]

Technique	Description
Muscle Energy	The patient's muscles are actively used, on request, from a precisely controlled position, in a specific direction, and against a distinctly executed physician counterforce to engage a restrictive barrier.
High Velocity, Low Amplitude	This technique involves brief application of a rapid force that travels a short distance within the anatomic range of motion of a joint and engages the restrictive barrier in ⩾1 plane of motion to release restriction (also known as thrust technique).
Counterstrain	Somatic dysfunction is thought to be due to continuing inappropriate strain reflex, which is inhibited by applying a position of mild strain in the direction exactly opposite to that of the reflex; this technique is accomplished by specific directed positioning around the point of tenderness to achieve the desired therapeutic response.
Myofascial Release	With continual palpatory feedback, the myofascial tissues are engaged by guiding them in the direction of least resistance until tissue release occurs and increased movement is achieved.
Balanced Ligamentous Release	The ligaments and joints are placed in a position that facilitates release of tension and increased motion.
Cranial Osteopathic Manipulative Treatment	This system of diagnosis and treatment by an osteopathic physician uses the primary respiratory manipulative treatment mechanism and balanced membranous tension.

Intervention

The intervention in this study was OMT, which was used to manage diagnosed somatic dysfunction; specific techniques included both direct (ie, muscle energy; high-velocity, low-amplitude) and indirect (ie, counterstrain, myofascial release, balanced ligamentous release, and cranial OMT) techniques. Because no evidence supports the use of a specific OMT technique in patients with vertigo, we concluded that a combination of techniques could be used to treat somatic dysfunction. Prior to the start of the study, all 4 treating osteopathic physicians met as a group to review the evaluation of tenderness, asymmetry, restricted range of motion, and tissue texture and treatment techniques as described in *Foundations of Osteopathic Medicine*[15] and in *Table 2*. After OMT, somatic dysfunction was reassessed to ascertain whether there was a perceived resolution, as well as improvement in restricted motion and tenderness and changes in tissue texture. All OMT was performed by the same faculty members who performed the osteopathic structural examinations.

The OMT was not restricted to a specific region of the body, because there is no evidence that somatic dysfunction of a specific region causes or is correlated with vertigo. This approach is also consistent with the theory of osteopathic medicine and its purpose to resolve structural imbalances and improve the overall function of the body.

Statistical Analysis

Statistical analysis was performed with SPSS 17.0 (SPSS Inc) and Microsoft Excel (version 2003, Microsoft Corp) software. Data were analyzed with paired *t* tests, and differences were considered statistically significant at $P<.05$. Analyses included mean CSs before, immediately after, and 1 week after OMT. The SMART Balance Master data (ie, CSs) and DHI scores were also correlated.

Results

Sixteen participants were recruited in a sequential manner. Patient demographic characteristics, including sex, age, and duration of symptoms, are listed in *Table 3*.

Table 3.
Demographic Characteristics in 16 Patients with Dizziness Receiving Osteopathic Manipulative Treatment

Characteristic	Data
Sex, No. of Patients	
Male	2
Female	14
Age, mean (range), y	49 (13-75)
Duration of Symptoms, mean (range), mo	84 (8-420)

SMART Balance Master provides graphic and quantitative analyses of sway with use of the SOT, which challenges participants to remain balanced while they stand on the instrument's platform. From the SOT, a global measure of balance—the CS— is calculated. Not only does the CS reflect overall postural control, but changes in its value can also be used to evaluate the effectiveness of interventions, such as OMT.[22,23]

Composite scores were calculated before, immediately after, and 1 week after OMT. The mean CS increased both immediately after OMT and 1 week later, indicating a decrease in sway for participants and improvement in overall balance and postural control. Both post-OMT scores differed significantly from the pre-OMT score (P<.001 for both); the 2 post-OMT scores were not significantly different from each other (P=.20). These results were also correlated with the improvement in DHI scores (correlation, 0.50; P=.047).

Osteopathic manipulative treatment seems to have an effect in individuals with dizziness and it may improve

Figure 4 shows the mean CSs for all 16 study participants before, immediately after, and 1 week after OMT, which represents overall balance and postural control; these scores were 63.9%, 74.8%, and 77.4%, respectively, for mean increases of 10.9% immediately after OMT and 13.5% 1 week later. The difference between pre- and post-OMT CSs was statistically significant both immediately and 1 week after OMT (both P<.001); there was no statistically significant difference between the immediate and the 1-week post-OMT CSs (P=.20) (*Table 4*).

Analysis of the DHI scores demonstrated a statistically significant difference after OMT for the total score, as well as the physical, functional, and emotional subscales (all P<.001). *Table 5* shows differences for the total score and each subscale before and 1 week after OMT. The changes in total DHI scores were correlated with the changes in CSs (correlation of 0.50; P=.047).

Comment

To our knowledge, this study is the first of its kind to examine the effects of OMT on balance and postural control in patients with dizziness, using computerized dynamic posturography and the SMART Balance Master, a validated instrument for measuring balance. The

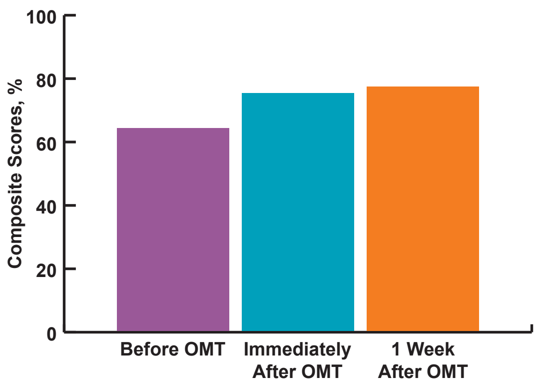

Figure 4.
Mean composite scores (CSs) for all 16 study participants before, immediately after, and 1 week after osteopathic manipulative treatment (OMT). The CS is a measure of balance and postural control. The mean increase in overall balance and postural control was 10.9% immediately after OMT and 13.5% 1 week later. The difference between pre- and post-OMT CSs was statistically significant both immediately and at 1 week (both P<.001).

balance by decreasing postural sway. Similar findings were discovered in a study by Lopez et al.[17] Although their study did not examine the effects of OMT in patients with dizziness, it did find that a weekly OMT protocol improved postural control in healthy elderly patients. Therefore, their findings and our current findings both support the notion that OMT may help improve balance and decrease postural sway. The data from these studies also seem to suggest that computerized dynamic posturography is a useful and objective tool for assessing the effects of OMT on balance and postural control, with results that correlate with those of the DHI. These are important considerations for future studies of OMT in patients with dizziness.

The most important limitation of this study was the lack of a control group or other group that did not receive OMT. Study participants showed statistically significant improvement in their balance, but we cannot conclude definitively that these changes resulted from OMT; they could reflect learned adaption as participants become more comfortable and proficient in using the SMART Balance Master. Although this important consideration should be taken into account for future studies, it should also be noted that Lopez et al did not see this adaptive response, reporting a statistically significant difference in balance between a control group and patients receiving OMT.[17]

Another limitation of the current study was that it was not randomized and did not compare nonsymptomatic with symptomatic participants. For future studies, it would be useful to randomly assign participants to control and to OMT groups and to determine with more

Table 4.
Statistical Analysis of Composite Scores for 16 Patients With Dizziness Receiving Osteopathic Manipulative Treatment (OMT)

	Composite Score, %	
Timing[a]	Mean (SD)	Median (Range)
Before OMT	63.9 (13.8)	68 (34-84)
Immediately After OMT	74.8 (9.8)	79.5 (46-83)
1 wk After OMT	77.4 (8.0)	79.5 (60-88)

[a] The difference between pre- and post-OMT composite scores was statistically significant both immediately and 1 week after OMT (both $P<.001$); there was no significant difference between the immediate and 1-week post-OMT scores ($P=.20$).

Abbreviation: SD, standard deviation.

Table 5.
Dizziness Handicap Inventory (DHI) Statistics Before and After Osteopathic Manipulative Treatment and Correlations of DHI Changes With Changes in SMART Balance Master Composite Scores (N=16)

DHI Scale Mean (SD)	Before OMT	After OMT	Difference (95% CI)[a]	Correlation With Composite Scores (*P* Value)
Emotional	22.1 (11.1)	6.5 (7.75)	15.6 (10.0-21.2)	0.49 (.052)
Functional	20.6 (7.75)	6.5 (7.43)	14.1 (9.4-18.9)	0.52 (.04)
Physical	21.6 (4.33)	7.0 (6.89)	14.6 (10.8-18.5)	0.35 (.18)
Total	64.4 (19.9)	20.0 (20.4)	44.4 (31.4-57.4)	0.50 (.047)

[a] $P<.001$ for all scales.

Abbreviations: CI, confidence interval; OMT, osteopathic manipulative treatment; SD, standard deviation.

certainty whether improvements in balance are in fact due to OMT. This would be particularly helpful in studies that incorporate more sessions with OMT and assess for changes in balance over a longer duration (ie, months vs weeks).

Because there is no definitive evidence that somatic dysfunction of a specific region causes or is correlated with vertigo, OMT in this study was not restricted to specific regions of the body. Moreover, no specific treatment protocol was used; this approach was seen as being more consistent with the theory of osteopathic medicine and its purpose to resolve structural imbalances and improve the overall function of the body. For future studies, it would be useful to document the location and severity of somatic dysfunction and clarify its frequency in patients with dizziness. It may be particularly helpful to understand whether patients with dizziness have somatic dysfunction in a particular region (ie, upper thoracic, cervical, or cranial), because this would help direct future treatment strategies and protocols.

Our study used multiple osteopathic physicians to treat participants because of limitations in time and resources. Future studies should ideally have a single osteopathic physician providing treatment, to reduce variability in OMT techniques, and a single osteopathic physician, blinded to treatment, diagnosing somatic dysfunction. This design would ensure greater integrity in data collection and reduce potential confounding variables, including interexaminer variability.

Conclusion

The results of this study support the hypothesis that OMT improves balance in individuals with dizziness. Although the current study had limitations, the results are promising enough to support further research on OMT and balance in patients with dizziness, including larger studies with appropriate controls, blinding, and randomization. Such studies are important, because dizziness and falls are common problems, frequently encountered in the clinical setting by osteopathic physicians. Evidence supporting the use of OMT in patients with dizziness may allow the provision of meaningful and cost-effective care, improve patients' quality of life, and decrease the burden of fall-related injuries in this patient population.

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