A Pilot Randomized Clinical Trial on the Relative Effect of Instrumental (MFMA) Versus Manual (HVLA) Manipulation in the Treatment of Cervical Spine Dysfunction

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ABSTRACT

Objective: To determine the relative effect of instrument-delivered thrust cervical manipulations in comparison with traditional manual-delivered thrust cervical manipulations in the treatment of cervical spine dysfunction.

Design: Prospective, randomized, comparative clinical trial.

Setting: Outpatient chiropractic clinic, Technikon Natal, South Africa.

Patients: Thirty patients diagnosed with neck pain and restricted cervical spine range of motion without complicating pathosis for at least 1 month were included in the study.

Interventions: The patients were randomized into 2 groups. Those in one group received mechanical force, manually assisted (MFMA) manipulation to the cervical spine, delivered by means of a hand-held instrument (Activator II Adjusting Instrument). Those in the other group received specific contact high-velocity, low-amplitude (HVLA) manipulation consisting of standard Diversified rotary/lateral break techniques to the cervical spine. Each group received only the specific therapeutic intervention, no other treatment modalities or interventions (including medication) being used, until asymptomatic status was achieved or a maximum of 8 treatments had been received.

Main Outcome Measures: Both treatment groups were assessed through use of subjective (Numerical Pain Rating Scale 101, McGill Short-Form Pain Questionnaire, and Neck Disability Index) and objective (goniometer cervical range of motion) measurement parameters at specific intervals during the treatment period and at 1-month follow-up. The data were assessed through use of 2-tailed nonparametric paired and unpaired analysis, descriptive statistics, and power analysis of the data.

Results: The results indicate that both treatment methods had a positive effect on the subjective and objective clinical outcome measures, no significant difference being observed between the 2 groups ($P < .025$). The subjective data from all 3 questionnaires showed statistically significant changes from initial to final consultations as well as from initial consultation to 1-month follow-up ($P < .025$). The objective range of motion measures showed statistically significant changes in the MFMA group for left and right rotation and left and right lateral flexion from initial consultation to final consultations and for right rotation and right lateral flexion from initial consultation to 1-month follow-up. The HVLA group showed only the change in left rotation from initial to final consultations and from initial consultation to 1-month follow-up to be statistically significant.

Conclusions: The results of this clinical trial indicate that both instrumental (MFMA) manipulation and manual (HVLA) manipulation have beneficial effects associated with reducing pain and disability and improving cervical range of motion in this patient population. A randomized, controlled clinical trial in a similar patient base with a larger sample size is necessary to verify the clinical relevance of these findings. (J Manipulative Physiol Ther 2001;24:260-71)

Key Indexing Terms: Biomechanics; Cervical Spine; Chiropractic Manipulation; Instrument; Pain; Range of Motion

INTRODUCTION

Spinal manipulation (SM) is a commonly used treatment for neuromusculoskeletal conditions, particularly for complaints of the low back.[1] As research has focused on the efficacy of SM in the treatment of low back pain (LBP),[2,3] interest has grown to investigate its efficacy in the treatment of neck pain and headache.[4] Just as LBP has been found to be prevalent in the population, recent studies have indicated that the prevalence of neck pain in the general population is considerable. The incidence of 1 or more attacks of neck pain in working people between the ages of 25 and 29 years has been reported to range between 25% and 30%; estimates of the incidence for those older than 45 years rise to 50%.[5] A recent Norwegian cross-sectional study corroborated these

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findings: 34% of the population reported neck pain, and 13.8% noted neck pain lasting more than 6 months.[6]

Somatic origins of neck pain arise from nociceptive stimulation in the respective tissues of the cervicothoracic spine. Recent neuroanatomic investigations have demonstrated the presence of nociceptive afferent fibers in human cervical zygapophyseal joints,[7] intervertebral disks,[8,9] the paracervical musculature, and other soft tissues.[10] The generating source of neck pain has been increasingly studied through use of diskography and medial branch blocks to anesthetize afferent fibers arising from the cervical zygapophyseal joints.[11-15] Studies have demonstrated that the cervical zygapophyseal joints are among the most common sources of chronic neck pain. Patients with somatic neck pain present with localized and/or referred pain commonly accompanied by point tenderness and restricted cervical range of motion (CROM).[5] Given the convincing evidence of a considerable source of neck pain arising from the spinal joints, treatment modalities aimed at influencing the spinal articulations through manual means have drawn attention from both clinicians and researchers. In a meta-analysis involving estimation of the effects of SM on cervical spine complaints, it was found that cervical SM probably provides at least short-term benefits in some patients.[4]

SM is used by clinicians to reduce pain from and improve range of motion in the cervical spine for so-called *dysfunctional spinal joints*.[16,17] In this regard, it has been thought to evoke mechanical and physiologic responses from paraphysiologic joint movement and reflexogenic stimulation; however, little basic scientific research exists to document these mechanisms.[18] From the only research available, it appears that apparent physiologic responses to SM are not influenced by the joint cavitation (audible) that many times accompanies SM.[18-21] Therefore, of a number of different types of techniques, some with and some without audible joint cavitation, clinicians practicing SM use whichever ones are, in their clinical judgment, best suited to particular patients.[22]

Although investigations have been undertaken to quantify pain and range of motion changes in the cervical spine after SM,[23-27] few randomized controlled trials—or other studies, for that matter—have compared the effectiveness of different forms of SM in the treatment of cervical spine complaints or dysfunction. The aim of the present study was to determine the relative effect of 2 common forms of SM in patients with cervical spine dysfunction: (1) Diversified manual manipulative thrusts and (2) thrusts delivered by mechanical force, manually assisted (MFMA) means with the Activator II Adjusting Instrument (AAI; Activator Methods, Inc, Phoenix, Ariz). Specifically, a pilot randomized clinical trial was undertaken to investigate the effects of these 2 forms of SM to compare their effectiveness in decreasing pain and improving range of motion in the cervical spine. The null hypothesis that no subjective or objective difference in clinical outcome exists between patients receiving Diversified manual manipulative thrusts and patients receiving MFMA AAI thrusts for cervical spine dysfunction was tested.

METHODS

Subjects

Eleven men and 19 women (age range, 23-59 years) consented to participate in the study after acknowledging that they had received an explanation of its design. Some subjects were recruited through use of advertising in local newspapers and on radio; others were outpatients presenting to the Technikon Natal Chiropractic Day Clinic. Thirty subjects, all with cervical spine complaints, including neck pain, and reporting restricted range of motion for at least 1 month, were randomly divided into 2 treatment groups. (In a blinded fashion, each patient was assigned to one of the treatment groups by randomly choosing a slip of paper from an envelope containing slips naming the 2 types of treatment.) Subjects were selected through use of consecutive sampling; occupation, sex, and previous manipulative treatment were therefore not taken into account.

Patients were considered to have cervical spine dysfunction if they presented with reports of neck pain and restricted painful CROM. In addition, for the condition to be considered dysfunction, the complaint had to be verified in physical examination by the presence of (1) painful cervical extension, local tenderness, and restricted intersegmental motion on palpation and (2) hypomobility on CROM testing in any plane. Specific inclusion criteria were that the patient had neck pain of at least 1 month's duration and had not received any manipulative therapy for at least 1 month before the study. Patients also had to agree not to take any medication or receive any other treatment for neck pain during the course of the study and had to be free of any contraindications to SM (eg, inflammation, infection, advanced degeneration, congenital malformations, trauma, cerebrovascular anomalies). Any patient with a positive neurologic examination (the presence of positive motor, reflex, or sensory abnormalities indicating spinal nerve root compression) or a positive extension-rotation (Wallenberg's) test was excluded from the study.

Examination

Each patient completed a medical history questionnaire, and subjective data were obtained through use of (1) the Neck Disability Index (to quantify the patient's perception of his or her disability), (2) the Numerical Pain Rating Scale 101 (to assess the patient's perception of the pain level), and (3) the McGill Short-Form Pain Questionnaire (to quantify the patient's perception of the sensory dimension of the pain). The validity and reliability of these questionnaires have been confirmed by Vernon and Mior,[28] Jensen et al,[29] and Melzack and Katz,[30] respectively. The patient next underwent a physical examination that included standard orthopedic tests (cervical and lateral compression, Kemp's, cervical distraction, dizziness rotation, brachial plexus tension tests, Lhermitte's sign, and tests for thoracic outlet syndrome) as well as neurologic tests to assess inclusion criteria. Objective data were collected from CROM measurements (flexion, extension, right and left rotation, right and left later-

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Table 1. *Age distribution of patients*

Age (y)	No. of patients		Percent of total sample
	Group A	Group B	
20-29	3	2	16.7
30-39	3	5	26.7
40-49	5	4	30.0
50-59	4	4	26.7

Table 2. *Sex distribution of patients*

Sex	No. of patients		Total
	Group A	Group B	
Male	5	6	11
Female	10	9	19

Table 3. *Distribution of pain duration before treatment*

Duration of pain	No. of patients		Percent of total sample
	Group A	Group B	
1-2 mo	2	3	16.7
3-5 mo	1	1	6.7
6-11 mo	0	1	3.3
12-23 mo	0	2	6.7
2-3 y	7	4	36.7
>3 y	5	4	30

al flexion) obtained by means of a CROM goniometer (Cervical Range of Motion Instrument, Performance Attainment Associates, St Paul, Minn). Subjective data obtained through use of questionnaires and objective data obtained from the physical examination were assessed on the initial consultation, at the end of treatment (final consultation), and at 1-month follow-up. The validity and reliability of the CROM instrument have previously been confirmed by Youdas et al.[31] All procedures and treatments that followed were applied by the principal author (T.G.W.).

Treatment

SM was the only intervention used in the 2 groups. No other treatment modalities, exercises, or education was prescribed to the patients in the study. Determination of the level and side on which to perform manipulation was made according to the clinical judgment of the treating chiropractic physician, specific consideration being given to pain and movement restriction on motion palpation, localized tenderness, and the presence of a positive Kemp's test (axial compression applied to the head with the neck in an extended and rotated position). We use the term *dysfunctional cervical spinal motion units* for areas presenting with these positive findings, and segmental contact point was made on the superior vertebra of the dysfunctional motion unit. The same clinical assessment was performed in each of the 2 groups. For the purpose of this study, the Activator Methods Chiropractic Technique of leg length analysis was used to determine treatment locations in either group. Each patient was treated until he or she was symptom-free or had received a maximum of 8 treatments over a period of approximately 4 weeks at a visit frequency of 2 or 3 treatments per week. Reexamination was performed at the end of the treatment period, and a follow-up consultation and examination was conducted 1 month after the end of treatment.

Group A

Patients in treatment group A received MFMA short-lever instrumental thrusts delivered by means of a hand-held AAI to the involved cervical spinal motion units. Each patient was treated in the prone position with the headpiece slightly low-

ered. Once the dysfunctional motion units were located, the rubber tip of the AAI was placed over the superior side of the dysfunctional motion unit on the posterolateral aspect of the vertebra on the lamina-pedicle junction. Contacts were made firm enough to prevent slipping of the rubber tip but not so firm as to load the spring, in consistence with customary clinical use of the instrument. The spring was then loaded by means of the instrument's trigger mechanism, and the impulse was delivered in an anterosuperior vector. The maximum force setting was used for all thrusts (ie, maximal spring tension) to ensure that the thrusts delivered to all patients were consistent.

Group B

Patients in treatment group B received specific contact manual thrust manipulations to the dysfunctional cervical spinal motion units. With all of the manual techniques, the patients were treated in the supine position. The techniques used were performed as taught by the National-Diversified system—specifically, they were the cervical rotary and lateral break techniques later published in the *Compendium of Chiropractic Technique*.[32] The head and neck were simultaneously rotated and laterally flexed over the contact point—namely, the superior spinal segment of the restricted motion unit—to the end of passive range of motion, and a high-velocity, low-amplitude (HVLA) spinal manipulative thrust was delivered in the direction of the posterior joint plane. Patients with more range of motion restriction in the lateral plane were given more lateral-to-medial directed thrusts; patients with more restriction in rotation were given thrusts with a greater emphasis in the direction of restricted axial rotation. An audible cavitation was not required to indicate a successful adjustment, though this phenomenon was observed to occur during most of the treatments in group B (frequency not recorded). The results of subjective outcome measures and CROM were compared both within groups and between groups for relationships of statistical significance. For the subjective measures and ranges of motion, median values were chosen over means as representative data, inasmuch as means are easily distorted by extreme values in a study with a small sample size such as this.[33]

Statistical Analysis

Statistical analysis was conducted in a 2-tailed format with a 95% CI ($\alpha/2 = 0.025$); the power of the test was then assessed at the 80% level ($\beta = 0.2$). Intragroup data were analyzed through use of the nonparametric Wilcoxon signed rank test and descriptive statistics for both treatment groups.

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Table 4. *Statistical results of goniometric measurements: comparison of initial cervical ranges of motion*

| | Initial consultation value | | | | | | | | | |
| | Group A: Instrument thrust | | | | | | Group B: Manual thrust | | | |
	Mean	Median	SD	SE	*P* value	Power	Mean	Median	SD	SE
Goniometer		r								
Flexion	53.2	56.0	7.9	2.0	.100	.207	60.2	62.0	20.2	5.2
Extension	60.3	58.0	14.2	3.7	.648	.097	53.4	56.0	19.7	5.1
Rotation										
Right	57.3	60.0	13.8	3.6	.802	.052	58.0	60.0	11.6	3.0
Left	60.5	60.0	9.9	2.6	.630	.111	57.6	60.0	10.6	2.7
Lateral flexion										
Right	38.5	40.0	7.0	1.8	.382	.126	41.6	46.0	11.8	3.1
Left	40.0	40.0	11.2	2.9	.467	.088	42.7	46.0	12.8	3.3

Table 5. *Statistical results of subjective findings: comparison of groups A and B at initial consultation*

| | Initial consultation value | | | | | | | | | |
| | Group A: Instrument thrust | | | | | | Group B: Manual thrust | | | |
	Mean	Median	SD	SE	*P* value	Power	Mean	Median	SD	SE
Questionnaire										
NDI	31.8	36.0	14.1	3.4	.262	.154	26.8	26	13.3	3.4
NRS 101	52.5	50	12.6	3.3	.095	.368	48	42.5	18.7	4.8
McGill	35.1	33.3	18.1	4.7	.724	.065	32.6	33.3	16.5	4.2

NDI, Neck Disability Index; *NRS 101,* Numerical Pain Rating Scale 101; *McGill,* McGill Short-Form Pain Questionnaire.

The subjective and objective measurements were compared (1) from the initial to the final consultation, (2) from the initial consultation to the 1-month follow-up, and (3) from the final consultation to the 1-month follow-up.

The intergroup data were assessed through use of the non-parametric Mann-Whitney *U* test and descriptive statistics. The subjective and objective data for the 2 treatment groups were compared at the initial examination, final examination, and 1-month follow-up. The statistical analyses were performed through use of the software program Statgraphics Plus (version 6; Manugistics, Inc, Rockville, Md).

RESULTS

The basic demographic data are shown in Tables 1, 2, and 3. The number of patients in each age grouping was evenly spread across the fourth (n = 8), fifth (n = 9), and sixth (n = 8) decade groupings. The youngest decade grouping (20-29 years) made up only 16.7% of the total sample. The 2 groups (A and B) had approximately equal numbers of patients in each decade grouping. Of those selected for the study, 63% of the patients in the total sample (n = 30) were female and 37% were male. This sex ratio was reflected in both groups.

When we reviewed the distribution of pain before treatment, we noted that two thirds of those in the total sample had been experiencing neck pain for 2 years or more, whereas only 16.7% of those in the sample had had pain for 1 to 2 months. A statistical comparison (*P* < .025) of the baseline measures (Tables 4 and 5) for the 2 groups revealed that they were similar in nature, according to the subjective and objective findings.

The results for all of the questionnaires indicate that both treatment groups showed statistically significant improve-

ment and that the 2 treatment methods acted with equal effectiveness (*P* < .025) both during the treatment period (Table 6 and 7) and up to the 1-month follow-up. For the Neck Disability Index, the median values after the treatment were a 26% improvement for group A and a 17% improvement for group B. These improvements were also maintained to the 1-month follow-up, at which time there was an increase in pain and disability of only 4% and 3% for groups A and B, respectively; these were not found to be statistically significant.

The data from the Numerical Pain Rating Scale 101 questionnaire showed a 30% improvement from the initial to the final consultations for group A; group B had a 17.5% improvement over the same period. After 1 month, the median value for group A showed a 2.5% relapse whereas group B continued to improve, a further 5% being noted; neither of these was statistically significant.

The results from the McGill questionnaires showed an improvement after the course of treatment of 24.4% and 26% for groups A and B, respectively. These median values were the same at the 1-month follow-up. Power analysis of these subjective data showed a high statistical power for the intratreatment results, whereas the intertreatment results revealed a low statistical power.

The objective results showed that there were some statistically significant changes in some rotation and lateral flexion ranges of motion after the treatment period (Tables 8 and 9), but as with the subjective data, these failed to show any difference when the 2 treatment groups were compared. There was also no statistically significant change in either group from the final consultation to the 1-month follow-up (*P* < .025). When the median values for group A were compared, statistically significant 6° and 4° improvements were noted for left and right rotation, respectively, after the treatment

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Table 6. *Statistical results of subjective findings: comparison of initial and final consultations in group A (instrument thrust group)*

	Group A: Initial consultation						Group A: Final consultation			
	Mean	Median	SD	SE	*P* value	Power	Mean	Median	SD	SE
Questionnaire										
NDI	31.8	36.0	14.1	3.4	**.0005**	.967	13.5	10.0	11.0	2.83
NRS 101	52.5	50	12.6	3.3	**.0019**	.997	23.5	20.0	18.2	4.7
McGill	35.1	33.3	18.1	4.7	**.0003**	.989	11.5	8.9	10.3	2.6

Boldface indicates statistical significance.
NDI, Neck Disability Index; *NRS 101,* Numerical Pain Rating Scale 101; *McGill,* McGill Short-Form Pain Questionnaire.

Table 7. *Statistical results of subjective findings: comparison of initial and final consultations in group B (manual thrust group)*

	Group B: First consultation						Group B: Final consultation			
	Mean	Median	SD	SE	*P* value	Power	Mean	Median	SD	SE
Questionnaire										
NDI	26.8	26.0	13.3	3.4	**.0009**	.954	11.0	9.0	9.8	2.6
NRS 101	48	42.5	18.7	4.8	**.0003**	.995	18.7	25.0	14.1	3.6
McGill	32.6	33.3	16.5	4.2	**.0003**	.979	10.5	6.7	12.0	3.1

Boldface indicates statistical significance.
NDI, Neck Disability Index; *NRS 101,* Numerical Pain Rating Scale 101; *McGill,* McGill Short-Form Pain Questionnaire.

period. These gains were maintained to the 1-month follow-up, only right rotation being of statistical significance from the initial to the follow-up consultations. Lateral flexion results showed comparatively large improvements, 6° for right and 10° for left lateral flexion; 2° and 4° losses were noted in these ranges of motion, respectively, at the 1-month follow-up, only right lateral flexion maintaining statistical significance from the initial to the follow-up consultations.

In group A, improvements in flexion (2°) and extension (8°) after the treatment period were found to be statistically insignificant. The flexion value was maintained to follow-up whereas the extension values dropped by 6°. The results for group B revealed only left rotation as statistically significant, with a 4° improvement after treatment. This statistically significant improvement continued, the median value being up by 6° at the follow-up. Flexion (6°), extension (4°), and right rotation (2°) improvements were not statistically significant. The same is true for the lateral flexion results, no improvement being noted for right lateral flexion and a 2° negative change being noted for left lateral flexion. The right lateral flexion median value had decreased by 4° at the follow-up whereas there was no change for the left lateral flexion value. The extension and right rotation median values each showed a 2° positive change from the final treatment to the 1-month follow-up. The flexion value over the same period decreased by 4°. The overall power of the objective data was relatively low.

From a review of the median CROM readings, shown in Figs 1 and 2, it can be seen that there is a general trend supporting the evidence from the statistically significant results toward an increase in range of motion after both interventions. This effect seems to have been maintained to the 1-month follow-up. The significant decrease in pain after the treatment and at the follow-up in both groups is well reflected in Figs 3 through 5. The null hypothesis was accepted, inasmuch as no significant differences between the 2 groups in clinical improvement, either subjective or objective, were documented by the outcome measures used in this study.

DISCUSSION

The results of this study suggest that both instrumental and manual thrust manipulations demonstrate a positive effect in the treatment of cervical spine joint dysfunction in this patient population. Improvement appeared to carry over to the 1-month follow-up, indicating an apparent lasting benefit in these patients.

Because the results of our pilot study are not controlled, they must be interpreted with caution. They cannot be taken as proof of the clinical efficacy of manipulation for cervical dysfunction; however, the positive trends observed are sufficient to justify a call for a well-designed, randomized, controlled clinical trial in a similar patient population. The correlation between an increase in cervical rotation and a decrease in pain in both groups provides documentation of the anecdotal claims of efficacy among clinicians using these forms of SM. Because group B did not exhibit a greater effect than group A in terms of subjective (pain and disability) and objective (range of motion) findings, as had been hypothesized, we found that the 2 treatment protocols had equal effects.

There are several limitations to the study that should be discussed. The questionnaires might not have been sensitive enough to detect subtle changes in pain and disability. Likewise, the goniometer might not have been sensitive enough to detect subtle changes, inasmuch as it is calibrated at increments of 2°. The subjective intragroup data had satisfactory statistical power, as did a small proportion of the objective data. Both the remainder of the intragroup statistical analysis for the ranges of motion and the intergroup (group A versus group B) analyses for subjective and objective data exhibited unsatisfactory power. This indicates that the likelihood of committing a type II error is strong. The strength of these 2 factors (the possibilities of test insensi-

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Table 8. *Statistical results of goniometric measurements: comparison of initial and final consultations in group A (instrument thrust group)*

	Group A: Initial consultation						Group A: Final consultation			
	Mean	Median	SD	SE	*P* value	Power	Mean	Median	SD	SE
Goniometer										
Flexion	53.2	56.0	7.9	2.0	.182	.354	60.3	58.0	14.2	3.7
Extension	60.3	58.0	14.2	3.7	.121	.235	65.5	66.0	7.4	1.9
Rotation										
Right	57.3	60.0	13.8	3.6	**.016**	.463	65.4	64.0	7.9	2.0
Left	60.5	60.0	9.9	2.6	**.006**	.216	65.5	66.0	12.0	3.1
Lateral flexion										
Right	38.5	40.0	1.8	3.1	**.003**	.809	47.1	46.0	8.9	2.3
Left	40.0	40.0	11.2	2.9	**.003**	.746	49.5	55.0	7.5	1.9

Boldface indicates statistical significance.

Table 9. *Statistical results of goniometric measurements: comparison of initial and final consultations in group B (manual thrust group)*

	Group B: Initial consultation						Group B: Final consultation			
	Mean	Median	SD	SE	*P* value	Power	Mean	Median	SD	SE
Goniometer										
Flexion	60.2	62.0	20.2	5.2	.683	.107	65.1	68.0	15.0	3.9
Extension	53.4	56.0	19.7	5.1	.121	.370	63.6	60.0	11.5	3.0
(R)Rotation	58.0	60.0	11.6	3.0	.061	.310	63.5	62.0	7.2	1.9
(L)Rotation	57.6	60.0	10.6	2.7	**.016**	.554	65.9	64.0	10.2	2.6
(R)Lat Flex.	41.6	46.0	11.8	3.1	.039	.249	46.8	46.0	8.9	2.3
(L)Lat Flex.	42.7	46.0	12.8	3.3	.096	.235	48.2	44.0	9.9	2.6

Boldface indicates statistical significance.

tivity and type II error) could be reduced by increasing the sample size. This would also make trends within the samples more apparent. In future studies, efforts should be made to ensure that the groups are more homogenous with respect to level of dysfunction, duration of symptoms, age, and sex. In addition, the data collection should be done by a blinded examiner to decrease the chance of examiner bias. Finally, including a control group and a sham group would allow a greater understanding of the true clinical benefits of these manipulative procedures.

Literature Review of Relevant Studies

Hurwitz et al[4] performed a systematic review of the literature to assess the evidence for the efficacy of cervical SM for the treatment of neck pain. As of 1996, they had identified 5 randomized controlled trials (Table 10), 1 cohort study, 4 case series, and 24 case reports that attempted to assess the effectiveness of cervical SM in patients with neck pain. Since then, other studies relevant to this work have appeared.

Randomized controlled trials. In 1996, Nilsson et al[34] sought to determine whether a 3-week series of SM had any lasting effect on passive CROM. Thirty-nine headache sufferers with reduced passive CROM were randomized into 2 groups to receive either HVLA cervical manipulation twice a week for 3 weeks or low-level laser therapy in the upper cervical region and deep friction massage in the lower cervical/upper thoracic region at the same frequency. The authors reported that though passive CROM increased in both groups during the trial period, there were no statistically significant differences between the 2 groups 1 week after the last treatment.

In a 1992 study, Cassidy et al[25] assessed the immediate effect of HVLA spinal manipulative therapy (SMT) with

mobilization (in the form of a muscle energy technique) in 100 consecutive patients with neck pain. Before and immediately after the treatments, cervical spine range of motion was recorded and pain intensity was rated. The authors reported that both treatments were found to increase CROM and manipulation was found to have a significantly greater effect on pain intensity. However, after reanalyzing their data using proper analysis of covariance, which adjusted the posttreatment scores to compensate for the differences among the pretreatment scores of their patients, no significant difference in pain relief was observed between the 2 treatment groups (*P* = .16).[35] In addition, the analyses of CROM were found to be susceptible to type II error.[35]

Also in 1992, Nansel et al[24] compared upper cervical and lower cervical spinal adjustments (HVLA SM) in 69 asymptomatic subjects who demonstrated restricted passive end-range lateral flexion asymmetries of 10° or more. Goniometric cervical spine range of motion values before and 30 minutes after treatment were compared. Upper cervical adjustments were found to improve axial rotation more than treatments to the lower cervical spine, whereas lower cervical spinal adjustments were found to result in greater improvement in amelioration of lateral flexion asymmetries. The clinical relevance of these findings in patients with neck pain could not be established because of the asymptomatic status of the subjects.

In a pilot randomized, controlled clinical trial conducted in 1990, Vernon et al[36] reported the results of pain thresholds of the cervical spine in 9 subjects assigned to receive HVLA cervical SM or oscillatory mobilization. Patients receiving SM showed statistically higher increases in pressure pain thresholds after treatment than those in the control group receiving mobilization. Although their findings are

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Table 10. *Summary of randomized controlled trials of cervical spinal manipulation in treatment of neck pain (adapted from Hurwitz et al[4])*

Authors (year)	Clinical history	Intervention [n]	Protocol	Outcome
Sloop et al[38] (1982)	Subacute-chronic, nonspecific neck pain without neurologic deficit or cervical spondylosis	(1) Diazepam plus rotational manipulation [21] (2) Diazepam only [18]	Group 1: 1 treatment by MD	57% in group 1 and 28% in group 2 felt that treatment was "helpful" after 3 wk; trend toward greater pain reduction for group 1 at 3 wk ($P = .20$)
Howe et al[37] (1983)	Acute neck, arm, or hand pain from cervical spine lesion with reduced cervical ROM	(1) Azapropazone plus rotational manipulation [26] (2) Azapropazone only [26]	Group 1: 1-3 treatments in 1 wk by MD	68% in group 1 and 6% in group 2 reported immediate subjective pain improvement; no significant differences after 1 and 3 wk. Immediate increase in cervical rotation in group 1 maintained at 1 and 3 wk
Vernon et al[36] (1990)	Chronic mechanical neck pain	(1) Rotational manipulation [5] (2) Mobilization (oscillation) [4]	Both groups: 1 treatment by DC	40% to 55% increase in pressure pain thresholds around joint fixation immediately in group 1; no changes in group 2
Koes et al[68-71] (1992, 1993)	Subacute, nonspecific neck pain with limited cervical ROM	(1) Manipulation and/or mobilization by MTs [13] (2) Exercise, massage, and physiotherapy modalities [20] (3) Detuned shortwave diathermy [14] (4) Continued GP treatment [17]	All groups: treatments ≤3 mo	Greater mean improvement in physical functioning (cervical ROM) in group 1 than in group 2 at 3 mo and in pain improvement at 1 y
Cassidy et al[25,35] (1992, 1993)	Acute-chronic, unilateral neck pain with referral to trapezius without neurologic deficit	(1) Rotational manipulation [52] (2) Muscle energy mobilization [48]	Both groups: 1 treatment by DC	No significant difference in pain relief observed between 2 treatment groups ($P = .16$)

MD, Medical physician; *DC,* chiropractor; *MT,* manual therapist; *GP,* general practitioner.

limited by a small sample size (n = 9), the study of Vernon et al[36] was one of the first to compare SM in a controlled trial assessing pain threshold.

Two earlier studies had investigated the effects of cervical SM in conjunction with other medical procedures. In 1983, Howe et al[37] investigated the effects of cervical SM and joint injection in 52 subjects and found favorable results. In 1982, Sloop et al[38] found that cervical SM was associated with no significant improvements in patients' subjective reporting of neck pain on a visual analog scale immediately after the treatment. Patients were given an amnesic dose of diazepam to provide the double-blind criteria used in the study; however, the method used does not allow generalization of the results to common clinical practice.

Other clinical trials. In 1998, Jordan et al[39] conducted a randomized, prospective clinical trial of 119 patients with chronic neck pain; participants received neck and shoulder exercises, physiotherapy, or HVLA SMT. Patients from all 3 groups demonstrated significant improvements regarding self-reported pain and disability on completion of the study and at 4- and 12-months' follow-up, no significant differences being noted among the groups.

A 1997 study by Rogers[40] compared 6 sessions of cervical and thoracic HVLA SMT over 3 to 4 weeks with twice daily cervicothoracic stretches over the same period in 20 patients with chronic neck pain. Patients receiving SMT

reported a decrease in pain levels of 44% on a visual analog scale, whereas a reduction of only 9% was reported in those performing the cervicothoracic stretches. Although only a small sample was used, the Rogers[40] study would seem to be supportive of the trend seen in the small but growing body of evidence—that manipulation of the cervical spine is helpful in reducing neck pain.

Comparison of Spinal Manipulative Techniques

Little research exists with regard to comparisons of different forms of SMT or chiropractic techniques; however, one study in particular was similar to the present investigation. Yurkiw and Mior[41] compared HVLA SM with MFMA SM using the AAI in patients with neck pain. Each of 14 subjects was randomly assigned to one of 2 groups, evaluated by a blinded examiner, and then given one of the 2 forms of SMT. The outcome measures used were lateral flexion and a subjective pain rating. Both treatment types seemed to yield clinical improvement in lateral flexion measures and visual analog scale scores; however, the findings were not statistically significant. The authors acknowledged that the small sample size and statistically insignificant results are consistent with type II error. Noteworthy in this study, however, is the fact that the "2 ring" setting was used for the AAI treatments, which limited the excursion or depth of penetration of the Activator thrust. Yurkiw and Mior[41] chose this setting

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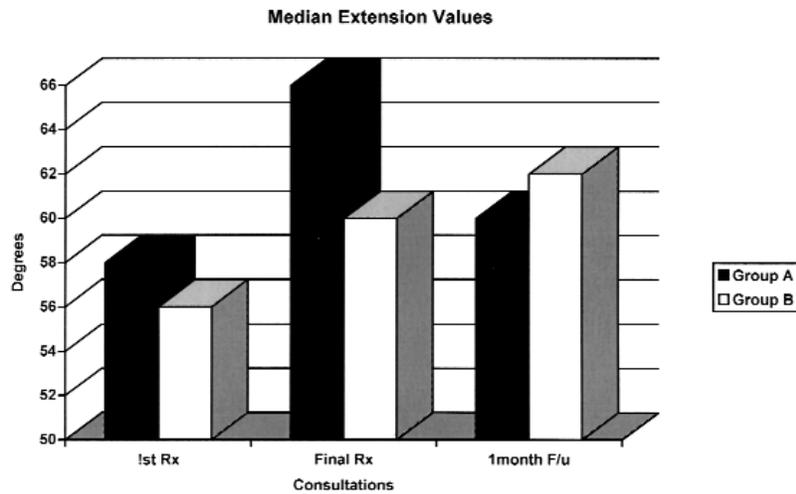**Median Extension Values**

Fig 1. *Median cervical spine extension range of motion values: comparison of groups A and B from initial consultation to outcomes at final consultation and 1-month follow-up.*
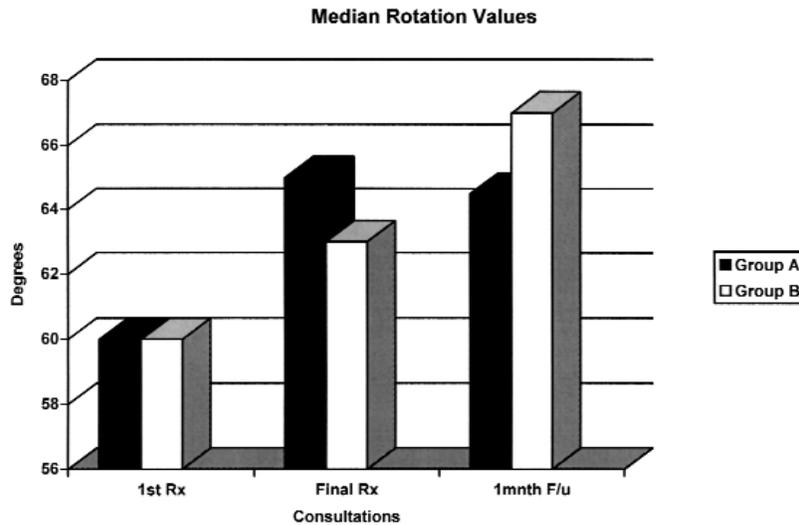
Median Rotation Values

Fig 2. *Median cervical spine rotation range of motion values: comparison of groups A and B from initial consultation to outcomes at final consultation and 1-month follow-up.*

because they believed it to be the standard setting for adjustment of the cervical spine according to the Activator Methods protocol, but the work that they cited was dated; a maximum setting is recommended in the cervical spine except when C1 is being contacted.[42] Use of the maximum setting of the AAI might have yielded different clinical results in this group of patients.

In a descriptive case series[27] of 10 consecutive patients with neck pain being treated for whiplash, it was reported that mean pain scores and mean active CROM improved after a 6-week treatment regimen that included MFMA SMT. When followed over the course of a year, most of the patients reported stability in their improvement.

Numerous SM techniques are used in the conservative treatment of patients with cervical spine complaints.[22,43] Concerns about deleterious effects of SM with respect to neurovascular accidents, however rare they might be, have caused the chiro-

practic profession to investigate alternative methods that might provide similar beneficial results in patients while involving the lowest risk possible. The risk/benefit ratio is an important consideration in any health care procedure, especially when the adverse sequelae include paralysis or death.[44-46] This is complicated by the fact that cerebrovascular screening tests have not been found to be helpful in identifying those at risk.[47]

Conflicting reports have appeared with regard to cervical rotational SM procedures' being associated with an increased incidence of cerebrovascular incidents (CVIs) and cerebrovascular accidents (CVAs).[48-50] After a detailed search of the literature through 1993, it was reported by Haldeman et al[50] that "the literature does not assist in the identification of the offending mechanical trauma, neck movement, or type of manipulation precipitating vertebrobasilar artery dissection or the identification of the patient at risk." However, studies beginning in 1996 have found cervi-
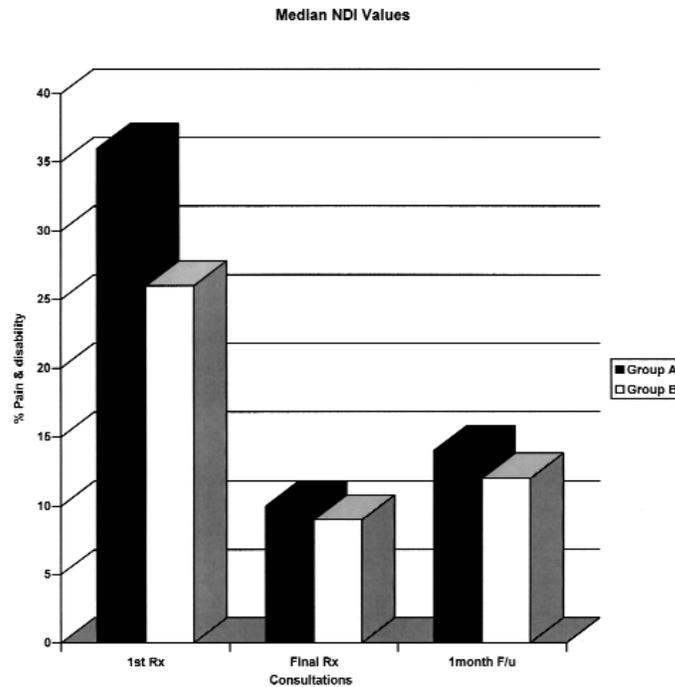
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Median NDI Values

Fig 3. *Median Neck Disability Index scores: comparison of groups A and B from initial consultation to outcomes at final consultation and 1-month follow-up.*
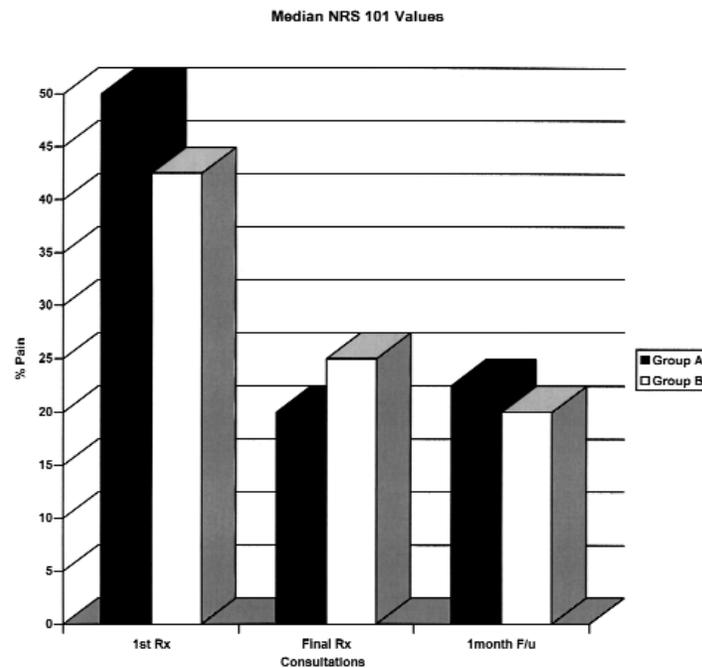
Median NRS 101 Values

Fig 4. *Median Numerical Pain Rating Scale 101 values: comparison of groups A and B from initial consultation to outcomes at final consultation and 1-month follow-up.*

cal spine rotational maneuvers to be associated with CVAs and CVIs after SM more strongly than other "nonrotational" techniques.[4,48,49,51] The purported safety of using MFMA-driven SM with a device such as the AAI is thought to be due to the prone neutral positioning of the patient during the SM procedure (nonrotation) combined with the controlled, repeatable force of the thrust in the joint plane line.[52]

Currently, investigations have begun to differentiate mechanical and physiologic responses of SMT.[18,43,53-58] Neurophysiologic models theorize that SMT stimulates the somatosensory system and can subsequently evoke neuromuscular reflexes.[53,59-61] Although there is little research pertaining to the cervical spine in this regard, MFMA SMT has been found to elicit significant neuromuscular reflexes
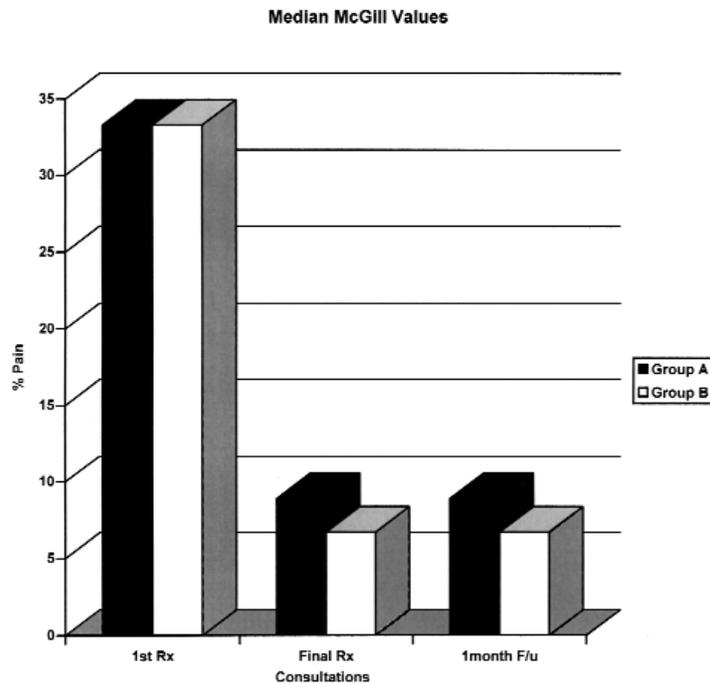
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Median McGill Values

Fig 5. *Median McGill Short-Form Pain Questionnaire values: comparison of groups A and B from initial treatment to outcomes at final treatment consultation and 1-month follow-up.*

in the erector spinae musculature in patients with LBP.[57,62] Traditional SMT has also been found to elicit neuromuscular responses in the cervical spine in asymptomatic subjects.[53] Such mechanical and neurophysiologic studies indicate that joint manipulation might have both direct and indirect clinical benefits. Beneficial effects of SMT have been thought to be associated with mechanosensitive afferent stimulation and presynaptic inhibition of nociceptive afferent transmission in the modulation of pain,[63,64] inhibition of hypertonic muscles,[18,53,65] and improved functional ability.[1,66,67] Such theories must be substantiated by well-designed investigations to verify the clinical relevance of these mechanisms.

CONCLUSION

This study demonstrated that HVLA manual thrust manipulations to the cervical spine show no benefit over MFMA instrumental thrusts with respect to objective and subjective clinical findings in patients with chronic cervical spine dysfunction. Furthermore, there is sufficient clinical and statistical evidence (except for some ranges of motion) to suggest that both treatment protocols had an effect on the participants in this study, but these results would have supported the use of MFMA and HVLA manipulation for cervical spine dysfunction only if a control group had been included in the investigation. Visual inspection of the data suggests that both treatment groups experienced a decrease in pain and disability and an increase in CROM after treatment and at the 1-month follow-up. Such findings are encouraging and form the basis for a larger-scale, randomized, controlled clinical trial to further investigate their clinical relevance. As technique options become available to clinicians, research

must continue to identify SM techniques that maximize therapeutic outcomes while minimizing patient risk.

REFERENCES

1. Shekelle PG. Spinal manipulation. Spine 1994;19:858-61.
2. Koes BW, Assendelft WJ, van der Heijden GJ, Bouter LM, Knipschild PG. Spinal manipulation and mobilisation for back and neck pain: a blinded review. BMJ 1991;303:1298-303.
3. Shekelle PG, Adams AH, Chassin MR, Hurwitz EL, Brook RH. Spinal manipulation for low-back pain. Ann Intern Med 1992;117:590-8.
4. Hurwitz EL, Aker PD, Adams AH, Meeker WC, Shekelle PG. Manipulation and mobilization of the cervical spine: a systematic review of the literature. Spine 1996;21:1746-59.
5. Bland JH. Disorders of the cervical spine: diagnosis and medical management. 2nd ed. Philadelphia: WB Saunders; 1994.
6. Bovim G, Schrader H, Sand T. Neck pain in the general population. Spine 1994;19:1307-9.
7. McLain RF. Mechanoreceptor endings in human cervical facet joints. Spine 1994;19:495-501.
8. Mendel T, Wink CS, Zimny ML. Neural elements in human cervical intervertebral discs. Spine 1992;17:132-5.
9. Bogduk N, Windsor M, Inglis A. The innervation of the cervical intervertebral discs. Spine 1988;13:2-8.
10. Bogduk N. The clinical anatomy of the cervical dorsal rami. Spine 1982;7:319-30.
11. Parfenchuck TA, Janssen ME. A correlation of cervical magnetic resonance imaging and discography/computed tomographic discograms. Spine 1994;19:2819-25.
12. Schellhas KP, Smith MD, Gundry CR, Pollei SR. Cervical discogenic pain: prospective correlation of magnetic resonance imaging and discography in asymptomatic subjects and pain sufferers. Spine 1996;21:300-11.
13. Barnsley L, Lord S, Bogduk N. Comparative local anaesthetic blocks in the diagnosis of cervical zygapophysial joint pain. Pain 1993;55:99-106.
14. Barnsley L, Lord SM, Wallis BJ, Bogduk N. The prevalence of

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chronic cervical zygapophysial joint pain after whiplash. Spine 1995;20:20-5.

15. Lord SM, Barnsley L, Wallis BJ, Bogduk N. Chronic cervical zygapophysial joint pain after whiplash: a placebo-controlled prevalence study. Spine 1996;21:1737-44.

16. Mennell JM. The validation of the diagnosis "joint dysfunction" in the synovial joints of the cervical spine. J Manipulative Physiol Ther 1990;13:7-12.

17. Gatterman MI. Foundations of chiropractic: subluxation. St. Louis: Mosby; 1995.

18. Herzog W. Mechanical, physiologic, and neuromuscular considerations of chiropractic treatments. In: Lawrence DJ, Cassidy JD, McGregor M, Meeker WC, Vernon HT, editors. Advances in chiropractic. St. Louis: Mosby–Year Book; 1996. p. 269-85.

19. Herzog W. On sounds and reflexes. J Manipulative Physiol Ther 1996;19:216-8.

20. Herzog W, Conway PJ, Zhang YT, Gal J, Guimaraes AC. Reflex responses associated with manipulative treatments on the thoracic spine: a pilot study. J Manipulative Physiol Ther 1995;18:233-6.

21. Suter E, Herzog W, Conway PJ, Zhang YT. Reflex response associated with manipulative treatment of the thoracic spine. J Neuromusculoskeletal Syst 1994;2:124-30.

22. Christensen MG; Delle Morgan DR. Job analysis of chiropractic: a project report, survey analysis and summary of the practice of chiropractic within the United States. Greeley (CO): National Board of Chiropractic Examiners; 1993.

23. Nansel D, Peneff A, Cremata E, Carlson J. Time course considerations for the effects of unilateral lower cervical adjustments with respect to the amelioration of cervical lateral-flexion passive end-range asymmetry. J Manipulative Physiol Ther 1990;13: 297-304.

24. Nansel DD, Peneff A, Quitoriano J. Effectiveness of upper versus lower cervical adjustments with respect to the amelioration of passive rotational versus lateral-flexion end-range asymmetries in otherwise asymptomatic subjects. J Manipulative Physiol Ther 1992;15:99-105.

25. Cassidy JD, Lopes AA, Yong-Hing K. The immediate effect of manipulation versus mobilization on pain and range of motion in the cervical spine: a randomized controlled trial. J Manipulative Physiol Ther 1992;15:570-5.

26. Cassidy JD, Quon JA, LaFrance LJ, Yong-Hing K. The effect of manipulation on pain and range of motion in the cervical spine: a pilot study. J Manipulative Physiol Ther 1992;15:495-500.

27. Osterbauer PJ, Derickson KL, Peles JD, Deboer KF, Fuhr AW, Winters JM. Three-dimensional head kinematics and clinical outcome of patients with neck injury treated with spinal manipulative therapy: a pilot study. J Manipulative Physiol Ther 1992;15:501-11.

28. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. J Manipulative Physiol Ther 1991;14:409-15.

29. Jensen MP, Karoly P, Braver S. The measurement of clinical pain intensity: a comparison of six methods. Pain 1986;27: 117-26.

30. Melzack R, Katz J. The McGill Questionnaire: appraisal and current status. In: Melzack R, Turk R, editors. Handbook of pain assessment. New York: The Guilford Press; 1992. p. 152-68.

31. Youdas JW, Carey JR, Garrett TR. Reliability of measurements of cervical spine range of motion: comparison of three methods. Phys Ther 1991;71:98-104.

32. Szaraz ZT. Compendium of chiropractic technique. Toronto: Canadian Memorial Chiropractic College Technical Publications; 1990. p. 46,50,57,60,77.

33. Crichton NJ. The importance of statistics in research design. In: Lewith GT, Aldridge D, editors. Clinical research methodology for complimentary therapies. London: Hodder & Stroughton; 1994. p. 3-20.

34. Nilsson N, Christensen HW, Hartvigsen J. Lasting changes in passive range motion after spinal manipulation: a randomized, blind, controlled trial. J Manipulative Physiol Ther 1996;19: 165-8.

35. Cassidy JD, Lopes AA, Yong-Hing K. The immediate effect of manipulation vs. mobilization on pain and range of motion in the cervical spine: a randomized controlled trial. J Manipulative Physiol Ther 1993;16:279-80.

36. Vernon HT, Aker P, Burns S, Viljakaanen S, Short L. Pressure pain threshold evaluation of the effect of spinal manipulation in the treatment of chronic neck pain: a pilot study. J Manipulative Physiol Ther 1990;13:13-6.

37. Howe DH, Newcombe RG, Wade MT. Manipulation of the cervical spine: a pilot study. J R Coll Gen Pract 1983;33:574-9.

38. Sloop PR, Smith DS, Goldenberg E, Dore C. Manipulation for chronic neck pain: a double-blind controlled study. Spine 1982; 7:532-5.

39. Jordan A, Bendix T, Nielsen H, Hansen FR, Host D, Winkel A. Intensive training, physiotherapy, or manipulation for patients with chronic neck pain: a prospective, single-blinded, randomized clinical trial. Spine 1998;23:311-8.

40. Rogers RG. The effects of spinal manipulation on cervical kinesthesia in patients with chronic neck pain: a pilot study. J Manipulative Physiol Ther 1997;20:80-5.

41. Yurkiw D, Mior S. Comparison of 2 chiropractic techniques on pain and lateral flexion in neck pain patients: a pilot study. Chiropr Technique 1996;8:155-62.

42. Fuhr AW, Colloca CJ, Green JR, Keller TS. Activator methods chiropractic technique. St. Louis: Mosby-Year Book; 1997.

43. Kawchuk GN, Herzog W. Biomechanical characterization (fingerprinting) of five novel methods of cervical spine manipulation. J Manipulative Physiol Ther 1993;16:573-7.

44. Braun IF, Pinto RS, De Filipp GJ, Lieberman A, Pasternack P, Zimmerman RD. Brain stem infarction due to chiropractic manipulation of the cervical spine. South Med J 1983;76:1199-201.

45. Mas JL, Henin D, Bousser MG, Chain F, Hauw JJ. Dissecting aneurysm of the vertebral artery and cervical manipulation: a case report with autopsy. Neurology 1989;39:512-5.

46. Powell FC, Hanigan WC, Olivero WC. A risk/benefit analysis of spinal manipulation therapy for relief of lumbar or cervical pain. Neurosurgery 1993;33:73-8.

47. Bolton PS, Stick PE, Lord RS. Failure of clinical tests to predict cerebral ischemia before neck manipulation. J Manipulative Physiol Ther 1989;12:304-7.

48. Klougart N, Leboeuf-Yde C, Rasmussen LR. Safety in chiropractic practice, I; the occurrence of cerebrovascular accidents after manipulation to the neck in Denmark from 1978-1988. J Manipulative Physiol Ther 1996;19:371-7.

49. Klougart N, Leboeuf-Yde C, Rasmussen LR. Safety in chiropractic practice, II: treatment to the upper neck and the rate of cerebrovascular incidents. J Manipulative Physiol Ther 1996; 19:563-9.

50. Haldeman S, Kohlbeck FJ, McGregor M. Risk factors and precipitating neck movements causing vertebrobasilar artery dissection after cervical trauma and spinal manipulation. Spine 1999;24:785-94.

51. Assendelft WJ, Bouter LM, Knipschild PG. Complications of spinal manipulation: a comprehensive review of the literature. J Fam Pract 1996;42:475-80.

52. Colloca CJ, Fuhr AW. Safety in chiropractic practice, II: treatment to the upper neck and the rate of cerebrovascular incidents. J Manipulative Physiol Ther 1997;20:567-8.

53. Herzog W, Scheele D, Conway PJ. Electromyographic responses of back and limb muscles associated with spinal manipulative therapy. Spine 1999;24:146-52.

54. Gal JM, Herzog W, Kawchuk GN, Conway PJ, Zhang YT. Forces and relative vertebral movements during SMT to unem-

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balmed post-rigor human cadavers: peculiarities associated with joint cavitation. J Manipulative Physiol Ther 1995;18:4-9.

55. Herzog W, Conway PJ, Kawchuk GN, Zhang Y, Hasler EM. Forces exerted during spinal manipulative therapy. Spine 1993; 18:1206-12.

56. Keller TS, Colloca CJ, Fuhr AW. Validation of the force and frequency characteristics of the activator adjusting instrument: effectiveness as a mechanical impedance measurement tool. J Manipulative Physiol Ther 1999;22:75-86.

57. Colloca CJ, Keller TS, Fuhr AW. Muscular and mechanical behavior of the lumbar spine in response to dynamic posteroanterior forces. Proceedings of the 26th annual meeting of the International Society for the Study of the Lumbar Spine. Toronto: International Society for the Study of the Lumbar Spine; 1999. p. 136A.

58. Colloca CJ, Keller TS, Gunzburg R, Van de Putte K, Fuhr AW. Neurophysiological response to intraoperative lumbosacral spinal manipulation. J Manipulative Physiol Ther 2000; 23:447-57.

59. Colloca CJ. Articular neurology, altered biomechanics, and subluxation pathology. In: Fuhr AW, Colloca CJ, Green JR, Keller TS, editors. Activator methods chiropractic technique. St. Louis: Mosby–Year Book; 1997. p. 19-64.

60. Pickar JG, McLain RF. Responses of mechanosensitive afferents to manipulation of the lumbar facet in the cat. Spine 1995;20:2379-85.

61. Wyke B. Articular neurology and manipulative therapy. In: Glasgow E, Twomey L, Scull E, Kleynhans A, Idczak R, editors. Aspects of manipulative therapy. 2nd ed. New York: Churchill-Livingstone; 1985. p. 72-7.

62. Colloca CJ, Keller TS. Electromyographic reflex response to mechanical force, manually-assisted spinal manipulative therapy. Spine. In press 2001.

63. Wyke B. Articular neurology and manipulative therapy. In: Idczak RM, Dewhurst D, Glasgow EF, Tehan P, Ward AR, editors. Apects of manipulative therapy. Proceedings of a Multi-disciplinary International Conference on Manipulative Therapy, Melbourne, August, 1979. Carlton, Australia: Lincoln Institute of Health Sciences; 1980. p. 67-72.

64. Willis W, Coggeshall R. Sensory mechanisms of the spinal cord. 2nd ed. New York: Plenum Press; 1991.

65. Thabe H. Electromyography as a tool to document diagnostic findings and therapeutic results associated with somatic dysfunctions in the upper cervical spinal joints and sacroiliac joints. Manual Medicine 1986;2:53-8.

66. Meade TW, Dyer S, Browne W, Frank AO. Randomized comparison of chiropractic and hospital outpatient management for low back pain: results from extended follow up. BMJ 1995; 311:349-51.

67. Triano JJ, McGregor M, Hondras MA, Brennan PC. Manipulative therapy versus education programs in chronic low back pain. Spine 1995;20:948-55.

68. Koes BW, Bouter LM, van Mameren H, Essers AH, Verstegen GJ, Hofhuizen DM, et al. A randomized clinical trial of manual therapy and physiotherapy for persistent back and neck complaints: subgroup analysis and relationship between outcome measures. J Manipulative Physiol Ther 1993;16:211-9.

69. Koes BW, Bouter LM, van Mameren H, Essers AH, Verstegen GM, Hofhuizen DM, et al. Randomized clinical trial of manipulative therapy and physiotherapy for persistent back and neck complaints: results of one year follow up. BMJ 1992; 304:601-5.

70. Koes BW, Bouter LM, van Mameren H, Essers AH, Verstegen GM, Hofhuizen DM, et al. The effectiveness of manual therapy, physiotherapy, and treatment by the general practitioner for nonspecific back and neck complaints: a randomized clinical trial. Spine 1992;17:28-35.

71. Koes BW, Bouter LM, van Mameren H, Essers AH, Verstegen GM, Hofhuizen DM, et al. A blinded randomized clinical trial of manual therapy and physiotherapy for chronic back and neck complaints: physical outcome measures. J Manipulative Physiol Ther 1992;15:16-23.