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Original Articles

Effects of Cervical Adjustments on Lateral-Flexion Passive End-Range Asymmetry and on Blood Pressure, Heart Rate and Plasma Catecholamine Levels

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ABSTRACT

The biomechanical and physiological effects of a single, unilateral lower cervical spinal adjustment delivered to the most restricted side of cervical lateral-flexion passive end-range were examined. Only healthy, asymptomatic male subjects who exhibited goniometrically verified lateral-flexion passive range of motion asymmetries of 10° or greater on the morning of the experiment were chosen for the study. Posttreatment goniometric measurements revealed that in sham-adjusted controls, mean lateral-flexion asymmetries had not changed significantly during the 4-hr time period examined. However, in subjects who received lower cervical adjustments, dramatic ameliorations of asymmetry magnitude were observed which persisted throughout the entire 4-hr posttreatment time period. On the other hand, in the face of this rather robust biomechanical effect, heart rate and blood pressure measurements obtained at -60 and -15 min prior to treatments, and at 5, 30, 60, 120 and 240 min following treatments, revealed no significant differences between adjusted and sham-adjusted subjects at any of the time periods examined. Consistent with this, analysis of the plasma concentrations of norepinephrine, epinephrine and dopamine in serial blood samples collected at these same times also failed to reveal significant differences between treatment groups at any of the time periods examined. The results of this investigation indicate that lower cervical adjustments are capable, at least in asymptomatic subjects, of inducing relatively robust biomechanical effects related to passive cervical end-range capability without simultaneously inducing significant alterations in the overall activity of the sympathetic nervous system. (J Manipulative Physiol Ther 1991; 14:450–456).

Key Indexing Terms: Cervical Vertebrae, Chiropractic, Norepinephrine, Epinephrine, Dopamine, Heart Rate, Blood Pressure.

INTRODUCTION

Results obtained from previous experiments carried out in this laboratory have demonstrated a fairly consistent and rather robust side-specific effect of unilateral lower cervical adjustments with respect to the amelioration of cervical lateral-flexion passive end-range asymmetries (1, 2). However, in those earlier studies, no information was obtained concerning other physiologic changes which might have occurred in association with or as a result of this manipulation-induced biomechanical effect. During the past 60 yr, a growing number of reports have accumulated which strongly suggest that somatic dysfunction involving various connective tissue elements associated with the spinal column can produce "scleratogenous" pain referral patterns which may *mimic* those produced by primary visceral disease. This is due to the fact that nociceptive afferents from connective tissue structures and visceral pain afferents from regionally-related visceral structures converge on common pools of interneurons in the dorsal horn of the spinal cord (3–7).

With respect to the lower cervical region specifically,

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a number of reports indicate that somatic nociceptive signals not only may produce pain referral patterns remarkably similar to those seen in cardiac angina, but in turn, may produce reflex-induced alterations in sympathetic efferent discharge related to lower cervical-upper thoracic cord levels as well (8–22). Of particular interest is whether subjects exhibiting significant cervical range of motion asymmetries, even though pain free, might exhibit alterations, albeit subtle ones, in parameters known to be influenced by changes in the activity of the sympathetic nervous system. If so, do lower cervical adjustments, by ameliorating those biomechanical asymmetries, concomitantly induce ameliorative changes in these associated physiologic parameters? Additionally, information about possible increases in sympathetic tone following cervical adjustments would also address the question of whether the therapy is traumatic for asymptomatic subjects. Therefore, we decided to reexamine the effect of single, unilateral lower cervical adjustments with respect to cervical lateral-flexion passive end-range capability, and with respect to heart rate, blood pressure and the circulating levels of norepinephrine and epinephrine.

MATERIALS AND METHODS

Subject Selection Criteria

Only healthy, asymptomatic, nonsmoking male subjects ranging from 22–37 yr of age were screened goniometrically for inclusion in this study. All volunteer subjects were instructed to eat a substantial breakfast and arrive at the laboratory at 7:00 a.m. on the day of the experiment. Subject selection was then based solely on the demonstration of a goniometrically-determined cervical lateral-flexion passive end-range asymmetry of 10° or greater. Seventy-eight individuals had to be screened goniometrically in order to obtain 24 such subjects (12 subjects for each of two treatment categories).

Goniometric Assessment Protocol

The experimenter in charge of passive manipulation of the subject's head stood directly behind the seated subject and placed a pendulum goniometer (inclinometer) on top of the subject's head in neutral position. The dial of the inclinometer was faced forward, and all values were read and recorded by another experimenter (recorder) who stood in front of the subject. Subjects were instructed to hold on to the bottom of the chair seat in order to stabilize their shoulders, and to close their eyes and relax during the taking of the measures. Previous work in our laboratory had demonstrated that repeated passive end-range measures are much less variable if subjects are assessed with their eyes closed (23). The goniometric assessor, while holding the inclinometer firmly in place with his thumbs, used his fingers and palms to clasp the sides of the subject's head in neutral position. In order to avoid anterior flexion and/or rotational head displacements which might influence the lateral-flexion measure, the assessor then repositioned his feet (forward or backward) so that his elbows rested comfortably and symmetrically at his side. The subject's head was then moved symmetrically to the right and then to the left, pausing at maximum end-range for an instant until signaled by the recorder that the left or right end-range measure had been read and recorded. Five left and five right alternating measures (which took a minute or two) were obtained from each subject, and the mean right vs. mean left difference computed. As mentioned earlier, only individuals exhibiting mean right-left passive end-range differences of 10° or greater were selected as subjects for the study.

Postural and Environment Maintenance

Since it has been well established that abrupt postural changes as well as varying degrees of discomfort can have rather dramatic, albeit transient, influences on general sympathetic tone, great care was taken to provide a posturally stable, warm, quiet, comfortable and reasonably pleasant environment for the selected subjects during the 5 hr of the experiment.

Following subject selection, subjects were instructed to walk quietly to the restroom and attempt to void, since they would not be allowed to get up and move around for the next couple of hours. Subjects were then ushered into another room where they were seated (semirecumbent) in a row of reclining chaise-style lounge chairs. Pillows were also supplied for additional comfort. Once seated subjects were instructed to relax and not to converse or fidget during the remainder of the experiment. Room lights were dimmed and subjects were entertained by means of video tapes (NOVA series) throughout the entire 5 hr.

Serial Blood Withdrawal, Heart Rate, Blood Pressure and Goniometric Assessments

Following a 30 min equilibration period (60 min prior to treatment), three pairs of experimenters began moving from subject to subject in a quite orderly fashion. Two teams were comprised of a phlebotomist and another experimenter in charge of heart rate and blood pressure measurements. The third team consisted of

the goniometric assessor and recorder. Blood samples (by venipuncture) and heart rate and blood pressure assessments were obtained from each subject at -60 min and -15 min pretreatment, and at +5 min, +30 min, +60 min, +120 min and +240 min posttreatment. Goniometric assessments were performed at -60 min pretreatment, and at +30 min, +60 min, +120 min and +240 min posttreatment. Goniometric assessments were carried out by first pushing the reclining subject up into the upright seated position. Alternating 5 left × 5 right passive end-range assessments were then obtained according to the protocol described earlier (see goniometric assessment protocol).

Blood withdrawal, and heart rate and blood pressure assessments were performed with subjects in the reclining position. Two heart rate and two blood pressure measurements were obtained in immediate sequence from each subject at each time period, and the two heart rate measures as well as the two sets of blood pressure values (systolic and diastolic) were then averaged and recorded. Ten milliliters of blood were collected from each subject for each of the first six time periods in vacutubes pretreated with 200 μl of a solution containing 90 mg/ml ethylene glycol-bis-[3-aminoethyl ether]-N,N,N',N'-tetraacetic acid and 60 mg/ml glutathion (an antioxidant) at a pH of 7.4. For the last sample (240 min posttreatment) an additional 10 ml sample was withdrawn in a serum resin vacutube (for routine laboratory determinations).

Subjects were allowed to get up and quietly walk to the restroom immediately following their +60 min or +120 min blood sample, but were instructed to return to their seats within 15 min in order to allow for adequate postural stabilization in advance of the next timed sample 45 min or 105 min later.

All members of the blood sampling, heart rate, blood pressure and goniometric assessment teams were kept blinded from subject treatments (see treatment categories) throughout the entire experiment.

Preparation of Blood Plasma Aliquots

Immediately following their collection, blood-filled vacutubes were quickly transported to an adjacent laboratory, centrifuged for 5 min (900 × g) to separate cells from plasma, and placed upright in an ice water bath. Within 5–10 min following centrifugation, plasma was removed with a Pasteur pipette and approximately 1 ml aliquots transferred to 1.5 ml capped conical polyethylene tubes. Plasma was then quick-frozen (by placing conical tubes against a slab of dry ice) and stored in freezer boxes (also packed in dry ice). At the end of the experiment, all frozen aliquots were transported to San Jose State University and stored in a -80° C freezer until assayed for plasma epinephrine, norepinephrine and dopamine (see catecholamine assay procedures). Routine blood laboratory determinations (for serum obtained 4 hr posttreatment only) were performed at Central Diagnostic Laboratories, Tarzana, CA.

Treatment Categories

Following the -15 min blood sample and heart rate-blood pressure assessments, the two teams of experimenters responsible for those parameters were asked to leave the room, and another investigator and the adjusting doctor entered. Subjects were then assigned to one of two treatment groups, taking care to balance the groups as best as possible with respect to the magnitudes of passive end-range asymmetry. Treatment groups were as follows.

1. *Adjusted:* those subjects receiving a single seated lower cervical adjustments delivered to the goniometrically-determined side of greatest end-range restriction ($n = 12$).
2. *Sham-adjusted:* those subjected to all preliminary palpatory and "set-up" procedures, but without the adjustive thrust ($n = 12$).

Spinal Manipulative Procedures

Cervical adjustments were performed in the following manner. The subject was pushed from the reclining position up to the upright seated position. The adjusting doctor then placed his stabilization hand on top of the subjects head, and the head was flexed slightly in order to effect separation of the spinous processes. The tip of the index finger of the contact hand was then placed on the end of the spinous process of the cervical vertebrae below the one to be adjusted. Then the contact finger was moved up so that it fit under and slightly lateral to the spinous of the vertebra being adjusted.

The thumb of the contact hand was then placed on the ramus of the jaw so that an arch was formed between the thumb and index finger (spinous contact). Using the stabilization hand, the head was then brought back into a more relaxed position, and the stabilization hand was then placed along the posterior-lateral portion of the cervical spine opposite the side to be adjusted. The chin was then elevated slightly and the head was flexed laterally about 10–15° and rotated slightly toward the side to be adjusted. The slack was then reduced (taken to tension) by applying pressure on the spinous process with the contact finger.

The thrust was made (high velocity) with the contact hand. The function of the stabilization hand was merely to guide the motion of the head as the thrust was applied, and not to pull the head back across the contact finger. The thrust, which was made almost entirely with a rotational motion of the wrist and forearm, acted to lift the spinous process upward while also moving it anteriorly and medially. Depending on the palpatory "impression" of the adjusting doctor, all subjects received adjustments directed at C6, C7 or T1 vertebral segments on the side of most restricted passive end-range. It should be noted, however, that this procedure almost always yielded multiple "audibles," suggesting multiple segment involvement.

For sham-adjusted controls, the adjuster was instructed to direct his palpatory procedure to the most restricted side of passive end-range and was allowed to take the subject "to tension" (see procedure, above), but was then instructed to release the subject at the last instant, just prior to delivering the thrust.

Plasma Catecholamine Assay Procedure

A single isotope assay for norepinephrine, epinephrine and dopamine similar to that first described by Passon and Peuler (24) was utilized for plasma catecholamine determinations. This assay utilizes the enzyme catechol-*O*-methyltransferase to catalyze the transfer of a [^{3}H]-methyl group from *S*-adenosyl-L-(methyl-^{3}H) methionine (^{3}H-SAM) to norepinephrine, epinephrine and dopamine. The resulting products, (^{3}H)-normetanephrine (^{3}H)-metanephrine, and (^{3}H)-dopamine are then isolated by thin-layer chromatography. Each labelled derivative is converted by periodate oxidation to [^{3}H] vanillin and extracted. The radioactivity attributable to each catecholamine is then determined by liquid scintillation counting. The assay for catecholamine described here follows the basic principles of Passon and Peuler using the Cat-A-Kit assay system by Amersham (Arlington Heights, Illinois).

In this procedure, it is important to examine each sample for hemolysis, cloudiness, or solid material to avoid erroneous results. All water used must be glass-distilled deionized water. Particular care should be taken to vortex the reagent mixture after addition of *S*-adenosyl-L-(methyl-^{3}H) methionine, which is strongly acidic, so as not to layer the enzyme onto the acid and cause extensive denaturation.

The catecholamine assay by Cat-A-Kit assay system is linear to 3000 pg per assay sample for noradrenaline, adrenaline and dopamine when the standards are added to samples from a plasma pool at 0.5 log intervals. In the dilution step, 10 μl each of Tris buffer (ph 8.5) containing ethylene glycol-bis (B-amino ethyl ether), *N*-*N*-tetra acetic acid and MgC12, *S*-adenosyl-L-(methyl^{3}H)methionine, rat liver catechol-*O*-methyltransferase and deionized distilled water, produces a standard with a content of 100 pg of each catecholamine in the 10 μl aliquot added to the mixture.

Since this assay is dependent at several steps upon partitioning of labelled product from one phase to another, it is important that the vortexing action be robust enough to ensure thorough mixing of the phases. The best mixing was achieved by several brief vortexings with a pause of approximately 20 sec between them. The samples were stoppered and stored below -20° C after the extraction of catecholamines. The thin layer chromatography plates used for the separation of catecholamines were placed in a desiccator and stored below -20° C. In this system, it is not necessary to separately count instrument background. The background is part of the assay blank and is therefore subtracted in the calculations. To achieve adequate counting statistics, a counting time of 10 min for each vial was found to be satisfactory.

Assay Sensitivity

The radioactivity in the respective blanks was equivalent to approximately 1.8 pg norepinephrine, 1.2 pg epinephrine and 8.0 pg dopamine. Thus, the realized sensitivity of the assay (at twice the radioactivity equivalents in the blank) was norepinephrine (3.6 pg), epinephrine (2.4 pg) and dopamine (16.0 pg) per 50 μl sample. The expected sensitivity should range from 2.5–5.9 pg for norepinephrine and epinephrine and 17–23 pg for dopamine per 50 μl sample (24).

Assay Precision

As measured in groups of four, for additions of standards at 0.5 log intervals from blank (0 pg) to 3000 pg, the average coefficient of variation was 5.1%, 4.2% and 5.8% for norepinephrine, epinephrine and dopamine, respectively. The coefficients of variation for between-assay performance of a plasma sample spiked with the three catecholamines were, norepinephrine (7.8%), epinephrine (13.5%) and dopamine (11.8%). Individual values for these experiments were norepinephrine (191 ± 15 pg/ml), epinephrine (53 ± 7 pg/ml) and dopamine (228 ± 27 pg/ml).

Statistical Analysis

Six repeated measures of analyses of variance (ANOVA) (subjects × treatments × time) were performed:

three on the plasma concentrations of norepinephrine, epinephrine and dopamine, two on diastolic and systolic blood pressure measurements, and one on heart rates. Each ANOVA used data collected at seven times (relative to real or sham treatment) during the experiment: -60 min, -50 min, +5 min, +30 min, +60 min, +120 min and +240 min. SOLO (BMDP Statistical Software, Inc., Los Angeles, 1988) was used for the analysis. The repeated measures ANOVA procedure analyzes data from an experimental design represented by the following mathematical model.

$$Y_{ijkl} = \text{Mean} + A_i + S_{ij} + B_k + AB_{ik} + E_{ijkl}$$

In this model (in split-plot jargon), A is the whole-plot treatment, S is the whole-plot error, B is the split-plot (repeated) treatment and E is the split-plot error.

For analysis of routine blood laboratory data (4 hr posttreatment only), a Students *t*-test was performed for between group comparisons.

RESULTS

As in previous studies (1, 2), single unilateral lower cervical adjustments delivered to the most restricted side of passive end-range were found to induce significant ($p < .001$) reductions in lateral-flexion asymmetry magnitudes 30 min following treatment (Figure 1, top panel). This effect was maintained at 60, 120 and 240 min as well. Sham-adjusted control subjects, on the other hand, continued to exhibit close to their original degrees of asymmetry throughout the same time period.

In the face of this rather robust biomechanical effect, mean heart rate and blood pressure measurements for the two groups (-60 and -15 min prior to treatment and 5, 30, 60, 120 and 240 min following treatment) were found to be virtually unchanged and not significantly different at all time periods examined (Figure 1, middle three panels). As might be expected in subjects lying down for more than 5 hr, some significant heart rate and blood pressure effects were detected in both sham and adjusted groups by the repeated measures ANOVA. Because these general relaxation effects were in the expected direction and essentially the same in both sham and treatment groups, they are not particularly interesting findings. On the other hand, the detection of this subtle effect does illustrate the sensitivity of the repeated measures ANOVA, and its ability to have detected equally subtle between-treatment group differences had they occurred.

Mean plasma concentrations of epinephrine, norepinephrine and dopamine in serial blood samples obtained from the two groups were also found to be highly stable and not significantly different from one another

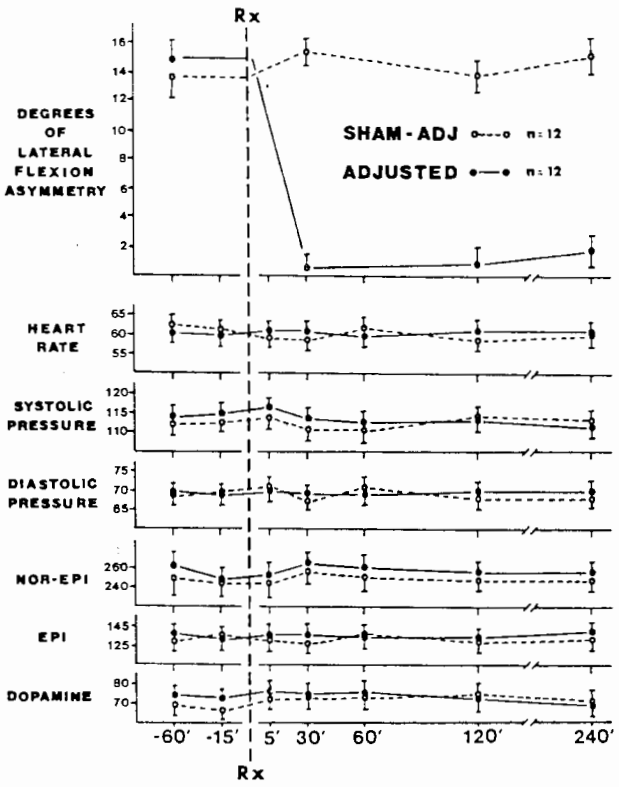

Figure 1. Effect of unilateral lower cervical adjustments delivered to the most restricted side of end-range in otherwise asymptomatic male subjects exhibiting passive cervical lateral-flexion asymmetries of greater than 10°. Whereas lateral-flexion asymmetry magnitudes (top panel) in sham-manipulated subjects were found to remain relatively unchanged throughout the 4-hr posttreatment time period (O—O), asymmetry magnitudes were greatly ameliorated in the group of subjects who received lower cervical adjustments (●—●). On the other hand, in the face of this rather robust biomechanical effect, heart rate and blood presssures (middle three panels) as well as plasma catecholamine concentrations (lower three panels) in the two treatment groups were found to be relatively stable and not significantly different from one another over the 4-hr posttreatment time period examined.

at these same pre- and posttreatment time periods (Figure 1, bottom three panels). There were no significant main or interaction effects in any of the ANOVAs with regard to changes in catecholamines over time or across groups.

Additionally, routine laboratory serum analyses of blood samples obtained +240 min posttreatment revealed no significant differences ($p > .05$) between the two treatment groups for any of the 24 factors examined (Table 1).

DISCUSSION

Possibly the most significant contribution made by this study is the demonstration that highly stable heart rate, blood pressure and plasma catecholamine levels

TABLE 1. 240 min posttreatment routine blood chemistry values

	Sham adjusted (mean ± SD) $n = 12$	Adjusted (mean ± SD) $n = 12$	t-test (p value)
Glucose mg/dl	88.8 ± 6.5	86.6 ± 3.9	>.05
Blood urea nitrogen (BUN) mg/dl	15.3 ± 3.3	13.5 ± 2.8	>.05
Creatinine mg/dl	1.11 ± .099	1.09 ± .099	>.05
BUN/Creatinine ratio	13.8 ± 2.9	12.3 ± 2.1	>.05
Aspartate aminotransferase (SGOT) u/l	34.2 ± 12.3	25.9 ± 8.1	>.05
Alanine aminotransferase (SGPT) u/l	34.8 ± 15.7	27.8 ± 18.1	>.05
Lactate dehydrogenase u/l	148.5 ± 26.7	137.2 ± 20.2	>.05
GGTP u/l	27.3 ± 18.8	21.3 ± 12.4	>.05
Bilirubin mg/dl	.46 ± .191	.37 ± .162	>.05
Alkaline phosphate u/l	68.8 ± 16.3	77.3 ± 14.2	>.05
Calcium mg/dl	9.71 ± .31	9.63 ± .26	>.05
Phosphorus mg/dl	4.05 ± .51	4.1 ± .38	>.05
Sodium meq/l	141.3 ± 1.2	142 ± 1.4	>.05
Potassium meq/l	4.61 ± .37	4.42 ± .26	>.05
Chloride meq/l	105 ± 1.4	104 ± 3.1	>.05
CO_2 meq/l	28.9 ± 1.1	28.7 ± 1.2	>.05
Uric acid mg/dl	6.28 ± 1.52	5.75 ± .99	>.05
Triglyceride mg/dl	90 ± 34	81 ± 22	>.05
Cholesterol mg/dl	186 ± 41	174 ± 36	>.05
Total protein gm/dl	6.7 ± .29	6.6 ± .24	>.05
Albumin gm/dl	4.61 ± .23	4.62 ± .27	>.05
Globulin gm/dl	2.11 ± .29	2.13 ± .26	>.05
A/G ratio	2.23 ± .37	2.26 ± .28	>.05
Iron meq/dl	97.8 ± 22	94.3 ± 27	>.05

Routine laboratory data obtained from blood samples collected 4 hr following sham-manipulation or lower cervical adjustments. Treatment group comparisons revealed no significant differences ($p > .05$) for any of the 24 factors analyzed.

can be maintained in asymptomatic human subjects, provided that a warm, quite, comfortable and posturally consistent experimental laboratory setting is provided. Considering the low levels of variability observed for these potentially volatile parameters in both groups of subjects, statistical evaluations indicate that differences of as little as 25% between treatment groups could have been detected, had they occurred at any of the sample periods examined.

The questions of whether changes might have been detected had subjects been symptomatic, or whether other manipulative techniques performed at the same or at other vertebral levels (e.g., upper cervical) would have induced significant changes in any of the parameters examined in this investigation, remain unanswered. At best, the results do appear to indicate that in otherwise normal asymptomatic subjects, lower cervical adjustments of the type employed in this study are capable of producing significant biomechanical and/or neuromuscular changes (i.e., the amelioration of passive cervical lateral-flexion end-range asymmetry) without concomitantly inducing significant alterations in the overall activity of the sympathetic nervous system, at least over the 4-hr posttreatment time period investigated. Therefore, considering the sensitivity of the sympathetic nervous system to even moderate levels of acute stress, the type of lower cervical adjustment employed in this study certainly did not appear to be particularly traumatic in this group of asymptomatic subjects. Of course, the possible pathophysiologic and/or clinical relevance of the biomechanical changes brought about by lower cervical adjustments in this study also remain to be elucidated.

CONCLUSION

This paper studied the biomechanical and physiological effects of a single chiropractic adjustment upon motion abnormality and various physiologic parameters in otherwise healthy subjects. Results are intriguing and raise many questions for future study.

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