

The Impact of Chiropractic Adjustments on Intracranial Blood Flow: A Pilot Study

Robert M. Scott, D.C., Ph.D.,¹ Christopher L. Kaufman Ph.D.,² Donald R. Dengel, Ph.D.^{3,4}

ABSTRACT

Background: A limited number of studies have addressed the impact of extracranial vascular blood flow and positional changes of the cervical spine. Fewer have addressed the specific effects of chiropractic adjustments and vertebral artery blood flow via Doppler Ultrasound techniques. Identifying the effects on blood flow may prove helpful in identifying the relationship of flow to mechanism of action and subsequent application of chiropractic care to vascular health and the onset of disease.

Objective: To investigate the effect of a single chiropractic adjustment on middle cerebral artery blood flow and radial artery blood pressure response.

Design and Setting: A randomized controlled study involving 20 healthy chiropractic students. Data were analyzed utilizing a two-group repeated measures ANOVA with 6 levels followed by a post hoc multiple comparison analysis.

Results: A transient but significant change in middle cerebral artery blood flow occurred in subjects receiving a chiropractic adjustment. Peak flow was reached within one minute of receiving the adjustment and returned to baseline values by minute five. A single cervical adjustment had no effect on systolic or diastolic blood pressure.

Conclusion: This Doppler study looked at the effect of a chiropractic adjustment on intracranial blood flow. The results indicate that asymptomatic subjects experience small, transient increase in blood flow immediately following an adjustment.

Key Words: *Chiropractic Adjustment, Blood Flow, Transcranial Doppler Ultrasound, Blood Pressure, Subluxation*

INTRODUCTION

Current research in the field of vascular dysfunction is focused on the effect of both exogenous and endogenous blood-borne substances on endothelial function and blood flow. It is evident from this research that vascular dysfunction is often associated with cardiovascular risk factors including hyperlipidemia, Type 2 diabetes mellitus, hypertension and smoking.¹ A key element that is overlooked in this relationship is the effect that neural control may play in vascular dysfunction.

Chiropractors have long claimed to achieve positive outcomes in their patients with hypertension, raynauds disease, migraine headaches and a variety of systemic conditions related to vascular function. A key characteristic associated with many vascular diseases is that of reduced blood flow. A change in peripheral blood flow, *visa vi* measurement of skin temperature, has been demonstrated in conjunction with adjustments.² Cervical adjustments in particular were correlated with slight increases in distal finger temperature. Other studies have looked at the effects of rotation of the cervical spine on blood flow of the extracranial circulation measured in the vertebral artery.³⁻⁹

Two studies have investigated the effect that chiropractic spinal manipulation have on blood flow in the vertebral artery

1. Dean, Life University, College of Chiropractic, Marietta, GA.
2. Senior Research Scientist, St. Paul Heart Clinic. St. Paul MN.
3. School of Kinesiology, University of Minnesota, Minneapolis, MN.
4. GRECC, Minneapolis Veterans Affairs Medical Center, Minneapolis, MN.

Circulation.^{10,11} Licht et al.¹¹ studied the effect of vertebral artery flow in students during cervical rotation, as well as, before and after spinal manipulation. They found no significant changes in blood flow following manipulation in human subjects. Attempts at utilizing animal models to measure flow related changes via implantation of flow tonometers found significant increases in vertebral artery flow following cervical adjustments.¹⁰ The purpose of this pilot study was to investigate the possible effect of a single cervical adjustment on Transcranial Doppler (TCD) ultrasound measurements of intracranial blood flow.

METHODS

Subjects were recruited from among the student body in the College of Chiropractic at Northwestern Health Sciences University. Potential participants were screened by questionnaire and an informed consent interview, and if qualified were scheduled for an initial evaluation examination/screening. Evaluation consisted of a health history, physical examination, a chiropractic spinal assessment, screening of middle cerebral artery blood flow by Transcranial Doppler Ultrasound, and review of plain film cervical radiographs which were on record with the University Health Services at Northwestern Health Sciences University. Eligible participants were scheduled within three days for the intervention phase. All eligibility data were collected and recorded by the primary investigator (PI) who made the final determination for study participation. Following a screening visit to determine their eligibility for participation as described above, subjects signed an informed consent form approved by the University of Minnesota and College of Chiropractic at Northwestern Health Sciences University Institutional Review Boards.

Inclusion and Exclusion Criteria

To be eligible for the study, subjects had to be between 18 to 40 years of age; enrolled in the college of chiropractic; possess no contraindication to cervical manipulation; be normotensive and currently not be taking medication for hypertension; have a TCD flow reading between 30 and 60 cm/sec; and have identifiable cervical vertebrae subluxation.

Subjects were excluded from participating if they had previous cervical spine surgery, congenital anomalies of the cervical spine, inflammation or destructive tissue changes of the cervical spine, the presence or history of vascular disease of the head and neck, or insufficient TCD reading. Also excluded were potential participants who were under ongoing care for neck pain, or injury, by another health care provider.

Upon completion of the second evaluation, eligible participants were randomly assigned to one of two treatment groups. Random number generation software was used to assign groups and each subject was appropriately allocated and blinded to the upcoming intervention assignment.

Intervention

To minimize diurnal variability all data was collected between 7:00 a.m. and 9:00 am. Subjects arrived at the clinic setting and changed into comfortable, loose fitting clothing.

Prior to receiving the intervention the examiner evaluated the cervical spine to confirm the presence of spinal subluxation as classified by the PARTS acronym. Each subject was required to lie supine on a standard chiropractic elevation table and rest for 10 minutes. At the 10-minute interval, the subject received either a single High Velocity, Low Amplitude chiropractic adjustment (Adjustment Group) or gentle soft tissue massage with cervical rotation to 45 degrees in one direction for 10 seconds (Control Group) as predetermined by their group assignment. Following the intervention each subject rested for an additional 10-minutes.

Hemodynamic measurements

Electrocardiograph (ECG) readings were obtained via a standard 5-lead electrode placement utilizing four limb leads and a single precordial lead placed at V6. Signals were captured via a Colin Pilot 7000 (Colin Electronics Co. Ltd., San Antonio, TX), which was connected to an analog-to-digital (A/D) converter and subsequently relayed to a computer supporting Windaq Pro data acquisition software (DataQ Instruments, Akron, OH). ECG tracings were recorded in real time on a single channel throughout the duration of the test. Systolic (SBP) and diastolic blood pressure (DBP) measurements were obtained by way of a tonometer that was placed over the radial artery of the subjects' right wrist. The tonometer was connected to the A/D converter and signals were relayed to the computer and recorded on the Windaq Pro data acquisition software. A sphygmomanometer inflation cuff was placed on the subject's right arm approximately one inch above the antecubital fossa. Calibration of blood pressure measurement was automatically performed by the Colin Pilot 7000 with periodic comparison of cuff measurements with tonometric measurements. SBP, DBP and ECG measurements were continuously recorded on separate channels throughout the duration of the test and were electronically exported to a computer for offline analysis.

Cerebral Blood Flow Measurements

Cerebral artery blood flow measurements were obtained with a Transcranial Doppler ultrasound (TCD) via the right middle cerebral artery (MCA) with a Companion Series Transcranial Doppler Ultrasound (Nicolet Vascular, Madison, WI). The TCD unit was connected to an A/D converter and the signal was relayed to the WinDaq Pro data acquisition software. Data were recorded continuously throughout the experiment and electronically exported to a computer for future offline analysis. A 2-MHz hand-held transducer probe was utilized to insonate through the temporal window approximately 1 cm above the zygomatic arch at a depth between 40 and 60 mm depending on the cranial thickness and signal quality. This insonation technique was described by Giller and Giller¹² and corresponds with the proximal M-1 segment of the MCA.¹³

The transtemporal window was located superior to the zygomatic arch over the temporal bone. A "flash light" technique was used over the transtemporal window covering posterior, middle, anterior, and frontal regions of the window. Initially the transducer was placed over the posterior region and the ultrasound beam was aimed anteriorly and superiorly with the sample volume depth set at 55 mm.

Differentiation of the vessels was achieved by sequentially decreasing the sample volume depth to a depth shallower than 55 mm. Upon identifying the MCA, the vessel was examined by using the audible signal as a guide and increasing the depth 5 mm at a time until the signal was optimized. This commonly occurred between depths of 30 to 60 mm with mean velocities of 55 ± 12 cm/sec in a directional flow towards the transducer. To ensure that minimal movement occurred in the insonation angle of the probe, every effort was made by the examiner to maintain the strength and quality of the signal throughout the experiment. To ensure consistency with the TCD measurement technique, the same examiner conducted the TCD technique on all subjects.

Cerebral blood flow velocity was determined as the mean of the maximum and minimum flow velocities averaged over time throughout the cardiac cycle. The signals recorded during baseline were averaged over the last two minutes of the 10-minute pre-intervention period. Signals were averaged over each minute for the first five minutes of the post intervention time interval. No less than 30 waveforms per minute were averaged to calculate mean blood flow velocity. This technique has been shown to provide reliable and reproducible data predating to changes in cerebral blood flow velocity in TCD^{14,16}.

Pulsatility index was calculated according to the formula of Gosling and King¹⁷:

$$PI = (V_{sys} - V_{dias}) / V_{mean}$$

where V_{sys} is the maximal recorded blood flow velocity through the middle cerebral artery during systole; and V_{dias} is the minimum recorded blood flow velocity during diastole; and V_{mean} is the mean velocity recorded through the MCA.

Sample Size and Statistical Analysis

The absence of data regarding effect size for blood flow prevented an a priori calculation of power. Baseline data were calculated using the last 2-minutes of the 10-minute pre-intervention period. Following the intervention, data from each of the first 5-minutes were averaged and reported. Group characteristics and group mean pre and post data were calculated for each of the three hemodynamic variables. Data analysis was performed using SPSS Base 10.0 Windows based program. Between group comparison was performed using a repeated measures general linear model (ANOVA) with 6 levels: Baseline, 1, 2, 3, 4 and 5-minute post. Additionally, a post hoc multiple comparison analysis was performed to identify which level(s) were significant.

RESULTS

A total of 25 participants were evaluated for inclusion in the study. Twelve were randomly assigned to the chiropractic adjustment (Adjustment Group) and 10 were assigned to the control (Control Group). Of the 12 assigned to Adjustment Group, only 10 completed the study. Two subjects were excluded by the investigator as a result of weak TCD signal.

The Adjustment Group consisted of 4 males and 6 females with a mean age of 24.2 ± 2.0 years (range 22 to 28 yrs).

The average weight of subjects in this group was $69.9 \text{ kg} \pm 10.5 \text{ kg}$ (range 59.0 to 91.2 kg). Mean BMI was $21.3 \pm 2.8 \text{ kg/m}^2$ (range 18.6 to 26.3 kg/m^2) (Table 1).

The Control Group was comprised of 6 males and 4 females with an average age of 25.7 ± 2.5 years (range 21 to 30 yrs). Subjects in Control Group had an average weight 11.7 kg greater than those in the Adjustment Group. Mean weight was $81.5 \text{ kg} \pm 15.8 \text{ kg}$ (range 59 to 91.1). BMI for subjects in the Control Group was also slightly higher than that of the Adjustment Group with a mean of $23.7 \pm 4.7 \text{ kg/m}^2$. Differences between groups for these two variables were not found to be significant.

Blood Flow

The baseline blood flow for the Adjustment Group was 62.6 ± 10.7 cm/sec as compared to 52.9 ± 12.1 cm/sec for the Control Group. The observed variability of 9.3 cm/sec appears to be within the normative range of 55 ± 12 cm/sec for MCA blood flow¹⁶ (Table 2). Over the course of the first five-minutes post intervention, blood flow values in the Adjustment Group increased sharply from baseline of 62.6 ± 10.7 cm/sec to 65.2 ± 10.3 cm/sec at one-minute post intervention. The one-minute time interval represented the maximum flow observed throughout the five-minute post intervention time period. By two-minute post intervention the blood flow began to slowly decline reaching a similar baseline value of 62.9 ± 11.1 cm/sec by the five-minute mark. In the Adjustment Group the blood flow ranged from 62.6 ± 10.7 cm/sec to 65.2 ± 10.3 cm/sec representing a 4.1 % (2.6 cm/sec) increase in flow. During the same 5-minute post intervention time interval blood flow in the Control Group remained steady and did not fluctuate more than .04 cm/sec staying within the range of 52.9 ± 12.1 cm/sec to 53.3 ± 11.5 cm/sec. Repeated measures ANOVA for within and between group differences found that the observed increase in blood flow between groups was significant ($P = 0.045$). When correcting for the post hoc error rate by dividing the $\alpha = .05$ equally by 15 different post hoc pairwise contrasts, a more statistically stringent value of $p \leq 0.003$ continued to show a significant change in flow rate between groups at the one minute post adjustment interval. SBP and DBP did not vary significantly from baseline measures throughout the 5-minute post intervention period between groups ($P = 0.307$ and $P = 0.743$ respectively).

Pulsatility

PI is an indicator of the hemodynamic resistance of distal vascular beds and has a normal range in healthy individuals of between .80 and 1.10. Values for both groups were well within the normal values ranging between $.92 \pm .21$ to $.98 \pm .23$ for the treatment group and $.89 \pm .11$ to $.92 \pm .11$ for the Control Group. Variability within each group was small and limited to .06 and .03 for the Adjustment and Control Groups respectively. The results for PI indicate that there was no significant difference observed between groups ($P = 0.593$).

DISCUSSION

The findings of this study suggest that a small but significant transient increase (4.1%, $P = 0.045$) occurs in middle cerebral artery blood flow immediately following a cervical

adjustment. Our findings appear to be consistent with those of Licht et al.¹⁰ who observed a similar transient effect in an animal model. The increase flow observed in Licht's study was, however, of greater magnitude (20%) which may be attributable to flow measures being obtained on an anaesthetized pig. Contrary to our results Licht et al.¹¹ observed no significant changes in vertebral artery flow among students in a similarly pre/post-test design. Of note however, is that Licht utilized a significantly larger time interval between which flow was measured. The initial flow measurement did not occur until three minutes after the adjustment and subsequently thereafter at greater intervals. It would appear based upon our results that the observed change in flow may have already occurred prior to the 3-minute marker utilized by Licht. This would suggest the necessity to obtain continuous flow measurements throughout the post adjustment time interval to ensure capturing any potential changes. Of additional note is that little is known about the temporal relationship of vertebral artery and MCA flow.

Our study would indicate that no changes in either SBP or DBP occurred with a cervical adjustment. It would appear that literature to date is inconclusive regarding the effect of manipulation on blood pressure showing hypertensive effects,^{18,19} hypotensive effects,²⁰⁻²⁵ or no effect on blood pressure.²⁶⁻²⁸ According to Poiseuille's formula blood flow through a vessel is determined by several hemodynamic factors including: the driving pressure across a vessel; the vascular resistance of the vessel and of the tissue bed it perfuses; and the viscosity of the blood.¹² The relationship of these factors to blood flow through a vessel can be represented by the equation:

$$Q = (\pi r^4 / 8\eta) \Delta P / L$$

where, Q is the flow; πr^4 is the cross sectional area of the vessel; 8η is the fluid viscosity; ΔP is the change in pressure, and; L is the vessel length. Arterial blood pressure measures obtained through conventional sphygmomanometer procedure is customarily utilized as the measure of driving pressure. The observed lack of BP response would suggest that the observed change in flow was not attributable to a change in driving pressure as required by Poiseuille's equation.

Resistance of the distal vascular bed may contribute to changes in blood flow. TCD reading can be utilized to ascertain potential changes in resistance in the distal vascular bed through the pulsatility of the waveform reading. An increased pulsatility index signifies an increase in the resistance of the distal tissue bed or vasoconstriction, while a decrease signifies a decrease in resistance or vasodilation. Our study found that no change occurred in PI between groups. The average range for PI for both groups was well within the normal range of 0.80 and 1.2. As with blood pressure, our results would suggest that a change in vascular resistance did not contribute to the change observed in flow.

Hematocrit, or cell volume, can directly affect blood viscosity and therefore resistance to flow. Although our study did not address the constituents of blood chemistry, others have looked at the fibrinolytic activity of the blood following osteopathic manipulations.¹⁹ Significant reductions in hematocrit and fibrolytic activity were observed during the 30-minute post manipulation period. The fibrinolytic enzyme

system and fibrinogen levels are thought to be among the most sensitive indicators of subtle changes in autonomic activity. In general, fibrinolytic states or hyperfibrinogenemia are associated with a shift in sympathetic autonomic tone. A decrease in fibrinolytic activity and the subsequent lowering of fibrinogen are associated with an increase in tone of the parasympathetic nervous system. In the absence of changes in blood pressure or vascular resistance, which could contribute to flow, alterations in viscosity may be accountable for the change in flow observed in the present study. This would appear extremely unlikely, however, as the reactivity of the fibrinolytic enzyme system would require more than one minute to manifest as an alteration in flow.

Of consideration in our study is the high degree of autoregulation that exists in cerebral circulation. The brain has a tremendous ability to maintain flows to the tissues during changes in pressure. It is interesting to note that the assumption that driving pressure of the peripheral conduit arteries of the arm is identical to that of the cerebral arteries is an incorrect assumption.¹² According to Poiseuille's formula flow is related to vessel diameter (πr^4), therefore, slight changes in diameter can result in significant alterations in flow. It is feasible that fluctuations of the cerebral vascular pressure may occur, resulting in changes to either vessel diameter and/or vessel length. Small changes in cerebral vessel diameter will result in significant changes in flow. Subsequently, in the absence of noticeable alterations in peripheral blood pressure and pulsatility as observed in our study, it is feasible that the observed change may have resulted from changes in vessel diameter. Unfortunately, TCD ultrasound technique does not have the ability to measure diameter so no conclusive hemodynamic factor can be attributed to the observed flow.

A second observation of our study deserves mentioning and further investigation. Both groups of subjects received mechanical stimulation of the joints and stimulation of the superior cervical ganglia. The distinction that separates the two groups is the cavitation of the joint associated with the adjustment. The increase blood flow observed in the adjustment group might suggest that alteration of proprioceptive feedback from the joints themselves occurred in subjects receiving the adjustment as proposed in the dysafferentation hypothesis for subluxation. Again, however, neurologic mechanisms were not measured in this study.

The pilot nature of our study contained several limitations that prevent meaningful conclusion being drawn from the results. Based upon the sample size of our study and the observed effect size the study was underpowered (.57) limiting the usefulness of the results. Future studies should utilize adequate samples to reduce this likelihood. Restrictions on recruitment of subjects may prove to be a limitation. Requiring healthy, young, asymptomatic subjects could result in minimizing the effect that may result in an unhealthy older population.

Despite these limitations, the outcome of this study presents some promising direction for further research into the impact of chiropractic care on vascular function. Two lines of inquiry can be suggested. The first is related to mechanism of action and the second pertains to outcomes of care. If a single chiropractic adjustment results in a 4% increase in flow, can

an adjustment result in enhanced endothelial dependent flow mediated dilation- an indicator of endothelial function? Subsequently, it would follow that if endothelium is considered to play an important role in vascular function; and endothelial dysfunction is thought to be important in disease states characterized by vasospasm, vasoconstriction, inflammation and vascular smooth muscle proliferation; can chiropractic adjustments affect flow sufficiently to improve the bioavailability of endothelial nitric oxide and enhance and promote vascular health? If the existence of endothelial dysfunction in a subject affects vessel elasticity, what magnitude of change, if any, can be achieved with spinal adjustments in an individual with endothelial dysfunction?

Additional inquiry should be made into the outcome of chiropractic care on vascular disease states. Future research regarding outcomes of care could include the following questions: Will extended periods of chiropractic care impact either the onset or outcome of conditions associated with vascular dysfunction? If so, what is the frequency of care necessary to achieve such effects? Do certain conditions respond more favorably to the intervention than others? Does an individual's age, or sex, affect the outcome?

CONCLUSION

This study investigated the effects of chiropractic adjustments on intracranial blood flow. The results suggest that a significant, small but transient increase in cerebral blood flow occurs following a single chiropractic adjustment of the cervical spine. No significant changes in blood pressure were observed. These results would suggest that the increase in blood flow observed is not the result of a change in blood pressure or peripheral resistance. Subsequently, we can suggest that the observed change in flow is likely not the result of positional rotation and compression of the extracranial cervical vessels as this occurred in both subjects groups.

Acknowledgments

We would like to thank the students of Northwestern College of Chiropractic who volunteered to participate as subjects in this study. Dr. Julia Bartlett for her cooperation in accommodating this study within the University Health Services clinic at Northwestern. Finally, Jim Hulbert, Ph.D. for his statistical assistance and advice.

REFERENCES

1. Schroeder S, Enderle MD, Ossen R, Meisner C, Baumbach A, Pfohl M, et al. Non invasive determination of endothelium-mediated vasodilation as a screening test for coronary artery disease: Pilot study to assess the predictive value in comparison with angina pectoris, exercise electrocardiography, and myocardial perfusion imaging. *American Heart Journal* 1999;138(4):731-739.
2. Harris W, & Wagnon RJ. The effects of chiropractic adjustments on distal skin temperature. *Journal of Manipulative Physiologic Therapeutics* 1987;10(2):57-60.
3. Stevens AJJE. Doppler sonography and neck rotation. *Manual Med* 1984;1:49-53.
4. Stevens A. Functional Doppler sonography of the vertebral artery and some consideration about manual

- techniques. *Manual Medicine* 1991;6:102-5.
5. Weingart JR, Bischoff HP. Doppler sonography of the vertebral artery with regard to head positions appropriate to manual medicine. *Manuelle Medizin* 1992;30:62
6. Thiel H, Wallace K, Donat J, Yong-Hing K. Effect of various head and neck positions on vertebral artery flow. *Clinical Biomechanics* 1994;9:105-110.
7. Haynes MJ. Cervical rotation effects on vertebral artery flow. *Chiropractic Journal Aust* 1995;25:73-6.
8. Haynes MJ. Doppler studies comparing the effects of cervical rotation and lateral flexion on vertebral artery blood flow. *Journal of Manipulative Physiological Therapeutics* 1996;19:378-84.
9. Litch PB, Christensen HW, Hojgaard P, Hoilund-Carlsen PF. Triplex ultrasound of vertebral artery flow during cervical rotation. *Journal of Manipulative Physiological Therapeutics* 1998;21:29-31.
10. Licht PB., & Christensen HW. Vertebral artery flow and cervical manipulation: An experimental study. *Journal of Manipulative Physiologic Therapeutics* 1999; 22:431-435.
11. Licht PB, Christensen HW, & Hojgaard, P. Vertebral artery flow and spinal manipulation: A randomized, controlled and observer-blinded study. *Journal of Manipulative Physiologic Therapeutics* 1998; 21:141-144.
12. Giller CA. & Giller A. Basic transcranial Doppler waveform analysis in hemodynamics. *Journal of Vascular Technology* 2000; 24: 23-26.
13. Aaslid R, Markwalder TM, & Nornes H. Noninvasive Transcranial Doppler ultrasound of flow velocity in basil cerebral arteries. *Journal of Neurosurgery* 1982; 57:769 – 774.
14. Kontos HA. Validity of cerebral blood flow calculations from velocity measurements. *Stroke* 1989;20:1-3.
15. Nedeltchev K, Arnold M, Nirkkoo A, Sturzenegger M., Rishs F, et al. Changes in blood flow velocity in the middle cerebral and anterior cerebral arteries evoked by walking. *Journal of Clinical Ultrasound* 2002;30:132-8.
16. Nonoshita-Karr L, & Fujioka K. Transcranial Doppler sonography freehand examination techniques. *The Journal of Vascular Technology* 2000; 24:9-16.
17. Gosling RC, & King DH. Arterial assessment by Doppler-shift ultrasound. *Pro. R. Social. Medicine.*1974;67:447-449.
18. Goodheart GJ, Hypertension. *Digest of Chiropractic Economics* 1968; 11:20.
19. Hood R. Blood pressure. *Chiropractic Digest* 1974;16: 36.
20. Feichera A, & Celandier D. Effect of osteopathic manipulative therapy on autonomic tone as evidenced by blood pressure changes of the fibrinolytic system. *Journal of the American Osteopathic Association* 1969;68:72-74.
21. Tran T, & Kirby J. The effects of upper cervical adjustment upon the normal physiology of the heart. *Journal of Chiropractic*1977;11:S58-S62.
22. Duglar G, Hill D, Sirucek A, & Davis B. Evidence for a possible anti-hypertensive effect of basic technique apex contact adjusting. *Journal of Chiropractic* 1980;14: S97-S102.
23. McKnight M, & DeBoer K. Preliminary study of blood pressure changes in normotensive subjects undergoing chiropractic care.

Journal of Manipulative Physiologic Therapeutics 1988;11: 261-266.

24. Yates R, Lamping D, Abram N, & Wright C. Effects of chiropractic treatment on blood pressure and anxiety: a randomized controlled trial. *Journal of Manipulative Physiologic Therapeutics* 1988;11(6):484-488.
25. Knutson G. Significant changes in systolic blood pressure post vectored upper cervical adjustment vs. resting control groups: a possible effect of the cervicosympathetic and/or Pressor reflex. *Journal of Manipulative Physiologic Therapeutics* 2001;24(2): 101 – 108.
26. Morgan J, Dickey J, Hunt H, & Hudgins P. A controlled trial of spinal manipulation in the management of hypertension. *Journal of the American Osteopathic Association* 1985; 85(5):79-84.
27. Nansel D, Jansen R, Cremata E, Dhami MS, & Holley D. Effects of adjustments on lateral- flexion passive end-range asymmetry and on blood pressure, heart rate and plasma catecholamine levels. *Journal of Manipulative Physiologic Therapeutics* 1991; 14(8):450-6.
28. Goertz CM, Grimm RH, Svendsen K, & Grandits G. Treatment of hypertension with alternative therapies (THAT) study: a randomized clinical trial. *Journal of Hypertension* 2002; 20(10): 2063-2068.

Table 1. Physical Characteristics by Group.

	Group 1 (adjustment) n = 10	Group 2 (control) n = 10
Gender	(4 M, 6F)	(6 M, 4 F)
Age (yrs)	24.2 ± 2.0	25.7 ± 2.5
Height (inches)	66.9	67.8
Weight (lbs)	154.1 ± 23.1	179.8 ± 34.8
BMI (kg/m ²)	21.3 ± 2.8	23.7 ± 4.7

Table 2: Summary of TCD, SBP, DBP and PI data between subjects and across groups.

TCD Interval	Group 1 (Adjustment) mean (SD)	Group 2 (control/sham) mean (SD)	Between Group Mean (SD)	P Value Repeated Measures ANOVA $\alpha = .05$
--------------	-----------------------------------	-------------------------------------	----------------------------	---

Group TCD Cm/sec

Baseline	62.6 (10.7)	52.9 (12.1)	57.8 (12.2)	P=.045
Post-1	65.2 (10.3)	53.2 (11.9)	59.2 (12.6)	
Post-2	65.1 (11.2)	53.2 (11.9)	59.1 (12.8)	
Post-3	64.6 (10.6)	53.1 (11.5)	58.9 (12.3)	
Post-4	63.4 (11.1)	53.3 (11.7)	58.4 (12.3)	
Post-5	62.9 (11.1)	53.0 (11.5)	57.9 (12.1)	
	x = 63.9	x = 53.1	X = 58.5	

Group SBP mmHg

Baseline	125.3 (14.6)	133.1 (13.5)	129.2 (14.3)	P = .307
Post-1	123.9 (15.8)	131.7 (15.8)	127.8 (15.9)	
Post-2	122.9 (16.0)	129.8 (15.5)	126.4 (15.8)	
Post-3	123.1 (16.8)	127.0 (14.8)	125.2 (15.6)	
Post-4	122.7 (16.1)	127.5 (14.2)	125.1 (15.0)	
Post-5	121.8 (15.2)	131.3 (15.4)	126.6 (15.7)	
	x = 123.4	x = 130.1	X = 126.8	

Group DBP mmHg

Baseline	71.4 (8.6)	73.3 (9.8)	72.4 (9.1)	P= .743
Post-1	71.5 (9.9)	71.6 (13.2)	71.6 (11.4)	
Post-2	71.0 (9.3)	71.9 (13.4)	71.5 (11.3)	
Post-3	71.7 (9.3)	73.6 (12.4)	72.7 (10.7)	
Post-4	72.5 (9.1)	73.4 (12.4)	73.0 (10.6)	
Post-5	73.6 (8.4)	77.0 (9.3)	75.3 (8.6)	
	x = 71.9	x = 73.5	X = 72.7	

Group PI

Baseline	.94 (.23)	.90 (.13)	.92 (.18)	P = .593
Post-1	.93 (.22)	.89 (.11)	.91 (.17)	
Post-2	.92 (.21)	.89 (.13)	.91 (.17)	
Post-3	.92 (.22)	.92 (.11)	.92 (.17)	
Post-4	.98 (.23)	.89 (.11)	.94 (.18)	
Post-5	.94 (.17)	.89 (.09)	.92 (.13)	
	x=.94	x=.89	X = .92	

Figure1. Group mean TCD blood flow across time

