J. Phys. Ther. Sci.
24: 509–501, 2012

Comparison of Blood Pressure and Heart Rate Variability in Saunders Cervical Traction at Three Different Forces

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Abstract. [Purpose] This study investigated the alteration of blood pressure and heart rate variability (HRV) of healthy subjects before, during and after Saunders cervical traction at different traction forces. [Subjects and Methods] One hundred eighty healthy volunteers were divided randomly into A (5% body weight, *n* = 60), B (15% body weight, *n* = 60) and C (25% body weight, *n* = 60) groups. Changes of the blood pressure, oxygen concentration and HRV in the three groups after completing the three evaluation sessions were examined by comparing results from a session with the previous one. [Results] During Saunders cervical traction, significant differences were found within groups B and C, in the change of systolic and diastolic blood pressure, heart rate and HRV. In group C, significant differences in these changes were also observed after cervical traction. [Conclusions] HRV, which is induced by changes in blood pressure, reduced with increasing cervical traction force. Our results suggest that traction forces of 15% and 25% body weight should be carefully used for patients with cardiovascular diseases.

Key words: Saunders cervical traction, Heart rate variability, Blood pressure

(This article was submitted Dec. 20, 2011, and was accepted Jan. 26, 2012)

INTRODUCTION

Cervical pain or numbness is a common orthopedic disease. The clinical etiology of painful symptoms in the head or cervicoclavical region may include herniated intervertebral disc, cervical spondylosis, myofascial pain syndrome or acute fibrositis induced by subluxation of facet joints[1)]. In a previous study, cervical traction was shown to be effective for relieving cervical soreness and pain[2)], and it is often used in physical therapy. A cervical traction device delivers mechanical or manual traction force to the cervical spine and, therefore, relieves compression on the nerve root by stretching the spine and widening the intervertebral foramina[3)]. This traction force can also stretch the discs and surrounding neck muscles, supporting rehydration of the discs, recovery of the spineal alignment and relaxation of the muscles. However, traction force may also stretch or distort vertebral arteries, causing dizziness, vertigo and nausea, which would be a risk factor for developing cardiovascular diseases[3, 4)]. The dosage of mechanical cervical traction device is easy to record and control. In a previous study, Akinbo et al. indicated that a traction force under 10% of body weight had a favorable effect of relieving neck soreness and pain[5)]. However, few studies have investigated the effects of different traction forces on changes in blood pressure, heart rate, the cardiovascular system or the autonomous nervous system.

In the past, electrocardiograms were principally recorded for their waveforms and wave-to-wave distances. However, the diagnostic significance of heart rate variability (HRV), i.e. the changes in beat-to-beat intervals, has recently been recognized[6)]. HRV is obtained by measuring the differences between the peak-to-peak intervals over a certain duration and is affected by the activity and balance of the autonomous nerve system[7)]. Generally, factors influencing HRV include age, gender, race and posture[8)]. Many authors have proposed various analysis methods for the development of the analysis of electrocardiograms, such as the often seen time domain and frequency domain methods[6, 8, 9)]. In the time domain, the differences between R-R intervals are analyzed to compute the standard deviation of normal to normal intervals (SDNN). SDNN is commonly used as a predictor of HRV as well as of cardiovascular diseases[6)]. In the frequency domain, Fourier transforms of electrocardiograms allows analysis of several clinical indices, such as the percentage of the high frequency (HF) component (reflecting parasympathetic tone), the percentage of the low frequency (LF) component (reflecting sympathetic tone) and the LF/HF ratio (an index of the balance between the parasympathetic and sympathetic nervous tone)[9)]. Therefore, the alteration of HRV and cardiac autonomous nervous activity can be evaluated through time domain and frequency domain analysis.

Although cervical traction has been commonly used for cervical spine disorders, it may be pose risks for patients with cardiovascular diseases. However, only a few studies have been undertaken evaluating the influences of cervical traction on alteration of blood pressure and autonomous nervous regulation[4, 10]. HRV is also easily influenced by pain and uncomfortable symptoms[11]. Therefore, our study aimed to investigate the alteration of blood pressure and HRV in healthy participants before, during and after Saunders cervical traction at forces of 5%, 15% and 25% of body weight.

SUBJECTS AND METHODS

This study used a randomized, single-blind protocol and was performed at a teaching hospital in Taiwan. All the procedures were approved by the medical ethics committee of the local teaching hospital, and all the participants provided their written informed consent. The inclusion criteria were healthy persons without cervical diseases and neck pain. The participants were aged between 30 to 35 years old and had body mass index (BMI) within the normal range (18 to 24 kg/m^2). Exclusion criteria were a history of hypertension, cardiopulmonary diseases, or endocrine-related diseases, taking medication, smoking history or consumption of any caffeine or alcoholic beverages within the 24 hours before the tests. The participants matching the inclusion criteria were randomly divided into three groups. The forces of cervical traction used for groups A, B and C were 5%, 15% and 25% of the body weight, respectively. All participants lay on the traction bed at the start of the tests. They were secured with the cervical traction belt and their forearms were placed by their sides. A period of 5 minutes rest was followed by the first pre-traction evaluation, which included a one-minute assessment of blood pressure and heart rate, then measurement of HRV and autonomous nervous function for another 5 minutes. Each evaluation lasted for 6 minutes with the first session conducted before twenty minutes of cervical traction. The second evaluation started at the 10th minute of traction, and the third evaluation was conducted after the 20 minutes of traction had been completed. The tests were conducted in a quiet, air-conditioned rehabilitation center (27 °C). Subjects were placed in a lying posture for the cervical traction which utilized a Saunders cervical traction device combined with an electrically controlled mechanical Saunders traction unit (Eltrac471, Enraf-Nonius, Netherlands) which provided sustained traction for 20 minutes. Traction force differed among the three groups: 5% of body weight in group A, 15% of body weight in group B, and 25% of body weight in group C. Participants lay down on the traction bed with the neck slightly flexed at 20 to 30 degrees. The traction belt providing the traction force was controlled by the mechanical device. All the treatments were operated by the same therapist who could release the traction immediately if the participants felt any discomfort.

In this study, changes in systolic and diastolic blood pressure was measured using an electrical sphygmomanometer (ET-SP302, Terumo, Japan) with a brachial cuff wrapped above the elbow of the right arm. The change of oxygen concentration was measured via SpO_2 pulse oximeter (SA210, Full-young, Taiwan). The electrocardiograms were recorded with limb leads (CheckMyHeart, DailyCare BioMedical, Taiwan). The left and right electrodes were bilaterally placed on the wrists above the radial artery, and each measurement session was five minutes. All the R waves were calculated using the fast Fourier transform provided by computing software (HRV Analysis Software). The following parameters were defined according to the European Society of Cardiology and the North American Society of Pacing and Electrophysiology[7].

Percentage of the HF component (%): the spectral band from 0.15 to 0.4 Hz presented as a percentage. HF (%) = HF power / (HF power+ LF power).

Percentage of the LF component (%): the spectral band from 0.04 to 0.15 Hz presented as a percentage. LF (%) = LF power / (HF power+ LF power).

LF/HR ratio: the ratio of low- to high-frequency power.

HRV (ms): the standard deviation of normal R-R intervals (SDNN) as an index of HRV.

Statistic analyses were conducted with SPSS13.0. The non-parametric Mann-Whitney U test was used to check age, body weight and BMI, and differences among the three groups were examined. Baseline differences in heart rate, blood pressure, SpO_2, HRV, HF, LF and LF/HF ratio before traction of the three groups were analyzed by ANOVA. Within group changes after completion of the three evaluation sessions were examined by comparing results from a session with the previous one. Post hoc comparisons between groups were also performed. All values are presented as the mean ± SD. We used a two-tailed α value of 0.05 for the significance level in all analyses.

RESULTS

This study recruited 180 healthy volunteers (aged 32.1 ± 1.4 years, body weight of 52.1 ± 6.4 Kg, BMI 20.6 ± 3.0 kg/m^2) who were randomly divided into groups A, B and C with 60 participants in each group. All the participants completed the test procedure. The characteristic data of each group before traction are given in Table 1. There were no significant differences among the groups in age, height, body weight, BMI or traction force ($p > 0.05$). As shown in Table 2, no significant differences were found among the three groups in systolic and diastolic blood pressure, heart rate, SpO_2, HRV, LF, HF and LF/HF ratio ($p > 0.05$) during the first pre-traction evaluation after 5 minutes rest. Using the results of the first evaluation as a baseline, the differences between the results of the second and the first evaluations are shown in Table 3. Significant differences were found within the groups in systolic and diastolic blood pressure, heart rate, HRV, LF, and HF ($p < 0.05$), but not in the LF/HF ratio. Furthermore, the post hoc test revealed significant differences between group A and group C in systolic blood pressure ($p = 0.001$), diastolic blood pressure ($p = 0.04$), heart rate ($p = 0.04$), HRV ($p = 0.02$), LF ($p = 0.02$) and HF ($p = 0.02$). A comparison of group B and group C showed that there were significant differences in systolic blood pressure ($p = 0.02$), heart rate ($p = 0.01$), HRV ($p = 0.03$), LF ($p = 0.01$) and HF ($p = 0.01$). However, no significant differences were found between group A and group B in any

Table 1. Characteristic data of the three groups

	Group A n = 60	Group B n = 60	Group C n = 60
Age	32.4 ± 1.4	32.4 ± 1.7	31.7 ± 0.9
Height (cm)	160.2 ± 6.8	157.6 ± 5.8	159.0 ± 6.7
Weight (kg)	50.7 ± 6.5	52.8 ± 6.2	52.9 ± 6.5
BMI (kg/m^2)	19.8 ± 2.6	21.3 ± 2.9	20.9 ± 3.3
Traction force (kg)	2.53 ± 0.32	7.92 ± 0.94	13.23 ± 1.64

Table 2. The first evaluation results for the three groups

	Group A n = 60	Group B n = 60	Group C n = 60
Systolic BP (mmHg)	107.2 ± 6.4	106.7 ± 7.3	105.5 ± 5.1
Diastolic BP(mmHg)	67.4 ± 6.4	68.1 ± 3.6	67.5 ± 4.2
SpO_2 (%)	96.2 ± 0.8	95.7 ± 1.4	96.0 ± 1.4
Heart rate (beats/min)	75.5 ± 8.3	73.3 ± 7.2	77.0 ± 11.0
SDNN (ms)	50.6 ± 17.6	46.1 ± 13.9	49.3 ± 18.0
HF (%)	40.9 ± 18.3	46.1 ± 21.3	45.5 ± 15.1
LF (%)	59.1 ± 18.3	53.9 ± 21.3	54.41 ± 15.1
LF/HF	1.96 ± 1.31	2.05 ± 2.12	1.44 ± 0.86

BP, blood pressure; SDNN, normal standard deviation of normal to normal intervals; HF, high frequency; LF, low frequency.

Table 3. The differential values of the second and first evaluation

	Group A n = 60	Group B n = 60	Group C n = 60
Systolic BP (mmHg)	–0.86 ± 5.33	4.76 ± 7.34*	16.42 ± 12.61†
Diastolic BP(mmHg)	–0.12 ± 3.87	3.12 ± 4.96	10.47 ± 9.54†
SpO_2 (%)	–0.01 ± 1.21	0.00 ± 1.74	0.23 ± 1.85
Heart rate (beats/min)	–2.18 ± 3.28	–0.64 ± 1.58*	–7.35 ± 7.98†
SDNN (ms)	1.02 ± 6.57	–0.87 ± 17.59*	–19.97 ± 23.08†
HF (%)	–0.12 ± 9.85	–2.35 ± 10.38*	11.01 ± 8.10†
LF (%)	0.12 ± 9.85	2.35 ± 10.38*	–11.01 ± 8.10†
LF/HF	5.42 ± 15.98	–0.38 ± 1.28	–0.60 ± 0.67

BP, blood pressure; SDNN, normal standard deviation of normal to normal intervals; HF, high frequency; LF, low frequency. Post hoc test: Group B vs. Group C, * $p < 0.05$; Group C vs. Group A, † $p < 0.05$.

Table 4. The differential values of the third and second evaluation

	Group A n = 60	Group B n = 60	Group C n = 60
Systolic BP (mmHg)	–4.49 ± 9.53	–4.24 ± 8.33	–8.01 ± 14.24
Diastolic BP(mmHg)	1.51 ± 3.63	–3.36 ± 8.64	–7.37 ± 10.48*
SpO_2 (%)	–0.66 ± 1.49	0.13 ± 2.48	–0.13 ±1.13
Heart rate (beats/min)	–2.15 ± 3.54	0.86 ± 2.57	3.25 ± 9.55
SDNN (ms)	–5.86 ± 10.78	1.87 ± 13.88	9.01 ± 7.33*
HF (%)	11.12 ± 10.97	–4.23 ± 10.56	–13.86 ± 25.23*
LF (%)	–11.12 ± 10.97	4.23 ± 10.56	13.86 ± 25.23*
LF/HF	–5.94 ± 15.87	0.84 ± 1.37	1.55 ± 2.63

BP, blood pressure; SDNN, normal standard deviatio n of normal to normal intervals; HF, high frequency; LF, low frequency. Post hoc test: Group C vs. Group A, * $p < 0.05$.

of the parameters ($p > 0.05$).

In Table 4, the results of the comparison of the second and third evaluations are listed. There were no significant differences in any of the parameters of the three groups ($p > 0.05$). The post hoc comparison of group A and group C found significant differences in diastolic blood pressure ($p = 0.04$), HRV ($p = 0.01$), LF ($p = 0.01$) and HF ($p = 0.01$). However, no significant differences in any of the parameters between group B and group C and between group A and group B were observed ($p > 0.05$).

DISCUSSION

This study investigated the influences of various traction forces on changes in blood pressure and HRV. Our results indicate that, during cervical traction, subjects in group B with a traction force of 15% body weight and in group C with a traction force of 25% body weight had blood pressure increases. In group B, the average increase in systolic blood pressure was 4.76 ± 7.34 mmHg and in diastolic blood pressure was 3.12 ± 4.96 mmHg. In group C, the average increase in systolic blood pressure was 16.42 ± 12.61 mmHg and in diastolic blood pressure was 10.47 ± 9.54 mmHg. Group C had the most significant increase of the three groups, indicating that a traction force of 25% body weight can induce a marked increase in blood pressure. With regard to heart rate, there was a decrease of 0.64 ± 1.58 beats/min in group B, whereas it was 7.35 ± 7.98 beats/min in group C. This most significant decrease in group C indicates that the blood pressure change was regulated by the heart. Regulation of blood pressure is associated with cardiac function and the resistance of arterial walls. Furthermore, signals from sensors, such as baroreceptors, chemoreceptors and proprioceptors, are important in the regulation of blood pressure. The baroreceptors are the most important and exist in the human heart, aortic arch and carotid sinus. Previous studies revealed that cervical traction stretches neck muscles and baroreceptors in the carotid sinus, possibly causing increases of blood pressure[12].

Utti et al. utilized traction of 10% body weight in their study and found that cervical traction led to an increase of systolic blood pressure from 114.62 ± 10.43 mmHg to 123.51 ± 9.82 mmHg, an increase of diastolic blood pressure from 72.44 ± 9.51 mmHg to 77.92 ± 8.94 mmHg and an increase of heart rate from 71.72 ± 5.92 beats/min to 78.24 ± 5.75 beats/min[4]. Their results suggest that cervical traction increases blood pressure and heart rate, however, this was not the case in group A of our study which received a traction force of 5% body weight. Possible explanations for this are a different traction position and insufficient force. The results for groups B and C were similar to those of Utti et al. Blood pressure increased as the traction force increased, and greater changes in blood pressure occurred as the traction force increased. However, the increases of blood pressure occurred with a marked decrease of heart rate. This might be because the second evaluation began at the 10th minute of cervical traction, and increase of blood pressure may have occurred in the previous 10 minutes despite the traction force. As a result of regulation by the vagus nerve on cardiac function, the homeostasis of blood pressure would have been attained through a slower heart rate in the case of increased blood pressure.

Previous studies revealed that the vasomotor center in the reticular formation of the medulla oblongata receives sensory input from sensors[13, 14]. When blood pressure increases, baroreflex sensitivity is enhanced and impulses are transmitted via the afferent nerves to the vasomotor center. Thereafter the vasomotor center activity is changed and the depressor reflex is excited, causing the peripheral resistance to decrease, blood vessels to dilate and cardiac contraction force to weaken, consequently decreasing blood pressure[14]. A decrease in blood pressure would result in signals from receptors again being transmitted to the vasomotor center, prompting the mechanism for regulating homeostasis. The peripheral resistance would increase, blood vessels would constrict and cardiac contraction force would increase, altogether leading to increased blood pressure. The results of this study indicate that the blood pressure of participants in group B and group C recovered when the traction session was completed and no force was applied. In group B and group C, systolic blood pressure decreased 4.24 ± 8.33 mmHg and 8.01 ± 14.24 mmHg, respectively, and diastolic blood pressure decreased 3.36 ± 8.64 mmHg and 7.37 ± 10.48 mmHg, respectively. Despite the obvious decrease of diastolic blood pressure in group C, the increase in heart rate of this group (3.25 ± 9.55 beats/min) was not significant among the three groups.

Cardiac function is associated with the regulation of blood pressure. Although the control center of the heart is in the medulla oblongata, the signals regulating blood pressure come from the receptors in the heart and the arteries[15]. Nervous impulses are then transmitted to the vasomotor center in the reticular formation through the glossopharyngeal nerve and the vagus nerve. Increased blood pressure induces vagal activity, whereas decreased blood pressure excites a sympathetic nervous reaction[16]. The frequency domain analysis of the electrocardiographic signals is a suitable method for clinical evaluation of the cardiac autonomic nervous system[9]. In frequency domain analysis, HF and LF represent the activities of the parasympathetic nerves and the sympathetic nerves, respectively, with the LF/HF ratio reflecting the balance between the parasympathetic and sympathetic nervous activity. The results of this study indicate that during cervical traction of 25% body weight, participants in group C showed an increase in the percentage of the HF component of 11.01 ± 8.10%, which means that the vagal activity was enhanced. The finding of decreased heart rate in group C also supports this interpretation of vagal regulation of blood pressure. A decrease in the percentage of the LF component was also found in group C, and this change reflects baroreflex modulation[17]. Hedman et al. found that HF reflects the parasympathetic regulation of the heart, i.e. HF represents the cardiac vagal activity[18]. By stimulating the vagus nerves of animals, Iwao et al. found decreases in heart rate and HRV, and the decrease in HRV was reflected in the HF component[19]. Therefore, during the process of traction, the HF component increased, indicating that cardiac vagal activity was enhanced to accommodate the changes in heart rate and HRV.

This study found that during traction, HRV decreased 0.87 ± 17.59 ms in group B and 19.97 ± 23.08 ms in group C. With traction force of 25% body weight in group C, blood pressure increased, heart rate decreased and HF increased, and HRV was reduced by the greatest amount among the three groups. Changes in blood pressure decreased HRV, which reflects the interaction between the sympathetic and parasympathetic nervous systems[20)]. Friberg et al. found in their study of spontaneous hypertension in rats that increased blood pressure prompted regulation by increasing vagal nervous activity and an obvious trend of decreasing HRV[21)]. In the study of Goldberger et al., increased blood pressure of 20 to 30 mmHg was artificially induced by injecting healthy subjects with phenylephrine[22)]. A reduction in HRV was found, and the administration of drugs inducing vagus nerve blockage did not result in changes in HRV. Their results indicate that the reduction in HRV was not associated with constant vagal nervous activity, but was associated with temporal changes in the vagus nerve. Shin et al. suggested that HRV decreases and HF increases during resting in healthy subjects, while the sensitivity of LF and baroreceptors does not change[23)]. Macor et al. also found that increased HF had effects on veins with higher vagal activity, but had no effects on the sensitivity of baroreceptors[24)]. Therefore, traction of 25% body weight induces obvious changes in blood pressure along with a reduction in HRV and an increase in the HF component.

HRV has been found to be associated with changes in blood pressure, as a result of cardiac autonomic nervous activity. An increase in blood pressure is associated with a decrease in HRV, especially in patients with cardiovascular diseases[20)]. Santos-Hiss et al. found that the decrease of HRV is an essential tool for assessing acute myocardial infarction[6)]. Lammers et al. further suggested that the decrease in HRV could be used to estimate the risk of sudden death in patients with cardiovascular diseases[25)]. HRV decreases after acute myocardial infarction due to severe changes in cardiac autonomic activity[6)]. Also, it has been found that patients requiring cervical traction are older people with shoulder-neck pain due to cervical degeneration[26)]. Besides, the incidence of cardiovascular diseases is higher in this age group. Our study found that cervical traction of 25% body weight induced a greater reduction in HRV than that of 15% body weight. Therefore, a heavy pulling force administered to subjects with cardiovascular diseases during cervical traction could be a highly dangerous treatment.

One participant in group C receiving 25% body weight was dropped from the tests due to discomfort. Common side effects of cervical traction included dizziness, vertigo and nausea, which are induced by stretching of the carotid artery; therefore, special caution is needed for patients with cardiovascular diseases[4)]. Akinbo et al. found that the most effective dose for relieving cervical pain and increasing cervical range of motion was a traction force of 5% body weight, whereas a pulling force of 15% body weight was more potent at inducing side effects[5)]. We consider cervical traction of 5% body weight has less likelihood of inducing changes in blood pressure and the autonomic nervous system. A pulling force of 15% body weight, and especially of 25% body weight, caused changes in blood pressure and subsequently changed the autonomic nervous system and HRV. In summary, the results of this study indicate that more caution is needed when administering traction to patients with cardiovascular diseases.

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