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RESEARCH ARTICLE

Cardiovagal and Autonomic Impacts of Suboccipital Release for Autonomic Rehabilitation

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Abstract

Introduction: Physiatrists may be able to utilize Osteopathic manipulative treatment (OMT) for autonomic rehabilitation to manually to reset the autonomic nervous system (ANS). The impact of specific OMT techniques on ANS can be measured by heart rate variability (HRV) and can be used to indicate stress, pain, and chronic disease.

Objective: Analyze the impact of suboccipital release OMT technique (SR) on vagal tone measured through HRV.

Design: Within-subject design with 5-minute HRV measurements pre and post-OMT treatment.

Setting: Clinical examination suites at an osteopathic medical school.

Participants: Twenty-five healthy osteopathic medical school students, three faculty, and three staff.

Interventions: SR performed by osteopathic physicians trained in osteopathic neuromusculoskeletal medicine to treat somatic dysfunction.

Main Outcome Measures: HRV variables related to vagal tone, including root mean square of successive differences (RMSSD), percentage of successive normal sinus RR intervals more than 50ms (pNN50), high frequency (HF), Parasympathetic Index (PNSI), and Sympathetic Index (SNSI). Repeated measures t-test analyzed the differences in mean HRV values before and after OMT. Grubbs test was used to remove outliers using alpha=0.05 significance level.

Results: There were statistically significant increases in each of the HRV measures after OMT. Participants had a mean (95% confidence interval) RMSSD of 38.5ms (30.1, 46.8; n=30) at baseline and 49.5ms (38.1, 60.9; p=0.012) at post-OMT. pNN50 was 22.1% (14.1, 30.0; n=31) at baseline and 27.9% (19.5, 36.3; p=0.022) at post-OMT. HF was 754.5ms^2 (485.7, 1023.2; n=29) at baseline and 1227.4ms^2 (756.9, 1697.8; p=0.003) post-OMT. PNSI was -0.07 (-0.6, 0.5; n=3) at baseline and

0.4 (-0.2, 1.0; p=0.002) at post-OMT, and SNSI was 0.5 (-0.02, 1.0; n=31) at baseline and 0.08 (-0.4, 0.6; p=0.005) at post-OMT.

Conclusion: SR may provide clinical benefit through increased vagal tone and withdrawal of sympathetic activity. These effects need further investigation for clinical benefits in rehabilitation practices to reduce fatigue, burnout, and stress.

Keywords: Heart Rate Variability; Autonomic; Suboccipital Release; Vagus Nerve; Parasympathetic Nervous System

Introduction

In physical medicine and rehabilitation, fatigue can indirectly affect overall recovery by reducing compliance and confidence in the treatments and fostering negative emotions, leading to longer recovery times [1]. Chronic fatigue can be caused by persistent sympathetic activation (PSA) which is a consequence of reduced parasympathetic capacity [2]. Physiatrists' extensive experience in spinal cord and brain injury rehabilitation along with autonomic dysreflexia has led to a strong understanding of the connection between autonomic dysregulation, fatigue, and chronic disease processes [2]. Physicians who practice osteopathic manipulative treatment (OMT) may be able to improve rehabilitation treatments by addressing PSA. The target would be to reduce fatigue and improve recovery outcomes.

Focusing on the autonomic nervous system (ANS) may also play a direct role in rehabilitating individuals with impairments in motor activity and functions after ischemic stroke. Addressing ANS system is also important in the recovery of patients with post-concussion symptoms, long-COVID, and chronic pain cycles due to related pathologies [2-8]. Chronic stress and its two fundamental elements of threat and uncertainty activate the sympathetic nervous system, contributing to PSA [9, 10]. High--stress environments such as that of medical education and practice can stimulate the sympathetic nervous system (SNS) in medical students and educators. Such environments can serve as settings to investigate autonomic rehabilitation of conditions directly or indirectly related to the ANS [11-13]. Students in such high stress environments have exhibited symptoms of burnout, sleep disorders, depression, and suicidal ideation [14]. Currently not thoroughly explored, OMT may support being a practical addition to rehabilitation treatments by manually stimulating the vagus nerve to provide a reset and improvement in autonomic function.

OMT restores structure and function in the musculoskeletal system and is indicated for the treatment of somatic dysfunctions. Somatic dysfunctions are diagnosed based on the presence of at least two cardinal signs including tissue texture changes (vasodilation, edema, tissue contraction, itching, fibrosis, paresthesia, bogginess, ropiness, and hypertonicity), asymmetry (compare one anatomical landmark to another, left side/right side), restriction of motion, and subjective tenderness [15-17]. Stimulating the vagus nerve, which is the primary nerve of the parasympathetic nervous system (PNS), may be helpful in combatting PSA [18]. The vagus nerve is anatomically associated with the suboccipital region. Similar studies targeting structures in the suboccipital region, including the occipital-atlanto joint, resulted in increased parasympathetic activity. Electrical and manual HVLA stimulation to the occipital-atlanto joint was used to demonstrate this physical relationship [19]. OMT to the suboccipital region, particularly suboccipital release (SR), may allow a passive reset of the ANS to address PSA [2, 15]. SR is an OMT technique that is safe, gentle, and not high-velocity with low amplitude.

Heart rate variability (HRV) has been thoroughly studied to find its connection with cardiovascular, metabolic, and physiological health decline in the United States [2]. It is a direct measure of parasympathetic (PNS)/cardiovagal tone and an indirect metric of sympathetic tone (SNS). HRV describes the variation in the time interval between heartbeats and is associated with the body's ability to adapt to internal and external stressors to maintain homeostasis [18, 20]. An increase in the SNS activity leads to an increase in heart rate, and an increase in the PNS can result in a lower heart rate [21]. Increases in HRV have been associated with improved health outcomes, while decreases in HRV have been shown to be related to morbidity and mortality [22, 23]. HRV can also demonstrate regulation of emotions, stress, and resilience [24]. The study aims to characterize the effect of SR on parasympathetic/cardiovagal tone by using HRV as a potential adjunct treatment for rehabilitation. Our study is novel in quantifying the somatic dysfunction among the participants before OMT and then measuring whether it is resolved, improved, unchanged, or worse after OMT through a validated method. We hypothesize that SR would improve somatic dysfunctions by stimulating the PNS and increasing HRV measurements among medical students at an osteopathic medical school.

Materials and Methods

We used a within-subject, repeated measures design for this study. Such design accounts for individual differences and requires fewer participants with an increased statistical power and reduced bias [25]. A within-subject design rather than utilizing a control group was recommended in the literature due to predictable significant inter-individual variations and interactions that can impact HRV. This design also allows for greater statistical power since all participants receive OMT [26]. Lavazza et al. report that control groups should be avoided in single-technique performance studies and that true placebos in OMT studies are impossible to achieve [27]. A systematic review by Cerritelli et al. found high heterogeneity and a higher probability of unmatched groups in osteopathic studies that incorporated control groups, which could alter the impact estimation of OMT [28]. Additionally, controlling for diverse touch methods for control groups could confound the effects [29-31].

We followed a strict inclusion and exclusion criteria to recruit participants from the same medical school and prevent selection bias. The recruitment target was between 21-61 participants to ensure 80% power and a type 1 error of 5% to detect a large and medium effect size, respectfully [32]. The Cohen's guidelines to addressing effect sizes tend to underestimate for magnitude in small or large studies. Due to this reason, effect size distribution (ESD) was used that corresponded with effect sizes of 0.25, 0.5, and 0.9 to represent small, medium, and large effect sizes [32]. A prior power analysis using G*Power indicated that for a repeated measures study, assuming the effect size $f = 0.25$ [equivalent to Cohen's $d \approx 0.50$], alpha of 0.05, and a power of 0.80, a minimum of 34 participants would be required. Our final sample size of 31 therefore did not meet this threshold according to G*Power. Though not meeting the sample threshold for G*Power, it was met with the ESD that was recommended by the Quintana study for research regarding HRV [32]. Additionally, no faculty at the medical school were involved in any part of the study besides supervision for performing OMT correctly and safely. The inclusion criteria required participants to be medical students, faculty members, or staff at the medical school. The exclusion criteria included having self-reported chronic cardiovascular diseases (such as heart failure, myocardial infarction, or hypertension), diabetes, asthma, regular smoking, arrhythmias, or systolic blood pressure greater than 150 mmHg or less than 90 mmHg. Data collection took place in private examination suites at the osteopathic medical school. Somatic dysfunction assessments and treatments were conducted by second-year medical students supervised by the board-certified osteopathic physician, TF. Demographic data was obtained via Qualtrics survey and included participant sex, exercise, last consumption of meal/drink, smoking, and medication, among other information before the procedure. Additionally, participants' height, weight, and sleep duration were collected. The demographic information was based on Laborde et al. to assess any confounding variables with respect to ANS and remove potential outliers [25].

The study utilized the validated American Academy of Osteopathy's Louisa Burns Osteopathic Research Committee outpatient SOAP note to quantify somatic dysfunction at the cranial and cervical regions before and after performing OMT [33]. The cervical region was also assessed due to its proximity to the suboccipital region and because the muscles targeted by SR have attachments in the cervical region. Before OMT, characteristics were graded on a scale from 0-3 with 0 being no dysfunction present or background levels, 1 being more than background levels, 2 reflecting a prominent TART with or without symptoms, especially when considering restriction of motion and tenderness, and 3 reflecting key lesions, symptomatic, and restriction of motion and tenderness that stands out. After OMT, somatic dysfunction was reassessed and given a rating of resolved (R), improved (I), unchanged (U), or worsened (W) as compared to pre-OMT.

All participants received the SR treatment. The suboccipital release was performed with the participant in supine position. Bilateral finger pads of digits 2-5 were first placed in the suboccipital region with the practitioner at table's head. The suboccipital region is made of the area near the four major muscles that support the neck and help neck movement: the rectus capitis posterior major, obliquus capitis superior, rectus capitis posterior minor, and obliquus capitis inferior [34]. A constant, gentle force from posterior to anterior relative to the supine participant was applied to the area for 2 minutes as demonstrated in Figure 1. The pressure was then released, and the subject was returned to a neutral supine position. Before enrollment, participants were informed of the risk of post-OMT soreness, which, according to the authors' clinical experience with OMT, is generally considered the most common, low-impact risk. Studies analyzing the side effects of different OMT techniques have reported a low rate of 2.5% for overall incidence of adverse effects (n=1847), with pain or discomfort, similar to soreness, being the most frequently observed, occurring at a rate of 0.9%. SR is classified as a soft tissue technique based on muscle inhibition by direct pressure to the targeted area. SR OMT techniques have been shown to have similar effectiveness in improving somatic dysfunctions , with pain or discomfort as the most common reported adverse effect [35]. The authors note that although this is an osteopathic technique, it is not difficult for all practitioners, MD or DO, to perform and adapt into their practice.

Measurements began with an initial 3-minute adjustment period followed by a 5-minute baseline and a 5-minute post-treatment period based on established guidelines [36]. The 3-minute adjustment period minimizes potential anxiety and attention to respiration and heart rate before baseline readings [37]. Participants did not receive compensation beyond attempted improvement or resolution of somatic dysfunction in the suboccipital region. All procedures were performed during the same encounter to avoid repetition and altered response by the participant.

Figure 1: Hand placement with a participant (top) and skeleton (bottom) for SR.

We used FirstBeat Body Guard 3 electrocardiogram (ECG) devices and Kubios HRV software (version 4.0.2, Kuopio, Finland) to obtain HRV measurements for data analysis. Based on FirstBeat specifications, electrodes were placed on the anterior chest just inferior to the right collar bone and mid-clavicular line as well as over the left anterior ribs inferolateral to the cardiac point of maximal impulse. Specific HRV variables relevant to vagal tone were chosen based on published recommendations, which included root mean square of successive differences (RMSSD), percentage of successive normal sinus RR intervals more than 50 ms (pNN50), and high frequency (HF) [25]. HF represents parasympathetic tone filtered between 0.15 Hz and 0.4 Hz frequency bands [36, 38-40]. Confidence intervals were determined using a t score for variables with a sample size less than 30 and a z score for variables with a sample size greater than 30. For statistical analysis, a paired two-sample t-test was used with a 95%

confidence interval (α = 0.05). Grubbs test was used to remove outliers at a significance level of 0.05.

Results

In total, 45 participants, including faculty, staff, and students from an osteopathic medical school were recruited for this study. Removal of participants due to exclusion criteria resulted in the final study sample size of 31 participants. In total, 12 of the participants were male and 19 were female. The age of the recruited participants ranged between 21 and 63 years old.

Table 1: Demographic information reported by the study participants

Participant activity involvement (n)	Yes (%)	No (%)
Vigorous exercise* over the past 24 hours (n=31)	9 (29%)	22 (71%)
Food consumption over the past 2 hours (n=31)	22 (71%)	9 (29%)
Caffeine intake over the past 2 hours (n=31)	14 (45%)	17 (55%)
Alcohol consumption over the past 24 hours (n=31)	1 (3%)	30 (97%)
Tobacco smoking** (n=31)	0 (0%)	31 (100%)
Oral contraceptive use (n=19)	3 (16%)	16 (84%)
Depression/anxiety (n=31)	8 (25%)	23 (75%)
Current urge to void bladder (n=31)	0 (0%)	100 (100%)

Values represent the number of participants who answered "yes" or "no" to each demographic characteristic. All other data points were removed due to exclusionary criteria or being an outlier. *Vigorous activity is defined as activity done with a large amount of effort, resulting in a substantially higher heart rate and rapid breathing. ** Refers to smoking tobacco in general, but not including within the last 2 hours.

Participants who received SR showed statistically significant improvements from baseline values in RMSSD, pNN50, and HF. All data points for somatic dysfunction either improved or remained unchanged. No participant experienced a worsening of somatic dysfunction. Data regarding somatic dysfunction characterizations are shown in Figures 3 and 4. The reduction of somatic dysfunction by using SR did not differ by the initial severity, as noted in Supplemental Tables S1 and S2.

Table 2: HRV values related to parasympathetic tone (RMSSD, pNN50, and HF before and after SR technique. Data represents numbers after outliers had been removed.

	Pre-Intervention Mean Values (95% confidence interval)	Post-Intervention Values (95% confidence interval)	p-value from paired t-test	Sample Size
RMSSD (ms)	38.5 (30.1, 46.8)	49.5 (38.1, 60.9)	0.01	30
pNN50 (%)	22.06 (14.1, 30.0)	27.91 (19.5, 36.3)	0.02	31
HF (ms^2)	754.5 (485.7, 1023.2)	1227.4 (756.9, 1697.8)	0.002	29

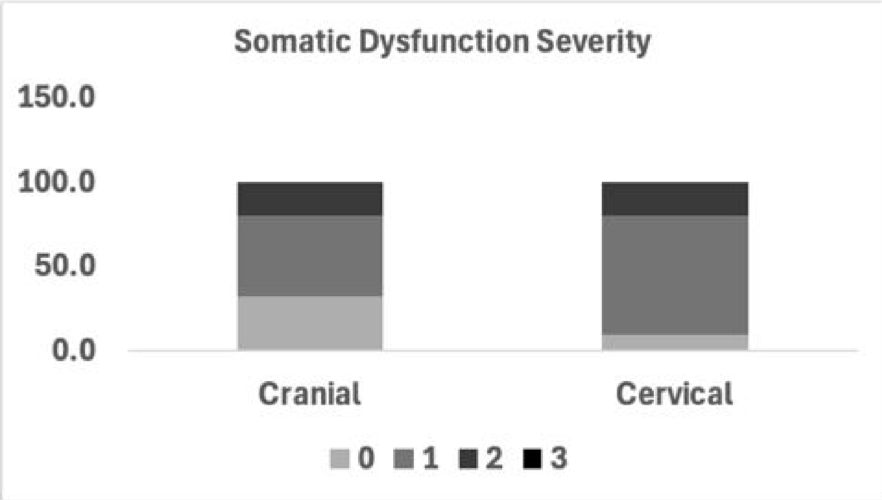

Figure 2: The proportion of participants with initial somatic dysfunction were assessed under the supervision of TF for cranial and cervical regions. Characteristics were graded on a scale from 0-3 with 0 being no dysfunction present or background levels, 1 being more than background levels, 2 reflecting a prominent TART with or without symptoms, especially when considering restriction of motion and tenderness, and 3 meaning key lesions, symptomatic, and restriction of motion and tenderness that stands out.

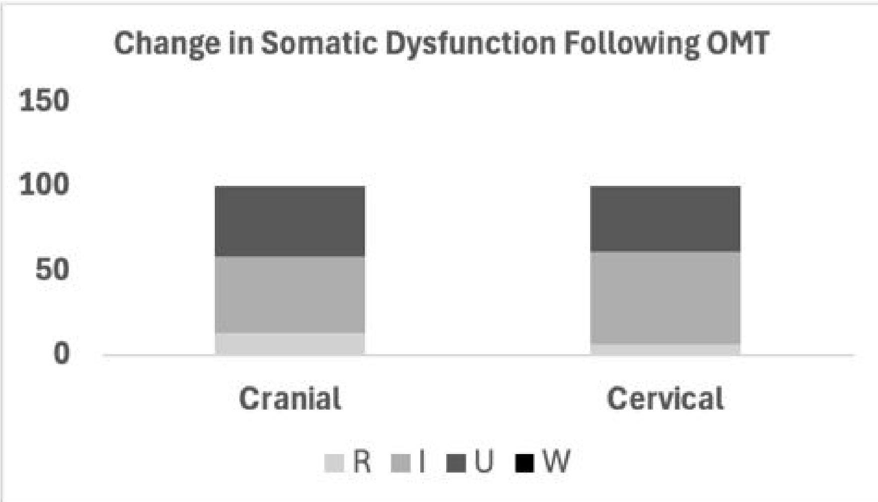

Figure 3: The proportion of participants' responses to treatment of suboccipital release was assessed under the supervision of TF. OMT somatic dysfunction was reassessed and given a rating of resolved (R), improved (I), unchanged (U), or worsened (W) as compared to pre-OMT.

Discussion

SR technique showed statistically significant ($p<0.05$) changes in RMSSD, pNN50, and HF compared to their baseline readings. Other studies focusing on musculoskeletal structures associated with the vagus nerve, such as the occipitomastoid suture and upper cervical spine, and employing single, targeted osteopathic manipulative techniques with comparable experimental designs and HRV measurements, yielded results that were less significant and profound compared to those observed with SR [41, 42]. Interestingly, despite a significant increase in all HRV variables, a proportion of participants did not show any change in somatic dysfunction assessed post-OMT. This lack of change may suggest that SR improves parasympathetic tone by directly stimulating the vagus nerve and that somatic dysfunction might not play a significant role. This phenomenon may be specific to SR, as other studies have shown that OMT techniques like post-isometric muscle energy to the upper cervical spine, which are repeatedly reassessed until somatic dysfunction improves, are associated with improvement in somatic dysfunction with a significant increase in HRV variables, except HF [41]. In contrast, for this study, SR was only performed once for 2 minutes regardless of reassessment results but had significantly enhanced RMSSD, pNN50, and HF. It is unclear whether this is technique-specific or whether somatic dysfunction plays a role. Another study by Vismara et al. (2022) single-center cross-sectional study (n=69) evaluated the functional correlation of somatic dysfunction with HRV using a multivariate linear model and showed a linear relationship between somatic dysfunction and HF [43]. Thus, regardless of whether somatic dysfunction is present, this OMT technique could increase parasympathetic tone and improve outcomes in rehabilitation settings.

OMT has been seen to benefit HRV and participants' health outcomes. OMT techniques have been shown to influence the ANS and decrease morbidity and mortality by addressing musculoskeletal abnormalities related to inflammation and sympathetic tone [21]. Other cranial OMT techniques have shown similar improvements in vagal tone measured using HRV. Besson et al. (2023) (n=30) compared a balanced membranous OMT technique, specifically occipitomastoid suture normalization, to a placebo control, revealing significant improvements in RMSSD and pNN50 and an improvement in HF that was not statistically significant [44]. Miller et al. (n=30) completed a similar within-subject design for a modified occipitomastoid suture v-spread technique based on balanced ligamentous/balanced membranous tension and had the same general results [42]. A study in high--stress firefighter cadets (n=57) discovered increased HF post cranial OMT that was insignificant after exposure to minor and major stressors [45]. Other studies by Shi et al. (n=21) and Giles et al. (n=19) exhibited enhanced HF after performing cranial OMT. Giles et al. used suboccipital decompression, similar to suboccipital release in this study [46, 47]. Bayo-Tallón et al. (n=50) displayed increased HF and RMSSD in healthy children after manual cranial therapy sequences [48].

Support of HRV's effect on health outcomes are also shown in studies as the vagus nerve influences the body's baseline regulatory status as well as response to stressors [18,21]. Examples include sports recovery and overtraining, combating proinflammatory mediators, regulating systolic blood pressure, and the hypothalamic-pituitary-adrenal axis (HPA axis). SR is a technique that can be taught without major difficulties and may provide a preventative or additional strategy in combating negative health effects of stressful events and chronic health conditions [21]. This is further backed by the observed effects in the frequency ranges (HF, LF, VLF, and ULF) and its connection to processes of the body. The HF band (respiratory band) is representative of the respiratory changes to heart rate and cardiovascular health as deficient vagal inhibition is implicated in increased morbidity. The VLF band has associations with all-cause mortality and has been seen in arrythmias, PTSD, and proinflammatory states. LF and ULF also has involvement of baroreceptor activity and renin-angiotensin system, respectively [18]. As SR is shown to have positive effects on HRV in our study, the frequency bands and its related effects may show improvement to overall patient health with long term treatment.

Current studies on the effectiveness of OMT on ANS show promising implications for future treatments. Future studies investigating more direct impact on patients with disorders related to the ANS, including long COVID, postural orthostatic tachycardia syndrome, and autonomic dysreflexia are needed. Additionally, future directions using OMT directly in the rehabilitation setting to combat fatigue, burnout, and negative perceptions and how it impacts outcomes and speed of recovery are warranted.

Limitations

The main limitation of our study is the short-term measurement of study outcomes. More data on the long-term impact on HRV to identify the length of effect of the treatment is warranted. This study also has a small sample size that can only detect a large effect size with sufficient power. Based on published statistics on medical students and faculty, the study assumes stress levels and autonomic imbalance and did not directly measure stress using a validated metric during enrollment [11-13]. The study was performed at an osteopathic medical school where participants are more educated and possibly supportive of OMT as a treatment practice compared to those at allopathic medical schools or other disciplines where OMT is unknown as a modality. Additionally, more substantial investigation of the effects of SR on HRV may be found with a randomized controlled trial (RCT) if potential sham procedure method is found. Absence of a placebo may raise concerns through lack of a control group, a reasonable point of question in study design. To address the concern, Lavazza et al. describes difficulties of using a placebo in a trial for manual therapies due to physical touch providing possible benefit on health itself. The opposite has also been observed in studies in which participants drop out of the control group due to physical touch and its potential adverse effects on the participant. Due to the variable responses, a true placebo has not been found at this current time for manual therapy [27]. Though difficult to create an environment for a true shame treatment for a control group, other methods such as replacing human touch with objects such as books or blocks may provide avenues to tackle this concern. Despite its limitations, this study provides early evidence of the efficacy of the SR technique on autonomous vagus tone in individuals with somatic dysfunction. The study strengths include a within-subject design based on standardized, repeated measures design performed by experienced, well-qualified interventionists who are experts in the field of OMT. This study also utilizes ECG, considered the gold standard for HRV metrics, at the level of the heart to measure vagal tone as compared to PPG measured at a further distance from the heart.

Conclusion

This study applied a suboccipital release OMT technique on medical school students, faculty, and staff in a high-stress environment. It demonstrated a safe technique with significant statistical increases in HRV variables related to vagal tone. These benefits could be of noteworthy clinical value adjunctively in rehabilitation practices to reduce fatigue, burnout, and negative emotions. There may be enhanced significance for those with disorders of dysautonomia. Future research is needed, especially concerning persistent sympathetic activation and its relationship to inflammation and metabolic rigidity in a larger group of individuals in high-stress environments.

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