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The effectiveness of an osteopathic manual technique compared with a breathing exercise on vagal tone as indicated by heart rate variability, a crossover study

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ABSTRACT

Introduction: Parasympathetic nervous system (PSNS) function can be inferred by heart rate variability (HRV) providing indications about an individual's health. Manual therapy may influence PSNS function, however the research outcomes in this regard are equivocal. This study explored the PSNS effect of a measured breathing technique with suboccipital balanced ligamentous tension, an osteopathic manipulative therapy technique. *Methods*: Healthy adult participants in this crossover study ($n = 18$) were randomly allocated into two groups with differing order of interventions. A 1:1 breathing rate of 6 breaths per minute maintained for 5 min was compared to the osteopathic intervention. HRV was measured for 5 min before and after each intervention and analysed using the root mean square of successive differences (RMSSD) between normal heartbeats and high frequency normalised units (HFnu). *Results:* The RMSSD data demonstrated no significant difference between groups or within groups ($p > 0.05$) over time. HFnu results showed a significant between-group difference over the four time points ($p = 0.004$) with a medium effect size ($\eta p^2 = 0.240$), and no significant within-group difference ($p > 0.05$). *Discussion:* The osteopathic intervention raised HRV to a small extent, however measured breathing lowered HRV. In the group that received the osteopathic technique first, HFnu values continued to rise post-osteopathic treatment possibly indicating an increasing parasympathetic effect over time. Recommendations for future studies include changing the breathing ratio to ensure parasympathetic response, take into account potential delayed effects of interventions, consider outcome measures less variable than HRV, and longer follow up times. *Conclusion*: This study suggests parasympathetic stimulation may occur with the application of suboccipital balanced ligamentous tension and sympathetic stimulation from measured breathing.

1. Introduction

Autonomic nervous system (ANS) balance is an indicator of health intrinsically related to human adaptive ability. With stress, anxiety or fear, the sympathetic nervous system (SNS) dominates, and parasympathetic nervous system (PSNS) functions such as digestion and repair are inhibited (Freeman and Chapleau 2013). PSNS function is reflected by cardiac vagal tone, the mean effect of the cardiac branch of the vagal nerve on heart rate (Grossman and Taylor 2007). Cardiac vagal tone may be indicated by the cardiac beat-to-beat interval changes, referred to as heart rate variability (HRV) (Shaffer et al., 2014). HRV is considered a reasonable measure despite being influenced by multi-factorial and interdependent extrinsic factors (Fatisson et al., 2016). Respiratory sinus arrhythmia (RSA) and high frequency (HF) are the specific elements of HRV that are reported to indicate PSNS function (Shaffer et al., 2014; Freeman and Chapleau 2013).

High HRV is reportedly related to higher resilience, better emotional regulation and cognitive performance (Blase and Waning 2019; Shaffer et al., 2014). Conversely, low HRV is associated with increased risk of mortality (Shaffer et al., 2014; Thayer et al., 2011) and is a predictor of disease including cardiovascular disease, anxiety, depression and chronic pain (Koenig et al., 2016; Shaffer et al., 2014).

During inhalation, heart rate increases due to the cardiac reflex activating sympathetic afferents, the cardiovascular centre inhibiting vagal outflow, and the lung inflation reflex (Freeman and Chapleau 2013; Porges 2007; Shaffer et al., 2014). Slow, measured breathing has been shown under experimental conditions to increase levels of beneficial carbon dioxide which causes vasodilation, activation of the PSNS and increased HRV (Deadman 2018; Larson et al., 2020). Conversely, rapid shallow breathing reportedly lowers HRV (Grossman and Taylor 2007). A breathing rate of six breaths per minute (BPM) has been found to maximise HRV amplitude and acetylcholine release which optimises RSA (Russo et al., 2017).

Preliminary research suggests that osteopathic manipulative therapy (OMT) may affect the autonomic nervous system (Cerritelli et al., 2020), with myofascial release (MFR), balanced ligamentous tension (BLT) and cranial techniques reported to increase HRV (Seifert et al., 2018; Curi et al., 2018; Ruffini et al., 2015). The pressure of touch may raise HF

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(Diego and Field 2009). Manual therapy applied to the upper cervical region, particularly manipulation, has been reported to increase PSNS activity (Win et al., 2015).

Manual therapy applied to the suboccipital region, especially suboccipital decompression (SD), a manual therapy technique, is considered to influence the efferent fibres of the vagus nerve exiting the cranium through the jugular foramen (Giles et al., 2013; Cuoco et al., 2016; Stauss et al., 2020). SD focuses on treating articular compression between the occiput and atlas with stretching and traction, aiming to reduce muscular or articular impingement upon the vagus nerve (Giles et al., 2013). Balanced ligamentous tension (BLT), another osteopathic manual therapy technique that aims to take tissues into a position of relaxation, is also reported to influence the vagus nerve within the suboccipital region by creating less tension within the surrounding musculoskeletal structures (Tozzi 2018). The proposed mechanism is reported as an activation of ligament mechanoreceptors and a lowering of sympathetic drive, while enhancing anatomical function and reducing nerve impingement (Tozzi 2018).

The current study aimed to compare the separate and cumulative effect of measured breathing (MB) and suboccipital BLT (SBLT) on HRV. No known studies have compared the efficacy of MB vs decompression of the suboccipital region on the ANS.

2. Methods

2.1. Participants

Inclusion criteria was healthy adults between the ages of 18 and 70 years. They were recruited via email, flyer and social media, provided with a participant information sheet and screened via a phone call. Ethics approval was obtained from the University (xx).

Exclusion criteria included current pregnancy, smokers, or recreational drug users. Chronic conditions including previous or current trauma to the neck, chronic pain, chronic mental illness such as depression and anxiety, diabetes, cardiovascular disease and pulmonary disease were excluded, as these have all been shown to affect HRV data (Chinthakanan et al., 2018; Freeman and Chapleau 2013; Koenig et al., 2016; Mulkey and du Plessis 2019; Shaffer et al., 2014). Those who agreed to participate were instructed not to consume alcohol, caffeine or recreational drugs in the morning and night prior to the procedure and to abstain from exercise the morning of the procedure given its influence on HRV measurements (Brock et al., 2017; Shaffer and Ginsberg 2017).

3. Materials

Heart rate variability was measured by a 3-lead Power Lab 5 ECG monitor with data recorded and analysed using LabChart 5 software. The sample rate used in this study was 300–1000 Hz, ensuring sufficient data quality (Freeman and Chapleau 2013; Shaffer et al., 2014).

3.1. Procedure

The study utilised a randomised, cross-over design. The study protocol involved a single practitioner, a postgraduate osteopathic student, performing all interventions. Each data recording and intervention session was performed in the morning for consistency across the participants (Vila et al., 2019). Based upon results from an initial pilot study using the stretching and traction SD technique ($n = 8$), which the researchers noticed lowered HRV levels, the SBLT method was instituted as the OMT intervention for the main data collection ($n = 18$). The SBLT was performed for 3 min and MB for 5 min with 5-min ECG recordings taken pre- and post-intervention. There was a 5-min rest before the first recording and the third ECG recording. Participants were randomly allocated via computer algorithm into two groups with differing intervention order by a blinded researcher – group 1 received the SBLT first followed by the MB, whereas Group 2 received the MB followed by the SBLT.

Consistent with previous research (Freeman and Chapleau 2013), patients were placed in a supine position with ECG leads attached slightly medial and inferior to the coracoid process on the left and right, and at the left sixth intercostal space in the midclavicular line. Five-minute ECG recordings were taken in accordance with the literature to provide consistency in data collection methods (Brock et al., 2017, Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996; Vila et al., 2019).

3.2. Breathing intervention

A 1:1 breathing rate of 6 BPM was utilised (Russo et al., 2017; Lin et al., 2014). Participants were instructed to breathe diaphragmatically and with minimal strain. The technique was built up in stages, starting with a simple diaphragmatic breath and then adding a count increasing from 3 to 4 and then to 5 s for both the inhale and exhale. This staged introduction took 1–2 min. Once this breathing pattern was established participants were instructed to continue in an easeful way until told to stop and return to their normal breathing pattern.

3.3. Suboccipital intervention

The SBLT was performed with each participant supine and the practitioner at the head of the table. The practitioner contacted the participant's suboccipital musculature. The practitioner positioned the musculature into multiple planes of reduced tension (flexion, extension, side-bending, rotation, compression or traction) (Tozzi 2018), and held that multiplane position for 3 min.

3.4. Analysis of recordings

To analyse the ECG data ($n = 18$) two common HRV measures were chosen. RMSSD (root mean squared of successive differences between normal heartbeats) is a measure in the time domain and is commonly used in the literature to assess RSA, especially in short recordings (Shaffer et al., 2014; Koenig et al., 2016). High Frequency (HF), 0.15–0.4 Hz, is the frequency linked to parasympathetic activation specifically, as it influences the sinoatrial node of the heart. HFnu is a measurement in the frequency domain and is a way of measuring relative power of the HF values of the data expressed in normalised units. It is especially useful in allowing comparisons between people with varied total power measures (Shaffer and Ginsberg 2017), which was the case with the data collected in this study. Data were analysed by a blinded researcher using descriptive and inferential statistics with effect size calculations where appropriate. Alpha was set as $p > 0.05$.

4. Results

Twenty healthy adults who initially met the screening criteria were recruited, aged from 21 to 59 and evenly split between sexes. Two participants were subsequently excluded – one due to failure to complete the trial and another due to late reporting of a chronic respiratory condition. Group 1 (SBLT-MB) ($n = 9$) received the SBLT followed by MB interventions, and Group 2 (MB-SBLT) ($n = 9$) received MB followed by SBLT. The age range in Group 1 (SBLT-MB) was 28–54 years, with a mean age of 36.9 ($\pm$ 6.3) years, and with a mix of 44.4% female ($n = 4$) and 55.6% male ($n = 5$). The age range in Group 2 (MB-SBLT) was 21–59 years, with a mean age of 34.4 ($\pm$ 11.3) years and with a mix of 66.6% ($n = 6$) female and 33.4% ($n = 3$) males. The groups were not statistically different in terms of age ($p = 0.583$) or sex ($p = 0.343$). Descriptive statistics for the two HRV measurement parameters, RMSSD and HFnu, are described in Table 1.

HFnu results showed a significant between-group difference over the 4 time points ($p = 0.004$) with a medium effect size (Partial Eta squared

Table 1
Mean (SD) of HRV values for the two groups.

Data analysis	Group 1 (SBLT-MB; n = 9)		Group 2 (MB-SBLT; n = 9)	
	RMSSD	HFnu	RMSSD	Hfnu
Pre-intervention 1	66.257 (86.808)	41.872 (23.324)	56.077 (45.101)	51.344 (26.777)
Post-intervention 1	75.896 (81.259)	41.996 (25.454)	48.357 (36.691)	37.921 (25.596)
Pre-intervention 2	80.976 (94.045)	47.970 (18.875)	51.747 (37.865)	42.926 (25.060)
Post-intervention 2	56.784 (53.844)	36.192 (26.793)	54.656 (39.463)	51.807 (26.106)

The RMSSD data violated the ANOVA sphericity assumption (Mauchly's Test of Sphericity, p = 0.001). A repeated-measures ANOVA with Greenhouse-Geiser correction demonstrated no significant difference between groups over time (p = 0.058), nor within group difference over time (p = 0.563). A graph of the RMSSD values is shown below in Fig. 1, comparing the estimated marginal means of the 4 measurements for the two groups.

= 0.240) (Fig. 2). There was no significant within group difference observed (p = 0.722).

5. Discussion

The current study sought to compare a directed breathing intervention (MB) with an osteopathic technique (SBLT) that were both reported to affect the PSNS (Larson et al., 2020; Tozzi 2018). Two HRV measures widely used in the literature were calculated to provide an indication as to PSNS function in the current work. The current work suggests using a cross-over design is limited with respect to PSNS function in otherwise healthy participants, due to each technique's ongoing influence regardless of the order in which they are applied.

Overall trends were increasing HRV after SBLT and decreasing HRV after MB. The crossover design was chosen in anticipation that both would rise, however the interaction between opposing forces made the results difficult to interpret due to potential delayed effect. The RMSSD trend varied depending upon the order of intervention, and the data had large standard deviation due to physiological differences between participants. Larson et al. (2020) found increases in time domain values from a 6bpm breathing ratio. However, the RMSSD values in the current work decreased after the breathing intervention, albeit the within-group differences were not statistically significant. The aim of the SBLT included releasing nerve entrapment and balancing the ANS, and was expected to increase HRV (Tozzi 2018; Ruffini et al., 2015). In this study SBLT raised RMSSD to a small extent, possibly continuing to increase over time and MB lowered RMSSD slightly in general, markedly after prior administration of the SBLT had raised the values. The SBLT-MB

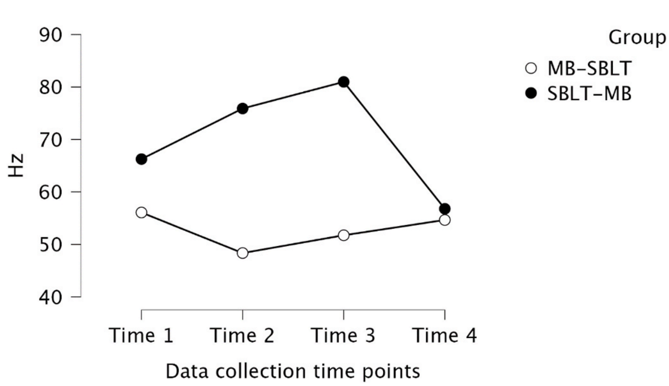

Fig. 1. Mean RMSSD measurements between Group 1 (SBLT-MB, black dots) and Group 2 (MB-SBLT, white dots) across the four data collection points, ECG recordings taken pre and post each intervention, interventions given between times 1 and 2 and between times 3 and 4.

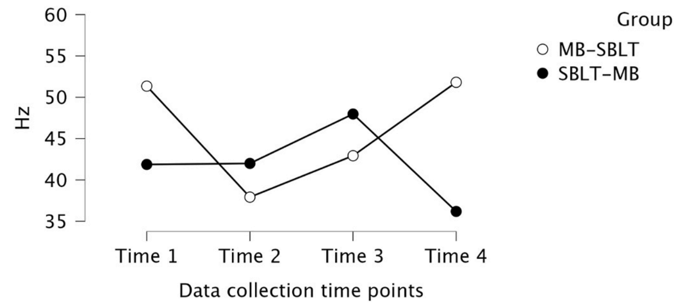

Fig. 2. Mean HFnu measurements between Group 1 (SBLT-MB) and Group 2 (MB-SBLT) across the four data collection points, ECG recordings taken pre and post each intervention, interventions given between times 1 and 2 and between times 3 and 4.

group demonstrated a rise in RMSSD values after the SBLT, and continued to rise after the post-intervention recording, but the RMSSD value returned to below baseline after MB. This outcome suggests that SBLT had a PSNS influence but the SNS influence of the subsequent MB lowered the raised values. The MB-SBLT group demonstrated a slight reduction in the RMSSD value after MB and showed a small increase after the SBLT. This outcome suggests that SBLT performed following MB corrected the SNS influence of the MB. Both groups returned to around baseline at the completion of the two techniques suggesting that the interventions may only exhibit a short-term impact on HRV or that they have opposing actions.

The HFnu is a frequency measure measuring relative power reported to indicate PSNS influence, as it is eliminated with vagal blockade (Shaffer et al., 2014). Larson et al. (2020) found an increase in HF values with all breathing techniques, and Ruffini et al. (2015) also found raised HF after OMT. This study found a consistent downward effect on HFnu values for both groups after MB. In contrast, post-SBLT measurement showed increased HFnu values in the MB-SBLT group, returning to baseline by the conclusion of the trial. However, in the SBLT-MB group it took an additional 5 min from post intervention recording to show an upward trajectory in HFnu values. This continued rise post-SBLT treatment may indicate the SBLT effect increases over time, or alternative factors such as resting supine for longer. There was no change in HRV between sexes, contradicting previous studies that showed lower HRV in middle aged males (Huang et al., 2013; Voss et al., 2015).

Overall, the results of the current study would suggest that MB lowers HRV, contrary to the literature (Russo et al., 2017; Deadman 2018). This decrease in HRV may be the result of participants in the current study experiencing uncertainty or strain while performing the breathing technique, contributing to sympathetic activation (and affected HRV). Control of the breath may cause stress, increase SNS tone and lower HRV without emphasis on a given rate due to induced mental effort (Gerritsen and Band 2018; Sasaki and Maruyama 2014). There is little consensus on how to instruct MB, however most studies use either training, device -guided visual aids (Sasaki and Maruyama 2014; Tsai et al., 2015; Kromenacker et al., 2018) and this study relied on verbal instruction. It would therefore be advisable for future studies to include visual and/or device-guided aids to assist with facilitating breathing exercises to reduce mental stress.

Other strategies that may assist with MB include further training time and addressing the breathing rate. Training times for MB cited in the literature were highly variable from 6 min in duration (Russell et al., 2017), to 15 days of training (Pal and Velkumary, 2004). Adjusting the breathing ratio may also be indicated. Several studies found comparable HRV values at 6 BPM with both 1:2 and 1:1 inhale/exhale ratios (Shaffer and Ginsberg 2017), and the addition of a post-exhalation rest period at 6 BPM improved HF/HRV (Russell et al., 2017). Therefore, a longer exhale or shorter breath pattern with a rest may have made the technique more comfortable for participants. It is possible that with these alterations MB may have a more positive effect on HRV.

Limitations include the large variance between individual results due to the physiological nature of the measurements, resulting in large standard deviations. External influences on HRV may be difficult to control despite attempting to minimise HRV extrinsic factors via exclusion and abstention from known influencing factors. Larger group sizes may provide more consistent results for future studies. Varying stress levels between participants could also affect results as high initial stress levels may have led to greater increases in HRV. HRV is one measure of PSNS and future research should look at multiple measures, including HRV. The cross-over methodology proved problematic due to the potential delay in effect of the interventions and their opposing effects, however the results provide some good directions for future research, for example exploring just one of the techniques at a time.

Results showed that SBLT appeared to increase in effectiveness over time, therefore a delayed therapeutic effect should be considered, especially within a cross-over design. It may be advisable for future research to explore medium to large analysis times, as well as exploring 24-h follow up times.

5.1. Implications for osteopathic practice

SBLT may be useful for eliciting parasympathetic change, however the changes seen in this study were mild and need to be explored further in singular intervention repeated measures research or in medium-term cross-over in randomised control trials. Breathing techniques in practice should be adapted to the individual's capacity to ensure that they encourage a parasympathetic effect.

6. Conclusion

The current study suggests that a minimal change in HRV can be achieved through the application of an SBLT and MB. Regardless of the order of applications, HRV returned to baseline over the short term. Overall trends were increasing HRV after SBLT and decreasing HRV after MB. Additional research is required to understand if the SBLT applied in isolation would result in longer lasting effects on HRV, compared to applying the technique alongside MB. Participant stress and mental effort when performing breathing exercises should be considered in future study designs, and participant comfort should be optimised for effectiveness of the breathing technique.

CRediT authorship contribution statement

Marian Cavanagh: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. **Taylor Cope:** Conceptualization, Investigation, Writing – original draft. **Dylan Smith:** Conceptualization, Data curation, Investigation, Writing – original draft. **Inez Tolley:** Conceptualization, Investigation, Project administration, Writing – original draft. **Paul Orrock:** Methodology, Supervision, Writing – review & editing. **Brett Vaughan:** Formal analysis, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

All authors declare that there is not conflict of interest.

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