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Heart Rate Variability to Assess the Changes in Autonomic Nervous System Function Associated With Vertebral Subluxation

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Review Article

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ABSTRACT

Analysis of the beat-to-beat intervals of the heart may be used to evaluate the balance between the sympathetic and parasympathetic divisions of the autonomic nervous system. Variability in heart rate reflects the vagal and sympathetic function of the autonomic nervous system, and has been used as a monitoring tool in clinical conditions characterized by altered autonomic nervous system activity. Spectral analysis of beat-to-beat variability is a simple, non-invasive technique to evaluate autonomic dysfunction.

Vertebral subluxations are changes in the position or motion of a vertebra which result in the interference with nerve function. Vertebral subluxations may result in altered autonomic nervous system activity. Heart rate variability is a reliable and valid tool that may be used to assess the changes in autonomic activity associated with the reduction and correction of vertebral subluxations. A search of the relevant literature addressing heart rate variability and the reduction or correction of vertebral subluxation from 2000 to 2017 was conducted, and the results summarized.

INTRODUCTION

Heart Rate Variability (HRV) is measurement of the time intervals between adjacent heartbeats [1]. Variability in heart rate reflects the vagal and sympathetic function of the autonomic nervous system, and has been used as a monitoring tool for clinical conditions characterized by altered autonomic nervous system function [2]. Spectral analysis of beat to beat variability is a simple, noninvasive technique to evaluate autonomic dysfunction [3]. Normative data on heart rate variability have been collected [4-7].

CLINICAL SIGNIFICANCE

Alterations in HRV have been observed in a variety of clinical conditions. Early studies reported that HRV may be useful in the assessment of diabetic neuropathy and to predict the risk of arrhythmic events following myocardial infarction [3]. The technique has also been used to investigate autonomic changes associated with physical exercise [8], anorexia nervosa [9], brain infarction [10], angina [11], and panic disorder [12].

HRV appears to hold promise for assessing overall fitness. Gallagher et al. [13] compared age matched groups with different lifestyles. These were smokers, sedentary persons, and aerobically fit individuals. The authors found that smoking and a sedentary lifestyle reduces vagal tone, whereas enhanced aerobic fitness increases vagal tone. Dixon et al. [14] reported that endurance training modifies heart rate control through neurocardiac mechanisms. In occupational health, the effects of various stresses of the work environment of heart patients and asymptomatic workers may be evaluated using heart rate variability analysis [15].

Recent studies have reported the potential utility of HRV in the evaluation of conditions and states associated with autonomic dysregulation. These include carotid intima media thickness [16], prediction of mortality [4], multiple sclerosis [17,18], eating behavior [19], burnout and depression [20], chronic posttraumatic stress disorder [21], working memory performance [22], dementia [23], inflammation in rheumatoid arthritis [24], insulin resistance and metabolic syndrome [25], type 1 diabetes [26], cardiac autonomic nerve function in obese school-age children [27], cancer prognosis [28,29] and cognition [30,31].

HEART RATE VARIABILITY MEASUREMENT

Heart rate variability data may be collected using an electrocardiogram or plethysmograph. The time between inter-beat intervals is measured. Standards of measurement, physiological interpretation, and clinical use have been established [32]. Analysis of heart rate variability data includes time domain, frequency domain, sample entropy, and proprietary methods.

Calculations are done on both the 'time domain' of the inter-beat interval (IBI) and heart rate, and on the 'frequency domain'. Frequency analysis is done via sophisticated mathematical calculations such as Fast Fourier Transforms (FFTs), which analyze the variability of the IBI/heart rate by looking at its frequency. Comparing low frequency to high frequency results show the level of sympathetic vs. parasympathetic activity in the autonomic nervous system.

The measurements used, and their significance, are as follows [1]:

Time Domain

- Time domain analysis is used to assess autonomic nervous system activity.
- Mean IBI. The mean interval between heartbeats averaged on the entire recording. Measured in milliseconds.
- Mean BPM. The mean heart rate value averaged on the entire recording.
- Standard Deviation of IBI, also known as the SDNN, is the standard deviation of the interbeat intervals, measured in milliseconds.
- Root Mean Square Standard Deviation IBI (RMSSD) is the root mean square of successive differences between normal heartbeats. RMSSD estimates the vagally-mediated (parasympathetic) changes in HRV. It is measured in milliseconds.

Frequency Domain

- Frequency Domain measurements are used to evaluate autonomic nervous system balance.
- Total Power reflects overall autonomic activity, measured in milliseconds squared.
- Very Low Frequency (VLF), Low Frequency (LF) and High Frequency (HF) are measured in milliseconds squared.
- Normalized LF and Normalized HF are calculated in percentile units.
- LF/HF Ratio is the ratio between Low Frequency and High Frequency bands.

Other methods of HRV analysis include sample entropy, which gives an estimate of nonlinear signal complexes the in cardiac time series and can give information beyond linear high-frequency heart rate variability [33]. The Institute of Heart Math has developed a coherence model which employs proprietary software.

VERTEBRAL SUBLUXATION—HISTORY AND PROPOSED MECHANISMS

The author previously reviewed clinical models of vertebral subluxation [34]. The term subluxation has a long history in the healing arts literature. According to Haldeman [35] it was used at the time of Hippocrates [36], while the earliest English definition is attributed to Randall Holme in 1688. Holme [37] defined subluxation as "a dislocation or putting out of joint". The possible neurological consequences of subluxation were described by Harrison in 1821, as quoted by Terrett [38]. "When any of the vertebrae become displaced or too prominent, the patient experiences inconvenience from a local derangement in the nerves of the part".

In 1906, DD Palmer and BJ Palmer [39] defined subluxation as follows: "A (sub)luxation of a joint, to a chiropractor, means pressure on nerves, abnormal functions creating a lesion in some portion of the body, either in its action, or makeup". Lantz [40] noted, "Common to all concepts of subluxation are some form of kinesiologic dysfunction and some form of neurologic involvement".

Mechanical and degenerative changes associated with vertebral subluxation may result in a variety of neurological consequences:

1. Cord compression: Compression of the spinal cord may result from disc protrusion, ligamentum flavum hypertrophy/corrugation, or osteophytosis. Myelopathy may result in cord pressure and/or pressure which interfere with the arterial supply [41-44].

2. Nerve root compression: Compromise of the nerve roots may develop following disc protrusion or osteophytosis [45].

3. Local irritation: This includes irritation of mechanoreceptive and nociceptive fibers within the intervertebral motion segments.

4. Vertebral artery compromise: MacNab advises that osteophytes may cause vertebral artery compression [44].

5. Autonomic dysfunction: Symptoms associated with the autonomic nervous system have been reported in patients with cervical spine trauma. The Barre'-Lieou syndrome includes blurred vision, tinnitus, vertigo, temporary deafness, and shoulder

pain. This phenomenon is also known as the posterior cervical syndrome [46]. Stimulation of sympathetic nerves has been implicated in the pathogenesis of this syndrome [47].

OPERATIONAL MODELS OF VERTEBRAL SUBLUXATION

An operational definition is a description of the procedures used to determine the means for measuring or observing something [48]. Smith et al. stated, “The potential exists for subluxation resolution to be conceptualized as a legitimate intermediate health outcome, pending the development of a sufficient and requisite body of scientifically derived clinical evidence [49]. This body of evidence must, by necessity, include (1) scientifically valid and reliable measures of subluxation, in order to (2) scientifically examine the relationship between a patient’s subluxation and that patient’s health”.

The author has proposed an operational model for the assessment of neurological dysregulation associated with vertebral subluxation [50]. The four components of this model include:

1. Dysafferentation: The intervertebral motion segment is richly endowed with nociceptive and mechanoreceptive structures [51-56]. As a consequence, biomechanical dysfunction caused by vertebral subluxation may result in altered nociception and/or mechanoreception.

2. Dyskinesia: Dyskinesia refers to distortion or impairment of voluntary movement [57]. Spinal motion may be reliably measured using inclinometry [58]. Alterations in regional ranges of motion may be associated with vertebral subluxation [59].

3. Dysponesis: Dysponesis is evidenced by abnormal tonic muscle activity. Dysponesis refers to a reversible physiopathologic state consisting of errors in energy expenditure, which is capable of producing functional disorders. Dysponesis consists mainly of covert errors in action potential output from the motor and premotor areas of the cortex and the consequences of that output. These neurophysiological reactions may result from responses to environmental events, bodily sensations, and emotions. The resulting aberrant muscle activity may be evaluated using surface electrode techniques [60,61]. Typically, static SMEG with axial loading is used to evaluate innate responses to gravitational stress [62].

4. Dysautonomia: The autonomic nervous system regulates the actions of organs, glands, and blood vessels. Acquired dysautonomia may be associated with a broad array of functional abnormalities [63-69]. Sympathetic tone may be evaluated by measuring skin temperature differentials using paraspinal infrared thermography [70]. Such techniques have been used to monitor changes in neurological function associated with vertebral subluxations [71]. Heart rate variability is a reliable and valid technique for the assessment of changes in autonomic nervous system function.

LITERATURE REVIEW

A search was made of PubMed, the Index to Chiropractic Literature (ICL), and McCoy Press journals. The latter was included as these publications are focused on vertebral subluxation. A hand search at the Sherman College of Chiropractic Library was also performed. Search terms included *chiropractic and heart rate variability, spinal manipulation and heart rate variability, vertebral subluxation and heart rate variability,* and *spinal adjustment and heart rate variability.* The time range was from 2000-2017. *Spinal manipulation* was included as a search term to differentiate papers addressing spinal manipulation from those concerned with the correction or reduction of vertebral subluxation. Review papers, theoretical discussions, abstracts presented at symposia, and editorials were excluded. In determining if the intervention studied was manipulation or adjustment, the author used the definitions of the World Health Organization [72]. To be assigned as a vertebral subluxation paper, assessment of both a biomechanical and neurological indicator was required.

RESULTS

Nineteen papers met the inclusion criteria. Two involved publication of the same study to two journals, leaving a total of eighteen distinct papers. Seven papers addressed spinal manipulation, nine addressed vertebral subluxation, and in two cases a determination could not be made. There were seven controlled trials, eight case studies, two pre-post intervention studies, and one study comparing subjects with and without neck pain. Seven papers specifically addressed the cervical spine, two involved thoracic spine manipulation, and the rest were not limited to a specific spinal region. All seven controlled studies employed manipulation. All eight case report papers addressed vertebral subluxation. Results are summarized in **Table 1**.

Table 1. Peer-reviewed articles addressing heart rate variability and vertebral subluxation correction (VSC) vs. spinal manipulation 2000-2017 [73-89].

Peer-reviewed articles addressing heart rate variability and vertebral subluxation correction (VSC) vs. spinal manipulation 2000-2017			
Journal Reference No.	**Title**	**Spinal Assessment**	**Intervention**
[73]	Neuro-Endocrine Response Following a Thoracic Spinal Manipulation in Healthy Men (randomized controlled trial)	None. Subjects were randomized to receive a T5 manipulation or a sham intervention	Manipulation of the fifth thoracic vertebra

[74]	Upper cervical specific pattern analysis utilizing paraspinal thermography, leg length inequality and heart rate variability in two patients with tachycardia (case report)	Thermography. Radiography. Leg length inequality	Upper cervical adjustment of vertebral subluxation
[75]	Effects of upper and lower cervical spinal manipulative therapy on blood pressure and heart rate variability in volunteers and patients with neck pain: a randomized controlled, cross-over, preliminary study (randomized controlled trial)	Pain scale Static palpation Motion palpation Posture in sitting position	Upper and lower cervical spinal manipulation
[76]	Improvement in signs and symptoms of ADHD, migraines and functional outcomes while receiving subluxation based torque release chiropractic and cranial nerve auriculotherapy (case report)	Breathing Movement Heel Tension Abductor Tendency Foot Flare Foot Pronation/Supination Functional Leg Length Inequality Cervical Syndrome Test Bilateral Cervical Syndrome Test Derefield Test	Adjustment of vertebral subluxations Auriculotherapy
[77]	Suboccipital Decompression Enhances Heart Rate Variability Indices of Cardiac Control in Healthy Subjects (randomized crossover trial)	Palpation	Upper cervical manipulation
[78]	Improvement in signs and symptoms of ADHD and functional outcomes in four children receiving Torque release chiropractic: A case series (case series)	Torque Release Technique (TRT) indicators Paraspinal infrared thermography Paraspinal surface electromyography	Adjustment of vertebral subluxations
[79]	Resolution of infertility in a 31-year-old female undergoing chiropractic care for the reduction of vertebral subluxation: A case report (case report)	Postural examination Radiography Paraspinal infrared thermography Paraspinal surface electromyography	Adjustment of vertebral subluxations
[80]	Improvement in pattern analysis, heart rate variability & symptoms following upper cervical chiropractic care (case series)	Leg length inequality Radiography Paraspinal infrared thermography	Upper cervical adjustment of vertebral subluxation
[81]	Resolution of atrial fibrillation & hypertension in a patient undergoing upper-cervical chiropractic care (case report)	Leg length inequality Postural examination Radiography Paraspinal infrared thermography	Upper cervical adjustment of vertebral subluxation
[82]	Resolution of infertility, healthy pregnancy and delivery in a patient previously diagnosed with polycystic ovarian syndrome [PCOS]: A case report and selective review of literature (case report)	Leg length inequality Static palpation Motion palpation Paraspinal infrared thermography Paraspinal surface electromyography	Adjustment of vertebral subluxations
[83]	Heart rate variability modulation after manipulation in pain-free patients vs. patients in pain (randomized controlled trial)	Activator Methods ® assessment Static palpation Motion palpation	Spinal manipulation
[84]	Sympathetic and parasympathetic responses to specific diversified adjustments to chiropractic vertebral subluxations of the cervical and thoracic spine (pre- and post- intervention study)	Leg length inequality Static palpation Motion palpation Paraspinal infrared thermography	Specific spinal adjustments
[85]	Effects of Biofreeze and chiropractic adjustments on acute low back pain: a pilot study (randomized controlled trial)	Not stated	Biofreeze and chiropractic adjustments

[86]	The effects of thoracic manipulation on heart rate variability: A controlled crossover trial (controlled crossover study)	Palpation for muscle tone Motion palpation	Thoracic spine manipulation
[87]	Effect of chiropractic care on heart rate variability and pain in a multisite clinical study (pre- and – post intervention study)	Not stated. Left to the discretion of participants	Chiropractic adjustments
[88]	Effect of chiropractic care on heart rate variability and pain in a multisite clinical study (pre- and – post intervention study)	Toftness sensometer	Specific spinal adjustments
[89]	Response of arrhythmia to spinal manipulation: Monitoring by ECG with analysis of heart rate variability (case report)	Static palpation Motion palpation	Upper cervical and upper thoracic spinal manipulation

DISCUSSION

In some cases, there was insufficient detail provided in the description of methods to make a determination of what specific criteria were used for intervention and the nature of the interventions applied. There were also instances where the intervention was applied without any apparent criteria for doing so. In a minority of papers, there was insufficient detail to determine if an intervention was directed toward vertebral subluxation correction, or was a spinal manipulation. WHO [76] describes the two procedures as follows:

Adjustment : Any chiropractic therapeutic procedure that ultimately uses controlled force, leverage, direction, amplitude and velocity, which is applied to specific joints and adjacent tissues. Chiropractors commonly use such procedures to influence joint and neurophysiological function.

Joint manipulation: A manual procedure involving directed thrust to move a joint past the physiological range of motion, without exceeding the anatomical limit.

These definitions are congruent with the Sherman College Philosophic Lexicon:

Adjustment (adjustive thrust): A controlled force, employing leverage, direction, amplitude and velocity, applied to a specific vertebra for the purpose of correcting vertebral subluxation.

Manipulation: The forceful passive movement of a joint beyond its physiological range of motion; it is not done for the correction of vertebral subluxation and is not synonymous with adjustment.

The putative neurobiological mechanisms resulting from a vertebral subluxation have been described. Pressure and stretch of neural structures due to misalignment of the vertebra may affect the function of the sympathetic and parasympathetic portions of the autonomic nervous system. Segmental facilitation (lowered thresholds of lateral horn cells) may lead to elevated sympathetic tone [35,51].

Burcon summarized the innervation of the heart, and the role of the vagus nerve: “Parasympathetic innervation of the heart is mediated by the vagus nerve. Specifically, the vagus nerve acts to lower the heart rate. The right vagus innervates the sinoatrial node. Parasympathetic hyperstimulation predisposes those affected to bradyarrhythmias. The left vagus when hyperstimulated predisposes the heart to atrioventricular blocks” [75].

Burcon further noted that, “The heart rate variability (HRV) examination is becoming more commonplace in the chiropractic clinic. It is a natural fit for the chiropractor wanting to evaluate the function of the autonomic nervous system (ANS). It readily measures the overall activity of the ANS, a direct measure of ANS health and adaptability. HRV also measures balance between the sympathetic and parasympathetic branches of the ANS”.

CONCLUSION

A small number of controlled studies suggest that spinal manipulation may alter heart rate variability. Case reports suggest that favorable changes in heart rate variability may follow reduction or correction of vertebral subluxations. Higher quality studies of larger populations should be conducted. It is biologically plausible that the changes in autonomic nervous system function following reduction or correction of vertebral subluxation may be objectively assessed using heart rate variability.

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