Association Between Heart Rate Variability and Novel Pulse Rate Variability Methods

John Hart, DC, MHSc
Assistant Director of Research
Sherman College of Chiropractic
Spartanburg, SC

Abstract

Introduction: A neurological component, which includes an autonomic component, is assumed to exist within the condition known as vertebral subluxation (VS). High tech methods of autonomic assessment (e.g., heart rate variability) are typically used only periodically (e.g., every 6 or 12 visits). Lower tech methods of autonomic assessment such as skin temperature measurements are sufficiently convenient to use on all patient visits. As an additional option for autonomic assessment on all patient visits, this study introduces a new and potentially valid method of autonomic assessment that uses radial pulse variability.

Methods: Thirty-two participants were examined with: a) regular heart rate variability, using the standard deviation of normal-to-normal beats (SDNN) and b) novel pulse rate variability procedures. The novel methods are based on four manually palpated radial pulse measurements taken within a two minute period which in turn were subjected to five different methods of calculation.

Results: Two predictors emerged as having the strongest association with SDNN in this study. One, which is already established as a valid biomarker, is pulse rate mean. The other predictor, which is novel, is the pulse rate mean minus the difference between maximum and minimum pulse rates.

Conclusion: Chiropractors may have a new option for assessing autonomic function on every patient visit in the form of low-tech radial pulse rate variability. Further outcomes research with a random sample of patients is indicated as a next step in this study.

Keywords: pulse rate, heart rate variability, novel pulse rate, autonomic assessment

Introduction

Chiropractors are said to have a focus that is primarily on the spine. Two components within this focus include structure (e.g., a slight misalignment) and function (e.g., nerve disturbance) as with the condition known as vertebral subluxation (VS). While the neurological aspect is assumed to be present, its operational properties (e.g., its nature and how it is measured) remain vague\(^1\) with various possible explanatory mechanisms suggested.\(^2\)\(^-\)\(^3\)

In the tradition of R.W. Stephenson,\(^4\) VS has historically been said to inhibit nervous system adaptability in response to internal and external challenges. This loss of adaptation is acknowledged in modern terminology as a “loss of complexity,”\(^5\) where patterns of physiological findings are predictable, that is, they become less dynamic over time. In
addition, loss of complexity is thought to lead to “an impaired ability to adapt to physiologic stress.” This viewpoint appears consistent with that of R.W. Stephenson and other chiropractic pioneers of the VS model.

One method a chiropractor might use to assess loss of complexity is with pattern analysis of neurophysiological measures, e.g., skin temperatures. The term “neuro-adaptability,” used by this author, may also appropriately describe what is being assessed. Diminished neuro-adaptability of autonomic function could represent one possible neurological model in chiropractic practice for chiropractors interested in assessing a neurological component.

One potential problem with chiropractic clinical assessments, neurological or bony, is the lack of objective measurement. For example, a motion palpation finding (e.g., restriction of C2 upon passive head rotation to the right side) on two different visits might show more severity on one of the visits. The chiropractor could apply a numerical value to both visits, e.g., 0 = less severe while 1 = more severe, but this application would still have a subjective component, e.g., how severe is severe when comparing visits? An example of quantifying one chiropractic test to assess autonomic function pertains to paraspin temperatures where strong examiner reliability was observed. Validity is another issue and typically more difficult to establish compared to reliability.

Another potential problem with clinical assessments is that the more high tech they are, the less frequently they tend to be used. For example, elaborate thermography units or heart rate variability assessments are typically used only periodically, e.g., every 6 or 12 visits. This means that some visits may not include a clinical assessment that is specific for neurological function. Some lower tech methods of skin temperature measurement are sufficiently convenient to use on all patient visits. Skin temperature is one of very few options for the practicing chiropractor to use for specific neurological analysis. Thus, there is a need for additional options for neurological analysis, particularly autonomic analysis, that are sufficiently convenient to use on all patient visits.

Regular heart rate variability (rHRV) is a clinical assessment specific for autonomic function. As with any chiropractic procedure, not every chiropractor uses rHRV. However, rHRV does have a track record in chiropractic research and practice. rHRV is considered “a” (but not necessarily “the”) valid gold-standard in assessing autonomic function. Autonomic health would seem to be a key area of interest of the chiropractor since the neurological aspect is a key component of chiropractic practice.

Various values are produced by rHRV. The SDNN value, which is the standard deviation of normal-to-normal beats in milliseconds between R waves in the QRST complex, is the most commonly used value in rHRV studies and is the value used in the present study for rHRV. The terms “rHRV” and SDNN are used interchangeably in this study.) A larger SDNN value indicates greater variability and is considered healthier than a smaller SDNN value.

Impediments to using rHRV, or using it on every visit may include: a) its cost (new units can cost thousands of dollars), and b) lack of information and/or precise understanding about how the numbers are actually generated. Attempts have been made to investigate lower tech alternatives to rHRV.

Nussinovitch et al for example compared 10-second heart rate measurements to heart rate variability. These researchers found a number of correlations with rHRV indices, including an inverse correlation between the 10-second heart rate and standard deviation of normal-to-normal beats (SDNN). Although these authors mentioned the possible feasibility of using simple manual pulse for heart rate determination for evaluating autonomic function, they used an ECG unit for their actual study.

Similarly, Kageyama et al found good correlations between pulse rate parameters derived from finger plethysmogram and rHRV parameters derived from ECG. The literature however is not completely consistent on whether pulse rate and heart variability have adequate agreement. Constant et al found that pulse rate variability, using technology (a Finapres unit) is not an ideal substitute for rHRV. However, these authors state that pulse information is acceptable if ECG equipment is not available. Although the aforementioned studies assessed methods that could be considered lower tech than rHRV, they nonetheless use more complex forms of technology than the present study uses.

In the present study, the author introduces novel potential options for autonomic assessment that can be used on all patient visits. The appeal of such methods is that generation of the data is a simple and transparent process which in turn improves understandability by both doctor and patient regarding the meaning of the numbers.

If a low tech autonomic assessment shows acceptable association with rHRV (or some other established autonomic marker), evidenced by at least a moderate statistically significant correlation, and verified with follow-up studies, then the chiropractor may have an additional valid option for analyzing the patient’s nervous system on every visit.

The novel low tech method in the present study consists of taking the pulse on the radial artery a number of times within a couple of minutes and then performing five different calculations on the pulse rate numbers. Average pulse rate as a stand-alone number is one of the five calculations and is well-established and therefore not novel. Moreover, pulse rate is an indicator for health in general as well as autonomic health in particular.

Methods

The study received approval from the Institutional Review Board at Sherman College of Chiropractic. Thirty-two relatively healthy volunteers, consisting of 31 chiropractic students and one faculty member were recruited as a convenience sample (23 males and 9 females). The mean age for the participants was 27.5 (SD 6.4) years, ranging from 22-49.
Data collection occurred in 2011 and 2012. Participants pre-rested quietly in the seated position for a minimum of 5 minutes. The first procedure was rHRV followed by the manual radial pulse rates. rHRV was performed with the Biopac Active ECG instrument, Version 1, Clinical Edition (Biocom Technologies, Poulsbo, WA), a device that has been used in previous research.\textsuperscript{14} The equipment uses three leads; one on each arm and one on the left leg. Contact areas for these leads were briefly scrubbed with a wet paper towel to help ensure good conduction.

For the lower tech methods, manually palpated radial pulse rates were obtained from the right wrist, taken four times, 15 seconds each, with 15 seconds between each trial (allowing enough time to chart the pulse rate for each of the four times) over a period of approximately two minutes.

A digital wrist watch was used to time the pulse rates. The first pulse was counted as “1” as the target number on the watch was observed (e.g., beat #1 on the “00” second mark and the last beat on the “15” second mark). The measurements were analyzed five different ways, as follows (with research hypothesis in relation to SDNN in parentheses). As previously mentioned, Method 1, pulse rate mean, is obviously not novel whereas the others methods are novel:

1. Pulse rate mean (PM) (inverse relationship expected)
2. Maximum-minimum difference among pulse rates (MMD) (direct relationship expected)
3. Mean pulse – MMD (P-D) (inverse relationship expected)
4. Mean + MMD (P+D) (direct relationship expected)
5. Pulse rate coefficient of variation (PCV; calculated with: SD/mean); (direct relationship expected).

Table 1 provides a scenario for how the five methods of calculation were performed.

Initial data analysis consisted of comparing the five methods (predictors) to SDNN using the Pearson correlation test performed in Stata IC 12.1 (StataCorp, College Station, TX). Because five tests were performed in correlation analysis, a Bonferroni-adjusted alpha of 0.01 (0.05/5) was applied to the correlation coefficients. Thus, two-tailed p-values $\leq$ this alpha in correlation analysis are considered statistically significant. Multiple linear regressions were also performed, using the traditional alpha of 0.05 for statistical significance.

Observations thought to exert undue influence on coefficients (“outliers”) were assessed in: a) correlation, using visual inspection of scatter plots, as shown in Figure 1 for predictor P-D, and b) regression, using delta-beta calculations in Stata. For the latter, a difference in the regression coefficient is calculated with versus without an observation.

A large difference is assumed to be present if it exceeded the value calculated with the formula $2/\sqrt{n}$.\textsuperscript{25} Thus, results are reported with and without outliers for both statistical tests (correlation and regression). Coefficients with a minus sign represent inverse relationships, while those with no sign, meaning a positive sign, represent direct relationships.

**Results**

Descriptive statistics are provided in Table 2. The directions for all coefficients were consistent with their predicted directions (e.g., inverse for PM, direct for PCV). Two moderate strength statistically significant correlations were observed with outliers while four were observed without outliers (Table 3). These two strongest predictors in correlation analysis, with or without outliers, were P-D and PM (Table 3).

Multiple linear regression (MLR) was attempted for all predictors combined, though unsuccessfully due to collinearity among the predictors (where variance inflation factors exceeded 10). A second MLR model was attempted, with the two predictors having the strongest correlations (P-D and PM). Collinearity continued to be a problem here as well. Consequently, simple linear regression was performed separately for both of these predictors (PM and P-D). Here, both predictors revealed statistically significant associations with SDNN, with and without outliers (Table 4).

**Discussion**

Findings of the study were not appreciably affected by the presence of outliers. In regard to the two predictors showing the relatively strongest correlations, one of these predictors, PM (pulse mean), is already established, as previously noted, as a biomarker for health in general and autonomic function in particular. In addition, previous studies have assessed heart rate as a stand-alone value and found an inverse association with rHRV\textsuperscript{17, 21, 25} and the present study’s finding for PM is consistent with this finding.

Moreover, a number of chiropractic studies have included a comparison of heart rate before and after chiropractic care.\textsuperscript{26–29} Welch and Boone\textsuperscript{28} observed a reduction in pulse rate that was not statistically significant though showing a moderate effect size. Similarly, Bakris et al\textsuperscript{29} found a reduction in heart rate following chiropractic care that was not statistically significant. As with Welch and Boone, Schwartzbauer et al\textsuperscript{26} found a reduction in pulse rate following chiropractic that had a moderate effect size. Budgell and Polus\textsuperscript{27} found statistically significant reductions in pulse rate in a chiropractic group but they also found the reduction in their sham group.

In regard to the other relatively strong predictor in this study, the novel predictor P-D, which also showed an inverse association with SDNN, a decrease in the P-D value is considered a healthy sign of autonomic function to the extent that: a) a lower pulse rate is considered healthier than a higher one,\textsuperscript{20, 24} and b) difference in the maximum and minimum pulse rates, viewed as representing the amount of heart rate variation is therefore similar to heart rate variability where more variability is considered healthier than less.\textsuperscript{8}

Perhaps with the added dimension of variability, as P-D provides, a more comprehensive (albeit low-tech) assessment of autonomic function can be realized versus pulse rate alone. P-D also has the advantage of incorporating the early chiropractic idea (by R.W. Stephenson and others), which
enjoys scientific support today, that adaptability of the nervous system is a key component of health. Nonetheless, regression coefficients and confidence intervals for both PM and P-D are similar. A one unit decrease in either of these predictors is essentially expected to predict an increase of approximately 2-7 SDNN units 95% of the time (Table 4).

Implementation of the PM or P-D method into practice could consist of simply noting whether the value decreases (considered more healthy compared to an increase) or increases (considered less healthy compared to a decrease). For example, a P-D value of 18.5 on one visit decreasing to 17.5 on the next visit would be considered as a healthy change for this latter visit where the patient may be considered having a healthier nervous system and therefore not in need of a chiropractic adjustment on this latter visit.

Occasionally, heart rate variation may be due to premature ventricular contractions (PVCs), which may be noticeable to the patient as a “skipped beat” sensation in their chest. In a healthy heart, “occasional PVCs are nothing to worry about.” However, patients with heart problems, along with the PVCs may require medical attention.

Limitations to the study are that participants: a) are not a random sample, b) are relatively healthy, and c) examined only on one visit.

Conclusion

Indications from this preliminary study suggest that chiropractors may have easy-to-use options for assessing autonomic function with either the established PM method or the new P-D method. Either of these methods are: a) feasible to use on every visit and b) easy for both practitioner and patient to understand. Further outcomes research is indicated involving a random sample of patients, on multiple visits to verify these findings.

References

Table 1. Case scenario example for pulse rate variation calculations.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Beats/15 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
</tr>
</tbody>
</table>

SD = 0.82
PM = 20
PCV = 4.10%
MMD = 2
P-D = 18
P+S = 22

PM = pulse rate mean; SD = standard deviation; PCV = coefficient of variation for the pulse rate measurements; MMD = maximum – minimum pulse rate difference; P-D = mean pulse rate – MMD; P+S = mean pulse rate + MMD

========================================================================
Table 2. Descriptive statistics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDNN</td>
<td>32</td>
<td>58.3</td>
<td>32.5</td>
<td>23.3</td>
<td>191.5</td>
</tr>
<tr>
<td>PM</td>
<td>32</td>
<td>17.9</td>
<td>3.3</td>
<td>12.3</td>
<td>24.5</td>
</tr>
<tr>
<td>MMD</td>
<td>32</td>
<td>1.3</td>
<td>0.8</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>P-D</td>
<td>32</td>
<td>16.6</td>
<td>3.2</td>
<td>11.3</td>
<td>23.5</td>
</tr>
<tr>
<td>P+D</td>
<td>32</td>
<td>19.2</td>
<td>3.6</td>
<td>13.3</td>
<td>25.5</td>
</tr>
<tr>
<td>PCV</td>
<td>32</td>
<td>3.7</td>
<td>2.3</td>
<td>0</td>
<td>9.4</td>
</tr>
<tr>
<td>Age</td>
<td>32</td>
<td>27.5</td>
<td>6.4</td>
<td>22</td>
<td>49</td>
</tr>
</tbody>
</table>

SDNN = standard deviation of normal-to-normal beats in regular heart rate variability; PM = pulse rate mean; SD = standard deviation; PCV = coefficient of variation for the pulse rate measurements; MMD = maximum - minimum pulse rate difference; P-D = mean pulse rate – MMD; P+S = mean pulse rate + MMD.

Table 3. Pearson correlation of the five predictors with SDNN.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>All Data</th>
<th>Without Outliers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>r</td>
</tr>
<tr>
<td>P-D</td>
<td>32</td>
<td>-0.566</td>
</tr>
<tr>
<td>PM</td>
<td>32</td>
<td>-0.507</td>
</tr>
<tr>
<td>P+D</td>
<td>32</td>
<td>-0.426</td>
</tr>
<tr>
<td>PCV</td>
<td>32</td>
<td>0.406</td>
</tr>
<tr>
<td>MMD</td>
<td>32</td>
<td>0.197</td>
</tr>
</tbody>
</table>

PM = pulse rate mean. MMD = maximum-minimum pulse rate difference. P-D = pulse rate mean – MMD. P+D = pulse rate mean + MMD. PCV = pulse rate coefficient of variation. r = correlation coefficient. p = p-value for r. Bonferroni-adjusted alpha = 0.01 (0.05/5). Statistically significant correlations are bolded.

Table 4. Simple linear regression for predictors P-D and PM in separate models with SDNN as the response variable.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>All Data</th>
<th>Without Outliers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Coef</td>
</tr>
<tr>
<td>P-D</td>
<td>32</td>
<td>-5.7</td>
</tr>
<tr>
<td>PM</td>
<td>32</td>
<td>-5</td>
</tr>
</tbody>
</table>

Coef = regression coefficient. CI = confidence intervals.
One observation in the lower left and one in the upper left are considered as outliers (overly-influential observations). Results are reported with and without outliers. With these outliers (n = 32), r = -0.566, p = 0.0007. Without the outliers (n = 30), r = -0.674, p = 0.0000.)