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SPECIAL ISSUE

The Application of Heart Rate Variability Biofeedback to Medical and Mental Health Disorders

Donald Moss, PhD,[1] and Fredric Shaffer, PhD[2]

[1]College of Integrative Medicine and Health Sciences, Saybrook University, Oakland, CA, [2]Department of Psychology, Truman State University, Kirksville, MO

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Heart rate variability (HRV) is a medical index for morbidity and wellness. Lower HRV accompanies many illnesses; high HRV accompanies healthy states, resilience, and optimal functioning. Heart rate variability biofeedback (HRVB) uses real-time electronic feedback of the moment-to-moment changes in HRV to train patients to produce increases in HRV. Outcome studies on HRVB have shown therapeutic benefit for a wide variety of medical and mental health disorders. Lehrer and colleagues have published evidence-based protocols for HRV assessment and HRV treatment. Here, the authors review outcome studies on a sampling of common disorders: asthma, chronic muscle pain, depression, heart failure, hypertension, and posttraumatic stress disorder. HRVB offers promising therapeutic benefit for any medical or mental health disorder known to be accompanied by autonomic nervous system dysregulation.

Introduction to Heart Rate Variability

Heart Rate Variability as an Index of Health and Disease

Low heart rate variability (HRV) has been identified in medical research as an index of morbidity; lower HRV accompanies illness states as varied as anxiety disorders (Chalmers, Quintana, Abbott, & Kemp, 2014), excessive alcohol use (Karpyak, Romanowicz, Schmidt, Lewis, & Bostwick, 2014), major depression (Nahshoni et al., 2004), diabetes (Kudat et al., 2006), and posttraumatic stress disorder (PTSD; Cohen et al., 2000). In the case of diabetes, lowered HRV may precede diabetic neuropathy (Braune & Geisendörfer, 1995). Conversely, higher HRV is associated with states of resilience, adaptiveness, and health/wellness, when HR oscillation amplitudes are higher (Lehrer & Gevirtz, 2014; McCraty & Shaffer, 2015). A healthy heart is not a metronome (Shaffer, McCraty, & Zerr, 2014). Robust biological systems are characterized by organized variability.

Heart Rate Variability Biofeedback

Heart rate variability biofeedback (HRVB) is a behavioral intervention that uses electronic feedback of the moment-to-moment changes in HRV to enable patients to increase overall HRV as measured by the amplitude of oscillations in heart rate, as well as time domain and frequency domain measures of HRV (Moss & Shaffer, 2016).

Several authors have provided evidence that HRVB training can increase HRV and reduce symptoms accompanying many disorders (Gevirtz, 2016; McCraty & Shaffer, 2015; Wheat & Larkin, 2010). Lehrer and Gevirtz (2014) have reviewed relevant research and identified a number of physiological mechanisms positively affected by HRVB: improved autonomic regulation, enhanced baroreflex sensitivity, and stimulation of the vagal efferent system.

Current Evidence-Based Applications

Credible research has shown efficacy of HRVB for a growing number of medical and mental health disorders (Gevirtz, 2016).

Medical Disorders

- Asthma (Lehrer et al., 2004; Lehrer, Smetankin, Potapova, 2000)
- Chronic muscle pain (Vagedes et al., 2011)
- Chronic obstructive pulmonary disease (Giardino, Chan, & Borson, 2004)
- Coronary artery disease (Cowan et al., 1992; Del Pozo, Gevirtz, Scher, & Guarneri, 2004; Nolan et al., 2005)
- Fibromyalgia (Hassett et al., 2007)
- Heart failure (Swanson et al., 2009)
- Hypertension (Reinke, Gevirtz, & Mussgay, 2007; Wang et al., 2010)
- Irritable bowel syndrome (Dobbin, Dobbin, Ross, Graham, & Ford, 2013)
- Preeclampsia (Cullins et al., 2013; Siepmann et al., 2014)
- Prehypertension (Lin et al., 2012)

- Recurrent abdominal pain (Ebert, 2013; Sowder, Gevirtz, Shapiro, & Ebert, 2010)

Mental Health Disorders

- Anxiety disorders (Henriques, Keffer, Abrahamson, & Horst, 2011; Moss, 2016; Prigatano, 1972; Reiner, 2008)
- Depression (Karavidas et al., 2007; Katsamanis, 2016; Siepmann et al., 2008)
- PTSD (Tan, Dao, Farmer, Sutherland, & Gevirtz, 2011; Tan, Wang, & Ginsberg, 2016; Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009)
- Substance abuse and cravings (Eddie, Kim, Lehrer, Deneke, & Bates, 2014; Eddie, Vaschillo, Vaschillo, & Lehrer, 2015)

See Tables 1 and 2 for details on these research reports on mental health applications.

Clinical Protocols

Assessment Protocol for HRVB

Lehrer et al. (Lehrer, Vaschillo, & Vaschillo, 2000; Lehrer et al., 2016) have established two manuals for the biofeedback training of HRV, with the later manual presenting a shorter treatment period. The Lehrer manuals prescribe both the assessment and training processes. The primary investigative procedure for HRVB involves a resonance frequency (RF) assessment. RF is the rate of breathing that produces the optimal level of HRV. The patient must submit to an initial training process, to establish or strengthen his or her ability to breathe at a regular rate, following a computer-displayed breath pacer. The rate of breathing is measured by a respiratory biofeedback device, using an abdominal band to measure the expansion and contraction of the abdomen with breathing. Once the individual is able to accurately follow the breath pacer, the assessment can take place.

The individual is guided to breathe at 5.5 or 6 breaths per minute (BPM) until he or she can breathe evenly at this rate. After the values for the power and peak frequency in the low-frequency band have stabilized, the clinician asks the client to stop paced breathing for 1 to 2 minutes and describe the experience. This assessment procedure is repeated for 6.5, 5.5, 5, and 4.5 BPM with 1- to 2-minute pauses between breathing rates. After the client has completed breathing from 6.5 to 4.5 BPM, the clinician estimates the RF-based effects on indices such as phase convergence between breathing and instantaneous heart rate, peak-to-trough heart rate difference, and low-frequency power. The clinician fine-tunes the estimated RF during the second visit by asking the client to breathe at this rate and one-half breath above and below it.

Treatment Protocol for HRVB

Lehrer et al. (Lehrer et al., 2016; Lehrer, Vaschillo, & Vaschillo, 2000) have established a manual for the biofeedback training of HRV. During Session 1, the clinician orients the client to HRVB equipment and monitoring and measures the RF. In Session 2, the clinician fine-tunes the RF, reviews RF breathing in which exhalation is longer than inhalation, teaches the client to breathe abdominally at the RF using pursed lips, and assigns home practice of this skill. In Session 3, the clinician reviews abdominal breathing, asks the client to practice RF breathing using a pacer, provides HRVB of the heart rate waveform without a pacer, and assigns RF breathing practice. In Sessions 4 and 5, the clinician reviews abdominal breathing, asks the client to practice RF breathing with a pacer, provides HRVB of the heart rate signal using a pacer if needed, and discusses how the client can use HRV self-regulation skills to treat symptoms.

Evidence-Based Applications of HRVB

This section reviews outcome studies on a sampling of common medical and mental health disorders, showing promising therapeutic benefits from HRVB.

Asthma

Lehrer and colleagues (2004) examined the clinical efficacy of HRVB in a study of 94 adult asthma patients. After prestabilization with controller medication, they randomly assigned these patients to HRVB with abdominal breathing training, HRVB alone, placebo electroencephalogram biofeedback, or a waiting list control. Subjects in the two HRV conditions were prescribed less steroid medication and showed improved pulmonary function (measured by forced oscillation pneumography) than control subjects. The two HRV groups did not significantly differ in clinical outcome. All groups showed improved asthma symptoms and did not differ in the frequency of severe asthma flares. The authors concluded that HRVB shows promise as an adjunctive treatment for asthma that could reduce reliance on steroid medication.

Chronic Muscle Pain

Vagedes and colleagues (2011) reported a randomized controlled study of 109 patients diagnosed with musculoskeletal pain. They examined the therapeutic efficacy of core stabilization exercises, myofascial release with trigger point therapy, and paced breathing to induce increased HRV. The group combining breath training with myofascial release and trigger point therapy showed superior gains for almost all measures, including pain reduction.

Table 1. Applications of HRVB to mental health disorders

Disorder	Interventions	Sample Size	Control Group	Random Assign/ Blinding	Measures	Findings	Reference
Anxiety disorders	HRVB plus CBT	20 Ss with anxiety	None	None	STAI, PSQI, STAEI	Reduced state, trait anxiety, reduced anger, improved sleep time	Reiner (2008)
College anxiety	HRVB	Pilot study, 9 Second study, 35	None in pilot; second study: immediate treatement versus delayed treatment	Second study random assignment	Pilot: STAI, MASQ; second study: MASQ, SPWB (well-being)	Consistent reductions in anxiety; no improvements in positive mood, negative mood, or well-being	Henriques et al. (2011)
Major depressive disorder	HRVB	11 Ss with major depression	None	1	Ham-D, BDI-II	Ham-D Total score, neuroveg. and cognitive, BDI all reduced	Karavidas et al. (2007)
Depression	HRVB	14 depressed Ss, 24 healthy Ss	First control: healthy Ss received HRVB; second control: healthy Ss seated at computer	Only healthy Ss were randomized	BDI, STAI	Depression and anxiety reduced	Siepmann et al. (2008)
Posttraumatic stress disorder	HRVB plus TAU	20 Ss with PTSD, 10 healthy volunteers	Control group received TAU only	PTSD Ss randomized	PCL-S, CAPS	Reduced scores on PCL-S anc CAPS in HRV group	Tan et al. (2011)
Posttraumatic stress disorder	HRVB	38 Ss with PTSD and substance abuse	Control group received progressive relaxation	Random assignment	PTS-T scale from DAPS, PCL-C, BDI-II	Both groups reduced PTS-T and PCL-C scores; HRV group reduced BDI-II scores	Zucker et al. (2009)

Note. HRVB = heart rate variability biofeedback; CBT = Cognitive Behavioral Therapy; Ss = subjects; STAI = State Trait Anxiety Inventory; PSQI = Pittsburgh Sleep Quality Index; STAEI = State Trait Anxiety Expression Inventory; MASQ = Mood and Anxiety Symptom Questionnaire; SPWB = Scales of Psychological Well-Being; Ham-D = Hamilton Depression Rating Scale; BDI-II = Beck Depression Inventory (second edition); BDI = Beck Depression Inventory (first edition); TAU = treatment as usual; PCL-5 = PTSD Checklist for *DSM-5*; CAPS = Clinician Administered PTSD Scale; PTS-T = Posttraumatic Stress (Total) scale of the Detailed Assessment of Posttraumatic Stress; DAPS = Detailed Assessment of Posttraumatic Stress; PCL-C = PTSD Checklist–Civilian Version.

Table 2. Physiological changes following HRV training in mental health disorders					
Disorder	**Instrumentation**	**HRV Measures**	**Other Physiological Measures**	**Findings**	**Reference**
Anxiety disorders	StressEraser (Helicor, NY)	None	None	None	Reiner (2008)
College anxiety	Study 1: Freeze-Framer 2.0; Study 2: emWave PC 1.0 and emWave portable (Boulder Creek, CA)	Study 2: 5-minute and 15-minute coherence ratios: Peak Power/(Total Power−Peak Power), and Peak Power in LF range	None	Study 2: one group of subjects showed an increase in average 5-minute coherence ratio from Week 1 to 4; overall coherence ratios did not increase for either group and did not correlate with changes in mood and anxiety	Henriques et al. (2011)
Major depressive disorder	J & J I-330 DSP-12 Physiograph (Poulsbo, WA)	SDNN, pNN50, HF power, LF power, VLF power, HR mean	Respiration	SDNN, LF, and HR mean changes were highly significant at Session 4, even when controlled for respiration, but then attenuated; these changes did not correlate with changes in depressed mood; posttreatment HRV baselines were not significantly changed from pretreatment baselines	Karavidas et al. (2007)
Depression	Stressball, BioSign, Germany. Periflux laser-Doppler flux meter (Perimed, Sweden)	pNN50, power for HF, LF, VLF, total power; ratio of LF/HF; vasoconstrictive response		pNN50 increased significantly from baseline to training sessions and again to 2-week follow-up, both in rest condition and paced breathing condition; median HF, LF, VLF, and total power all increased from baseline to follow up in both resting and paced breathing conditions but (with exception of TP in paced breathing condition) did not achieve statistical significance	Siepmann et al. (2008)
Posttraumatic stress disorder	Thought Technology Infiniti (Montreal, Canada) and Biosignal Analysis Program	Baseline SDNN		PTSD group showed significantly lower SDNN than healthy controls; the article does not present changes in HRV data from pre- to posttreatment	Tan et al. (2011)

Table 2. Continued

Disorder	Instrumentation	HRV Measures	Other Physiological Measures	Findings	Reference
Posttraumatic stress disorder	Pre- and post-HRV measurements recorded with J & J I-330 C-2 (Poulsbo, WA) and Biosignal Analysis Program; training conducted on StressEraser (Helicor, NY)	SDNN at baseline, paced breathing, and recovery stages, both pre- and posttraining	Respiration: breaths/min	The HRV group had significant increases in baseline SDNN from pre- to posttraining; the HRV group also had reduced respiration rate from pre to post; when controlled for breathing, change in SDNN was a significant contributor to reductions in PTSD symptoms on the PCL-C	Zucker et al. (2009)

Note. HRV = heart rate variability; LF = low frequency; HF = high frequency; VLF = very low frequency; HR = heart rate; TP = total power; PTSD = posttraumatic stress disorder; PCL-C = PTSD Checklist–Civilian Version.

Depression

Zucker et al. (2009) conducted a controlled pilot study with 38 participants recruited from a residential therapeutic community for substance use disorder who were diagnosed with PTSD symptoms. They randomly assigned individuals to either HRVB (StressEraser) or progressive muscle relaxation (PMR) recording. They instructed subjects to practice 20 minutes per day and complete weekly logs. The HRVB group achieved lower Beck Depression Inventory (BDI–II) scores and increased HRV (SDNN) compared to PMR group. (The SDNN is a widely used time domain statistical index for HRV; SDNN is the standard deviation of the normalized interval in milliseconds between R-waves in the electrocardiogram.) Both groups significantly reduced PTSD symptoms on the Posttraumatic Stress–Total scale and PTSD Checklist–Civilian Version. Increased HRV predicted improvement, even when respiration rate was statistically controlled.

Heart Failure

Swanson et al. (2009) randomly assigned 29 patients with heart failure to an experimental group that received six weekly sessions of respiratory training, HRVB, and daily practice or a comparison group that received six weekly sessions of sham alpha-theta biofeedback and daily practice. The experimental group increased exercise tolerance from baseline to follow-up. These subjects did not improve on their quality of life or SDNN. The authors concluded that combined training could improve exercise tolerance in heart failure patients with a left ventricular ejection fraction of 31% or higher.

Hypertension

Wang et al. (2010) compared the effects of 10 sessions of slow abdominal breathing with frontal surface electromyographic (SEMG) biofeedback with 10 sessions of slow abdominal breathing on blood pressure (BP) in 22 prehypertensive postmenopausal women. The researchers trained subjects to breathe at 6 BPM. They assigned all subjects to daily home practice. The researchers randomly assigned the subjects to the experimental or control conditions. Experimental subjects, who received combined SEMG biofeedback and slow abdominal breathing training, decreased systolic BP 8.4 mmHg and diastolic BP 3.9 mmHg. Control subjects, who received only slow abdominal breathing training, decreased systolic BP 4.3 mmHg. The experimental group achieved greater BP reductions than the control group and increased the average RR interval (the time interval between heart beats). Both groups increased their SDNN.

PTSD

Tan et al. (2011) reported a randomly controlled trial that compared HRVB and treatment as usual (TAU) versus TAU with 30 veterans who were diagnosed with PTSD. HRVB combined with TAU increased HRV and reduced PTSD symptoms, whereas TAU did not achieve gains on any measure.

Conclusions

The procedure of HRVB is noninvasive, nonpainful, and relatively short term, with minimal or no adverse effects for patients. HRVB has been shown in repeated clinical trials to be effective in reducing symptoms of a wide variety of medical and mental health disorders. HRVB is effective alone or in combination with other medical interventions and mental health therapies. Although only small studies are available in some of the areas of application, the consistent evidence for therapeutic efficacy is persuasive. HRVB should be considered as a primary or complementary intervention, whenever a patient presents with disorders known to include autonomic nervous dysregulation.

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Donald Moss

Fredric Shaffer

Correspondence: Donald Moss, PhD, 9782 Lakeshore Drive, West Olive, MI 49460, email: dmoss@saybrook.edu.