Biofeedback
Volume 41, Issue 3, pp. 110–120
DOI: 10.5298/1081-5937-41.3.01

SPECIAL ISSUE

The Promise of Heart Rate Variability Biofeedback: Evidence-Based Applications

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Keywords: heart rate variability, biofeedback, autonomic homeostasis, vagal afferent nerve, anti-inflammatory

Heart rate variability biofeedback has enjoyed increased popularity in recent years. In this review, empirical evidence from multiple sources is presented from the point of view of possible mechanisms of effect. While more research is clearly needed, the data thus far are certainly promising.

Introduction

Heart rate variability biofeedback (HRVB) has enjoyed a good deal of popularity in recent years. A number of commercial products have been introduced ranging in price from $80 (MyCalmBeat by Brain Resource®) to over $200 (Alive™ by Somatic Vision, Inc.). The advertising for these products claims efficacy for a large number of disorders and, in fact, we are quite optimistic about the potential for these techniques, especially when combined with mindfulness-based interventions (Khazan, 2013). In this article, I will review the state of the empirical literature for the use of HRVB with and without other clinical components. Wheat and Larkin (2010) reviewed some of the HRVB literature and concluded that "Results revealed that HRV biofeedback consistently effectuates acute improvements during biofeedback practice, whereas the presence of short-term and long-term carry-over effects is less clear" (p. 229). A substantial number of studies have appeared since that review.

As developed in the early 1980s, HRVB was conceived as an intervention that would target the parasympathetic nervous system (PNS) in contrast to other peripheral techniques that focused the sympathetic nervous system (SNS) or muscles (see Lehrer, this issue for a history). We now think of the training as affecting cardiovascular homeostatic reflexes so as to increase flexibility and recovery from fight/flight adaptive situations. In addition, we are now investigating the vagal afferent pathways that may explain some of the central effects described below (MacKinnon, Gevirtz, McCraty, & Brown, 2013). A third pathway has been described by Tracey (2002) and involves the cholinergic or parasympathetic systems regulating the inflammatory response. The following review is organized by these possible mechanisms of action. Much more research will be necessary to elucidate these and other mechanisms, but the trend to organize treatments by mechanistic pathways has become useful in many areas of science.

Possible Mechanism I: Restoring Autonomic Homeostasis

The primary proposed mechanistic path for HRVB has been the restoration of autonomic balance or homeostasis as a product of the training. Thus, disorders such as asthma, functional gastrointestinal disorders (FGID), cardiovascular disorders, fibromyalgia (FM), hypertension, and chronic muscle pain seem to respond to HRVB in a manner that suggests improved autonomic regulation. Table 1 lists the studies that fall into these categories.

Asthma and Chronic Obstructive Pulmonary Disorder (COPD)

HRVB has been shown to be a powerful intervention for asthma. Lehrer and his colleagues (2004) have published a well-designed, comprehensive study in which HRVB with home practice was compared to three other credible treatments. The HRVB participants reported fewer symptoms, had better lung function, with no medication boosts (Lehrer, Smetankin, & Potapova, 2000; Lehrer et al., 2004). Dr. Lehrer's team is currently evaluating HRVB in a multisite, NIH-funded random control trial. One member of the original team (Giardino, Chan, & Borson, 2004) headed a group evaluating functional improvements in COPD.

Table 1. Disorders treated with HRVB that are hypothesized to have restoration of autonomic function as the primary mediator

Disorder	Intervention	Design (Control)	Measures	Results	Reference(s)
Asthma					
	HRVB + HT	vs. Sham EEG	Symptoms, lung function, medication	HRVB > control	Lehrer et al., 2000; Lehrer et al., 2004
Chronic Obstructive Pulmonary Disease					
	HRVB + oxymeter fdbk	vs. TAU	6-minute walk	HRVB > TAU	Giardino et al., 2004
Functional Gastrointestinal Disorders					
Recurrent Abdominal Pain	Slow breathing + temp fdbk	vs. TAU	Parent and child symptom ratings	Breathing > control	Humphreys & Gevirtz, 2000
Recurrent Abdominal Pain	HRVB	vs. Control	Symptom ratings and HRV measures	Symptom improvement associated with SDNN gains	Sowder et al., 2010
IBS	HRVB	vs. Hypnosis	IBS symptom severity scale, HADS	Both groups improved equally (HRVB slightly better)	Dobbin, Dobbin, Ross, Graham, & Ford, 2013
Recurrent Abdominal Pain	HRVB integrated into other therapies	Case study	Symptom log	Greatly improved	Masters, 2006
Cyclic Vomiting	HRVB	Case study	Vomiting frequency	Greatly improved	Slutsker, Konichezky, & Gothelf, 2010
Recurrent Abdominal Pain	HRVB	TAU	IBS symptom measures	HRVB > TAU	Ebert, 2013
Fibromyalgia					
Cardiac Rehabilitation	HRVB	vs. TAU	Standard FM scales	BFD > TAU	Hassett et al., 2007
Congestive Heart Failure	HRVB	vs. Sham EEG	6-minute walk	HRVB > sham EEG if LVEF > 31	Swanson et al., 2009
Coronary Artery Disease	HRVB	vs. TAU	HRV measures (SDNN)	HRVB > TAU	Del Pozo, Gevirtz, Scher, & Guarneri, 2004

Table 1. Continued.

Disorder	Intervention	Design (Control)	Measures	Results	Reference(s)
Coronary Artery Disease	HRVB + CBT	HRVB + CBT vs. stress management	HRV measures + adjustment scales	HRVB + CBT > stress management	Nolan et al., 2005
Congestive Heart Failure	HRVB + stress management	Case studies	Harvested heart tissue viability	Training group equal to LVAD	Moravec, 2008; Moravec & McKee, 2013
Hypertension					
	HRVB	vs. Sham EEG	Medication adjustment and BP	HRVB maintained BP with fewer meds	Reinke et al., 2007
Prehypertensives	HRVB	vs. Slow breathing and control, 3 month FU	BP, HRV, BRS	HRVB > either control, improved on BP, HRV, and BRS measures	Lin et al., 2012
Prehypertensives	Slow abdominal breathing + EMG biofeedback	vs. Slow breathing alone	BP, HRV	Slow breathing = EMG feedback > slow breathing alone	Wang et al., 2009
Chronic Muscle Pain					
	HRVB + myofascial release	Four groups: stabilization exercises, HRVB alone, myofascial release alone, or combination	Pain and function measures	Combination superior to other interventions	Gordon & Gevirtz, 2006; Vagades, 2011
	HRVB	Case studies	Trigger point pain	HRVB combined with physical release relieves pain	Gevirtz, 2006

Table 1. Continued.

Disorder	Intervention	Design (Control)	Measures	Results	Reference(s)
	HRVB	vs. TAU	Measures of pain, vitality and social functioning	HRVB > TAU	Hallman, Olsson, von Scheele, Melin, & Lyskov, 2003
OB/Gyn					
Preterm Labor	HRVB	vs. Control sessions	Preterm stress, preterm delivery	HRVB > control for stress 13% vs. 33% preterm delivery (n.s.)	Siepmann et al., in press
PIH	HRVB (StressEraser	vs. Matched case histories	BP, birth weight, gestation length	HRVB > controls for birth weight and gestation length	Cullin et al., in press
PIH	Breathing and temperature	vs. activity management vs. TAU	BP levels logged daily	Biofeedback group halted; rising BPs vs. other groups	Sommers, Gevirtz, Jasin, & Chin, 1989

Functional Gastrointestinal Disorders

In recent years (Gershon, 1998), a great deal of progress has been made in understanding the enteric nervous system and its autonomic regulation. There now exists an institute in London devoted to neurogastroenterology (Wingate Institute, Barts University). This group has shown that esophageal pain thresholds are dramatically affected by six-per-minute breathing maneuvers (Botha, Naqvi, Chua, Knowles, & Aziz, 2012). For these reasons, it seems likely that the HRVB techniques may be working through the autonomic regulation pathway. A number of outcome studies are listed, most of which report very large effect sizes. One study coming out of our research group (Sowder, Gevirtz, Shapiro, & Ebert, 2010) showed that improvement was mediated by the restoration of vagal tone presumably influenced by the HRVB. A recent study from the U.K. compared hypnosis to HRVB for irritable bowel syndrome. Both groups showed nice improvements with the HRVB group reporting slightly more reduction in symptoms (though the difference was not quite significant). The HRVB group improved by six standard deviations. This application appears to be one of the most promising for the HRVB.

Fibromyalgia (FM)

The vast literature on FM does include some references to HRVB (Hassett & Gevirtz, 2009; Hassett et al., 2007), though it appears that a more integrated approach is necessary that includes exercise, therapies such as acceptance and commitment therapy (ACT) or cognitive-behavioral therapy (CBT), exercise (Jones & Liptan, 2009), and sleep hygiene. The leading rheumatologists in the field do urge integrated treatment and often include biofeedback among the components (Benett, 2013; Hassett & Gevirtz, 2009)

Cardiac Rehabilitation

As Table 1 shows, there is a promising literature using HRVB for various cardiologic disorders. Within cardiology, it is increasingly recognized that balancing SNS and PNS activity is a crucial component of cardiac health (Sabbah, 2011; Sabbah et al., 2011). The work at the Cleveland Clinic led by Chris Moravec is especially exciting in that it shows the potential impact of HRVB on the heart muscle itself (Moravec & McKee, 2013).

Hypertension

The use of biofeedback in treating essential hypertension is well known within the field. However, results using finger temperature or electromyography (EMG) feedback have been limited (Linden & Moseley, 2006). Here we see HRVB as a potential modality that might work more efficiently by strengthening the baroreflex. More research is needed to determine the strength of the baroreflex as a mediator. Both Reinke, Gevirtz, and Mussgay (2007) and Vaschillo, Lehrer, Rishe, and Konstantinov (2002) have shown substantial gains in baroreflex sensitivity with HRVB training).

Chronic Muscle Pain

As shown in Table 1, a few studies have shown the efficacy of using HRVB with chronic pain syndromes. Our group has demonstrated that "trigger points" (TPs) are sympathetically mediated (Gevirtz, 2006; Hubbard, 1996, 1998; Hubbard & Berkoff, 1993). A recent study (Vagades et al., 2011) carried out in Germany has shown that adding HRVB to traditional back exercises and trigger point release produced the greatest pain relief in back pain patients. The mechanism hypothesized to be in play for TPs is known as "accentuated antagonism" (Olshansky, Sabbah, Hauptman, & Colucci, 2008; Schwegler & Jacob, 1975; Yang & Levy, 1984). It has been shown that good autonomic balance allows the PNS to govern the SNS in nonemergency situations. Therefore, the use of HRVB may be effective by blocking some of the sympathetic overflow to TPs.

Obstetric/Gynecological Conditions

As can be seen in Table 1, a few studies have recently appeared that seem to show promise for conditions such as pregnancy-induced hypertension and preterm labor. In our recent study, which we hope to replicate soon, the HRVB group had almost two weeks added gestation period with significantly heavier babies (Cullin et al., in press).

Possible Mechanism II: Central Effects by Way of the Vagal Afferent Nerve

A second proposed mechanism grows out of the work on vagal nerve stimulation and deep brain stimulation (Ching et al., 2012; Christopher et al., 2012; Garcia-Navarrete et al., 2012; George et al., 1994; George et al., 2000; Hauptman & Mathern, 2012; Holtzheimer et al., 2012; Lozano et al., 2012; Mayberg, 2003). The fact that a pacemaker or electrical stimulation can sometimes reverse intractable depression or epilepsy leads to attempts to see whether HRVB, which promotes slow diaphragmatic breathing, and which in turn stimulates subdiaphragmatic vagal afferents (Porges, 2011), can have central effects. Whether or not this is the primary mechanism, it appears that HRVB is a promising intervention for depression, anxiety, sleep, and possibly optimal performance. I include optimal performance in this grouping because several groups have used neurofeedback as well with mixed results. For all of these disorders, factors such as cognition, mindfulness, and self-efficacy changes are likely a part of the picture.

Further evidence for these central effects comes from heart period evoked potential (HEP) studies that show that

Table 2. Disorders treated with HRVB that are hypothesized to involve central nervous system mediators

Disorder	Intervention	Design (Control)	Measures	Results	References
Depression					
	HRVB	No control, single group trial	BDI & Hamilton	Depression reduced markedly	Karavidas et al., 2007
	HRVB with StressEraser + DBT	vs. DBT + relaxation	BDI & Hamilton	HRVB group superior	Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009
	HRVB	Depressed vs. healthy control	BDI	Depressed patients reduced on BDI, no changes in controls	Siepmann, Aykac, Unterdorfer, Petrowski, & Mueck-Weymann, 2008
	HRVB	vs. TAU after cardiac surgery	CES-D	HRVB > TAU	Patron et al., 2013
	HRVB	vs. Relaxation	BDI & Hamilton	HRVB > relaxation	Rene, Gevirtz, Muench, & Birkhead, 2011
	HRVB + DBT + Zoloft	vs. Zoloft	BDI & Hamilton	HRVB + Zoloft alone	Rene et al., 2011
Anxiety Disorders					
PTSD	HRVB	vs. TAU	CAPS, trauma symptom checklist	HRVB > TAU	Tan, Dao, Farmer, Sutherland, & Gevirtz, 2011
	HRVB	vs. Control	Information processing	HRVB > information processing	Ginsberg, Berry, & Powell, 2010
	HRVB + DBT	vs. Relaxation	PCL	HRVB = relaxation	Zucker et al., 2009
Phobia	HRVB	Case example	approach phobic object	Improved phobic avoidance	Prigatano, 1972
Anxiety	HRVB	vs. Matched controls	Somatic symptoms	HRVB using HeartMath + control	Nada, 2009
	HRVB	vs. Delayed treatment	Anxiety and mood	HRVB > control	Henriques, Keffer, Abrahamson, & Horst, 2011

Table 2. Continued.

Disorder	Intervention	Design (Control)	Measures	Results	References
Stress	HRVB + stress management	vs. Control	Cholesterol, glucose, heart rate, blood pressure, positive outlook, and overall psychological distress.	HRVB +> control on all measures, projected cost savings	McCraty, Atkinson, Lipsenthal, & Arguelles, 2009
	HRVB + therapy	Single group study	Anxiety measures	Improvement	Reiner, 2008
Sleep					
	HRVB (StressEraser)	Case report	Sleep log	Insomnia improvement long-term maintenance	McLay & Spira, 2009
Sleep Lab Insomnia	HRVB	vs. Control	Sleep disturbance scale + actigraphy	HRVB > controls	Ebben et al., 2009
Performance					
Baseball	HRVB	vs. Sports psychology control	Hitting performance	HRVB > controls	Strack & Gevirtz, 2011
Golf	HRVB	Case study	Golf performance	Reduced anxiety, improved performance	Lagos, Vaschillo, Vaschillo, Lehrer, & Bates, 2008
Dance	HRVB	vs. Neurofeedback vs. control	Refereed dance ratings	HRVB and neurofeedback > control	Raymond, Sajid, Parkinson, & Gruzelier, 2005
Dance	HRVB	vs. Neurofeedback vs. control	Refereed dance ratings	No effect on dance HRVB reduced anxiety	Gruzelier, Thompson, Brandt, & Steffert, in press
Music	HRVB (emWave)	vs. Control	Performance anxiety measures	HRVB > control	Thurber, 2006
	HRVB or slow breathing	vs. Control	State anxiety	HRVB and slow breathing > control	Wells, Outhred, Heathers, Quintana, & Kemp, 2012

factors such as interoception, heartbeat detection, or slow breathing affect the brain (Fukushima, Terasawa, & Umeda, 2011; MacKinnon et al., 2013; Terhaar, Viola, Bar, & Debener, 2003).

Depression

As can be seen in Table 2, there have been a number of studies showing decreased depression levels with HRVB. In fact, we have found this to be a common result even in studies where the depression is secondary to trauma or anxiety. We have just completed another study comparing HRVB to EMG biofeedback, which showed reduced depression in a sample that only had mild levels of depression. This has been a somewhat unexpected finding, but one that bears future research, especially with the recent reports of the equivalence of SSRIs and placebo (Fournier et al., 2010; Kirsch et al., 2008; Turner, Matthews, Linardatos, Tell, & Rosenthal, 2008). Combining HRVB with other empirically based therapies will also contribute to our understanding of depression mechanisms.

Anxiety

Fewer studies have been reported for anxiety, though a lot of anecdotal evidence is out there on the stress reducing effects of HRVB. Devices like the StressEraser® or the emWave®, and now the MyCalmBeat and Inner Balance®, are testimonies to the perception of the antistress properties of HRVB. As can be seen in Table 2, there are some data to support this. An area of future interest is the use of HRVB for trauma symptoms. We are currently investigating adding HRVB to therapies such as prolonged exposure, cognitive processing, or ACT. The argument for this approach is laid out by van der Kolk (2001, 2006). Much more research is needed, especially given the escalating incidence of trauma symptoms reactive to military and civilian experiences of trauma.

Sleep

Sleep is an area that seems likely to respond to HRVB, but little has been reported as yet. The one study published that looked at lab-induced insomnia is a promising start (Ebben, Kurbatov, & Pollak, 2009).

Optimal Performance

Performance in sports and the arts is a potentially fruitful application. Vaschillo and colleagues (2002) first reported their results in the USSR in the early days of HRVB (see Lehrer, 2013, this issue). At professional meetings, we have seen a number of exciting anecdotal reports with golfers, gymnasts, baseball hitters, dancers, and musicians. Unfortunately, only a few studies with adequate controls have been reported.

Possible Mechanism III: The Cholinergic Anti-Inflammatory System

Kevin Tracey and others have investigated regulation of an inflammatory response mediated by the PNS (Tracey, 2002; Tracey, Alexander, Eyre, & Singh, 1985). These researchers suggest that PNS interventions might be able to modulate inflammatory responses that are not functional and that might create problems such as autoimmune disease or poor healing. Thus far only one study has attempted to investigate this with HRVB (Lehrer et al., 2010). The results were impressive in that HRVB reduced cytokine symptoms compared to controls, but did not affect the interleukins themselves. This may prove to be an important application, but it is still in its infancy.

Conclusion

In summary, a number of research studies have given at least tentative support for the effectiveness for a wide range of medical and emotional disorders. Each cluster of disorders discussed here shows a probable psychophysiological pathway of action, by means of which heart rate variability biofeedback is likely to ameliorate the production of symptoms. Additional research is needed to further demonstrate the efficacy of HRVB in each cluster of disorders, and to solidify current understandings of the likely mechanisms of action.

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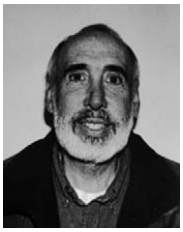

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