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Biofeedback of Heart Rate Variability and Related Physiology: A Critical Review

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Abstract Low heart rate variability (HRV) characterizes several medical and psychological diseases. HRV biofeedback is a newly developed approach that may have some use for treating the array of disorders in which HRV is relatively low. This review critically appraises evidence for the effectiveness of HRV and related biofeedback across 14 studies in improving (1) HRV and baroreflex outcomes and (2) clinical outcomes. 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. Some evidence suggests HRV biofeedback may result in long-term carry-over effects on baroreflex gain, which is an area most promising for future investigations. On the other hand, concerning clinical outcomes, there is ample evidence attesting to efficacy of HRV biofeedback. However, because clinical and physiological outcomes do not improve concurrently in all cases, the mechanism by which HRV biofeedback results in salutary effects in unclear. Considerations for the field in addressing shortcomings of the reviewed studies and advancing understanding of the way in which HRV biofeedback may improve physiological and clinical outcomes are offered in light of the reviewed evidence.

Keywords Heart rate variability · Biofeedback · Baroreflex · Respiratory sinus arrhythmia

Introduction

Knowledge of the interplay between physiological and psychological phenomena, and how these phenomena might be manipulated to promote health, have been persistent areas of growth in both medical and psychological fields of study since the inception of psychophysiology and behavioral medicine. Heart rate variability (HRV) is one of the newest physiological parameters that has gained attention in such a context.

HRV originally was considered to be error variance that prevented researchers from discerning valid signals of cardiac activity (Lehrer 2007). However, knowledge of physiological processes evolved to reveal HRV's value as a variable of independent interest. The magnitude and complexity of HRV signify the ability to adapt to physiological changes, and low HRV increases susceptibility to stress and disease. HRV reflects several mechanisms working in concert to maintain a sufficient level of cardiovascular activity. When these systems are not functioning at an adequate level, an individual's stress response may be more severe or temporally extended. The consequence is a more deleterious effect of stress that may lead to physical or psychological illnesses, such as cardiovascular disease, metabolic syndrome, depression, and anxiety (McGrady 2007). It follows that optimizing HRV could better equip individuals to manage stress and potentially reduce risk for, or severity of, stress-related disease states.

In recent years, investigators have drawn attention to the potential prognostic value of HRV due to relations between low HRV-associated parameters and several

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physical and mental health problems. For example, low HRV and/or baroreflex sensitivity have been shown to be associated with all-cause mortality and sudden cardiac death in myocardial infarction patients (Bigger et al. 1993; La Rovere et al. 1998), hypertension (Schroeder et al. 2003), fibromyalgia (Martinez Lavin et al. 1998), diabetic neuropathy (Boysen et al. 2007), depressive symptomology (Agelink et al. 2002; Yeragani et al. 2002), anxiety symptoms (Watkins et al. 2002), generalized anxiety disorder (Thayer et al. 1996), panic disorder (Cohen et al. 2000), and post-traumatic stress disorder (Cohen et al. 1997, 2000), among other conditions. It is apparent that low HRV and baroreflex sensitivity pervade several undesirable physical and mental health conditions. As a marker of decreased autonomic health, low HRV may play a significant role in conveying risk for perseveration, if not worsening, of symptoms, as well as morbidity and mortality. Efforts to identify effective treatments that target HRV and baroreflex function therefore are warranted, particularly if such treatments produce desirable clinical outcomes and are viable for use as adjuncts to standard medical treatments.

Biofeedback (BF) has been implemented recently as a method for altering HRV parameters and/or baroreflex functioning. This review provides an evaluation of the literature examining whether HRV and baroreflex BF are successful in altering physiological parameters as well as disease-related outcomes (across a range of samples exhibiting either medical disease or psychiatric illness). The effectiveness of such BF in changing physiological outcomes of interest in healthy samples also is examined. Research involving HRV BF is reviewed critically, and suggestions are provided for areas of improvement in understanding the effects of such BF through future empirical endeavors.

Literature was assembled for the current review by searching Medline, PsycArticles, and PsycInfo databases, using “heart rate variability biofeedback” and “baroreflex biofeedback” as search terms. To supplement the articles located in the preceding manner, references from those articles were screened for additional relevant studies. Studies were only included that (a) incorporated HRV or baroreflex BF and (b) analyzed HRV and/or baroreflex data as physiological outcomes. Seven articles were excluded because they met the first criterion, but failed to report physiological outcome data of interest. Although not all of the 14 studies that met both criteria reported clinical outcomes, most did so, and clinical results are reviewed as well. The review is organized primarily by the type of BF involved (i.e., HRV or baroreflex), followed by disease state (i.e., no disease, medical disease, or psychiatric illness). Table 1 summarizes descriptive details of the all studies.

HRV Biofeedback Studies

Healthy Adults

Lehrer et al. (2003) investigated the efficacy of HRV BF in improving baroreflex gain in a healthy adult sample. The authors randomized participants to treatment and control groups. The treatment group underwent a manualized HRV BF protocol (Lehrer et al. 2000), which is commonly employed across many studies reviewed herein. Details regarding the protocol may be found in the published manual.

Concerning treatment effects during biofeedback practice, low frequency (LF) and total HRV were significantly higher in the treatment group, but that difference was not found in the control group. High frequency (HF) HRV was significantly lower during BF sessions than during rest periods for the treatment group only, which may be expected due to slowed breathing during HRV BF that precipitates a shift in respiratory sinus arrhythmia (RSA) from the HF to the LF range. Controlling for respiration rate, no significant changes in baroreflex gain occurred between rest and BF periods in either group. Finally, long-term carry-over effects of treatment were examined by analyzing differences in the initial baseline measures from Sessions 1 and 10. No long-term differences were evident in either group for HRV. However, long-term carry-over effects were evident for baroreflex gain, which increased significantly at rest from Session 1 to Session 10 in the treatment group only. Therefore, it is plausible that HRV BF functionally exercised the baroreflexes by maximizing oscillations within participants’ resonance frequency, making the baroreflexes more efficient at rest over time. The authors noted that such an effect has not been found previously and that it evidences neuroplasticity of the baroreflex.

Asthma

Lehrer et al. (1997) examined the effects of HRV BF, compared to electromyography/incentive inspirometry (EMG) BF and to a wait list control (WLC) condition, in patients with asthma. Participants were randomly assigned. HRV BF was modeled after a previously developed method that is functionally similar to the manualized method described above by Lehrer et al. (2000). Briefly, EMG BF entailed breathing automatically and abdominally (without ‘trying too hard’), while relaxing chest, shoulder, and neck muscles.

Concerning HRV within the THM frequency (comparable to LF), analyses revealed that increased HRV was evident during BF practice compared to pre- and post-task rest periods for the HRV BF group, but not for the EMG

Table 1 Descriptive characteristics of studies reviewed

Study	Disease/disorder	Sample characteristics[a]	Exclusion criteria	HRV-related outcomes
Lehrer et al. (2003)	None (healthy)	$N = 54$ (38 women, 16 men); treatment group, mean age = 30.55; control group, mean age = 27.93	Smoking; psychosis history; mental deficiency; heart disease; arrhythmias; chronic pulmonary disease; serious neurological illness; medication affecting autonomic nervous system	LF HRV, HF HRV, total HRV, baroreflex gain
Lehrer et al. (1997)	Asthma	$N = 17$ (12 women, 5 men); ages 18–65 ($M = 37.8$, SD = 12.9)	History of chronic bronchitis or sinusitis; history of emphysema or non-asthma respiratory disease; smoking within 2 years prior; experience with a self-regulation procedure (e.g., yoga); psychiatric disease requiring medication; cardiovascular or neurological disease	THM rhythm HRV
Lehrer et al. (2004)	Asthma	$N = 94$ (64 women, 30 men); mean age, 37.3 (SD = 10.2)	Disorder impeding ability to perform BF procedure (e.g., arrhythmia); failed test for asthma; abnormal diffusing capacity; current self-regulation practice	LF HRV, baroreflex gain
Lehrer et al. (2006)	Asthma	$N = 45$ (26 women, 10 men); mean age ranges across groups, 27.55 (SD = 6.30) to 50.44 (SD = 3.23)	See exclusion criteria for Lehrer et al. (2004)	LF HRV, total HRV, baroreflex gain
Cowan et al. (2001)	Coronary artery disease	$N = 133$ (27% female)	Diabetes; moderate or severe anoxic encephalopathy; life-threatening comorbidity (e.g., renal failure); coronary artery bypass surgery or similar procedure within 6 months prior	HF HRV
Del Pozo et al. (2004)	Coronary artery disease	$N = 63$ (21 women, 42 men); ages 45–84; treatment group, mean age = 66.81 (SD = 8.4); control group mean age = 67.97 (SD = 8.98)	Class IV congestive heart failure; pacemaker; atrial fibrillation or other arrhythmia prohibiting BF; current participation in another clinical trial	SDNN, LF HRV
Nolan et al. (2005)	Coronary heart disease	$N = 46$ (6 women, 40 men); treatment group, mean age = 54.22 (SD = 1.04); control group, mean age = 54.95 (SD = 1.52)	Class III–IV chronic heart failure; 2nd–3rd degree atrioventricular block; active unstable angina; atrial fibrillation; significant arrhythmia; sick sinus syndrome; valvular disease	HF HRV
Giardino et al. (2004)	Chronic obstructive pulmonary disease	$N = 20$ (10 women, 10 men); ages 48–79 ($M = 63$, SD = 9.6)	Defective atrioventricular cardiac conduction; severe neurocognitive impairment	RSA
Hassett et al. (2007)	Fibromyalgia	$N = 12$ (female only); ages 18–60	None reported	LF HRV, HF HRV, total HRV, baroreflex gain

Table 1 continued

Study	Disease/disorder	Sample characteristics[a]	Exclusion criteria	HRV-related outcomes
Swanson et al. (2009)	Heart failure	$N = 29$ (6 women, 23 men); treatment group, mean age = 54 (SD = 11); control group, mean age = 56.4 (SD = 13.5)	Participation in another research study (last 30 days), acute coronary syndrome, recent acute myocardial infarction, CABG or PCI within past 6 months, non-bypassed left main coronary artery with a luminal stenosis of 50% or more, significant valvular heart disease, acute myocarditis, permanent pacemaker, cardiac arrhythmia, uncontrolled hypertension, cardiomyopathy with a beta-blocker, heart failure treated with injectable inotropic agent	SDNN, pNN50
Karavidas et al. (2007)	Major depressive disorder	$N = 11$ (7 females, 4 males); ages 25–58 ($M = 45$, SD = 10.8)	Non-MDD primary Axis I or II diagnosis; current substance abuse; cognitive impairment affecting ability to participate in BF; antidepressant, anti-anxiety, or psychotherapy treatment (unless unchanged in past 3 months); any medication other than antidepressant or anti-anxiety medication; history of psychosis, mental deficiency, coronary artery disease, heart disease, heart failure, kidney disease, hypertension, chronic low BP, hypoglycemia, or cardiac arrhythmia	LF HRV, HF HRV, total HRV, SDNN, PNN50,
Zucker et al. (2009)	PTSD	$N = 38$ (17 women, 21 men); ages 18–60	Non-elevated PTSD symptomology, <2 weeks abstinence from substance use behavior, inability to comply with procedures due to organic illness, inability to secure pulse reading for BF	SDNN
Reyes del Paso and González (2004)	None (healthy)	$N = 32$; ages 18–26	None reported	Baroreceptor sensitivity and power, RSA
Overhaus et al. (2003)	Hypertension (and normotension)	$N = 14$ (7 women, 4 men [completers only]); ages 25–59	Structural cardiovascular disease; diabetes; renal insufficiency; psychoactive drugs; beta-blockers; history of neurological or psychiatric illness; smokers	SDNN, baroreflex sensitivity

Note. BP = blood pressure; HRV = heart rate variability; HF = high frequency; LF = low frequency; PNN50 = percentage of successive normal interbeat intervals differing by at least 50 s (correlated with HF HRV); RSA = respiratory sinus arrhythmia; SDNN = standard deviation of normal-to-normal beats; THM = Traube–Hering–Mayer wave

[a] Differences in method of reporting sample characteristics (i.e., age) are due to differences in information provided by study authors

BF or control groups. There were no significant differences in HRV between initial and final rest periods of sessions for any group, indicating absence of short-term effects of BF on HRV within single sessions. Differences in HRV between the initial rest period for the first and final sessions were not analyzed, so long-term carry-over effects of BF across the entirety of treatment was not determined.

Airway impedence, the predominant clinical outcome of interest, decreased significantly in the HRV BF group, whereas no significant changes were evident in the other groups. Decreases were noted both within sessions, during BF practice, and were evident across sessions over time. The authors noted that clinical improvement in the HRV BF group may have resulted from mechanically derived reduction in bronchoconstriction due to BF. Another possibility is that baroreflexes may have grown more efficient via HRV BF, thereby contributing to clinical improvements in the HRV BF group. However, because baroreflex gain was not assessed, the likelihood of that possibility is indeterminable.

Another HRV BF study with asthma patients included a placebo condition (Lehrer et al. 2004). Participants were randomized in a restricted fashion to four conditions: full manualized HRV BF (Lehrer et al. 2000), HRV BF without pursed lips abdominal breathing, placebo BF, or WLC. The sham biofeedback administered to the placebo group involved frontal EEG alpha rhythms. Ratings of treatment credibility did not differ across groups. The HRV BF groups received equipment to assist with BF while practicing at home.

Treatment and session interacted whereby total and LF HRV increased significantly during BF practice within sessions in HRV BF groups only. Baroreflex gain also increased significantly within sessions during BF practice for the HRV BF groups, but not for placebo BF or WLC groups. No significant changes in physiological outcomes were evident across treatment sessions for any groups, indicating lack of long-term carry-over effects of treatment.

Several clinical improvements were evident in the two HRV BF treatment groups. Most importantly, no participants in the full HRV BF protocol group experienced an asthma exacerbation during the study. This is particularly important to consider as it presents the possibility that such treatment could allow individuals to avoid use of steroids for prevention of these exacerbations. This possibility remains to be assessed directly, however. Significant decreases in medication use were noted in the HRV BF and placebo groups, and the decrease was significantly larger in the HRV BF groups. Significant changes in asthma symptoms also were noted for the same three groups. A placebo effect is indicated, therefore, because symptom reports improved in all three groups, but more significant improvements in medication use (i.e., actual asthma severity) were noted for the HRV BF groups only.

Baroreflex gain was measured in this study (Lehrer et al. 2004), unlike the prior investigation (Lehrer et al. 1997), and changes were not evident across sessions. Therefore, the hypothesis offered by Lehrer et al. (1997) that improvement in asthma may be influenced by improvement in baroreflex efficiency is called into question. As the authors note (Lehrer et al. 2004), the feasibility of clinical effects being consequent to bronchodilation effects remains consistent in this study. HRV BF may have contributed to those effects, but concluding that from the current and prior investigation is not possible, and there is not strong evidence to suggest that clinical effects must be mediated by changes in autonomic functioning. Further, additional non-autonomic mechanisms that result from resonance frequency breathing during HRV BF (e.g., improvement in gas exchange, change in inflammatory processes) are plausible (Lehrer et al. 2004).

Additional analyses were conducted and published (Lehrer et al. 2006) on a portion of Lehrer et al.'s data (2004) to investigate how effects of HRV may differ in asthmatic patients dependent on age. Only data from the HRV BF groups were reanalyzed. Interestingly, when examining total HRV, age was significantly and negatively associated with change in HRV from rest to BF tasks *only* in the group receiving the protocol without pursed lips abdominal breathing. Significant findings for age and total HRV were not evident in the group receiving the full HRV BF protocol, suggesting that pursed lips abdominal breathing may be an important HRV BF component among older individuals with asthma. A significant negative association was also evident between age and baroreflex gain during BF practice for both treatment groups. Both of the previous findings utilized age as a continuous variable. Results only were available for LF HRV using age as a dichotomous variable (i.e., older or younger than 40 years). Older participants showed significantly smaller increases in LF HRV during BF practice than younger participants, but that effect again was only evident in the abbreviated protocol.

Medication usage was utilized again, as was the case in original data analysis (Lehrer et al. 2004), as the primary clinical outcome. Statistically and clinically significant decreases in prescription medication use were evident, and these changes did not differ between age groups.

Cardiovascular Disease

Within a sample of participants with coronary artery disease (CAD), Cowan et al. (2001) randomized patients to treatment or control groups. The control group received treatment as usual, and the treatment group received psychosocial therapy involving HRV and EMG BF, relaxation, cognitive behavioral therapy, and health education. Patients were instructed to increase respiratory sinus arrhythmia (RSA) by implementing abdominal breathing, progressive muscle relaxation, and other techniques.

The authors did not explicitly indicate which analyses were utilized for HRV outcomes, or which HRV outcomes were and were not assessed. They noted a lack of significant differences between treatment and control groups in HRV. No significant differences were observed between pre- and post-treatment HRV in the treatment group, which suggests a lack of long-term carry-over effects of treatment. There was a significant treatment effect when removing those with high baseline HRV, but that treatment effect was not described.

However, significant clinical differences were found, whereby the treatment group had a significantly lower risk of cardiovascular mortality compared to the control group. Further, that difference was maintained when controlling for other factors also found to relate significantly to risk for cardiovascular mortality (e.g., depression). The mechanism by which clinical effects were conferred is particularly difficult to extrapolate for this study because HRV BF was delivered as part of a larger psychosocial treatment package, which included other BF components, psychotherapy, and education. Additionally, measurement of HRV was not clearly delineated, and therefore it is possible that there were treatment effects on HRV or baroreflex parameters that simply were not measured or discussed.

Del Pozo et al. (2004) examined the effects of HRV BF in a sample of patients with CAD as well. Lehrer et al.'s (2000) manual for HRV BF was utilized, and participants were randomized to receive either HRV BF treatment or treatment as usual. HRV measurement occurred during 15 min of rest at the first and last treatment session (i.e., Weeks 1 and 6) and at a 12-week follow-up session. In the treatment group only, standard deviation of normal-to-normal beats (SDNN), an index of overall HRV, increased over time. SDNN increased significantly from baseline to follow-up in the treatment group, whereas SDNN *decreased* significantly for the control group. Therefore, a long-term carry-over effect of treatment was evident solely in the treatment group. Similar patterns of findings were evident for two other measures of total HRV (i.e., RMSSD and SDANN). Additionally, the authors assessed LF HRV as a manipulation check of the treatment and found that it increased both within and between sessions, but no further details were given for LF HRV results. As the authors were interested in determining whether HRV BF could alter HRV in CAD patients, rather than determining whether the treatment resulted in clinical improvements, clinical outcomes were not measured.

The effects of HRV BF in patients with coronary heart disease were examined by Nolan et al. (2005). Participants were randomized to receive either a typical stress management protocol or a HRV BF protocol. Training first occurred without a stressor and progressed to production of a LF power spectrum peak during three stressor tasks. Assessment occurred without BF pre- and post-treatment during a stress reactivity protocol with three separate stress tasks. For the post-treatment assessment, only the treatment group showed significant increases in HF HRV from the stress tasks to stress recovery periods. Such increases only occurred during the physical stressor task (i.e., not during cognitive stressor and stressful event recall tasks). As HRV was the target outcome of interest, the authors did not report data related to coronary heart disease processes.

Chronic Obstructive Pulmonary Disease (COPD)

Due to previous findings that RSA is decreased in individuals with COPD, Giardino et al. (2004) implemented HRV BF in combination with pulse oximetry BF in a sample of 20 COPD patients. All participants underwent HRV BF treatment, which was modeled after the Lehrer et al. (2000) manual. Significant increases in RSA were evident at post-treatment when participants breathed spontaneously. It is possible that HRV BF, by purportedly exercising the baroreflexes, improved RSA post-treatment in the absence of paced breathing due to increased efficiency in baroreflexes over time.

Primary clinical outcomes were distance traveled during a standard walking test and quality of life as assessed by a self-report measure for individuals with airway obstruction. Significant improvements in both clinical outcomes were evident. As the authors note, similar to studies of HRV BF with asthma patients (e.g., Lehrer et al. 1997), mechanical changes in airflow and improved gas efficiency may be the mechanism by which HRV BF contributes to clinical effects.

Heart Failure

One study examined the effects of HRV BF in patients diagnosed with heart failure (Swanson et al. 2009). Participants were randomized to HRV BF or attention placebo (i.e., quasi-false alpha-theta BF) groups. Analyses of a credibility measure indicated that the placebo procedure was viewed as credible. As measured from the baseline to the follow-up period, contrary to the authors' hypotheses, there were no consistent long-term carry-over effects of treatment on SDNN or pNN50 (proportion of consecutive interbeat intervals differing more than 50 ms).

Exercise tolerance, the primary clinical outcome in Swanson et al.'s (2009) investigation, was measured with distance walked by the participants in a standard 6-min walk test. When participants were divided based on disease severity (i.e., median split for high and low left ventricular ejection fraction), a three-way interaction emerged between group, disease severity, and time. The treatment group exhibited greater gains in distance walked compared to the control group, and those gains were more substantial in participants with less severe disease.

Fibromyalgia

Hassett et al. (2007) conducted a study in which individuals diagnosed with fibromyalgia participated in HRV BF according to the manualized protocol by Lehrer et al. (2000). Total and LF HRV increased significantly during BF practice. Baroreflex gain was significantly greater at the end of training sessions compared to the beginning of training sessions, providing evidence for a short-term carry-over effect of HRV BF on baroreflex gain. However, no long-term carry-over effects on any parameters were evident when comparing baseline measures from the first session and those from the 3-month follow-up session.

Several clinical improvements were noted in the study. Significant improvement in scores reflecting diminished functioning due to fibromyalgia symptoms was evident at a 3-month follow-up, as were improvements in reports of pain and depressive symptoms.

It is not possible for this study to conclude whether physiological effects of HRV BF can account for clinical differences. Increases in LF HRV during BF indicate that exercise of the baroreflexes may have occurred during biofeedback, and short-term carry-over effects on baroreflex gain support that possibility. The authors note that long-term carry-over effects were not evident in baroreflex gain in their sample of fibromyalgia patients, which contrasts with previous findings in healthy adults (Lehrer et al. 2003) where such long-term effects were present. Because the same protocol in the study was used, it is possible that the discrepancy in results is influenced by health status of the samples (i.e., healthy vs. fibromyalgia). However, the authors did not provide further comment on the issue.

Major Depressive Disorder (MDD)

Karavidas et al. (2007) conducted an open-label HRV BF study for treatment of MDD. The authors implemented HRV BF with 11 participants using the manual assembled by Lehrer et al. (2000). LF HRV and SDNN were both significantly higher during BF practice. Short-term carry-over treatment effects also were evident, as LF HRV and SDNN also were significantly higher during the post-BF rest period compared to the baseline rest period. Concerning long-term improvements, HRV, LF HRV, SDNN, and pNN50 significantly improved across earlier sessions (i.e., comparing sessions 1 and 4 or 7), which provides some evidence for long-term carry-over treatment effects. However, no significant physiological changes occurred between Sessions 1 and 10. The authors suggest that vagal stimulation occurred as evidenced by two results, namely the increase in LF HRV during BF practice (i.e., acute effect) and the paired increases in pNN50 and decreases in heart rate over time (i.e., chronic effect). It would be informative to discern whether baroreflex gain showed short- and/or long-term carry-over effects, but baroreflex gain was not measured.

Significant decreases in depressive symptoms were noted during and at the end of treatment, as indicated by both of the employed measures of depression. The first noted improvement across sessions in physiological parameters co-occurred with decreases in depressive symptoms. However, depressive symptoms continued to improve until the end of the treatment (i.e., session 10), whereas physiological outcomes did not show improvements beyond session 7. Therefore, initial resonance effects and cardiovagal stimulation may confer clinical improvements in depression symptoms that are successfully maintained without continued maintenance of HRV increases.

Post-traumatic Stress Disorder (PTSD)

One study compared the effects of RSA BF with the effects of progressive muscle relaxation (PMR) on PTSD symptoms (Zucker et al. 2009). The StressEraser (see Muench 2008) was utilized for RSA BF, and the treatment aimed to maximize RSA by using slow paced breathing (i.e., approximately six breaths per minute). In that way, heart rate and respiration should covary seamlessly, which is similar to what is achieved during HRV BF in studies described up to this point. Therefore, this study is considered in conjunction with other HRV BF investigations.

Participants were enrolled in a residential treatment program for substance use disorders, but had abstained from alcohol for at least 2 weeks. All participants displayed elevated PTSD symptomology on the Posttraumatic Stress Total (PTST) Scale of the Detailed Assessment of Posttraumatic States and endorsed at least one traumatic event experience. Thirty-eight participants were subjected to random assignment with stratification to make groups comparable (e.g., symptom severity, medication). Participants were given either a StressEraser or a PMR compact disc (and player) for home use. Information on the devices and how to use them were given, and participants were instructed to practice their respective treatments for 20 min each day for 4 weeks.

At pre- and post-treatment assessment periods, participants experienced a 5-min baseline period, a 10-min paced breathing period (i.e., at six breaths per minute), and a 5-min recovery period. An interaction effect showed that the RSA BF group increased resting SDNN at baseline from pre-treatment to post-treatment, whereas the same long-term effect was not apparent for the PMR group.

No additional significant differences were evident for the paced breathing exercise or the recovery period. Within-group analyses showed that both the RSA BF and PMR groups significantly reduced PTSD symptoms on the PTST and Posttraumatic Stress Checklist-Civilian Version from pre-treatment to post-treatment periods.

Baroreflex BF Studies

Healthy Adults

Reyes del Paso and González (2004) investigated whether baroreflex BF was capable of altering baroreflex function in a healthy sample. Participants attended three BF sessions that included a baseline period and two BF periods, followed by a brief rest period and another pair of BF periods. During BF periods, participants were instructed to increase ("increase condition") or decrease ("decrease condition") baroreflex sensitivity, and a visual display of baroreflex sensitivity served as BF. At the third and final session, BF was withheld so maintenance of baroreflex sensitivity regulation could be assessed in the absence of BF. Baroreflex sensitivity increased significantly during the increase conditions regardless of session, whereas it decreased significantly during decrease conditions in Sessions 2 and 3 only. Congruent findings were noted for RSA, which increased significantly during increase conditions, regardless of session. RSA decreased significantly during decrease conditions in Sessions 2 and 3 only. Finally, baroreceptor power significantly increased in the increase condition, whereas significant decreases were noted in the decrease condition.

Hypertension

A study preceding the Reyes del Paso and González (2004) investigation examined baroreflex BF in individuals with and without hypertension (Overhaus et al. 2003). All patients participated in the BF protocol, during which baroreflex sensitivity was calculated and displayed for participants, who were instructed to increase baroreflex sensitivity. Significant increases in baroreflex sensitivity were absent across and within sessions. SDNN increased during baroreflex biofeedback practice regardless of hypertensive status. Changes in baseline SDNN across treatment were not reported, so long-term carry-over effects cannot be determined. There was a significant correlation between baroreflex sensitivity and SDNN, so the lack of significant findings for baroreflex sensitivity is somewhat puzzling. It is possible that effects simply were insufficiently robust to reach the criterion level of significance during training. Finally, clinical improvements in blood pressure were not found.

Summary and General Critique

Overall HRV

Several studies analyzed total HRV or SDNN as an outcome of HRV BF treatment, and significant increases in total HRV during BF practice were reported across all of them (Hassett et al. 2007; Karavidas et al. 2007; Lehrer et al. 2003, 2004). Lehrer et al. (2006) additionally noted that such effects were stronger in younger than in older participants. Seven studies also examined long-term effects of HRV BF on total HRV or SDNN by analyzing differences between baseline measures at the first session and the final session (Lehrer et al. 2003, 2004; Karavidas et al. 2007; Swanson et al. 2009; Zucker et al. 2009) or at 3 months post-treatment (Del Pozo et al. 2004; Hassett et al. 2007). Significant increases in resting SDNN were evident in one study (Zucker et al. 2009), and Del Pozo et al. (2004) reported a significant increase in baseline total HRV at the 3-month follow-up assessment. Whereas these studies had several methodological limitations, the remaining five studies reported no significant long-term changes in total HRV or SDNN and had fewer methodological concerns. Overall, short-term carry-over effects of HRV BF on total HRV were noted consistently, whereas the evidence for long-term changes in total HRV or SDNN at rest is tenuous.

HF HRV

Of the studies examining HF HRV as an outcome, none found that it increased during BF periods (Hassett et al. 2007; Karavidas et al. 2007; Lehrer et al. 2003). No significant differences in HF HRV were reported between rest periods at baseline and follow-up sessions of treatment (Cowan et al. 2001; Hassett et al. 2007; Karavidas et al. 2007; Lehrer et al. 2003). One of these studies had several serious limitations (Cowan et al. 2001), another was less problematic (Hassett et al. 2007), and two were well-conducted studies. Despite variation in methodological soundness of the studies, all results are in agreement that HF HRV does not increase consequent to HRV BF treatment. As was discussed earlier in relation to Lehrer et al.'s (2003) investigation, the lack of changes in HF HRV is to be expected. As RSA shifts from the HF to the LF range of HRV during slow, paced breathing that is involved in BF practice, increases in HF HRV are unexpected. Therefore, absence of increases in HF HRV does not indicate lack of HRV BF's effectiveness.

As HF HRV is often equated with vagal tone, one may extrapolate HRV BF treatment does not improve vagal tone. However, caution must be exercised with such interpretations because vagal activity is influenced by two distinct autonomic pathways (i.e., originating in the dorsal motor nucleus or the nucleus ambiguous), but HF HRV and RSA are reflective of vagal activity from one pathway only (e.g., Porges 2007). Further, it has been illustrated that those parameters are subject to some sympathetic influence as well, which also negates them as purely representing vagal tone (e.g., Taylor et al. 2001). Therefore, whereas such measures are reflective of vagal activity to an extent, they cannot justifiably serve as absolute indicators of vagal tone.

LF HRV

Seven of twelve studies examining HRV BF included LF HRV as an outcome. Six of those studies found that LF HRV was higher during BF practice compared to rest periods (Hassett et al. 2007; Karavidas et al. 2007; Lehrer et al. 1997, 2003, 2004, 2006), and Lehrer et al. (2006) indicated that older participants showed significantly smaller increases than younger participants. It appears likely then that LF HRV increases during BF practice, suggesting that HRV BF acutely exercises baroreflexes. Four of the seven studies examining LF HRV outcomes assessed changes between the first to the last session of treatment, or from baseline to follow-up. No significant changes in LF HRV were noted (Hassett et al. 2007; Karavidas et al. 2007; Lehrer et al. 2003, 2004). Finally, Del Pozo et al. (2004) reported increases in LF HRV both within and between sessions, but did not provide specific details on what tasks they compared within sessions or which sessions were compared for between-session analyses. Overall, acute effects of HRV BF on LF HRV appear likely during BF practice, but short-term and long-term carry-over effects on LF HRV are not apparent.

However, as noted above, it is plausible that baroreflexes were exercised when LF HRV increased during BF practice and that changes in baroreflex measures, instead of LF HRV, would be more reasonably expected outside of BF practice. At resonance frequency (i.e., roughly 0.1 Hz), stimulation of baroreflexes results in resonance in the cardiovascular system (Vaschillo et al. 2006). When breathing occurs at this resonance frequency, the baroreflex is maximally stimulated in comparison to other frequencies, and this strengthens the baroreflex through exercise. As the baroreflex serves a homeostatic function and contributes to overall adaptability of the cardiovascular system, such conditioning of the baroreflex could prove quite beneficial regarding physiological functioning and disease risk.

Baroreflexes

The studies measuring effects of HRV BF on baroreflex outcomes differed in findings. One study failed to find significant changes in baroreflex gain during BF practice (Hassett et al. 2007), whereas two studies did find increases during BF practice (Lehrer et al. 2003, 2004). Investigations of baroreflex BF also showed mixed results; one study found significant changes in baroreflex sensitivity and power during BF (Reyes del Paso and González 2004), and the other study did not find such significant changes (Overhaus et al. 2003). Although findings were mixed, three of the studies that found significant changes in baroreflex measures during BF were methodologically strong (Lehrer et al. 2003, 2004; Reyes del Paso and González 2004) in comparison to two of the studies with null findings (Hassett et al. 2007; Overhaus et al. 2003).

Long-term baseline improvements in baroreflex outcomes were also assessed in some of the reviewed studies. Two studies with relatively sound methods found significant increases across treatment in baroreflex gain (Lehrer et al. 2003) or baroreflex sensitivity and power (Reyes del Paso and González 2004). The remaining studies, some having several important limitations, did not find long-term differences (Hassett et al. 2007; Lehrer et al. 2004; Overhaus et al. 2003).

As noted in the previous section, one breathes at resonance frequency during HRV BF, resulting in maximal stimulation and exercise of the baroreflex. Lehrer et al. (2003) illustrated a long-term carry-over effect of increased baroreflex gain at rest following treatment, which provides unique support for neuroplasticity of the baroreflex. Understanding that HRV BF can plausibly capitalize on such plasticity and improve the efficiency of the baroreflex, the possibility of increasing adaptability to stress is presented. Again, due to the major role that the baroreflex plays in supporting homeostasis within the cardiovascular system, such findings may provide insight into the way in which HRV BF may be clinically effective. This may be particularly relevant for individuals with illnesses related to cardiovascular dysfunction who are at heightened risk for disease progression or death due to restricted HRV or baroreflex functioning (e.g., La Rovere et al. 1998).

Clinical Outcomes

Significant improvements in clinical outcomes were overwhelmingly evident in the reviewed literature. This is particularly notable given that such changes cut across several disease states, namely asthma, cardiovascular disease, COPD, heart failure, fibromyalgia, MDD, and PTSD. Therefore, HRV BF should be considered seriously as a viable avenue through which to supplement traditional treatments of various illnesses.

With the singular exception of the HRV BF literature with asthmatic populations, it is somewhat premature to make conclusions regarding the efficacy of HRV BF in improving medical and psychiatric illness parameters. Each study is isolated, in that it is not embedded within a larger network of investigations of HRV BF's effects in the same clinical population. As independent replication is vital to establishing efficacy of a particular treatment at a higher level (e.g., efficacious vs. possibly efficacious), the current assessment of efficacy is necessarily incipient.

There are five levels for assessing evidence for psychophysiological interventions' clinical efficacy, with higher levels of efficacy requiring that more stringent criteria be met (La Vaque et al. 2002). The reviewed literature that offered clinical outcomes falls within the second level of clinical efficacy (i.e., possibly efficacious), due to the fact that typically only one study has been conducted with each particular illness group. Reaching the third (i.e., probably efficacious), and in a select few cases the fourth (i.e., efficacious) level of efficacy would occur if current findings were to be replicated. Specifically, HRV BF currently may be said to be possibly efficacious for improving various disease-related parameters in patients with coronary artery disease (Cowan et al. 2001), COPD (Giardino et al. 2004), heart failure (Swanson et al. 2009), fibromyalgia (Hassett et al. 2007), MDD (Karavidas et al. 2007), and PTSD (Zucker et al. 2009).

Regarding asthma, Lehrer et al. (1997, 2004) performed two original studies of HRV BF in patients with asthma. Both studies included random assignment to groups. Lehrer et al. (1997) utilized a WLC group and an EMG BF group, as well as a WLC group and sham BF condition. Both studies included an asthmatic sample for which inclusion criteria were adequately specified, and disease-related outcome measures were appropriate and clearly defined. Details of the procedure were sufficiently provided either directly in the document or through citation of other documents wherein such details could be located. Finally, the analytic strategies and statistical corrections employed were suitable for measuring the outcomes. Each of these criteria must be met for a treatment to be considered efficacious (La Vaque et al. 2002). However, there is an additional criterion in that category that was not met by Lehrer et al. (1997, 2004). Namely, the treatment effects must be demonstrated in two or more independent research settings. HRV BF as a treatment for asthma thereby is classified as probably efficacious according to the available literature.

In summary, investigations are needed that replicate findings for most of the conditions reviewed herein (i.e., all diseases except asthma), and replication specifically performed in at least one additional research setting are needed for the literature on HRV BF for asthma. Investigators conducting these studies should also note the criteria required for more advanced efficacy levels, as set forth by La Vaque et al. (2002) so that those criteria may be addressed as well to advance the field as efficiently as possible.

In considering clinical utility, HRV BF confers certain advantages. Compared to traditional treatments (e.g., medication regimens), HRV BF may serve as a very cost-effective alternative or supplement to standard medical or psychiatric treatment. Particularly regarding psychiatric services, however, third-party reimbursement is currently unavailable for BF treatments. This is an important obstacle to be addressed to promote delivery, and therefore further explore effectiveness, of HRV BF. Additionally, the intervention is relatively brief, and no studies reported any information indicating that participants perceived the treatment as adverse. One may thereby conclude that it is a relatively consumer-friendly treatment option. However, it must be recognized that efficacy is an issue that is separate from effectiveness. The current review largely targets efficacy of HRV BF, for which there remains much to be established. Thereafter, it will be essential to specifically determine whether HRV BF, if proven to be an efficacious and specific treatment, is transportable and effective in practice.

Critique

Table 2 indicates key strengths and weaknesses of the reviewed studies across nine major areas pertaining to internal, external, and/or statistical conclusion validity. Several studies clearly exhibit more strengths than weaknesses, whereas others suffer from several key weaknesses

Table 2 Critical summary of studies reviewed

Study	1	2	3	4	5	6	7	8
Lehrer et al. (2003)	✔	✔	✔	–	–	✔	✔	–
Lehrer et al. (1997)	✔	–	✔	✔	–	–	–	–
Lehrer et al. (2004)	✔	✔	✔	–	–	–	✔	–
Lehrer et al. (2006)	n/a	✔	✔	n/a	–	✔	✔	✔
Cowan et al. (2001)	✔	–	–	✔	–	–	✔	–
Del Pozo et al. (2004)	✔	–	✔	✔	✔	–	✔	✔
Nolan et al. (2005)	✔	✔	✔	✔	–	–	✔	✔
Giardino et al. (2004)	–	–	✔	n/a	–	–	–	✔
Hassett et al. (2007)	–	✔	✔	n/a	✔	–	–	✔
Swanson et al. (2009)	✔	–	✔	✔	✔	–	✔	✔
Karavidas et al. (2007)	–	✔	✔	n/a	–	–	–	✔
Zucker et al. (2009)	✔	–	–	✔	–	–	✔	–
Reyes del Paso and González (2004)	–	–	n/a	n/a	–	✔	–	✔
Overhaus et al. (2003)	✔	–	n/a	–	✔	–	–	✔

Note. 1 = control group, 2 = skewness acknowledged/corrected, 3 = Lehrer manual or similar protocol, 4 = baseline physiological comparisons, 5 = control for history effects, 6 = control for age, weight, and/or sex, 7 = ample/non-restricted sample, 8 = Type I error correction (e.g., lack of control group) that should be addressed in future HRV and baroreflex BF investigative endeavors. Checkmarks indicate that study conclusions are bolstered by (1) inclusion of one or more control groups, (2) acknowledgement and correction of skew in outcome data, (3) implementation of a HRV BF protocol similar to Lehrer et al.'s (2000) manual, (4) comparison of treatment groups at baseline to assess for pre-existing physiological differences, (5) controlling for caffeine, nicotine, vigorous exercise, etc. before sessions, (6) controlling for age, weight, and sex in analyses, (7) utilizing an ample and/or non-restricted sample, or (8) making statistical adjustments to reduce Type 1 error.

A general caveat that should be kept in mind when considering the current state of the literature on HRV BF's physiological effects is that interest in and measurement of HRV outcomes were typically secondary to exploration of clinical outcomes in the reviewed studies. Most authors were concerned with clinical outcomes (e.g., reduction in medication, change in symptoms), which are certainly important. However, rigorously examining HRV BF in healthy populations to establish reasonable expectations for physiological treatment effects is merited.

As evident throughout the review, the majority of studies reviewed implemented the same HRV BF protocol by Lehrer et al. (2000). Such regimented efforts increase procedural reliability and, consequently, internal validity. However, it is possible that the protocol can be improved, especially in the area of effectuating long-term changes in HRV outcomes. Long term treatment effects possibly were not found reliably due to the implemented treatment's inability to convey such salutary effects as it stands. Improvements in baroreflex function may reasonably be suspected to convey the most health benefits in normal and diseased samples, allowing individuals to better respond to internal and environmental challenges that exert stress on physiological systems. Baroreflex effects were not consistently assessed in the reviewed literature, so concluding whether those changes are feasibly achieved in various samples is not possible currently. However, Lehrer et al.'s (2003) results illustrating carry-over effects in baroreflex gain provide a compelling reason to investigate if, and for whom, those effects are reliably achievable. Therefore, efforts to develop a treatment with efficacy in producing improvements in baroreflex function are a key domain for progression in the HRV BF literature.

Studies that controlled for respiration did not necessarily seem to take into account whether or not such statistical control was necessary for interpretation of results. Sometimes, results for all parameters are reported both controlling and not controlling for respiration rate. Some studies applied statistical control for respiration rate to all HRV outcomes (e.g., Karavidas et al. 2007), whereas others (e.g., Giardino et al. 2004) did not implement such control when it may have been merited. It is particularly important for respiration to be accounted for when seeking to examine vagal effects of HRV BF, for example, because it can influence respiratory sinus arrhythmia exclusive of vagal activity (Eckberg 2003). Interpretation of baroreflex effects is somewhat more complex, as indicated by Lehrer et al.'s (2003) results. In their study, short-term effects of HRV BF on baroreflex gain during practice (compared to non-BF session epochs) were no longer present when respiration rate was accounted for, indicating that respiration did carry some influence. Conversely, significant effects within and across sessions on baroreflex gain remained after controlling for respiration rate, indicating effects in baroreflex gain independent of respiration rate. Care should be taken in future studies to determine whether controlling for respiration is necessary to interpret effects of HRV BF.

History effects also require greater attention than was evident in the studies reviewed. With the exception of three investigations (Del Pozo et al. 2004; Hassett et al. 2007; Overhaus et al. 2003), the effects of vigorous exercise, caffeine, nicotine, and/or alcohol were not addressed procedurally or statistically. Additional factors such as age, gender, height, etc. also were not controlled in all but three studies (Lehrer et al. 2003, 2006; Reyes del Paso and González 2004). In particular, given the moderation of treatment effects by age observed by Lehrer et al. (2006), controlling for age effects appears essential. Such control is necessary as such factors may alter or correlate with autonomic activity (e.g., Lehrer 2007; Task Force 1996). When these factors are uncontrolled, their contribution to findings relative to those of treatment effects cannot be determined. Another area of reducing history effects to increase internal validity relates to home practice of techniques learned during BF. A few studies tracked home practice (Del Pozo et al. 2004; Karavidas et al. 2007; Lehrer et al. 2004), but none incorporated amount of home practice into HRV analyses. Low rates of home practice could be responsible for unreliable long-term effects, especially given that baroreflexes are believed to strengthen through regular exercise.

A final point affecting the internal validity of the studies reviewed is that most studies, except where noted, did not explicitly address whether experimenters who edited data were blind to participant condition. Therefore, it is possible that bias was introduced to the data when artifacts were edited and when missing data were managed, which could subsequently affect comparisons between groups.

An additional factor to consider regarding the validity of findings is that published validation studies for measurement equipment used in the overwhelming majority of reviewed studies (i.e., J & J Engineering I-330 physiographs) are not available, to the authors' knowledge. However, such equipment is FDA approved and is widely used and accepted within research investigating cardiovascular outcomes. Details regarding data collection, processing, and biofeedback also are limited, when provided. For example, the sampling rate should be within a certain range (i.e., 250–500 Hz) for spectrum components to be estimated accurately (Task Force 1996), and this factor was commonly reported in the reviewed studies. However, there are other details that are important that are left unaddressed in published manuscripts, thereby making it difficult to determine the nature of analyses, biofeedback, and—ultimately—the validity of findings. Factors such as ectopic beats and missing data can affect calculation of HRV and must be handled appropriately (e.g., via acceptable interpolation methods). Further, there are various algorithms (e.g., Fast Fourier Transformation) when preparing physiological data for analysis, and each algorithm may potentially affect measurement differently (Task Force 1996). Biofeedback and HRV outcome parameters may be affected depending on how these and related factors are managed. Therefore, additional attention to such details when conducting research, as well as reporting of relevant details, is justified in future HRV BF efforts. In sum, efforts to validate methods of measuring and analyzing HRV, and of providing HRV biofeedback should be promoted.

One strength of the reviewed literature is that investigations have examined HRV or baroreflex BF across several medical disorders. Only two studies, however, were included that implemented HRV BF and reported HRV outcomes in a psychiatric sample (Karavidas et al. 2007; Zucker et al. 2009). Although psychiatric disorders may be comorbid within some health populations that were explored through studies reviewed herein, investigative efforts should be extended to explicitly target samples with mental illnesses. Such exploration of HRV BF effects are particularly warranted due to documented relations between several psychiatric disorders (e.g., generalized anxiety disorder, posttraumatic stress disorder) and low HRV.

Sufficient data were available to determine effect sizes for a few of the reviewed studies (Del Pozo et al. 2004; Lehrer et al. 1997, 2004; Swanson et al. 2009; Zucker et al. 2009). However, the effect sizes are not reported here because they are only a small portion of those that could potentially be obtained from the entire literature and may not be representative of the literature as a whole. The lack of relevant data is a shortcoming that is imperative to address in future investigations of HRV BF so the magnitude of treatment effects may be compared across investigations.

Conclusions and Future Directions

The effects of HRV and related BF is a recent and important area of empirical growth in psychophysiology and behavioral medicine, so naturally there is need for improvement in the execution of investigations. Nonetheless, attempts to strengthen procedures and analyses to optimize use of sophisticated research methods and designs should be recognized and emulated (e.g., inclusion of control groups, correction for Type I error). Results are encouraging, showing that parameters related to HRV are modifiable by HRV and baroreflex BF, at least in an acute timeframe that occurs during training sessions. Some evidence suggests the possibility of such effects extending to longer term improvements, which is yet to be determined with greater confidence. Experimental conditions that result in these longer term improvements in HRV need to be elucidated.

It is well established that low HRV is associated with a broad range of medical and psychological health problems. Due to (a) the encouraging preliminary results of the effectiveness of HRV and baroreflex BF in producing changes in related physiological parameters, and (b) the possibility of improving disease states through treatment of HRV, further investigation in the area of HRV and related BF is warranted. It should also be kept in mind, however, that other treatment approaches may be viable alternatives to impact HRV and baroreflex functioning. Although EMG BF was found to be inferior in inducing changes in LF HRV in one reviewed study (Lehrer et al. 1997), there is evidence that EMG BF may prove useful in improving HRV and related physiology (e.g., blood pressure) (Wang et al. 2007; Xu et al. 2007). Also, controlled breathing practice with (Elliot et al. 2004) or without (Joseph et al. 2005; Raghuraj and Telles 2008) BF may induce similar salutary changes in HRV parameters. Alternatives to HRV and baroreflex BF would need to be directly compared in their effects on HRV- and disease-related outcomes to determine which techniques are most efficacious and cost-effective. As long as future empirical work corroborates results from early investigations of HRV and baroreflex BF, larger scale clinical trials will be warranted using patients diagnosed with the range of diseases characterized by diminished HRV.

An additional area requiring attention in upcoming investigations of HRV BF involves exploring whether effects of treatment generalize from resting states to stressful periods. It is necessary to determine whether HRV BF training results in increased HRV during stress recovery, in addition to previously found increases during rest. Such external validation will be conceptually poignant. As discussed in the introduction, diminished HRV is believed to reduce individuals' capacity to physiologically withstand and recover from environmental pressures. Via such processes, low HRV is considered to contribute to or exacerbate multitudinous poor physical and mental health outcomes. Therefore, determining whether HRV BF treatment is efficacious in producing changes in HRV that generalize to stressful conditions is required. All but one study reviewed herein assessed effects of HRV BF on HRV-related parameters in the *absence* of stress. Nolan et al.'s (2005) study was the singular exception. They found that significant increases in HF HRV occurred between a physical stressor task and a stress recovery period for their treatment group only. Such analyses will bolster external validity of HRV BF findings to numerous stress-related conditions.

Finally, future investigations of HRV BF should make efforts to adhere to published standards (Task Force 1996) and respond to the criticisms identified in this review, particularly those summarized in the preceding section that apply to many studies. The neuroplasticity of the baroreflex was illustrated in one study (Lehrer et al. 2003), and efforts are needed to determine whether that effect is replicable. If such empirical efforts continue to produce encouraging results, they will provide a foundation from which implementation of these BF techniques in appropriate disordered patient populations (e.g., coronary artery disease, hypertension, depression) may begin. Further, due to the disconnect between physiological and clinical outcomes in several studies, a necessary area for investigation is the mechanism by which HRV BF confers clinical improvements. As it stands, the reasons for the incongruity between significant changes in physiological outcomes and clinical outcomes remains puzzling. It is not uncommon in the presented literature that impressive clinical improvements occurred without significant physiological changes. One explanation is that individuals utilize the technique and find it successful when experiencing an exacerbation of symptoms, which could confer clinical improvement without necessarily conferring significant changes in physiology at rest. Another possibility is that HRV BF and at-home practice influence other unmeasured physiological processes (e.g., inflammation, cortisol production) that in turn affect clinical symptoms—again, without noticeable improvements in resting HRV. An improved understanding of treatment effects in such a way could lead to improvements in HRV BF treatment methods and, ultimately, outcomes for consumers of HRV BF treatments.

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