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Meehan, Z., Muesenfechter, N., Gravett, N., Watson, T., Smith, A., Shearman, S., Bartochowski, Z., West, A., & Shaffer, F. (manuscript submitted). Breathing effort may not reduce heart rate variability when respiration rate is controlled. [Abstract]. *Applied Psychophysiology and Biofeedback*.

Clinical lore that breathing effort reduces heart rate variability (HRV) may conflate effort with respiration rate. The challenges in testing this belief were operationalizing breathing effort and preventing confounding by respiration rate. Breathing effort was operationally defined as the degree of abdominal excursion (i.e., the range of respirometer movement during each breathing cycle). An animated pacer kept respiration rate constant. This experiment examined whether greater excursion decreases HRV when participants breathe at a constant rate. Subjects were 36 healthy undergraduates (16 men and 20 women) ages 18 to 26. A Thought Technology ProComp™ Infiniti system monitored ECG, respiration, skin conductance level, and hand temperature. Active ECG electrodes were located on the lower torso. Skin conductance sensors were placed on the index and middle fingers, and a thermistor was placed on the web dorsum of the left hand. A respirometer was positioned over the navel to measure excursion and respiration rate. Subjects were randomly assigned to one of two treatment orders separated by a 3-min resting buffer period: normal excursion-high excursion or high excursion-normal excursion. For each 5-min condition, subjects sat upright with eyes open and followed a 6-bpm animated pacer without feedback. In the normal excursion (NE) condition, subjects were instructed to breathe effortlessly; in the high-excursion (HE) condition, subjects were instructed to allow their abdomen to deeply expand and contract. A natural log transformation normalized the data distribution. After manual artifacting, researchers compared the two excursion conditions using a General Linear Model Repeated Measures ANOVA. Depth of excursion was successfully manipulated since abdominal excursion was greater in the HE condition, $F(1,34) = 45.33$, $p = 0.001$, $\eta 2 = 0.57$, $d = 2.3$. Respiration rate was identical in both conditions. Excursion did not affect skin conductance or temperature. Contrary to clinical lore, HR Max – HR Min was greater in the HE condition, $F(1,34) = 10.02$, $p = 0.003$, $\eta 2 = 0.23$, $d = 1.09$, and increased excursion did not adversely affect HRV frequency domain, time domain, or nonlinear HRV indices. Future research should replicate these findings with clinical populations and convergent operational definitions of breathing effort.

Meehan, Z., Muesenfechter, N., Gravett, N., Watson, T., Smith, A., Shearman, S., Bartochowski, Z., West, A., & Shaffer, F. (manuscript submitted). A 1:2 inhalation-to-exhalation ratio does not increase heart rate variability during 6-bpm breathing [Abstract]. *Applied Psychophysiology and Biofeedback.*

A controversy continues as to whether a 1:2 inhalation-to-exhalation (I/E) ratio produces greater heart rate variability (HRV) than a 1:1 I/E ratio. An I/E ratio is the proportion of the breathing cycle during which subjects inhale and exhale. The present within-subjects randomized controlled trial (RCT) replicated a previous RCT that found no advantage for a 1:2 I/E ratio on time domain and frequency domain measures. Sixteen undergraduates (8 men and 8 women), ages 18-22, participated in this study. A Thought Technology ProComp Infiniti™ system monitored ECG, respiration, temperature, and skin conductance. Active ECG electrodes were located on the lower torso. A respirometer was positioned over the naval in order to measure abdominal excursion and respiration rate. Skin conductance sensors were placed on the index and middle fingers, and a thermistor was placed on the web dorsum of the left hand. Investigators randomly assigned subjects to begin with one of two 5-min I/E ratio conditions (either a 1:1 or 1:2) and then cross over to the other condition. In each I/E ratio condition, participants sat upright while effortlessly breathing at 6 breaths per minute (bpm) guided by a visual pacer. A 3-min buffer period between conditions minimized carryover by instructing participants to sit quietly without breathing instructions or feedback. The investigators monitored compliance with respiration rate and I/E ratio instructions during each experimental condition. The researchers analyzed data using a General Linear Model. Participants successfully followed the visual pacer and breathed at 6 bpm in both I/E ratio conditions. Breathing ratio did not affect autonomic (heart rate, skin conductance, temperature), HRV time domain (HR Max – HR Min, NN50, pNN50, RMSSD), frequency domain (LFnu, HFnu), or nonlinear measurements (DFalpha1, SampEn). The authors recommend that clinicians select the I/E ratio that their clients prefer since this parameter did not affect HRV when participants breathed at 6 bpm. Future research should replicate these findings at each individual's resonance frequency, instead of a fixed 6 bpm, and with clinical populations.

Meehan, Z., Muesenfechter, N., Gravett, N., Watson, T., Smith, A., Shearman, S., Bartochowski, Z., West, A., & Shaffer, F. (manuscript submitted). Ventral index and middle finger sites are warmer than homologous dorsal sites. [Abstract]. *Applied Psychophysiology and Biofeedback*.

This within-subjects parametric study compared skin temperatures obtained from thermistors for two dorsal and ventral finger placements on each hand. This methodological issue has not been previously addressed in published studies and could influence temperature measurements. Forty-nine subjects (29 women and 20 men), ages 18 to 26, participated in this study. A Thought Technology ProComp™ Infiniti system monitored hand temperature using thermistors placed on the dorsal and ventral aspects of the index and middle fingers of both hands. Investigators stabilized subjects for 10 minutes in a 74°F room. Subjects sat upright without breathing instructions or temperature feedback for two successive 5-min measurement periods. Researchers monitored temperature from dorsal and ventral sites on the left hand and then assessed the corresponding sites on the right hand after repositioning the thermistors. Data were analyzed using a General Linear Model Repeated Measures ANOVA. On the left hand, the ventral aspect of the index finger was warmer (82.0°F) than the dorsal surface (80.0°F), F(1, 48) = 20.34, p = 0.001, η2 = 0.130, d = 0.77. The ventral aspect of the middle finger was warmer (82.70F) than the dorsal surface (81.1°F), F(1, 48) = 22.85, p = 0.001, η2 = 0.32, d = 1.37. On the right hand, the ventral aspect of the index finger was warmer (81.5°F) than the dorsal surface (80.4°F), F(1, 48) = 9.65, p = 0.003, η2 = 0.17, d = 0.91. The ventral aspect of the middle finger was warmer (84.6°F) than the dorsal surface (82.8°F), F(1, 48) = 26.66, p = 0.001, η2 = 0.36, d = 1.5. These findings replicate previous results from this laboratory obtained using an infrared thermometer. Both experiments demonstrate that large-scale (about 1-2°F) dorsal-ventral temperature differences can be found on both hands and encourage standardization of thermistor placements to reduce measurement variability. Future research should utilize thermistors to measure the dorsal and ventral temperatures of the remaining recording sites on the hand.

Shearman, S., Meehan, Z., & Shaffer, F. (manuscript submitted). Ultra-short-term (UST) HRV measurements can achieve strong concurrent validity [Abstract]. *Applied Psychophysiology and Biofeedback*.

This within-subjects study investigated whether artifacted resting ultra-short-term (UST) HRV values can achieve strong concurrent validity for time domain, frequency domain, and nonlinear measurements in healthy undergraduates when compared to 5-min resting baseline values. Concurrent validity is the degree to which values obtained from proposed and established measurement procedures are correlated. A Thought Technology ProComp™ Infiniti system monitored ECG and respiration. Active ECG electrodes were located on the lower torso. A respirometer was positioned over the navel to measure abdominal excursion and respiration rate. Subjects were stabilized for 5 min and then monitored for 7 min sitting upright, with eyes open, no feedback, and instructions to breathe normally. The investigators extracted 10-, 20-, 30-, 60-, 90-, 120-, 180-, and 240-s segments from 5-min resting ECG recordings of 38 healthy undergraduates, 20 men and 18 women, ages 18 to 23. Concurrent validity between the UST and 5-min measurements were measured using a Pearson Product-Moment Correlation Coefficient. A conservative criterion ($r = .90$) was selected because the calculation of UST and 5-min measurements from the same data set should be expected to inflate correlation values. This cut-off ensured that UST values would account for at least 81% of the variability in 5-min values. Resting UST measurements achieved strong concurrent validity for all but one of the 5-min HRV metrics examined in this study. A 10-s segment estimated heart rate. A 60-s segment measured SDNN, RMSSD, NN50, and pNN50. A 90-s segment calculated TINN, LF power, SD1, and SD2. A 120-s segment approximated HRV triangular index and DFA α1. A 180-s segment computed LFnu, HF power, HFnu, LF/HF power, SampEn, DFA α2, and DET. A 240-s segment assessed ShanEn. No UST measurement interpolated correlation dimension. Based on these findings, resting baselines as brief as 1 min should be sufficient to measure heart rate, SDNN, and RMSSD for individuals who resemble Truman State University undergraduates assuming the data are carefully artifacted. The authors encourage further research employing this study’s rigorous concurrent validity criterion to determine minimum sample lengths for major demographic groups.

Meehan, Z., Muesenfechter, N., Gravett, N., Watson, T., Smith, A., Shearman, S., Bartochowski, Z., West, A., & Shaffer, F. (in press). Ventral index and middle finger sites are warmer than homologous dorsal sites [Abstract]. *Applied Psychophysiology and Biofeedback.*

This within-subjects parametric study compared skin temperatures obtained from thermistors for two dorsal and ventral finger placements on each hand. This methodological issue has not been previously addressed in published studies and could influence temperature measurements. Forty-nine subjects (29 women and 20 men), ages 18 to 26, participated in this study. A Thought Technology ProComp™ Infiniti system monitored hand temperature using thermistors placed on the dorsal and ventral aspects of the index and middle fingers of both hands. Investigators stabilized subjects for 10 minutes in a 74°F room. Subjects sat upright without breathing instructions or temperature feedback for two successive 5-min measurement periods. Researchers monitored temperature from dorsal and ventral sites on the left hand and then assessed the corresponding sites on the right hand after repositioning the thermistors. Data were analyzed using a General Linear Model Repeated Measures ANOVA. On the left hand, the ventral aspect of the index finger was warmer (82.0°F) than the dorsal surface (80.0°F), $F(1, 48) = 20.34$, $p = 0.001$, ɳ2 = 0.130, $d = 0.77$. The ventral aspect of the middle finger was warmer (82.70F) than the dorsal surface (81.1°F), $F(1, 48) = 22.85$, $p = 0.001$, ɳ2 = 0.32, $d = 1.37$. On the right hand, the ventral aspect of the index finger was warmer (81.5°F) than the dorsal surface (80.4°F), $F(1, 48) = 9.65$, $p = 0.003$, ɳ2 = 0.17, $d = 0.91$. The ventral aspect of the middle finger was warmer (84.6°F) than the dorsal surface (82.8°F), $F(1, 48) = 26.66$, $p = 0.001$, ɳ2 = 0.36, $d = 1.5$. These findings replicate previous results from this laboratory obtained using an infrared thermometer. Both experiments demonstrate that large-scale (about 1-2°F) dorsal-ventral temperature differences can be found on both hands and encourage standardization of thermistor placements to reduce measurement variability. Future research should utilize thermistors to measure the dorsal and ventral temperatures of the remaining recording sites on the hand.

Shaffer, F., & Zerr, C. L. (in press). Evidence-based practice review of neurofeedback and biofeedback for depressive disorders [Abstract]. *Applied Psychophysiology and Biofeedback*.

The authors conducted a literature review of biofeedback and neurofeedback treatment of depressive disorders for *Evidence-Based Practice in Biofeedback and Neurofeedback* (3rd ed.). The main interventions evaluated in this review include neurofeedback (EEG and fMRI) and biofeedback (EMG and HRV). While the majority of published reports have been case studies or single-group pre-test/post-test designs, there have been several randomized controlled trials (RCTs) and studies where participants assigned themselves to conditions. None of the RCTs utilized a double-blind control. Neurofeedback (NF) interventions for depression have included EEG protocols to correct frontal alpha asymmetry or enhance parietal-occipital upper alpha, and fMRI protocols to up-regulate targeted regions that mediate positive emotion. The authors examined seven EEG biofeedback studies (Baeher et al., 2001; Choi et al., 2011; Escalano et al., 2013; Kumano et al., 1996; Peters et al., 2014; Raymond et al., 2005) and two fMRI studies (Linden et al., 2012; Young et al., 2014). The authors also reviewed six studies involving biofeedback interventions for depression, including biofeedback-assisted isometric exercise (Dumus et al., 2005) and heart rate variability biofeedback (HRVB) (Hassett et al., 2007; Karavidas et al., 2007; Patron et al., 2013; Siepmann et al., 2008; Zucker et al., 2009). The authors awarded neurofeedback and biofeedback interventions for depression a level-4 rating of efficacious. For neurofeedback, both alpha-asymmetry (Choi et al., 2011) and fMRI (Young et al., 2014) protocols have been validated by randomized controlled trials (RCTs) using depressed participants. For biofeedback, HRV biofeedback protocols have been supported by RCTs for participants diagnosed with substance abuse and PTSD (Zucker et al., 2009) and depression following heart surgery (Patron et al., 2013).

Shaffer, F., & Mannion, M. (in press). Evidence-based practice review of biofeedback for hyperhidrosis [Abstract]. *Applied Psychophysiology and Biofeedback*.

The authors conducted a literature review of biofeedback treatment of hyperhidrosis, which is excessive sweating, for *Evidence-Based Practice in Biofeedback and Neurofeedback* (3rd ed.). The rationale for using electrodermal biofeedback to treat hyperhidrosis is that sympathetic activation can increase sweating, which raises skin conductivity, and that decreasing skin conductivity can both reduce sympathetic arousal and resultant perspiration. Also, in cases where hyperhidrosis is triggered or exacerbated by stressors, a biofeedback-assisted intervention could improve patient symptoms through better stress management. The evidence of biofeedback efficacy in hyperhidrosis is weak, based on small pretest-posttest studies without control groups and case studies. Preliminary studies (Duller & Gentry, 1980; Singh & Singh, 1993) and a single case study (Rickles, 1978) show that biofeedback may decrease hyperhidrosis symptoms. Duller and Gentry (1980) provided visual water vapor pressure biofeedback to 14 adults diagnosed with hyperhidrosis and reported that 11 of 14 patients reduced excessive sweating. Singh and Singh (1993) reported that a program of skin conductance (SC) biofeedback-assisted relaxation helped 6 of 10 male patients significantly reduce their sweating. Rickles (1978) trained a patient diagnosed with hyperhidrosis with auditory and visual vapor pressure biofeedback for 8 months, followed by desensitization for 5 months. The treatment outcomes were mixed. The limited evidence from uncontrolled studies and a single case study only warrants a level-2 rating of possibly efficacious. In both the Singh and Singh (1993) and Rickles (1978) reports, electrodermal biofeedback was administered with a behavioral intervention, so the specific contribution of biofeedback could not be isolated.

Meehan, Z., Bartochowski, Z., West, A., Muesenfechter, N., Owen, D., Crawford, A., Gravett, N., Myers, S., Schoetz, J., Watson, T., Zerr, C. L., Kane, A., Vodopest, T., Hannan, J., & Shaffer, F. (in press). Does hand position affect blood volume pulse amplitude (BVPA) and skin conductance measurements? [Abstract]. *Applied Psychophysiology and Biofeedback*.

When monitoring blood volume pulse amplitude (BVPA) and skin conductance level (SCL), clinicians may instruct clients to place their palms down or up. This within-subjects study investigated whether hand position affects BVPA and SCL measurements. Thirty-six undergraduates, 21 women, 15 men, ages 18 to 26, participated in this study. Participants were randomly assigned to start recording with either their hands placed palms down or palms up on the thighs, and then switched to the opposite position. A Thought Technology ProComp™ Infiniti system monitored BVPA and SCL from both hands. A BVP sensor was attached to the third phalanx on the palmar aspect of the middle finger and SC sensors were placed on the palmar aspect of the index and ring fingers of each hand. Conductive gel was applied to the SC sensors. Participants were monitored sitting upright without feedback for 5 minutes in each position, separated by a 3-minute buffer period. BVPA recorded from the left hand, but not the right, was greater with palms down ($M = 6.42$, $SD = 4.91$) than with palms up ($M = 3.39$, $SD = 2.40$), $F(1, 34) = 12.75$, $p = 0.001$, $\eta 2 = 0.27$, Cohen's $d = 1.22$. Hand position did not affect SCL recorded from either hand. These data show that left hand position can affect BVPA and that clinicians should standardize this variable to allow comparison among successive measurements. Future research should replicate this study and control for handedness.

Meehan, Z., Bartochowski, Z., West, A., Muesenfechter, N., Owen, D., Crawford, A., Gravett, N., Myers, S., Schoetz, J., Watson, T., Zerr, C. L., Kane, A., Vodopest, T., Hannan, J., & Shaffer, F. (in press). Large-scale differences between dorsal and ventral hand temperature sites [Abstract]. *Applied Psychophysiology and Biofeedback.*

This parametric study was designed to compare skin temperatures obtained from six dorsal and ventral placements on each hand. This methodological issue has not been previously addressed in published studies and could influence temperature measurements. Forty-two subjects (22 women and 20 men), ages 18 to 26, participated in this study. In this within-subjects design, participants were randomly assigned to either start measurement from the dorsal or ventral aspect of the hand. Using a grease pencil, 0.5-inch-diameter circles were drawn on both hands in the middle of the second phalanx of each finger (first phalanx of the thumb) on both the dorsal and ventral aspects of each digit and the web dorsum. These circles served as targets for recording temperatures. Beginning with the right hand, a Raytek Rayngr® ST was held 6 inches from the hand to record data for the second phalanx of the dorsal (top) side of the subject's pinky, ring, middle, and index finger, as well as the web dorsum and first phalanx of the thumb. The measurements were repeated for the ventral (bottom) aspect immediately after each dorsal measurement. This was repeated for the left hand. The ventral surface of the left middle finger was warmer (86.7^{0}F/30.4^{0}C) than the dorsal surface (85.1^{0}F/29.5^{0}C), $F(1, 21) = 6.29$, $p = 0.016$, $\eta^2 = 0.14$, Cohen's $d = 1.89$. Likewise, the ventral surface of the left index finger was warmer (88.0^{0}F/31.1^{0}C) than the dorsal surface (82.4^{0}F/28.0^{0}C), $F(1, 21) = 37.20$, $p = 0.001$, $\eta^2 = 0.48$, Cohen's $d = 4.50$. On the right hand, the dorsal web dorsum was warmer (88.9^{0}F/31.6^{0}C) than the ventral surface (86.5^{0}F/30.3^{0}C), $F(1, 21) = 10.53$, $p = 0.002$, $\eta^2 = 0.21$, Cohen's $d = 2.39$. These findings suggest that large-scale temperature differences between dorsal and ventral sites can be found on the left and right hands, and that clinicians and researchers should standardize placements to reduce measurement variability. Future researchers should replicate these findings using thermistors on homologous sites on both hands due to their greater accuracy.

Meehan, Z., Bartochowski, Z., West, A., Muesenfechter, N., Owen, D., Crawford, A., Gravett, N., Myers, S., Schoetz, J., Watson, T., Zerr, C. L., Kane, A., Vodopest, T., Hannan, J., & Shaffer, F. (in press). Quantifying thigh artifact during hand temperature measurement [Abstract]. *Applied Psychophysiology and Biofeedback*.

Thigh artifact occurs when a thermistor is warmed by heat radiated by the thigh through a client's clothing. This within-subjects study investigated the magnitude of this phenomenon during temperature measurement and whether a towel placed over the thigh could reduce it. Thirty-nine undergraduates, 20 women, 19 men, ages 18 to 25, participated in this study. All subjects' thighs were covered by clothing. Participants were randomly assigned to one of two conditions: thermistors placed over the thigh (contact) or thermistors insulated by a towel placed over the thigh (insulation). A Thought Technology ProComp™ Infiniti system monitored finger temperature using four identical SA9310M thermistors with a 1-inch bead in a 75°F/24°C room. Thermistors were placed on the palmar side of the distal phalanx of the left and right middle fingers and thumbs. A single layer of tape was placed over the thermistor beads to secure them. Subjects sat upright with no feedback for 5 minutes with their eyes open and hands on thighs or on towels placed over their thighs. There was a 3-minute buffer period while subjects sat quietly, which was followed by 5 minutes of recording in the other condition. The left middle finger ($p = 0.023$), left thumb ($p = 0.001$), right middle finger ($p = 0.020$), and right thumb ($p = 0.001$) were warmer in the contact than the insulation condition. The size of the thigh artifact ranged from 0.61°F/0.34°C (left middle finger) to 0.85°F/0.47°C (left thumb) and exceeded the largest standard error (0.54) when measuring either thumb. These data confirm the existence of a thigh artifact and support positioning a towel over the thigh when instructing clients to place their hands in their laps.

Zerr, C., Kane, A., Vodopest, T., Allen, J., Hannan, J., Cangelosi, A., Owen, D., Fabbri, M., Williams, C., Cary, B., Crawford, A., West, A., Shrestha, R., Palcheff, J., & Barylski, T. (2015). The nonlinear index SD1 predicts diastolic blood pressure and HRV time and frequency domain measurements in healthy undergraduates [Abstract]. *Applied Psychophysiology and Biofeedback, 40*(2), 134. doi:10.1007/s10484-015-9282-0

The present study explored the predictive relationship between the nonlinear index SD1, diastolic and systolic blood pressure, four heart rate variability (HRV) time domain, and three frequency domain measurements in healthy undergraduates. SD1 is the standard deviation of the distance of each point from the y = x axis of a Poincaré plot. SD1 measures short-term HRV in milliseconds, which makes it appropriate for brief measurement periods, and correlates with baroreceptor reflex sensitivity. Twenty-nine undergraduates (15 male and 14 female), 19 to 24 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored ECG and respiration. Active ECG electrodes were placed about 2 inches above the navel and 4 inches to the left and right of the midline and the reference electrode was centered over the angle of the sternum. A respirometer was positioned over the navel to measure abdominal excursion and respiration rate. Subjects were stabilized for 5 minutes and then monitored for 5 minutes sitting upright, with eyes open, no feedback, and instructions to breathe normally. Data were artifacted within CardioPro and then detrended in Kubios 2.1 using a smoothness priors procedure. Frequency domain analysis utilized a Fast Fourier Transformation (FFT)-based Welch's periodogram procedure. While SD1 was unrelated to systolic blood pressure, it predicted diastolic blood pressure, $F(1, 27) = 6.77$, $p = 0.015$, $\eta^2 = 0.20$. SD1 predicted four HRV time domain measures: HR Max – HR Min, $F(1, 27) = 57.79$, $p = 0.001$, $\eta^2 = 0.68$ RMSSD, $F(1, 27) = 3309.98$, $p = 0.001$, $\eta^2 = 0.99$, pNN50, $F(1, 27) = 25.94$, $p = 0.001$, $\eta^2 = 0.76$, and SDNN, $F(1, 27) = 174.51$, $p = 0.001$, $\eta^2 = 0.87$. SD1 also predicted three HRV frequency domain measures: low-frequency power, $F(1, 27) = 85.08$, $p = 0.001$, $\eta^2 = 0.76$, high-frequency power, $F(1, 27) = 237.60$, $p = 0.001$, $\eta^2 = 0.90$, and total power, $F(1, 27) = 173.90$, $p = 0.001$, $\eta^2 = 0.87$. Based on these findings, clinicians should consider utilizing SD1 to assess clients who resemble our healthy undergraduates. Future researchers should replicate these findings with a clinical population.

Zerr, C., Kane, A., Vodopest, T., Allen, J., Hannan, J., Fabbri, M., Williams, C., Cangelosi, A., Owen, D., Cary, B., & Shaffer, F. (2015). Does inhalation-to-exhalation ratio matter in heart rate variability biofeedback? [Abstract]. *Applied Psychophysiology and Biofeedback*, *40*(2), 135. doi:10.1007/s10484-015-9282-0

This randomized controlled study examined whether inhalation-to-exhalation ratio affects HRV frequency domain and time domain measures. Twenty-six undergraduates (10 female and 16 male) participated in this study. A Thought Technology ProComp Infiniti™ system monitored ECG, respiration, temperature, and skin conductance. Active ECG electrodes were placed on the upper chest below the sternum and the reference centered on the xyphoid process. A respirometer was positioned over the naval in order to measure abdominal excursion and respiration rate. A skin conductance sensor was placed on the palmar aspect of the second phalange of both the index and ring fingers. Finally, a thermistor was taped to the web dorsum of the nondominant hand. Participants were randomly assigned to begin with one of two conditions, either a 1:2 inhalation-exhalation ratio or a 1:1 inhalation-exhalation ratio. All participants were monitored during both ratios and compliance with breathing ratio instructions was confirmed. Participants were instructed to sit quietly with their back straight and their hands on their thighs, and to breathe following a visual pacer for each 10-minute recording session. Between conditions, participants sat quietly without breathing ratio instructions, a visual pacer, or feedback for 5 minutes to minimize carryover. Data were analyzed using a GLM analysis with familywise correction. Participants successfully followed the visual pacer and breathed at 6 bpm in both inhalation-to-exhalation ratio conditions. The breathing ratio did not affect heart rate, skin conductance, temperature, or HRV time domain or frequency domain measurements. Two nonlinear measurements, DFA alpha1 and sample entropy were affected by breathing ratio. DFA alpha1 was greater during a 1:1 ratio, $F(1, 24) = 6.06$, $p = 0.02$, $\eta^2 = .20$, Cohen's $d = 1.00$, while SampEn was greater during a 1:2 ratio, $F(1, 23) = 1157.40$, $p = 0.001$, $\eta^2 = .98$, Cohen's $d = 14.00$. Overall, inhalation-to-exhalation ratio does not appear to influence the time and frequency domain measurements that clinicians typically use during HRV biofeedback, and should be chosen based on client preference. Future researchers should replicate these findings with clinical populations.

Shaffer, F., Zerr, C. L., & Allen, J. (2015). The use of device-guided breathing in the treatment of hypertension: A meta-analytic review [Abstract]. *Applied Psychophysiology and Biofeedback, 40*(2), 131-132. doi:10.1007/s10484-015-9282-0

A meta-analysis on the effect of device-guided breathing (DGB) on hypertension was conducted to evaluate whether DGB lowers blood pressure (BP) in adults. Data were collected using PubMed, MEDLINE, and Google Scholar, and independently extracted and coded by researchers. A total of 10 randomized controlled studies were selected for analysis, which featured 573 hypertensive patients (56% male, average age of 56.6 years) training for an average of 7.7 weeks. Eight studies used a device known as RESPeRATE, while two used a Breathe with Interactive Music (BIM) device (both developed by InterCure Ltd., Israel). Compared with controls, DGB resulted in non-significant reductions with trivial effect sizes in both systolic (Cohen's $d = -0.12$, $SE = 0.09$, $z = -1.39$, $p = 0.16$, 95% C.I. = -0.29 to 0.05) and diastolic (Cohen's $d = -0.16$, $SE = 0.09$, $z = -1.89$, $p = 0.06$, 95% C.I. = -0.33 to 0.01) BP measures. Moderator analyses revealed no significant differences in effect size for the type of hypertension (essential, secondary, or mild) or whether or not the authors had a conflict of interest with the manufacturers of the device. These findings challenge the efficacy of DGB as a non-pharmacological treatment for hypertension. Further research should implement significantly longer training periods and incorporate follow-up assessment at 6 and 12 months to better evaluate DGB's potential.

Zerr, C., Kane, A., Vodopest, T., Allen, J., Fabbri, M., Williams, C., Cangelosi, A., Hannan, J., Owen, D., Cary, B., Fluty, L., & Shaffer, F. (2015). Are blanketing and stem artifacts real? [Abstract]. *Applied Psychophysiology and Biofeedback, 40*(2), 134-135. doi:10.1007/s10484-015-9282-0

This within-subjects study investigated the magnitude of blanketing and stem artifacts in temperature measurement. Blanketing artifact raises finger temperature by trapping heat in multiple layers of tape. Stem artifact lowers finger temperature when the first 3 inches of a thermistor cable are not secured against the skin. Sixty undergraduates (30 men and 30 women), 19 to 24 years of age, participated in this experiment. A Thought Technology ProComp™ Infiniti system monitored finger temperature using four identical SA9310M thermistors with a 1-inch bead in a 70 degrees F room. A thermistor was attached to the dorsal aspect of the second phalange of the middle and first finger of each hand using a single layer of Curad® 1-inch wide Gentle Paper tape placed around the circumference of a thermistor bead and along the next 3 inches of its cable. Subjects sat upright with their hands resting on their thighs with no feedback for 2 minutes to measure initial finger temperature to control for differences in blood perfusion. To measure the magnitude of blanketing artifact, two extra layers of tape were wrapped around the thermistor bead on the right middle finger, while the right index finger retained its single layer. To measure the magnitude of stem artifact, the 8 cm strip of tape was removed from the left middle hand so that the cable no longer touched the skin, while the cable remained attached to the skin on the left first finger. Subjects continued to sit upright without feedback for 5 minutes to measure both artifacts. After adjustment for differences between middle and first finger perfusion during the baseline period, data were analyzed using a General Linear Model (GLM) analysis. A significant blanketing artifact that averaged 0.87 degree F was found, $F(1,58) = 44.06$, $p = .0001$, $\eta^2 = 0.43$, and Cohen's $d = 1.74$, while there was no evidence of stem artifact.

Zerr, C., Kane, A., Vodopest, T., Allen, J., Fluty, E., Gregory, J., Schultz, D., DeBold, M., Robinson, G., Golan, R., Hannan, J., Bowers, S., Fabbri, M., Cangelosi, A., & Shaffer, F. (2014). Heart rate variability norms for healthy undergraduates [Abstract]. *Applied Psychophysiology and Biofeedback, 39*(3), 300. doi:10.1007/s10484-014-9254-9

The present study calculated heart rate variability (HRV), respiration, and accessory surface EMG norms for 29 variables in healthy undergraduates to aid clinicians and researchers. The calculation of norms for 9 nonlinear HRV measurements for this age group addresses an important deficiency in the literature. Fifty undergraduates (25 male and 25 female), 19 to 24 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored ECG, respiration, and accessory SEMG. Active ECG electrodes were placed about 2 inches above the navel and 4 inches to the left and right of the midline and the reference electrode was centered over the angle of the sternum. A respirometer was positioned over the navel to measure abdominal excursion and respiration rate. SEMG active electrodes were placed over the belly of the right trapezius and scalene muscles, with the reference electrode over the spine. Subjects were stabilized for 5 minutes and then monitored for 7 minutes sitting upright, with eyes open, no feedback, and instructions to breathe normally. The first 2 minutes of data were discarded to control for adjustment to the laboratory and the remaining 5 minutes were artifacted within CardioPro and then detrended in Kubios 2.1 using a smoothness priors procedure. Frequency domain analysis utilized a Fast Fourier Transformation (FFT)-based Welch's periodogram procedure. Means and standard deviations were calculated for HRV time domain measures (heart rate, HR Max – HR Min, HRV triangular index, NN50, pNN50, RMSSD, SDNN, and TINN), frequency domain measures (VLF, LF, and HF peak frequencies, absolute VLF, LF, and HF power, normalized LF and HF power, and LF/HF ratio), and nonlinear measures (SD1, SD2, ApEn, SampEn, D2, detrended fluctuation analysis (DFA) indices α1 and β1, and recurrence plot analysis (RPA) indices DET and ShanEn), respiration measures (respiration amplitude and rate), and accessory SEMG. Future researchers should replicate these findings with clinical populations.

Zerr, C., Kane, A., Vodopest, T., Allen, J., Fluty, E., Gregory, J., DeBold, M., Schultz, D., Robinson, G., Golan, R., Hannan, J., Bowers, S., Cangelosi, A., & Shaffer, F. (2014). Does sitting position matter in heart rate variability biofeedback? [Abstract]. *Applied Psychophysiology and Biofeedback, 39*(3), 298-299. doi:10.1007/s10484-014-9254-9

This randomized controlled study examined whether sitting position affects HRV frequency domain and time domain measures. Forty-one undergraduates (20 male and 21 female), 19 to 24 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored abdominal SEMG, ECG, HRV, and respiration. The SEMG active electrodes were placed 1-1/2 inches below the navel and 2 inches to either side. The reference electrode was equidistant from each active. ECG active electrodes were placed about 2 inches above the navel and 4 inches to the left and right of the midline and the reference electrode was centered over the angle of the sternum. A respirometer was positioned over the navel to measure abdominal excursion and respiration rate. Subjects were stabilized for 5 minutes and then were observed with eyes open and no feedback in each of the three sitting positions for 5 minutes with a 2-minute buffer period between conditions. These positions were leaning forward (45°), sitting upright (90°), and leaning backward (120°). Data were analyzed using a GLM analysis with familywise correction. Sitting position did not affect abdominal SEMG, abdominal excursion (the difference between maximum expansion and contraction), or respiration rate. However, an upright sitting position produced greater low frequency power (LF n.u.) than leaning forward, $F(1, 22) = 15.56$, $p = .001$, $\eta^2 = 0.41$, and leaning backward, $F(1, 22) = 7.94$, $p = .01$, $\eta^2 = 0.27$. Consistent with this finding, an upright position produced lower high frequency power (HF n.u.) than leaning forward, $F(1, 22) = 15.56$, $p = .001$, $\eta^2 = 0.41$, and leaning backward, $F(1, 22) = 7.94$, $p = .01$, $\eta^2 = 0.27$. These outcomes were not mediated by respiration rate, which did not vary across sitting positions. Sitting position did not affect any of the major time domain measures of heart rate variability (HR Max – HR Min, NN50, pNN50, RMSSD, SDNN). Since increasing LF power is a major goal of HRV biofeedback, we recommend training in an upright sitting position for subjects who resemble our undergraduates. Future researchers should replicate these findings with clinical populations.

Zerr, C., Kane, A., Vodopest, T., Allen, J., Fluty, E., Gregory, J., DeBold, M., Schultz, D., Robinson, G., Golan, R., Hannan, J., Bowers, S., Cangelosi, A., Korenfeld, D., Jones, D., Shepherd, S., Burklund, Z., Spaulding, K., Hoffman, W., & Shaffer, F. (2014). HRV biofeedback training raises temperature and lowers skin conductance [Abstract]. *Applied Psychophysiology and Biofeedback, 39*(3), 299. doi:10.1007/s10484-014-92549

The present study explored whether HRV biofeedback training can indirectly raise hand temperature and lower skin conductance level (SCL). Twenty-one undergraduates (7 male and 14 female), 18 to 22 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored ECG, HRV, respiration, SCL, and temperature. In this mixed-design study, subjects were pre-assessed on the State-Trait Anxiety Inventory, matched on State Anxiety scores, and then randomly assigned to four sessions of either HRV or temperature biofeedback. Each weekly training session consisted of stabilization (5 minutes), pre-baseline (5 minutes), biofeedback training (30 minutes), and post-baseline (5 minutes) conditions. The HRV biofeedback group (HRV) was instructed to sit upright, breathe six times per minute, and increase peak-to-trough heart rate differences. They received visual analog respirometer and heart rate feedback, and practiced breathing six times per minute for 15 minutes a day. The temperature biofeedback group (TEMP) was instructed to sit upright and increase index finger temperature. They received visual analog temperature feedback and practiced hand-warming for 15 minutes a day. Compliance was confirmed by weekly logs. Data were analyzed using a GLM analysis with familywise correction. Both biofeedback groups were successful. The HRV group, alone, increased the SDNN (standard deviation of all NN intervals) from session 1 (69.3 ms) to session 4 (93.8 ms), $F(1,11) = 12.81$, $p = .004$, $\eta2 = 0.54$. The TEMP group increased hand temperature from session 1 (88.8 ° F) to session 4 (92.2 ° F), $F(1,10) = 6.54$, $p = .028$, $\eta2 = 0.40$. Despite no temperature biofeedback or practice, the HRV group also increased hand temperature from session 1 (90.2 ° F) to session 4 (94.3 ° F), $F(1,11) = 19.21$, $p = .001$, $\eta2 = 0.64$, and achieved greater session 4 post-baseline hand temperatures (93.9 ° F) than the TEMP group (92.2 ° F), $F(2,20) = 6.87$, $p = 0.005$, $\eta2 = 0.41$, even with correction for pre-baseline differences. Finally, despite no SCL feedback or practice, the HRV group also reduced SCL from session 1 (5.8 uS) to session 4 (2.3 uS), $F(1,11) = 15.5$, $p = .002$, $\eta2 = 0.59$.

Zerr, C., Kane, A., Vodopest, T., Allen, J., Fluty, E., Gregory, J., DeBold, M., Schultz, D., Robinson, G., Golan, R., Hannan, J., Bowers, S., Cangelosi, A., Korenfeld, D., Jones, D., Shepherd, S., Burklund, Z., Spaulding, K., Hoffman, W., & Shaffer, F. (2014). HRV biofeedback training decreases Beck Depression Inventory (BDI) scores [Abstract]. *Applied Psychophysiology and Biofeedback, 39*(3), 300-301. doi:10.1007/s10484-014-92549

This analog study explored whether HRV biofeedback training can decrease the Beck Depression Inventory (BDI) scores of students with low self-reported levels of depression. Twenty-one undergraduates (7 male and 14 female), 18 to 22 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored ECG, HRV, respiration, SCL, and temperature. In this mixed-design study, subjects were pre-assessed on both the Beck Depression Inventory (BDI) and State-Trait Anxiety Inventory, matched on State Anxiety scores, randomly assigned to four sessions of either HRV or temperature biofeedback, and then post-assessed on both inventories. Each weekly training session consisted of stabilization (5 minutes), pre-baseline (5 minutes), biofeedback training (30 minutes), and post-baseline (5 minutes) conditions. The HRV biofeedback group (HRV) was instructed to sit upright, breathe six times per minute, and increase peak-to-trough heart rate differences. They received visual analog respirometer and heart rate feedback, and practiced breathing six times per minute for 15 minutes a day. The temperature biofeedback group (TEMP) was instructed to sit upright and increase index finger temperature. They received visual analog temperature feedback and practiced hand-warming for 15 minutes a day. Compliance was confirmed by weekly logs. Data were analyzed using a GLM analysis with familywise correction. Both biofeedback groups were successful. The HRV group increased the SDNN (standard deviation of all NN intervals) from session 1 (69.3 ms) to session 4 (93.8 ms), *F*(1,11) = 12.81, *p* = .004, η2 = 0.54. The TEMP group increased hand temperature from session 1 (88.8 ° F) to session 4 (92.2 ° F), *F*(1,10) = 6.54, *p* = .028, η2 = 0.40. The HRV group reduced BDI scores from pre-assessment (6) to post-assessment (4) over a 6-week period, *F*(1,10) = 6.37, *p* = .03, η2 = 0.39, while TEMP group scores did not change. Moreover, the HRV group achieved lower post-assessment BDI scores (4) than the TEMP group (5.9), *F*(2,23) = 11.80, *p* = 0.000, η2 = 0.51. Future replications should study a gender-balanced sample of students diagnosed with depression.

Citation Paper

Korenfeld, D., Shepherd, S., Jones, D., Burklund, Z., Kane, A., Zerr, C., Vodopest, T., Spalding, K., Hoffman, W., Allen, J., Bowers, S., McDermott, M., Fuller, J., Peterson, J., Westermann-Long, A., Francisco, A., Fluty, E., & Shaffer, F. (2013). Can heartfelt emotion attenuate the autonomic effects of a math stressor? [Abstract]. *Applied Psychophysiology and Biofeedback, 38*(3), 215-216.

The present study explored whether the induction of heartfelt emotion (HFE) can protect subjects against the autonomic effects of an experimental stressor. Twenty-four undergraduates (11 male and 13 female), 18 to 22 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored autonomic measures using their EKG, respiration, skin conductance, and temperature sensors. An Omega 1400 ™ automated sphygmomanometer measured blood pressure. HFE was assessed with a 5-point Likert scale and the PANAS-X Positive Affect subscale. In this within-subjects design, participants were randomly assigned to two sequences of 5-minute conditions that were separated by 5-minute buffer periods. Half of the subjects started with the HFE-serial sevens sequence and half with the control-serial sevens sequence. There was a 5-minute buffer period between each sequence. Subjects sat upright with eyes open in all conditions, were not given breathing instructions, and did not receive physiological feedback. In the HFE condition, participants utilized the Institute of HeartMath's Heart Lock-In Technique instructions, which they had practiced for 15 minutes per day for at least 2 weeks. In the control condition, participants sat quietly. After the HFE or control condition, subjects performed a 5-minute videotaped serial sevens task in which they reported their calculations out loud. Data were analyzed using a GLM analysis with familywise correction. *Heartfelt emotion (HFE) was successfully manipulated* since HFE scores were higher in the HFE condition than in the control condition, $F(1,23) = 70.94$, $p = .000$, $\eta^2 = 0.76$. HFE provided no more protection during serial sevens than the control condition for blood pressure, HRV time domain (HR Max-HR Min, NN50, pNN50, RMSSD, SDNN), frequency domain (VLF, LF, HF, LF/HF), heart rate, skin conductance, or temperature measurements. In contrast, HFE was associated with a greater increase in respiration rate during serial sevens than the control condition, $F(1,23) = 11.35$, $p = .003$, $\eta^2 = 0.33$. These findings do not support the use of HFE to buffer individuals who resemble our students against the autonomic effects of stressors. Future researchers should replicate our findings with a clinical population and more diverse experimental stressors.

Korenfeld, D., Shepherd, S., Jones, D., Burklund, Z., Kane, A., Zerr, C., Vodopest, T., Spalding, K., Hoffman, W., Allen, J., Bowers, S., McDermott, M., Fuller, J., Peterson, J., Westermann-Long, A., Francisco, A., Fluty, E., & Shaffer, F. (2013). Can heartfelt emotion facilitate autonomic recovery from a math stressor? [Abstract]. *Applied Psychophysiology and Biofeedback, 38*(3), 215.

The present study explored whether the induction of heartfelt emotion (HFE) following an experimental stressor can aid autonomic recovery. Twenty-four undergraduates (11 male and 13 female), 18 to 22 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored autonomic measures using their EKG, respiration, skin conductance, and temperature sensors. An Omega 1400 ™ automated sphygmomanometer measured blood pressure. HFE was assessed with a 5-point Likert scale and the PANAS-X Positive Affect subscale. In this within-subjects design, participants were randomly assigned to two sequences of 5-minute conditions that were separated by 5-minute buffer periods. Half of the subjects started with the serial sevens-HFE sequence and half with the serial sevens-control sequence. There was a 5-minute buffer period between each sequence during which subjects sat quietly. Subjects sat upright with eyes open in all conditions, were not given breathing instructions, and did not receive physiological feedback. In the HFE condition, participants utilized the Institute of HeartMath's Heart Lock-In Technique instructions, which they had practiced for 15 minutes per day for at least 2 weeks. In the control condition, participants sat quietly. After the HFE or control condition, subjects performed a 5-minute videotaped serial sevens task in which they reported their calculations out loud. Data were analyzed using a GLM analysis with familywise correction. *Heartfelt emotion (HFE) was successfully manipulated* since HFE, $F(1,23) = 54.64$, $p = .000$, $\eta^2 = 0.70$, and positive affect scores, $F(1,23) = 4.97$, $p = .035$, $\eta^2 = 0.16$, were higher in the HFE condition than in the control condition. HFE following a serial sevens stressor did not aid recovery more than the control condition for blood pressure, HRV time domain (HR Max-HR Min, NN50, pNN50, RMSSD, SDNN), frequency domain (VLF, LF, HF, LF/HF), heart rate, skin conductance, or temperature measurements. These findings do not support the use of HFE to facilitate autonomic recovery following exposure to stressors in individuals who resemble our students. Future researchers should replicate our findings with a clinical population and more diverse experimental stressors.

Korenfeld, D., Shepherd, S., Jones, D., Burklund, Z., Kane, A., Zerr, C., Vodopest, T., Spalding, K., Hoffman, W., Allen, J., Bowers, S., McDermott, M., Fuller, J., Peterson, J., Westermann-Long, A., Francisco, A., Fluty, E., Gregory, J., & Shaffer, F. (2013). Do the left and right hands differ in responsiveness to experimental stressors [Abstract]. *Applied Psychophysiology and Biofeedback, 38*(3), 215.

The present study evaluated whether left- or right-hand placements differ in their autonomic responsiveness to experimental stressors. This question has important implications for sensor placement when conducting psychophysiological profiles, biofeedback training, and monitoring patients during psychotherapy. Thirty-four undergraduates (18 male and 16 female), 18 to 23 years of age, who were all right-handed, participated in this study. Handedness was determined by the hand participants used to perform the majority of their daily activities. A Thought Technology ProComp™ Infiniti system monitored autonomic measures using their blood volume pulse (first phalange of the middle finger), skin conductance (second phalange of the second and third fingers) and temperature sensors (web dorsum). An Omega 1400 ™ automated sphygmomanometer measured blood pressure. A 7-point Likert scale assessed state anxiety. In this within subjects design, participants were randomly assigned to one of six orders of three 3-minute conditions (control, serial sevens stressor, and visualization stressor). Subjects sat upright with eyes open and received no feedback during all three conditions. In the control condition, they sat quietly. In the serial sevens stressor condition, they performed a 3-minute videotaped serial sevens task in which they reported their calculations out loud. In the visualization stressor condition, they mentally reviewed a recently upsetting event. We measured blood pressure after each experimental condition. Data were analyzed using a GLM analysis with familywise correction. Both the serial sevens and visualization stressors were effective as measured by changes in state anxiety. State anxiety was higher during serial sevens and visualization stressors than in the control condition. Diastolic blood pressure was higher during the serial sevens stressor than during the control condition. While we found no difference in responsiveness to our experimental stressors on average for blood volume pulse, skin conductance, or skin temperature, a subset of participants showed differences between left- and right-hand placements that exceeded 1 standard deviation (8/34 BVP, 5/34 skin conductance, and 5/34 temperature). These results support using a psychophysiological profile with bilateral placements to select the hand that should be monitored during biofeedback training and psychotherapy. Future researchers should replicate our findings with left- and right-handed clinical populations.

Citation Paper

Fuller, J., Wally, C., Carrell, D., Peterson, J., Ward, A., Westermann-Long, A., Korenfeld, D., Burklund, Z., Shepherd, S., Jones, D., Francisco, A., Kane, A., Zerr, C., & Shaffer, F. (2012). Does Adding Heartfelt Emotion to Resonance Frequency Breathing Increase Heart Rate Variability? [Abstract]. *Applied Psychophysiology and Biofeedback, 37*(4), 297.

The present study tested whether the addition of heartfelt emotion to resonance frequency (RF) breathing increases heart rate variability (HRV). Twenty-six undergraduates (18 male and 8 female), 19 to 23 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored heart rate and HRV using an Infiniti EKG™ sensor with leads placed on the upper chest and below the sternum, and respiration rate using an abdominal strain gauge placed over the navel. Heartfelt emotion was assessed with a 5-point scale and the PANAS-X Positive Affect subscale. HRV was measured using HR Max – HR Min, pNN50, RMSSD, SDNN, and VLF, LF, HF, LF/HF, and peak LF power. Data were analyzed using planned comparisons with a familywise correction with an alpha level of .05. In this within-subjects design, participants who had been trained to breathe at their resonance frequency were randomly assigned to three 5-minute conditions that were separated by 2-minute buffer periods: RF breathing, RF breathing with heartfelt emotion, and control. They were monitored sitting upright with their eyes open. Participants were instructed to follow an animated pacer set at their resonance frequency and received HRV biofeedback during the two RF conditions. In addition, during the RF breathing with heartfelt emotion condition, participants received the Institute of HeartMath's Heart Lock-In Technique® instructions. In the control condition, participants sat quietly without breathing instructions, a pacer, or HRV biofeedback. *Heartfelt emotion was successfully manipulated* since heartfelt emotion and positive affect scores were higher in the RF breathing with heartfelt emotion condition than in the RF breathing or control conditions. *Respiration rate was successfully controlled in this experiment* since respiration rates were identical during both RF breathing conditions. While both RF breathing conditions produced greater HR Max – HR Min, pNN50, RMSSD, and SDNN measurements than the control condition, *in no case did the addition of heartfelt emotion instructions to RF breathing produce greater HRV values than RF breathing alone*. Heartfelt emotion was not necessary to increase HRV nor did its addition to RF breathing enhance our participants' success. Future research should replicate these findings with a gender-balanced clinical sample.

Fuller, J., Wally, C., Carrell, D., Peterson, J., Ward, A., Westermann-Long, A., Korenfeld, D., Burklund, Z., Shepherd, S., Jones, D., Francisco, A., Kane, A., Zerr, C., & Shaffer, F. (2012). Does Heartfelt Emotion Increase Heart Rate Variability? [Abstract]. *Applied Psychophysiology and Biofeedback, 37*(4), 301.

Wally and colleagues (2011) found that adding heartfelt emotion to resonance frequency training did not increase heart rate variability (HRV). To determine whether inducing heartfelt emotion increases HRV, the present study compared heartfelt emotion to sitting quietly. Twenty-five undergraduates (18 male and 7 female), 19 to 23 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored heart rate and HRV using an Infiniti EKG™ sensor with leads placed on the upper chest and below the sternum, and respiration rate using an abdominal strain gauge placed over the navel. Heartfelt emotion was assessed with a 5-point scale and the PANAS-X Positive Affect subscale. HRV was measured using time domain (HR Max – HR Min, NN50, pNN50, RMSSD, SDNN), frequency domain (VLF, LF, HF, LF/HF power, and peak LF frequency power), and entropy indices (approximate entropy and sample entropy). Data were analyzed using a General Linear Model analysis of variance with an alpha level of .05. In this within-subjects design, participants were randomly assigned to two 5-minute conditions that were separated by 2-minute buffer periods: heartfelt emotion and control. Subjects sat upright with eyes open in both conditions, were not given breathing rate instructions, and did not receive feedback. Participants in the heartfelt emotion condition received the Institute of HeartMath's Heart Lock-In Technique® instructions to activate these emotions. In the control condition, they sat quietly. *Heartfelt emotion was successfully manipulated* since heartfelt emotion, $F(1,23) = 67.45$, $p = .000$, $\eta^2 = 0.75$, and positive affect scores, $F(1,23) = 4.17$, $p = .03$, $\eta^2 = 0.15$, were higher in the heartfelt emotion condition than in the control condition. *Respiration rates* were an identical 10 bpm during both conditions. Heartfelt emotion did not significantly increase HRV as measured by time domain, frequency domain, or entropy indices compared to a control condition. Since heartfelt emotion, alone, did not increase HRV, its contribution to HRV biofeedback remains unproven. Future research should replicate these findings with a gender-balanced clinical sample.

Fuller, J., Wally, C., Carrell, D., Peterson, J., Ward, A., Westermann-Long, A., Korenfeld, D., Burklund, Z., Shepherd, S., Jones, D., Francisco, A., Kane, A., Zerr, C., & Shaffer, F. (2012). Can ujjayi breathing increase the effectiveness of 6-bpm heart rate variability training [Abstract]? *Applied Psychophysiology and Biofeedback, 37*(4), 297-298.

The present study examined whether ujjayi breathing, also called ocean breathing, produces greater HRV when added to 6-bpm breathing than 6-bpm HRV breathing alone. Twenty-two undergraduates (18 male and 4 female), 19 to 23 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored heart rate and HRV using an Infiniti EKG™ sensor with leads placed on the upper chest and below the sternum, and respiration rate using an abdominal strain gauge placed over the navel. In this within-subjects design, participants were randomly assigned to three 5-minute conditions that were separated by 2-minute buffer periods. They sat upright in a straight-backed chair with their eyes open in all conditions. In the two experimental conditions, they were instructed to breathe at 6 bpm following an animated pacer. They breathed at 6 bpm in the paced breathing condition, they also practiced ujjayi breathing (slightly constricting the throat and producing an audible breathing sound) in the combined condition, and they sat quietly with no feedback in the control condition. Data were analyzed using planned comparisons with a familywise correction with an alpha level of .05. Respiration rate was effectively controlled in the two experimental conditions (6 bpm in each condition). Respiration depth was also identical in these conditions (8 relative units). We measured the effect of the experimental conditions on two time domain measures (SDNN and HR Max-HR Min) and two frequency domain measures (LF and the LF/HF ratio). In no case did the combined condition produce greater HRV than 6-bpm breathing alone. Only 6-bpm breathing increased SDNN compared to the control condition. Both 6-bpm breathing and ujjayi breathing combined with 6-bpm breathing increased HR Max-HR Min. Both experimental conditions increased LF percentage power. They also increased the LF/HF ratio. Since ujjayi breathing combined with 6-bpm breathing increased fewer HRV measures than 6-bpm breathing alone, and since in no case did the combined condition produce greater HRV than 6-bpm breathing alone, these findings discourage adding ujjayi breathing to increase HRV in subjects who resemble our undergraduates. Future research should replicate these findings with a gender-balanced clinical sample.

Peterson, J., & Shaffer, F. (2011). Breathing at six breaths per minute increases heart rate variability and lowers systolic blood pressure [Abstract]. *Applied Psychophysiology and Biofeedback, 36*(4), 299.

The present within-subjects study compared the effects of breathing at 3, 6, and 12 breaths per minute (BPM) on blood pressure and heart rate variability (HRV). Twenty-one normotensive undergraduates (19 men and 2 women), 18–23 years of age, participated in this study. A Thought Technology ProComp$^{\text{TM}}$ Infiniti system detected the EKG using an Infiniti EKG$^{\text{TM}}$ sensor with leads placed on the upper chest and below the sternum, measured respiration rate using a Resp-Flex/Pro$^{\text{TM}}$ sensor placed around the abdomen at the level of the navel, and systolic and diastolic blood pressure using a Omega 1400$^{\text{TM}}$ automated blood pressure monitor with the cuff placed over the brachial artery of the nondominant arm. Participants received four consecutive weekly 29-min sessions of HRV training at a 1:2 inhalation-to-exhalation ratio with instructions to breathe abdominally from 5 to 7 BPM and to increase low frequency amplitude. Then, they were randomly assigned to one of six orders of 10 min of 12-BPM, 6-BPM, and 3-BPM breathing at a 1:2 inhalation-to-exhalation ratio using a pacer display with 5-min buffer periods. Planned comparisons revealed that 6-BPM breathing produced lower systolic pressure than 12-BPM breathing, $F(1, 15) = 4.84$, $p = .04$, eta squared = 0.24, and 3-BPM breathing, $F(1, 15) = 5.76$, $p = .03$, eta squared = 0.28. There were no significant diastolic effects. SDRR was higher for 6-BPM, $F(1,15) = 108.65$, $p = .001$, eta squared = 0.88, and 3-BPM breathing, $F(1, 15) = 42.09$, $p = .001$, eta squared = 0.74, than for 12-BPM breathing; but 6-BPM breathing produced comparable SDRR values to 3-BPM breathing. HR Max-HR Min was higher for 6-BPM, $F(1,15) = 36.18$, $p = .001$, eta squared = 0.71 and 3-BPM breathing, $F(1, 15) = 54.37$, $p = .001$, eta squared = 0.78, than for 12-BPM breathing. These findings support teaching 6-BPM breathing to reduce systolic pressure and increase HRV and should be replicated with a gender-balanced hypertensive sample.

Wally, C., Fuller, J., Carrell, D. Korenfeld, D., & Westermann-Long, A. (2011). Chanting Om increases heart rate variability by slowing respiration [Abstract]. *Applied Psychophysiology Biofeedback, 36*(3), 223.

The present within-subjects study compared the effects of chanting “om” and singing a fundamental note on heart rate variability (HRV). Seventeen undergraduate males, 19 to 23 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system monitored heart rate and HRV using an Infiniti EKG™ sensor with leads placed on the upper chest and below the sternum, and respiration rate using an abdominal strain gauge placed over the navel. In this within-subjects design, participants were randomly assigned to three 10-minute conditions that were separated by 3-minute buffer periods: chanting “om,” singing the fundamental note “e,” or silence. They were monitored sitting upright with their eyes open and no feedback. Planned comparisons revealed that SDNN was 28% greater when chanting “om” than when sitting quietly, $F(1,5) = 5.99$, $p = .032$, eta squared = 0.35. Singing ”e” did not increase SDNN compared to sitting quietly. HR Max – HR Min was 63% greater when chanting “om” than when sitting quietly, $F(1,5) = 11.58$, $p = .006$, eta squared = 0.51 and 58% greater when singing “e” than when sitting quietly, $F(1,5) = 14.67$, $p = .003$, eta squared = 0.57. Respiration rate was 27% slower when chanting “om” than when sitting quietly, $F(1,5) = 15.71$, $p = .002$, eta squared = 0.59. Singing ”e” did not slow respiration rate compared to sitting quietly. Nonlinear regression analysis using a cubic model disclosed that slowed breathing accounted for 59% of the increase in SDNN, $F(3,13) = 6.21$, $p = .008$, and 52% of the increase in HR Max- HR Min, $F(3,13) = 4.72$, $p = .02$, when chanting “om” than when sitting quietly. Regular practice chanting “om” might help reinforce HRV training. Future research should replicate these findings with a gender-balanced clinical sample.

Fuller, J., Wally, C., Westermann-Long, A., Korenfeld, D., & Carrell, D. (2011). Resonance frequency measurements are reliable [Abstract]. *Applied Psychophysiology and Biofeedback, 36*(3), 219.

A within-subjects study examined the 2-week test-retest reliability of the resonance frequency and three global measures of heart rate variability (HRV). Nineteen undergraduates (16 males and 3 females), 19-22 years of age, participated in this study. A Thought Technology ProComp Infiniti™ system monitored HR Max – HR Min, pNN50, and SDNN using an Infiniti EKG™ sensor with leads placed on the torso and respiration rate using a strain gauge placed over the navel. The resonance frequency was the breathing rate that maximized the most global measures of HRV. Subjects sat upright in a straight-backed chair with eyes open throughout this study. Following 10-minutes stabilization and a 5-minute resting baseline without feedback, subjects were instructed to follow an animated pacing display designed to guide their breathing from 7.5 to 4.5 breaths per minute in seven descending ½-breath-per-minute steps. They breathed at each target rate for 5 minutes followed by a 1-minute buffer period. Subjects were retested using the same procedure 2 weeks later to assess the reliability of these measurements. They received no HRV training or breathing practice during this period. A Pearson Product-Moment Correlation Coefficient revealed that resonance frequency, $r(17) = 0.73$, $p = .000$; pNN50, $r(17) = 0.65$, $p = .002$; and SDNN measurements, $r(17) = 0.59$, $p = .008$, were reliable, but HR Max – HR Min measurements were unreliable, $r(17) = 0.30$, $p = .212$. These findings support protocols that train clients to breathe at their unique resonance frequency to maximize HRV.

Grant, J., Wally, C., & Truitt, A. (2010). The effects of Kargyraa throat-singing and singing a fundamental note on heart rate variability [Abstract]. Poster presented at the meeting of the Biofeedback Foundation of Europe, Rome, Italy.

This within-subjects study examined the comparative effects of Kargyraa throat-singing and singing a fundamental note on heart rate variability. Eleven male undergraduates participated in this study for academic credit. A Thought Technology ProComp™ Infiniti system monitored alpha and theta amplitude with a gold cup electrode at the vertex of the scalp and a linked ears reference, heart rate, SDRR, and HR Max – HR Min using an Infiniti EKG™ sensor with leads placed on the torso, respiration rate using a strain gauge placed over the navel, skin conductance level using electrodes on the 2nd and 4th fingers of the dominant hand, and temperature using a thermistor on the web dorsum of the dominant hand. In this within-subjects design, participants received from two to three 50-minute individual training sessions in Kargyraa throat-singing and were instructed to practice 30 minutes per day for 5 days a week. All 11 participants sustained singing of two notes at the same time for 180 seconds. They were randomly assigned to three 10-minute conditions that were separated by 5-minute buffer periods: Kargyraa throat-singing, singing a fundamental note (a, e, or u) used in throat-singing, or silence. They were monitored with their eyes open and no feedback. Planned comparisons revealed that SDRR was greater when singing a fundamental note than when sitting quietly, $F(1,5) = 11.29$, $p = .02$, eta squared = 0.69. Throat-singing did not increase SDRR compared to sitting quietly. HR Max – HR Min was greater when singing a fundamental note than when sitting quietly, $F(1,5) = 14.64$, $p = .01$, eta squared = 0.75 and when throat-singing than when sitting quietly, $F(1,5) = 12.67$, $p = .02$, eta squared = 0.72. Regular practice singing a fundamental note might help reinforce HRV training since it increases both SDRR and HR Max – HR Min.

Wally, C., Korenfeld, I., Brooks, K., Peterson, J., & Schafer, M. (2010). Postural effects on heart rate variability and blood pressure detected using electrocardiography [Abstract]. *Applied Psychophysiology and Biofeedback, 35*(4), 319.

The present within-subjects study examined how subtle postural changes affect global and power spectral measures of heart rate variability obtained from an EKG sensor. Fifty-one undergraduates (27 men and 24 women), 18 to 23 years of age, participated in this study for academic credit. A Thought Technology ProComp™ Infiniti system detected the EKG using an Infiniti EKG ™ sensor with leads placed on the upper chest and below the sternum, measured respiration rate using a Resp-Flex/Pro™ sensor placed around the abdomen at the level of the navel, and systolic and diastolic blood pressure using a Omega 1400™ automated blood pressure monitor with the cuff placed over the brachial artery of the nondominant arm. Participants were stabilized for 5 minutes sitting quietly with eyes open with no postural instructions and then were randomly assigned to one of six orders of sitting upright, sitting with a forward slouch, and sitting with a backward slouch. Each sitting condition included no feedback, lasted 3 minutes, and was separated by a 2-minute buffer period. Planned comparisons revealed that pNN50 was not affected by sitting position. SDRR was greater when sitting with a forward slouch than sitting upright, $F(1,45) = 5.36$, $p = .025$, eta squared = 0.11, or sitting with a backward slouch, $F(1,45) = 8.8$, $p = .005$, eta squared = 0.16. HR Max – HR Min was greater when sitting with a forward slouch than sitting with a backward slouch, $F(1,45) = 6.52$, $p = .014$, eta squared = 0.13. While systolic blood pressure did not significantly change with sitting position, diastolic blood pressure was higher when sitting upright than slouching forward, $F(1,45) = 9.82$, $p = .003$, eta squared = 0.18 and when slouching backward, $F(1,45) = 8.42$, $p = .006$, eta squared = 0.16. These effects were not mediated by respiration rate. We recommend that clinicians and researchers standardize sitting position when monitoring blood pressure and when detecting heart rate variability with an EKG sensor.

Wally, C., Korenfeld, I., Brooks, K., Peterson, J., & Schafer, M. (2010). The effects of three respiration rates on blood pressure and heart rate variability [Abstract]. *Applied Psychophysiology and Biofeedback, 35*(4), 319.

The present within-subjects study compared the effects of breathing at 3, 6, and 12 breaths per minute (BPM) on blood pressure and heart rate variability (HRV). Twenty-one normotensive undergraduates (19 men and 2 women), 18 to 23 years of age, participated in this study. A Thought Technology ProComp™ Infiniti system detected the EKG using an Infiniti EKG™ sensor with leads placed on the upper chest and below the sternum, measured respiration rate using a Resp-Flex/Pro™ sensor placed around the abdomen at the level of the navel, and systolic and diastolic blood pressure using a Omega 1400™ automated blood pressure monitor with the cuff placed over the brachial artery of the nondominant arm. Participants received four consecutive weekly 29-minute sessions of HRV training at a 1:2 inhalation-to-exhalation ratio with instructions to breathe abdominally from 5 to 7 BPM and to increase low frequency amplitude. Then, they were randomly assigned to one of six orders of 10 minutes of 12-BPM, 6-BPM, and 3-BPM breathing at a 1:2 inhalation-to-exhalation ratio using a pacer display with 5-minute buffer periods. Planned comparisons revealed that 6-BPM breathing produced lower systolic pressure than 12-BPM breathing, $F(1, 15) = 4.84$, $p = .04$, eta squared = .24, and 3-BPM breathing, $F(1, 15) = 5.76$, $p = .03$, eta squared = .28. There were no significant diastolic effects. SDRR was higher for 6-BPM, $F(1, 15) = 108.65$, $p = .000$, eta squared = .88, and 3-BPM breathing, $F(1, 15) = 42.09$, $p = .000$, eta squared = .74, than for 12-BPM breathing; but 6-BPM breathing produced comparable SDRR values to 3-BPM breathing. HR Max – HR Min was higher for 6-BPM, $F(1, 15) = 36.18$, $p = .000$, eta squared = .71, and 3-BPM breathing, $F(1, 15) = 54.37$, $p = .000$, eta squared = .78, than for 12-BPM breathing. These findings support teaching 6-BPM breathing to reduce systolic pressure and increase HRV, and should be replicated with a gender-balanced hypertensive sample.

Grant, J., Korenfeld, I., Wally, C., & Truitt, A. (2010). Inhalation-to-exhalation ratio affects HRV training success [Abstract]. *Applied Psychophysiology and Biofeedback, 35*(2), 181.

While there is strong empirical support in HRV biofeedback for teaching patients to slow their respiration rate to between 5 and 7 breaths-per-minute, there has been no definitive study of the best inhalation-to-exhalation ratio. In theory, a 1:2 ratio should increase global measures of HRV (SDRR, pNN50, HR Max-HR Min) more than a 1:1 ratio, because extended exhalation should prolong parasympathetic slowing of the heart. The present crossover study addressed this question. Ten male undergraduates, ages 18–22, were randomly assigned to one of two orders of HRV training: 1:1 ratio training followed by 1:2 ratio training, or 1:2 ratio training followed by 1:1 ratio training. A Thought Technology ProComp Infiniti data acquisition system using Infiniti 4.0 software measured HRV using a photoplethysmographic (PPG) sensor placed on the thumb of the nondominant hand and a respiration sensor placed over the navel. Participants received four consecutive weekly training sessions using their initial inhalation-to-exhalation ratio. Then, they received four additional training sessions using the second inhalation-to-exhalation ratio. During each session, they were instructed to follow a pacing display to guide their inhalation and exhalation, and watch analog feedback displays for heart rate, the very low frequency (VLF), low frequency (LF), and high frequency (HF) amplitude components of HRV, and strain gauge movement. Participants were encouraged to breathe abdominally from 5 to 7 breaths per minute and increase LF amplitude. Each session consisted of a 5-min stabilization period, 3-min eyes-open prebaseline, six 3-min training segments, and a 3-min eyes-open postbaseline. No feedback was provided during baseline measurements. A GLM Repeated Measures analysis found that only the 1:2 ratio training increased SDRR, *F*(1, 9) = 16.91, *p* = .003, eta squared = 0.65, and pNN50, *F*(1, 9) = 5.91, *p* = .038, eta squared = 0.40. Neither training method increased HR Max-HR Min, which is a third global measure of HRV. These findings should be replicated with a significantly larger, gender-balanced clinical sample to confirm their generality.

Urlakis, M. (2010). The physiological effects of Kargryya throat-Singing: Paradoxical arousal [Abstract]. *Applied Psychophysiology and Biofeedback, 35*(2), 181-182.

Kargryya throat-singing is an Eastern vocal technique that allows an individual to sing more than one note or pitch at the same time. Preliminary data showed that this meditative technique increased the percentage of power in the very low frequency (VLF) band of the heart rate variability spectrum. Since VLF activity may be associated with sympathetic arousal, it was hypothesized that Kargryya throatsinging would increase heart rate (HR) and skin conductance level (SCL), and decrease temperature. Three male undergraduates, ages 21–23, participated in this study. A Thought Technology Ltd. Pro- Comp Infiniti physiological data acquisition system with BioGraph 4.0 software monitored alpha and theta amplitude with a gold cup electrode at the vertex of the scalp and a linked-ear reference on the left and right ears, heart rate and SDRR using a photoplethysmographic (PPG) sensor on the middle finger of the nondominant hand, respiration rate using an abdominal strain gauge placed over the navel, skin conductance level using electrodes on the second phalanx of the 2nd and 4th fingers of the dominant hand, and temperature using a thermistor on the web dorsum of the dominant hand. In this small-*N* design, after three 50-min training sessions, the participants were monitored with eyes open and without receiving feedback. They sat upright during nine 5-min periods, which included a prebaseline, listening to prerecorded Kargryya throat-singing, a baseline, performing throat-singing, a baseline, listening to prerecorded throatsinging, a baseline, performing throat-singing, and a postbaseline. All three subjects showed sharply increased heart rate and skin conductance levels, and decreased temperature that coincided with both periods of performing Kargryya throat-singing. Subjects 2 and 3, whose respiration rates slowed to 6 breaths-per-minute during singing, displayed large-scale increases in SDRR and HR Max-HR Min that also coincided with the two periods of performing throat-singing. Subjects 1 and 2 showed increased alpha and theta amplitudes while singing. These findings suggest that meditative procedures may produce complex and paradoxical patterns of physiological activity, such as increased sympathetic arousal and HRV. These findings should be replicated using a large-*N* design with gender balance and greater control for order effects.

Grant, J. (2009). Sitting position influences heart rate variability [Abstract]. Poster presented at the meeting of the Biofeedback Foundation of Europe, Eindhoven, The Netherlands.

The present within-subjects study examined how subtle postural changes affect global and power spectral measures of heart rate variability obtained from a PPG sensor. Fifty-seven undergraduates (28 men and 29 women), 18 to 35 years of age, participated in this study for academic credit. Participants were stabilized for 5 minutes sitting quietly with eyes open with no postural instructions and then were randomly assigned to one of six orders of sitting upright, sitting with a forward slouch, and sitting with a backward slouch. Each sitting condition included no feedback, lasted 3 minutes, and was separated by a 2-minute buffer period. Planned comparisons revealed that pNN50 was greater during forward posture than sitting upright, F(1,56) = 17.11, p = .000, or sitting with a backward slouch, *F*(1,56) = 16.90, *p* = .000. SDRR was also greater during forward posture than sitting upright, *F*(1,56) = 5.39, *p* = .024 or sitting with a backward slouch, *F*(1,56) = 8.93, *p* = .004. HR Max – HR Min was greater during a forward slouch than a backward slouch, *F*(1,56) = 5.04, *p* = .029. Low frequency (LF) power was lower during forward posture than sitting upright, *F*(1,56) = 12.22, *p* = .001 or sitting with a backward slouch, *F*(1,56) = 4.45, *p* = .039. High frequency (HF) power was higher during forward posture than sitting upright, *F*(1,56) = 10.81, *p* = .002 or sitting with a backward slouch, *F*(1,56) = 7.10, *p* = .01. These findings show that sitting position affects pNN50, SDRR, and HR Max – HR Min global measures of heart rate variability and the percentage of power in the LF and HF bands. These effects were not mediated by respiration rate since this variable did not significantly vary across the three sitting positions.

Kabins, A., Goedde, J., & Shaffer, F. (Faculty Mentor). (2008). A Reevaluation of the web dorsum for monitoring hand temperature [Abstract]. *Applied Psychophysiology and Biofeedback, 34*(1), 69-70.

The present within-subjects study compared the web dorsum temperature monitoring site to five other sites on each hand during baseline and serial-sevens stressor conditions. Thirty-nine undergraduates (20 men and 19 women, 3 left-handed and 36 right-handed), ages 18–23, volunteered for academic credit. Researchers randomly assigned participants to 1 of 5 sequences of monitoring six sites (the first phalanx of each finger and the web dorsum of each hand) using a single Raytek Raynger ST infrared thermometer. Participants were stabilized for 15 min in a 77°F room and were then monitored sitting upright with eyes open during 2-min baseline and serial-sevens conditions. Researchers sequentially monitored six sites on one hand and then six sites on the other hand for 30 s. The starting hand was randomized across subjects. After each condition, participants rated their level of subjective stress on a 7-point Likert scale. For the left hand, a GLM Repeated Measures analysis found that there were no significant temperature differences between the web dorsum and the other five sites during baseline (Figs. 1, 2). During the serial-sevens stressor, there was a significant difference among the six temperature sites, $F(5, 190) = 3.52$, $p = .005$. A priori tests revealed that the web dorsum was 1–1.5°F warmer than every site but the thumb. For the right hand, there was a significant difference among the six temperature sites during baseline, $F(5, 190) = 4.60$, $p = .001$, and the serial-sevens stressor, $\mathrm{F}(5, 190) = 3.71$, $p = .003$. A priori tests revealed that the web dorsum was 1–2.1°F warmer than every site but the thumb and second finger during both the baseline condition and the serial-sevens stressor. These findings revealed that the relationship between temperatures at the web dorsum and five other sites depended on both the hand and experimental condition. The web dorsum was warmer than the majority of the other sites on the left hand during the serial-sevens stressor and on the right hand during both baseline and serial-sevens stressor conditions.

Citation Paper

Kabins, A., Goedde, J., Layne, B., & Grant, J. (2008). Brief coaching increases inhalation volume [Abstract]. *Applied Psychophysiology and Biofeedback, 33*(3), 174.

Surgical patients and outpatients treated for asthma, chronic obstructive pulmonary disease (COPD), and emphysema are often taught to use an incentive inspirometer to improve ventilation. The present study examined whether brief coaching can increase inhalation volume. Fifty-two undergraduates (26 men and 26 women), ages 18–24, volunteered for academic credit. In this within-subjects design, participants were randomly assigned to one of two orders of coaching separated by a 1-min buffer period. In both coaching and nocoaching conditions, participants received instructions to exhale before inhaling through an incentive inspirometer and received visual feedback from its rising cylinder. They sat upright with eyes open and completed five inhalations. In the coaching condition, an experimenter announced inhalation volume after each inhalation. When their volume was under 2500 ml, they were told ''You are doing well. Now let's see if you can go a little higher. Make sure that you don't start your next breath until you exhale most of the air from your lungs.'' When their volume was over 2500 ml, they were told ''Great job! Keep it up.'' In the no-coaching condition, the experimenter gave no verbal feedback. A Voldyne 5000 Volumetric Exerciser measured inhalation volume. Two Likert rating scales measured subjective effort and motivation after completing five breaths in each experimental condition. A GLM Repeated Measures analysis found that inhalation volume was significantly higher during the coaching than the no-coaching condition, 3002 ml versus 2845 ml, $F(1, 50) = 8.27$, $p = .006$, eta squared = 0.14. There were no differences in subjective effort or motivation. Participants rated the feedback as helpful ($M = 4.67$, $SD = 1.78$). The small significant 5% increase in inhalation volume produced by brief coaching should encourage healthcare providers to add a coaching component to the written instructions that surgical patients receive. Coaching could ensure greater patient skill in using an inspirometer and, post-surgically,more complete ventilation of the lungs.

Goedde, J., Kabins, A., & Koenig, R. (2007). Patient speech alters respiration rate, blood pressure, and heart rate [Abstract]. *Applied Psychophysiology and Biofeedback, 32*(2), 127.

This study explored the effects of patient speech on respiration rate, blood pressure, and heart rate, utilizing a within-subjects design with complete counterbalancing for order. Fifty-five undergraduates (28 men and 27 women), aged 19-34, volunteered for academic credit. Participants were randomly assigned to one of six orders of three 30-s speech conditions during automated blood pressure measurement, separated by 3-min buffer periods. The three conditions were silence, reading a positive personal health description while breathing continuously and reading the same description while taking as few breaths as possible. An Omega 1400 automated sphygmomanometer measured blood pressure and heart rate, and a ProComp Infiniti system assessed respiration rate. Data were analyzed using a GLM Repeated Measures procedure with Helmert contrasts. The experimental instructions successfully manipulated breath-holding as indexed by respiration rate. Speech decreased respiration rate and increased blood pressure and heart rate compared to silence. Breath-holding slightly amplified these effects on diastolic blood pressure and heart rate. Respiration rate was higher during silence than both speech conditions, *F*(1, 49) = 60.9, *p* = .000, *MD* = 3.3 bpm, and was higher during speech with continuous breathing than with breath-holding, *F*(1, 49) = 8.7, *p* = .004, *MD* = 1.1 bpm. Systolic blood pressure was lower during silence than both speech conditions, *F*(1, 49) = 88.4, *p* = .000, *MD* = 11.4 mm Hg. Diastolic blood pressure was lower during silence than both speech conditions, *F*(1, 49) = 174.4, *p* = .000, *MD* = 11.6 mm Hg, and was lower during speech with continuous breathing than with breath-holding, *F*(1, 49) = 7.5, *p* = .009, *MD* = 2.6 mm Hg. Heart rate was slower during silence than both speech conditions, *F*(1, 49) = 101.3, *p* = .000, *MD* = 14.1 bpm, and was slower during speech with continuous breathing than with breath-holding, *F*(1, 49) = 4.4, *p* = .04, *MD* = 2.4 bpm. We recommend that clinicians not solicit patient conversation when taking these vital signs.

Citation Paper

Kabins, A., Brenner, T., & Pacanowski, R. (2007). Validation of a heart rate variability tracking test [Abstract]. *Applied Psychophysiology and Biofeedback, 32*(2), 124.

Tracking tests ensure that physiological measurements mirror client activity. While there are well-established tracking tests for SEMG and temperature, there is no standardized procedure for heart rate variability (HRV). The present study compared the effects of a modified serial-sevens stressor and silence on self-rated stress and four HRV measures (HR max-min, very low frequency amplitude, low frequency amplitude, and high frequency amplitude) using a within-subjects design. Fifty-seven undergraduates (35 men and 22 women), aged 18-23, volunteered for academic credit. To simulate clinical practice, following 5-min stabilization, participants were randomly assigned to one of two orders of a serial sevens stressor and silence separated by a 2-min buffer period. In the serial sevens condition, they counted backwards out loud from 1000 by 7 for 90 sec. In the silence condition, they sat quietly for 90 sec. Participants sat upright with eyes open in all conditions. A Likert rating scale (1-7) measured self-rated stress. A Thought Technology ProComp Infiniti data acquisition system using Infiniti 2.5 software measured HRV using a PPG sensor placed on the thumb of the nondominant hand. A GLM Repeated Measures analysis found that self-rated stress was higher during the serial-sevens stressor than silence, $F(1, 55) = 243.0$, $p = .000$, eta squared = 0.82. The main findings were that HR max-min, low frequency amplitude, and high frequency amplitude were higher during the serial sevens stressor than silence. HR max-min was higher during the serial-sevens stressor than silence, $F(1, 55) = 15.44$, $p = .000$, eta squared = 0.22. Very low frequency amplitude did not significantly change. Low frequency amplitude was higher during the serial-sevens stressor than silence, $F(1, 55) = 6.67.0$, $p = .013$, eta squared = 0.11. High frequency amplitude was higher during the serial-sevens stressor than silence, $F(1, 55) = 13.63.0$, $p = .001$, eta squared = 0.20. The significant increase of three of four HRV measurements during the serial-sevens stressor supports its use as a tracking test during HRV biofeedback.

Citation Paper

Bax, A., Robinson, T., Goedde, J., & Shaffer, F. (Faculty mentor) (2007). The Cousins relaxation exercise increases heart rate variability [Abstract]. *Applied Psychophysiology and Biofeedback, 32*(1), 52.

Clinicians use Autogenic Training (AT) and the Cousins Relaxation Exercise (CRE) alone and as part of biofeedback training. Since their effects on heart rate variability (HRV) and respiration have been poorly studied, their value as adjunctive exercises in HRV training is unclear. The present experiment compared the effects of AT and the CRE on heart rate variability (HRV) and respiration. Fifteen undergraduates (9 men and 6 women), aged 17-23, participated in this within-subjects experiment. Participants were randomly assigned to one of two orders of relaxation exercises (AT and CRE) separated by a 3-min buffer period. A 3-min eyes-closed resting baseline preceded each relaxation exercise. Participants listened to the recorded 15-min relaxation scripts over loudspeakers while seated upright with eyes closed. A Thought Technology Ltd. ProComp Infiniti system using PPG and respiration sensors measured the standard deviation of the cardiac interbeat interval (SDNN), which is an important indicator of cardiac mortality and morbidity, and respiration rate and amplitude. A General Linear Model procedure for repeated measures revealed that AT did not affect SDNN, respiration rate, or respiration amplitude. In contrast, the CRE increased SDNN, $F(1,13) = 5.58$, $p = .034$, $\eta^2 = .30$, slowed respiration rate, $F(1,13) = 8.16$, $p = .022$, $\eta^2 = .34$, and increased respiration amplitude, $F(1,13) = 11.84$, $p = .004$, $\eta^2 = .48$ compared with the preceding resting baseline. This pattern of physiological change is important since clinicians often attempt to teach patients to slow respiration to a patient's resonant frequency in order to increase the low-frequency component of HRV and SDNN during HRV biofeedback. These findings support assignment of the Cousins Relaxation Exercise as a home practice exercise to enhance the effects of HRV training with patients who resemble our undergraduates. We recommend that future researchers attempt to replicate these findings with clinical populations.

Sappington, B., Whipple, J., Pacanowski, R., & Shaffer, F. (Faculty mentor) (2007). Patient conversation raises blood pressure and heart rate [Abstract]. *Applied Psychophysiology and Biofeedback, 32*(1), 59-60.

This study examined the contribution of patient conversation to white coat hypertension. Thirty-six undergraduates and faculty (18 women and 18 men), aged 19-55, simulated patients visiting the campus Health Clinic for a checkup. In this within-subjects design, participants were randomly assigned to one of six orders of three conversation conditions during automated blood pressure measurement, separated by 5-min buffer periods. The three conditions were silence, positive conversation (reading a positive health description), and negative conversation (reading a negative health description). An Omega 1400 automated blood pressure monitor measured blood pressure and heart rate. The PANAS-X measured affect after each blood pressure. A General Linear Model procedure for repeated measures with Bonferonni post hoc comparisons confirmed that the conversation scripts successfully manipulated affect. Positive conversation produced greater positive affect than silence ($p = .003$) and negative conversation ($p = .005$). Negative conversation produced greater negative affect than silence ($p = .003$) and positive conversation ($p = .003$). Both positive and negative conversations significantly increased systolic ($p = .000$, $M = 11.3$ mm Hg; $p = .000$, $M = 10.8$ mm Hg), diastolic ($p = .000$, $M = 9.1$ mm Hg; $p = .000$, $M = 9.9$ mm Hg), and mean arterial blood pressures ($p = .000$, $M = 9.5$ mm Hg; $p = .000$, $M = 11.3$ mm Hg), and heart rate ($p = .000$, $M = 10.3$ bpm; $p = .000$, $M = 9.2$ bpm) when compared to silence. Positive and negative conversations produced comparable changes on these measures. Since both positive and negative emotions involve sympathetic activation, patient conversations that result in affective arousal may contribute to white coat hypertension. We recommend that medical professionals control this variable so that readings taken by patients at home and staff during checkups can be meaningfully compared.

Brotman, J., Lecure, J., & Shaffer, F. (Faculty mentor) (2005). The comparative effects of Autogenics and Cousins relaxation scripts on web dorsum temperature [Abstract]. *Applied Psychophysiology and Biofeedback, 30*(4), 412-413.

There is a continuing controversy concerning whether relaxation scripts incorporating standard Autogenic formulae promote hand warming. The present study compared the impact of two recorded relaxation scripts on web dorsum temperature and self-ratings of calm, enjoyment, activation, and positive and negative affect. Seventeen undergraduates (6 men and 11 women), from 19 to 26 years of age, participated in this experiment. They listened to recordings of Norman Cousins and Autogenic relaxation scripts during two 45-minute sessions, spaced two days apart, with complete counterbalancing for treatment order. During each session, thermistors were placed over the web dorsum of the dominant hand. Participants sat upright, with eyes closed, stabilized for 15 minutes, and web dorsum temperature was measured 30 s before and after each 14-min script in a 70-degree F room. Following completion of each script, participants rated their calm, enjoyment of the exercise, and positive and negative affect using the PANAS-X. A General Linear Model Repeated Measures procedure revealed that pre-baseline web dorsum temperatures were equivalent for both the Cousins and Autogenic scripts, and there was no order effect. Both relaxation scripts produced hand warming. Pre-baseline to post-baseline temperature increased 3.23 degrees F during the Autogenics script (p = .000) and 1.59 degrees F during the Cousins script (p = .006). The Autogenic script produced greater temperature increases than the Cousins script (p = .047). While the Autogenic script produced greater self-rated psychological calm than the Cousins script (p = .028), there were no differences on self-rated enjoyment, activation, and positive and negative affect. These findings provide additional evidence that listening to a relaxation script incorporating Autogenic formulae can aid hand warming and increase self-rated calm.

Copeman, B., Fink, K., Costello, K., & Shaffer, F. (Faculty mentor) (2005). Music can lower heart rate [Abstract]. *Applied Psychophysiology and Biofeedback, 30*(4), 414.

Although undergraduates report that they relax by listening to music, research has not consistently supported this claim. For example, studies have not consistently shown an effect of music tempo on heart rate. The present within-participants experiment compared the effects of no music, and slow and rapid tempi on heart rate. Thirty-seven undergraduates (26 women and 11 men), 18–24 years of age, participated in this study. Photoplethysmographic sensors were placed over the index finger of the dominant hand. Participants wore headphones and sat upright with eyes open, stabilized for 10min, and were randomly assigned to one of six orders of no-music, and slow- and rapid-tempo selections. Each music tempo condition lasted 4 min and was separated by a 4-min buffer period. The rapid-tempo selection was Beethoven's Piano Sonata No. 14 in C Sharp Minor, Walker (2000), track 3, with a tempo of 168 beats per min. The slow-tempo selection was Quitmeyer and Wesley's (1999) *Musical Journeys*, track 2, with a tempo of 60 beats per min. We adjusted the average volume on the Sony CD Walkman so it was comparable for each selection. A General Linear Model Repeated Measures procedure revealed that music tempo significantly affected heart rate (p = .000). Mean contrasts revealed that heart rate was lower during the slow-tempo than the no-music condition (p = .000) and lower during the slow-tempo than rapid-tempo condition (p = .007). There was no difference in heart rate between the rapid-tempo and no-music conditions. These findings support the use of music with a slow tempo to lower heart rate. We recommend that future researchers examine the effect of these music selections on additional autonomic measures.

White, C., Meltzer, M., & Shaffer, F. (Faculty mentor) (2005). Comparison of three tracking tests for BVP and SCL [Abstract]. *Applied Psychophysiology and Biofeedback, 30*(4), 414-415.

Tracking tests ensure the validity of psychophysiological measurements. While tests for sEMG and temperature tracking are well-established, there are many procedures that may be used to evaluate blood volume pulse (BVP) and skin conductance level (SCL) tracking. The present study compared the effectiveness of three popular methods (exhalation of a deep breath, raising and lowering the dominant arm, and abruptly clapping hands behind a participant's head) in changing blood volume pulse and skin conductance level. Twenty-five undergraduates (13 men and 12 women), ranging from 19 to 26 years of age, participated in this experiment. Photoplethysmographic sensors were placed over the first finger, and skin conductance sensors were placed over the second and third fingers of the dominant hand. Subjects sat upright with eyes open, stabilized for 15 min, and were randomly assigned to one of six treatment orders of three tracking tests using a balanced Latin square. Each 30-s tracking test was separated by a 2-min buffer period. A General Linear Model Repeated Measures procedure revealed that each tracking test produced significant changes from baseline and counterbalancing successfully prevented order effects. SCL increased during breathing (15%), arm movement (11%), and clapping (14%). Bonferonni post-hoc comparisons revealed that breathing increased SCL more than arm movement (p = .026) and was equivalent to clapping. BVP also increased during breathing (80%), arm movement (603%), and clapping (84%). Bonferonni post-hoc comparisons revealed that arm movement increased BVP more than breathing (p = .000) or clapping (p = .000). Based on these findings, we recommend that clinicians and researchers use the breathing and arm movement procedures to separately test SCL and BVP tracking or use arm movement to simultaneously test both SCL and BVP tracking.

Copeman, B., Lynam, I., Brotman, J., & Shaffer, F. (Faculty mentor) (2004). Validation of infrared temperature comparisons between sites on the left and right hands [Abstract]. *Applied Psychophysiology and Biofeedback, 29*(4), 307.

The present study evaluated the concurrent validity of infrared temperature scanning using a single infrared thermometer and whether clinicians may compare measurements obtained from identical sites on both hands. Fifty-three undergraduates (13 men and 40 women) participated in this experiment. The infrared scanning protocol achieved high concurrent validity and allowed valid temperature comparisons between sites on the left and right hands. The authors recommend that clinicians utilize an infrared thermometer to supplement thermistor measurements during assessment and temperature training, and encourage researchers to validate this procedure with clinical samples balanced for age and gender when monitoring the hands and feet.

White, C., Lammy, D., & Shaffer, F. (Faculty mentor) (2004). Infrared hand temperature mapping [Abstract]. *Applied Psychophysiology and Biofeedback, 29*(4), 306.

The present study mapped the hand temperatures of undergraduates using a single infrared thermometer at six identical sites on both hands while resting. Fifty-three undergraduates (13 men and 40 women) participated in this experiment. While sites on a single hand and across both hands generally exhibited comparable temperatures, there was a main effect for recording location, which reflected a 0.92◦ F discrepancy between the left and right web dorsum sites. The authors recommend that researchers replicate these findings with a clinical sample balanced for age and gender and clinicians utilize infrared thermometers with the accuracy of clinical-grade thermistors.

Shaffer, F., Banks, A., Lipps, A., Franken, F., Giddings, L., Burden, A., & Schwyhart, J. (2003). The comparative effects of position and cordless phone equipment on upper trapezius and cervical paraspinal surface EMG [Abstract]. *Applied Psychophysiology and Biofeedback, 28*(4), 311.

The present factorial experiment examined the effects of position (sitting or standing) and equipment (phone or headset) on upper trapezius and cervical paraspinal sEMG. We studied 43 undergraduate volunteers (9 men and 34 women) using a repeated-measures design. Participants were randomly assigned to five, five-min treatment conditions, separated by 3-min buffer periods. These conditions included baseline, sitting-phone, sitting-headset, standing-phone, and standing-headset. Position and equipment independently influenced trapezius sEMG asymmetry. Equipment also affected cervical paraspinal sEMG asymmetry.

Shaffer, F., Banks, L., Lipps, A., Lynam, I., Jacobsmeyer, S., & Rumora, K. (2003). The effects of instructions, sitting position, and task on baseline measurements [Abstract]. *Applied Psychophysiology and Biofeedback, 28*(4), 322.

The present study examined the effect of instructional detail (low-detail or high-detail) and sitting position (upright or reclining) on frontal sEMG, blood volume pulse, heart rate, respiration rate, skin conductance level, and skin temperature. We studied 63 undergraduate volunteers (8 men and 55 women) using a mixed factorial design. All subjects completed the following 3-min conditions: baseline, mental arithmetic, buffer period, baseline, mental arithmetic. Sitting position significantly influenced several psychophysiological measurements, alone and in conjunction with task and instructions. The authors recommend that clinicians standardize this variable so that they may compare measurements within and across sessions.

Shaffer, F., Jacobsmeyer, S., Giddings, L., Sasfai, S., Luebbering, B., & Schlereth, M. (2003) Validation of an infrared temperature scanning procedure for the hands [Abstract]. *Applied Psychophysiology and Biofeedback, 28*(4), 324.

The present study evaluated the concurrent validity of infrared temperature scanning, the reliability of infrared temperature readings taken from six sites on each hand, and whether scanning sequence significantly influenced temperature. Seventy-one undergraduates (16 men and 55 women) participated in this experiment. An infrared thermometer achieved high concurrent validity and reliability, and scanning sequence did not confound temperature measurements. The authors recommend that clinicians incorporate an infrared thermometer in their practice to supplement thermistor measurements during assessment and temperature training, and urge researchers to validate this procedure with clinical populations for monitoring both hands and feet.

Shaffer, F., Banks, L., Lipps, A., Franken, F., & Steinman, S. (2002). Ergonomic skin-electrode impedance testing [Abstract]. *Applied Psychophysiology and Biofeedback, 27*(4), 314.

The present study compared the accuracy, speed, and subjective difficulty of impedance testing using test probes and 10-mm cup electrodes. We studied 10 undergraduate research technicians (6 men and 4 women) using a within-subjects design. They measured the skin-electrode impedance of 10-mm silver/silver-chloride surface electrodes placed over the frontales muscles. Although both methods were highly accurate, the cup electrode method was ergonomically superior to the test probe method. It was 27% faster and participants rated it as 35% easier. Therefore, we recommend that professionals who manually test skin-electrode impedance for surface EMG electrodes consider the cup electrode method.

Shaffer, F., Lipps, A., Banks, A., Franken, F., & Stokes, C. (2002). Comparison of three surface EMG placements during a psychophysiological profile [Abstract]. *Applied Psychophysiology and Biofeedback, 27*(4), 314.

The present study examined whether the FpN and corrugator placements discriminate as well as the frontalis placement among three typical psychophysiological assessment activities (sitting quietly, performing mental arithmetic, and reviewing recent upsetting experiences). We studied 39 undergraduates (14 men and 25 women) using a within-subjects design. Both the frontalis and corrugator placements discriminated between sitting quietly and two stressors: performing mental arithmetic and reviewing recent upsetting experiences. However, the frontalis placement accounted for more sEMG variability due to assessment condition than did the corrugator placement. These findings are limited to our relatively healthy sample and specific assessment procedures.

Shaffer, F., Lipps, A., Banks, L., & Schneider, B. (2002). Effort threatens relaxation training success [Abstract]. *Applied Psychophysiology and Biofeedback, 27*(4), 304.

The present study examined whether relaxation effort influences the physiological effects of brief autogenic and progressive relaxation exercises. We studied 20 undergraduate volunteers (8 men and 12 women) using a within-subjects design, and measured the effects of four 3-min relaxation effort conditions (low-effort autogenic, high-effort autogenic, low effort progressive relaxation, and high-effort progressive relaxation) on accessory sEMG, blood volume pulse, heart rate, skin conductance level, and skin temperature. This study provides preliminary evidence that excessive effort during a brief progressive relaxation exercise increases accessory sEMG activity and skin conductance level, and supports Luthe's emphasis on a relaxed attitude during relaxation training.

Shaffer, F., Malone, E., Callahan, C., & Lipps, A. (2001). Is prayer relaxing? [Abstract]. *Applied Psychophysiology and Biofeedback, 26*(3), 246.

This study compared the effects of two forms of prayer (silent Bible reading and silent self-composed prayer) with their secular counterparts (silent reading of a secular passage and silent review of the participant's day) on musculoskeletal (accessory sEMG) and autonomic (heart rate, skin conductance, and skin temperature) variables. Silently composing a prayer significantly lowered accessory sEMG 31% below baseline values, but did not affect any other physiological measurements. Silently reading a Bible passage did not affect any of the monitored variables. The authors encourage further study of the psychophysiological effects of self-composed prayer.

Shaffer, F., Malone, E., & Krebill, R. (2001). Magnitude statistics can quantify the results of inferential tests [Abstract]. *Applied Psychophysiology and Biofeedback, 26*(3), 230-231.

The value of reporting magnitude statistics, effect size, and proportion of variance accounted for, when presenting inferential test results, was examined. Data from two experiments were used to demonstrate how to calculate effect size (*effect size r* and Cohen's *f* statistic) and proportion of variance accounted for (estimated *omega-squared*) for *t*- and *F*-tests. We showed how these estimates of magnitude can help qualify inferential test results and enable the reader to make better informed judgments regarding the practical significance of the experimental findings.

Shaffer, F., Malone, E., Sippely, T., & Jos, A. (2001). A revised Truman breathing protocol [Abstract]. *Applied Psychophysiology and Biofeedback, 26*(3), 231.

A revised Truman Breathing Assessment Protocol, which monitors abdominal tension, ETCO2, SpO2, respiration rate, inhalation volume, respiratory sinus arrhythmia (RSA), and accessory sEMG, was described. Patients were evaluated during resting baseline, two stressor (serial-7s and visualization), two activities (talking and typing), and an inspirometer challenge (patients inhaled increasing volumes to detect excessive accessory muscle use). A male undergraduate breathing profile was presented to illustrate how this procedure may be used to assess patients and personalize diaphragmatic breathing training. The authors encouraged clinicians to develop their own protocols to screen for dysfunctional breathing behaviors and develop measurable training goals.

Shaffer, F., Malone, E., & Krebill, R. (2000). How to select the best transformation for psychophysiological data [Abstract]. *Applied Psychophysiology and Biofeedback, 25*(4), 256.

The present study compared the effectiveness of both natural logarithmic and Box–Cox transformations in normalizing EMG values as assessed by the Kolmogorov–Smirnov statistic. Neither the raw scores, *K–S* (48) = .201; *p* = .0001; nor the natural logarithm of these scores, *K–S* (48) = .153; *p* = .007; were normally distributed. Only a Box–Cox transformation produced a normal distribution, *K–S* (48) = .119; *p* = .086*;* and the least skew. The authors recommend that researchers should select the optimal transformation for a specific data set instead of automatically using a natural logarithmic transformation.

Citation Paper

Shaffer, F., Malone, E., Sippely, T., & Callahan, C. (2000). The comparative effects of book bags and carrying styles on upper trapezius and cervical paraspinal surface EMG [Abstract]. *Applied Psychophysiology and Biofeedback, 25*(4), 248.

The present study compared the effects of 3 book bag conditions (backpack, shoulder bag-same side, and shoulder bag-opposite side) on upper trapezius and cervical paraspinal sEMG. The same side condition produced higher preferred-shoulder sEMG levels and greater left–right sEMG asymmetry than that produced by the initial baseline, opposite side, or backpack conditions. We recommend that students avoid wearing a 1-strap bag on the same side to carry books because this could risk myofascial pain due to prolonged muscle contraction. Instead, we advise using a 2-strap backpack or 1-strap bag on the opposite side to minimize muscular strain.

Shaffer, F., Mayhew, J. L., Malone, E., & Hall, J. (2000). A revised survey of undergraduate breathing knowledge [Abstract]. *Applied Psychophysiology and Biofeedback, 25*(4), 256.

This study examined the breathing knowledge of 227 undergraduates because misconceptions about respiratory mechanics can interfere with diaphragmatic training. These students earned a “failing” score of 4.94 out of 12 on the multiple-choice Breathing Knowledge Exam. They had the greatest difficulty with questions that concerned relaxed breathing (goal, respiratory mechanics, and effort used). Participants were grouped into No-Disorder, No-Information, No Disorder-Information, Disorder-No Information, and Disorder-Information categories. An analysis of variance revealed no significant differences in breathing knowledge among these 4 groups. We recommend that health care providers review the factual information they impart to patients diagnosed with asthma and panic disorders.

Shaffer, F., Mayhew, J. L., Malone, E., & Miller, K. (2000). Dysfunctional breathing patterns in undergraduates [Abstract]. *Applied Psychophysiology and Biofeedback, 25*(4), 258.

This study screened 326 undergraduates (107 men and 219 women) to measure the frequency of functional and dysfunctional breathing behaviors, using a 37-item Truman Respiration Questionnaire. Most students breathed through their nose (61%). Chest expansion (68%), stomach expansion (56%), and shoulder elevation (52%) were reported during inhalation. Reverse abdominal breathing (28%) and reverse thoracic breathing (10%) were also observed during inhalation. Nine percent of reverse breathers combined both reverse movements. Finally, 25% of students suspended breathing as they stood up quickly. If these findings are replicated at other universities, they would suggest a high prevalence of dysfunctional breathing behaviors.

Shaffer, F., Dougherty, J., & Bradley, J. (1999). A survey of undergraduate breathing knowledge [Abstract]. *Applied Psychophysiology and Biofeedback, 24*(2), 135.

Because misconceptions about respiratory mechanics can interfere with diaphragmatic training progress, this study examined the breathing knowledge of 80 undergraduates. These students earned a "failing" score of 4.2 out of 10 on the multiple-choice Breathing Knowledge Exam. They had the greatest difficulty with questions that concerned relaxed breathing (goal, respiratory mechanics, and effort used) and hyperventilation (respiratory mechanics). When participants were divided into general, prior breathing training, and respiratory disorder groups based on their survey responses, data found that the prior training group had greater breathing knowledge than the respiratory disorder group.

Shaffer, F., Mayhew, J. L., Bergman, S., Dougherty, J., & Irwin, D. (1999). Designer jeans increase breathing effort [Abstract]. *Applied Psychophysiology and Biofeedback, 24*(2), 124-125.

This study examined the effect of jean tightness on normal, continuous respiration. Fourteen undergraduates were randomly assigned to either: loose jean, rest, tight jean; or tight jean, rest, loose jean conditions. Jean tightness did not affect tidal volume. However, minute volume increased 11% and oxygen uptake per kg of body weight increased 6% when participants changed from loose to tight jeans. Participants overcompensated for abdominal constriction by increasing minute volume and oxygen uptake. These results support Peper and Holt's guideline that clinicians should encourage patients receiving diaphragmatic training to wear nonrestrictive clothing.

Shaffer, F., Mayhew, J. L., Bergman, S., Dougherty, J., & Koester, A. (1999). Effortful breathing may lower end-tidal CO2 through increased tidal volume [Abstract]. *Applied Psychophysiology and Biofeedback, 24*(2), 124.

This study examined the mechanisms by which high breathing effort reduces end-tidal CO2. Fifteen undergraduates were briefly taught diaphragmatic breathing and randomly assigned to either: low effort, rest, high effort; or high effort, rest, low effort. Respiration rate decreased 28% from low to high breathing effort, tidal volume increased 61%, and the respiratory exchange ratio increased 8%. Tidal volume accounted for 43% of the variance in the respiratory exchange ratio. These results support the explanation that effortful breathing eliminated CO2 through larger tidal volumes and further confirmed the importance of effortlessness and ETCO2 monitoring during diaphragmatic training.

Shaffer, F., Bergman, S., & Dougherty, J. (1998). End-tidal CO2 is the best indicator of breathing effort [Abstract]. *Applied Psychophysiology and Biofeedback, 23*(2), 127.

This study evaluated six indicators of breathing effort during low and high breathing effort conditions. Fifty undergraduates were taught diaphragmatic breathing and randomly assigned to either: low effort, rest, high effort; or high effort, rest, low effort. Each condition lasted 3 min. A one-tailed *t*-test showed that ETCO2 decreased 14%, accessory sEMG increased 39%, frontalis sEMG increased 120%, SCL increased 13%, and heart rate increased 4% from low to high breathing effort conditions. Blood volume pulse did not change. ETCO2 was the best overall effort indicator, followed by accessory sEMG. Clinicians should use both indicators to warn of excessive breathing effort.

Shaffer, F., Bergman, S., & Gannon, L. (1998). Breathing effort depresses end-tidal CO2 [Abstract]. *Applied Psychophysiology and Biofeedback, 23*(2), 128.

This study examined the effects of low and high breathing effort on respiration to test Paper and Holt's thesis that diaphragmatic breathing should be effortless. Fifty undergraduates were taught diaphragmatic breathing and randomly assigned to either: low effort, rest, high effort; or high effort, rest, low effort. Each condition lasted 3 min. A one-tailed *t*-test showed that ETCO2 decreased 14% ($t(49) = 9.10$, $p < .0001$) and ETCO2 variability increased 74% ($t(49) = -5.38$, $p < .0001$) from low to high breathing effort conditions. These results replicated our previous findings and confirmed the importance of effortlessness and ETCO2 monitoring during diaphragmatic training.

Shaffer, F., Bergman, S., & Henson, M. (1998). Description of the Truman breathing assessment protocol [Abstract]. *Applied Psychophysiology and Biofeedback, 23*(2), 127.

This study standardized a 25-min breathing assessment protocol on 45 undergraduates. The profile measured abdominal excursion, abdominal strain gauge tension, accessory sEMG, ETCO2, inhalation volume, peak flow, respiration rate, and SpO2. Participants were screened for reverse breathing. Peak flow and inhalation volume were then measured. Participants were examined during 3-min serial-7s and visualization stressors, each followed by a 3-min recovery period. Finally, a 3-min inspirometer challenge evaluated accessory muscle use. A representative data record was examined to show how this protocol could help identify dysfunctional breathing behaviors and develop quantifiable training goals.

Citation Paper

Shaffer, F., Bergman, S., & Yochim, B. (1998). Subjective indicators warn against breathing effort [Abstract]. *Applied Psychophysiology and Biofeedback, 23*(2), 108.

This study evaluated three subjective indicators of breathing effort. Forty undergraduates were taught diaphragmatic breathing and randomly assigned to either: low effort, rest, high effort; or high effort, rest, low effort. Each condition lasted 3 min. Regression analysis showed that ratings of accessory muscle use and breathing loudness predicted 25% of the variance in ETCO2 in the high breathing effort condition (F (2, 37) = 7.65, p = .0017). Ratings of abdominal excursion force were unrelated to ETCO2. Patients should use self-monitoring of accessory muscle use and breathing loudness to warn against excessive breathing effort.

Shaffer, F., Bergman, S., & Hopkins, B. (1997). Breathing effort disrupts diaphragmatic breathing [Abstract]. *Applied Psychophysiology and Biofeedback, 22*(2), 144.

This study tested Peper and Holt's thesis that diaphragmatic breathing should be effortless. We compared the effects of low and high effort diaphragmatic breathing on respiration. Thirty undergraduates were taught diaphragmatic breathing and randomly assigned to either: low effort, rest, high effort; or high effort, rest, low effort. Each condition lasted 3 min. A one-tailed t-test showed that high effort decreased ETCO2 11% [$t(29) = 5.65$, $p < .0001$] and increased ETCO2 variability 72% [$r(29) = -3.72$, $p < .0004$] instead of raising and stabilizing ETCO2. These findings confirmed the importance of effortlessness and monitoring ETCO2 during diaphragmatic training.

Shaffer, F., Bergman, S., & White, K. (1997). Indicators of diaphragmatic breathing effort [Abstract]. *Applied Psychophysiology and Biofeedback, 22*(2), 145.

This study evaluated five indicators of breathing effort during low and high breathing effort instructions. Twenty eight undergraduates were taught diaphragmatic breathing and randomly assigned to either: low effort, rest, high effort; or high effort, rest, low effort. Each condition lasted three minutes. A one-tailed t-test showed that accessory muscle sEMG increased 53% from low to high effort, frontales sEMG increased 25%, skin conductance level increased 17%, and heart rate increased 3%. Blood volume pulse did not change. The data suggest that while accessory sEMG was the most sensitive indicator, monitoring all four significant measures may better detect breathing effort.

Shaffer, F., Mayhew, J. L., Bergman, S., & Gannon, L. (1997). The effect of diaphragmatic training on respiratory homeostasis [Abstract]. *Applied Psychophysiology and Biofeedback, 22*(2), 144.

This study examined whether diaphragmatic training decreases respiratory homeostasis. Twenty undergraduates were assessed on minute volume, respiration rate, tidal volume, and %ECO2 using a metabolic cart during resting and treadmill conditions. Next, they were assigned to a diaphragmatic training (two weekly 60-min group sessions) or control condition, and re-assessed 2 weeks after training. Planned comparisons revealed that neither diaphragmatic [$F(l, 9) = 0.89$, $p = .37$] nor control group [$F(l, 9) = 0.40$, $p = .557$] treadmill minute volume decreased across this study. Diaphragmatic training did not reduce respiratory homeostasis since ventilation continued to increase with workload.

Shaffer, F., Mayhew, J. L., Bergman, S., & Wheelehon, J. R. (1997). Does inhalation-to-exhalation ratio affect diaphragmatic training outcome? [Abstract]. *Applied Psychophysiology and Biofeedback, 22*(2), 145.

This study examined whether inhalation-to-exhalation ratio affects diaphragmatic training outcome. Thirty undergraduates were assessed on minute volume, respiration rate, and tidal volume while resting using a metabolic cart. They were assigned to 1:1 ratio training, 1:2 ratio training, or a control condition, and re-assessed 2-weeks after training. A Student-Newman-Keuls test revealed that the 1:1 ratio group increased %ECO, and tidal volume, and decreased respiration rate more than the control group. The 1:2 ratio group only improved on %ECO2. The two diaphragmatic groups achieved equivalent changes on all measures. We found weak support for favoring 1:1 ratio training.

Shaffer, F., Greve, E., & Parmenter, R. (1996). Validation of a two-session diaphragmatic breathing protocol [Abstract]. *Biofeedback and Self-Regulation, 21*(4), 383.

A previous investigation of our two-session group diaphragmatic breathing protocol validated its effectiveness with healthy undergraduates. The present study attempted to replicate and extend these results. Twelve healthy undergraduates were trained to breathe diaphragmatically during two weekly 60-minute group sessions, and were assigned daily exercises and charting. Inhalation volume increased 79% from 1108 to 1980 millimeters ($p = .005$). Tidal volume increased 51% from 660 to 1000 millimeters. The % ECO2 increased 16% from 3.3% to 3.8% ($p = .005$). Respiration rate decreased 31% from 17.31 to 11.98 breaths per minute ($p = .005$). This study replicated our previous findings and increased our confidence in this diaphragmatic breathing protocol.

Citation Paper

Shaffer, F., Greve, E., & Reinagal, K. (1996). Predictors of inhalation volume [Abstract]. *Biofeedback and Self-Regulation, 21*(4), 352.

Clinicians use an incentive inspirometer to assess diaphragmatic breathing proficiency. This study evaluated the relationship between abdominal excursion, respiration rate, and rib movement, with inhalation volume. Twelve healthy undergraduates were trained to breath diaphragmatically during two weekly 60-minute group sessions, and were assigned daily exercises and charting. Participants were instructed to breathe diaphragmatically throughout post-assessment. Abdominal excursion was the only measure associated with inhalation volume ($r(11) = .794$, $p < .003$). This study supports emphasis on abdominal excursion instead of respiration rate during diaphragmatic breathing instruction and discourages measurement of rib movement using a cloth tape to evaluate training success.

Citation Paper

Shaffer, F., Greve, E., & Teskey, J. (1996). The autonomic effects of diaphragmatic and thoracic breathing [Abstract]. *Biofeedback and Self-Regulation, 21*(4), 350-351.

Clinicians often incorporate diaphragmatic breathing instruction in stress management programs, believing that a shift from thoracic to diaphragmatic breathing impacts autonomic arousal. This study examined whether diaphragmatic and thoracic breathing patterns produce different autonomic effects. Twenty-four healthy undergraduates were randomly assigned to one of two orders: diaphragmatic breathing, rest, thoracic breathing; or thoracic breathing, rest, diaphragmatic breathing. Measurements were taken for three minutes in each condition. Blood volume pulse (BVP) was 17% higher during diaphragmatic (6.01) than thoracic breathing (5.05) ($t(23) = 2.267$, $p < .0165$). Conversely, skin conductance level (SCL) was 16% higher during diaphragmatic (18.50 μmhos) than thoracic breathing (15.95 μmhos) ($t(14) = 4.19$, $p < .0009$). These findings showed that diaphragmatic breathing produced weak and mixed autonomic effects on phasic measures (BVP and SCL) during a three-minute measurement period.

Citation Paper

Shaffer, F., Knight, D., & Greve, E. (1996). Autocorrelation discriminates between diaphragmatic and thoracic breathing [Abstract]. *Biofeedback and Self-Regulation, 21*(4), 351.

This study examined whether the autocorrelation of abdominal strain gauge tension values could assess breathing rhythm and discriminate between diaphragmatic and thoracic breathing patterns. Nine healthy undergraduates were trained to breathe diaphragmatically and thoracically during two weekly 60-minute group sessions. Participants were randomly assigned to one of two orders: diaphragmatic breathing, rest, thoracic breathing; or thoracic breathing, rest, diaphragmatic breathing. Strain gauge tension was recorded for three minutes (180 one-second measurements) during each condition. An autocorrelation (with lag 1) of the 180 tension values was calculated for each condition. Each autocorrelation was significant at the .0001 level. Autocorrelation was 73% stronger during diaphragmatic (.759) than thoracic breathing (.438) ($t(7) = -3.047$, $p < .009$). This study supported clinical use of the autocorrelation of abdominal strain gauge measurements to evaluate abdominal movement.

Shaffer, F., Simmons, J., Rever, C., Knight, D., & Rever, A. (1995). An evaluation of nasal and mouth effortless breathing protocols [Abstract]. *Biofeedback and Self-Regulation, 20*(3), 300.

This study replicated a previously validated two-session effortless breathing training protocol and compared the effectiveness of instructions to breathe through the nose or mouth. Following pre-assessment, 24 healthy undergraduates were matched on respiratory measures and randomly assigned to a two-session nasal breathing group, mouth breathing group, or a control group, which received no training. Participants in the nasal and mouth breathing groups were trained to breathe effortlessly in two weekly 60-minute group sessions and were assigned daily exercises and charting. Control participants received no training and only experienced pre- and post-assessment one week after completion of training. *A priori* orthogonal tests revealed that only the nasal and mouth training groups increased inhalation volume and abdominal excursion, and decreased respiration rate (from pre-assessment to post-assessment). Nasal and mouth protocols were equally effective. A repeated measures ANOVA showed that these gains were statistically significant. This study validated our two-session effortless breathing protocol and found no selective advantage for nasal or mouth breathing instructions when training healthy undergraduates. We suggest that nasal or mouth breathing should be chosen by patient preference when not dictated by medical concerns.

Shaffer, F., Simmons, J., Rever, C., Knight, D., & Rever, A. (1995). Assessment of a two-Session effortless breathing protocol [Abstract]. *Biofeedback and Self-Regulation, 20*(3), 301.

This report summarizes the effect of our two-session group effortless breathing protocol on 30 healthy undergraduates and identifies predictors of training success. Following pre-assessment, 30 healthy undergraduates were trained to breathe effortlessly in two weekly 60-minute group sessions and were assigned daily exercises and charted. We repeated the pre-assessment procedure during post-assessment one to two weeks after completion of training. A repeated measures ANOVA revealed that participants increased inhalation volume and abdominal excursion, and decreased respiration rate. Regression analysis disclosed that pre-assessment inhalation volume and respiration rate predicted respiratory changes. Finally, a Fisher's r to Z transformation showed that post-assessment inhalation volume was associated with slower respiration and increased abdominal excursion. This study supported clinical use of our effortless breathing protocol with patients who resemble our healthy undergraduates. Training should focus on slowing respiration while increasing abdominal excursion, and may be evaluated using an incentive inspirometer to measure inhalation volume.

Shaffer, F., Knight, D., Lubbe, C., Wehmeyer, T., Stratmann, J., *et al.* (1994). Diaphragmatic training reduces the disruptive effects of common activities on respiration [Abstract]. *Biofeedback and Self-Regulation, 19*(3), 271-272.

The present study explored the effects of routine activities on respiration in 30 healthy undergraduates before and after diaphragmatic training using a within-subjects design. We measured baseline abdominal excursion and respiration rate for 3 min and then randomly assigned subjects to a series of four 3-min activities (reading, writing, talking, and listening) during which we monitored abdominal excursion and respiration rate. After pre-assessment, we range-matched subjects and randomly assigned them to four 55-min weekly group diaphragmatic training sessions or a no-treatment control group. We repeated the initial screening procedure for both groups during post-assessment. At post-assessment, the diaphragmatic training group achieved greater abdominal excursion during the listening challenge, and lower respiration rate during both challenges, than during pre-assessment. The no-treatment control group did not improve on any measure. This study showed that these two common activities produced thoracic changes in healthy subjects not trained to breathe diaphragmatically and that diaphragmatic training reduced breathing disruption. We recommend that respiration training incorporate writing and listening challenges to promote generalization.

Shaffer, F., Knight, D., Lubbe, C., Wehmeyer, T., Stratmann, J., *et al.* (1994). The effects of preferred music and volume on undergraduate psychophysiological responses [Abstract]. *Biofeedback and Self-Regulation, 19*(3), 272-273.

Students report using music to stimulate or calm themselves. We explored the effects of preferred music selection (stimulating, calming, and ocean sounds) and volume on physiological responses using a within-subjects design with 30 undergraduates. This question is relevant to behavioral medicine since music exposure may influence cultivation of low arousal, and clinicians employ music in behavioral interventions. We measured baseline values for 3 min. Then, we randomly assigned subjects to one of three music orders for 3 to 5 min each, and recorded data for the first 3 min of each selection. Subjects provided their own selections and adjusted volume to preferred listening levels. We analyzed data for all measures using *a priori* orthogonal tests. Three findings should be emphasized. First, stimulating music produced changes in respiration rate, accessory muscle and frontal EMG, and blood volume pulse and temperature that were inconsistent with cultivated low arousal. Second, calming music did not lower our subjects' physiological arousal. Finally, the ocean selection also failed to lower arousal. We recommend that clinicians consider stimulating music a potential stressor and monitor the effects of "calming" music selections on individual patients before incorporating them in relaxation therapy.

Shaffer, F., Knight, D., Lubbe, C., Wehmeyer, T., Stratmann, J., *et al.* (1994). Validation of two diaphragmatic breathing protocols with healthy undergraduates [Abstract]. *Biofeedback and Self-Regulation, 19*(3), 271.

We developed a group diaphragmatic training protocol in two stages. In Study I, we compared a four-session diaphragmatic protocol against a no-treatment control group using a repeated measures design with 31 healthy undergraduates. After pre-assessment of abdominal excursion and respiration rate, we randomly assigned subjects to four, 55-min weekly group diaphragmatic training sessions or a no-treatment control group, and then repeated assessment. *A priori* orthogonal tests revealed that the diaphragmatic training group improved inhalation volume, abdominal excursion, and respiration rate, while the control group showed no gains. In Study II, after pre-assessment that added thoracic movement, we randomly assigned 30 subjects to four-session, two-session, or breathing audiotape groups, and then repeated assessment during midterms. *A priori* tests showed that the four- and two-session groups (which used trained models) comparably increased inhalation volume and abdominal excursion, while they decreased respiration rate from pre-assessment. The audiotape group only increased abdominal excursion. No group significantly reduced thoracic movement. These studies validated both two- and four-session protocols for teaching diaphragmatic breathing in groups using trained models and demonstrated maintenance of breathing skills 2-3 weeks after training ended during the stress of midterms.

Shaffer, F., Knight, D., Lubbe, C., Wehmeyer, T., Stratmann, J., *et al.* (1994). Comparison of diaphragmatic training methods [Abstract]. *Biofeedback and Self- Regulation, 19*(3), 270.

We compared three diaphragmatic training techniques, which required subjects to place their hands on their chest and stomach while sitting upright (hands); lay a book on their stomach while supine (book); and place one hand on the model's side to match his diaphragmatic breathing pattern (modeling). Study I compared these approaches with 42 healthy undergraduates using a within-subjects design. We measured inhalation volume and respiration rate during pre-assessment, individually coached subjects in all three methods, and then reassessed. *A priori* orthogonal tests showed that all three methods increased inhalation volume above prebaseline and that modeling produced the highest volumes. These methods also decreased respiration rate below baseline while modeling reduced respiration rate the most. In Study II, we examined 34 healthy undergraduates using a between-groups design to control for progressive error. We added abdominal excursion and thoracic measurements. Modeling improved all four parameters and was superior on all measures except thoracic movement. While the hands and book methods did not significantly affect inhalation volume or respiration rate, the book method increased abdominal excursion, and both hands and book methods reduced thoracic movement. These studies validated the modeling procedure and showed why clinicians must be effective models.

Shaffer, F., Knight, D., Sponsel, M., Belcher, J., Stratmann, J., *et al.* (1993). Vigilance reduces inhalation volume: Nintendo play may reinforce dysfunctional breathing [Abstract]. *Biofeedback and Self-Regulation, 18*(3), 198.

Behavioral factors like posture, accessory muscle contraction, restrictive clothing, and attentional focus can disrupt breathing and produce a faster, shallower thoracic pattern. Video games, which require constant vigilance, may also promote thoracic breathing. The present study assessed the effects of Nintendo play on breathing in 47 healthy undergraduates. We monitored male and female abdominal excursion, respiration rate, and accessory muscle contraction for 4-minute periods in prone and upright positions, at rest and while playing Tetris, a rapid-paced video game in which a player manipulates falling blocks. We predicted that playing Tetris would reduce male and female abdominal excursion, and increase respiration rate and accessory muscle contraction in both positions. A priori mean contrasts confirmed our predictions. These experimental findings have three important clinical implications. First, they show that playing video games can promote accessory muscle tension and thoracic breathing in both males and females. Second, they reveal that thoracic breathing occurs during both prone and seated play. Third, they suggest that playing video games may reinforce dysfunctional breathing in subjects who *already* breathe thoracically and encourage hyperventilation.

Shaffer, F., Krebill, R., & Kice, J. (1993). Double-blind evaluation of a subliminal relaxation audiotape [Abstract]. *Biofeedback and Self-Regulation, 18*(3), 195-196.

Subliminal perception involves the detection and analysis of weak stimuli without awareness. These stimuli are presented at intensities or durations below a dynamically changing signal detection threshold which fluctuates owing to internal noise. The present study assessed the physiological effects of auditory subliminal content on 15 healthy undergraduates using a double-blind design. Subjects received 10 55-min sessions in which they were exposed to either neutral or relaxation subliminal messages while monitored for frontal EMG, hand temperature, skin conductance level, and heart rate. The neutral subliminal slightly lowered frontal EMG across sessions and increased left and right web dorsum temperature both within and across sessions. Within-session changes were small and seen during only 2 of the 10 sessions. No subliminal effects were observed for skin conductance or heart rate. In contrast, the relaxation subliminal audiotape did not reduce arousal on any of the physiological measures within or across sessions. These results, viewed in the context of previous studies, discourage the use of subliminal audiotapes to reduce physiological arousal. Relaxation subliminal audiotapes may be inherently unable to reduce arousal if they operate by increasing vigilance for personally relevant messages like autogenic phrases.

Shaffer, F., Sponsel, M., Knight, D., Belcher, J., Stratmann, J., *et al.* (1993). Attention to the abdomen promotes diaphragmatic breathing [Abstract]. *Biofeedback and Self-Regulation, 18*(3), 197.

Clinicians who teach patients to breathe diaphragmatically routinely ask them to focus on the abdomen, increase diaphragmatic muscle activity while reducing thoracic activity, increase inhalation volume, and slow respiration rate. Instruction to focus on the abdomen reflects the assumption that focusing lower on the body best facilitates diaphragmatic breathing. The present study examined where untrained subjects normally focus attention and the effect on breathing of directing the focus of attention to different body regions. Forty-four healthy undergraduates were monitored for abdominal excursion, respiration rate, and inhalation volume during four randomly presented 3-minute trials in which they passively focused on a body region (mouth, chest, stomach, and feet) with eyes closed. Subjected focused outside these four regions 31% of the time and in descending order, on the chest (28%), abdomen (25%), mouth/nose (13%), and feet (2%). A priori mean contrasts revealed that abdominal focus strengthened more diaphragmatic breathing components than chest focus since it produced the greatest abdominal excursion and decreased respiration rate below baseline. While attention to the feet promoted thoracic breathing in our inexperienced subjects, this focus may distract respiratory patients from areas of concern, like the chest and head, and may help extinguish dysfunctional breathing responses.

Shaffer, F., Sponsel, M., Knight, D., Belcher, J., Stratmann, J., *et al.* (1993). A Double-blind test of brain-wave synchronizer effectiveness in inducing relaxation or alertness [Abstract]. *Biofeedback and Self-Regulation, 18*(3), 196.

Electronic devices that provide audiovisual stimulation emerged in the 1970s and reached the mass consumer market by the early 1990s. This double-blind study assessed the effectiveness of Inner Quest Model IQ-9110 alpha-theta and beta enhancement programs on EEG, autonomic, and respiratory measures in healthy undergraduates. Twenty-four undergraduate psychology students were randomly assigned to one of two coded orders during which they wore eye stimulation glasses and stereo headphones, and experienced both programs. We monitored theta, alpha, and beta amplitude, abdominal excursion and respiration rate, blood volume pulse and heart rate, skin conductance level, and skin temperature during 5-min baselines before and after each audiovisual program, and throughout the 30-min programs. A priori mean contrasts did not support the simplistic assumption that the alpha-theta program produces relaxation and the beta program increases arousal during one session. The two programs did not affect EEG amplitude at the site and frequencies examined. These programs produced similar changes in abdominal excursion, respiration rate, and blood volume pulse consistent with increased vigilance. Decreased skin conductance level and subjective arousal, in contrast, suggested adaptation to sensory stimulation. No changes were observed in heart rate or skin temperature.

Krebill, R., Sponsel, M., Shaffer, F., Duckro, P. N., Schultz, K. T., Belcher, Lewis, M., Hollensbe, J., & Soleman, T. (1992). The impact of EMG transformation on inferential test sensitivity [Abstract]. *Biofeedback and Self-Regulation, 17*(4), 336-337.

Electromyographic (EMG) data are often a skewed (measure of distribution) measurement of muscular activity. Severe skewness violates the assumptions of parametric inferential tests. This violation may decrease the inferential tests' sensitivity to real differences within an experiment group. To modify the data distribution, natural logarithmic ($\log_e$) transformation of the data may provide a more normally distributed data set for statistical comparison. To test this hypothesis, integrated EMG data were collected from 66 undergraduates in two conditions: neutral standing with and without feedback monitoring of left and right trapezius. Data analysis was done with a paired two-tailed *t*-test for correlated measures on raw data means and logarithmic transformed means to assess the impact of feedback. Findings revealed that a feedback effect was only apparent in logarithmically transformed data. The significant difference between the two data sets (raw mean and log transformed mean) was the decrease in skewness of the logarithmically transformed data. The decrease in skewness uncovered a feedback effect that was previously obscured by variability of the raw data. These findings underscore the importance of logarithmic transformation of physiological measurements which are not normally distributed. Data transformation increases inferential test sensitivity and therefore reduces the risk of Type II statistical error.

Shaffer, F., Sponsel, M., Belcher, J., Hollensbe, J., Hart, D., et al. (1992). The chewing gum effect: Imagery disrupts diaphragmatic breathing [Abstract]. *Biofeedback and Self-Regulation, 17*(4), 343.

Researchers have shown that cognitive processes like ideas and imagery affect respiration. It has been demonstrated that negative imagery decreased inhalation volume from baseline values. The present study examined the effects of positive and negative imagery on the breathing patterns of subjects not trained in diaphragmatic breathing. Seventy-two undergraduates were screened by questionnaire for epilepsy and obstructive respiratory disorders. These subjects were randomly assigned to one of two imagery sequences (positive-negative or negative-positive) and assessed during a single 50-minute session. Based on previous research findings, we predicted that negative imagery would produce lower inhalation volume and abdominal excursion, and higher respiration rate than positive imagery. *A priori* mean contrasts supported our predictions. Negative imagery produced significantly lower inhalation volume, less abdominal excursion, and more rapid respiration than positive imagery or the baseline condition. Positive imagery significantly reduced inhalation volume and abdominal excursion compared with the baseline condition. This study replicated earlier findings and revealed a *chewing gum effect* in which attention to imagery disrupts inexperienced subjects' breathing.

Shaffer, F., Sponsel, M., Hollensbe, J., Belcher, J., Knight, D., Sauder, M., & Lewis, M. (1992). Tight shoulders and designer jeans prevent diaphragmatic breathing [Abstract]. *Biofeedback and Self-Regulation, 17*(4), 309-310.

Behavioral factors like posture and clothing tightness can interfere with diaphragmatic breathing. It has been described that the startle response contracts the abdomen and produces shallow, rapid breathing. Researchers have identified a *designer jeans syndrome,* where tight clothing decreases inhalation volume. The present study assessed the relative effects of posture and clothing tightness on breathing in students not trained in diaphragmatic breathing. Thirty-five undergraduates were randomly assigned to one of four orders of shoulder tension and clothing tightness conditions. Accessory muscle EMG and inhalation volume were measured during each one-minute condition. Inhalation volume was calculated immediately afterwards.
We predicted that both shoulder tension and tight clothing would reduce inhalation volume. *A priori* mean contrasts supported our predictions, replicating a previous study on designer jeans syndrome with inexperienced subjects. While both shoulder tension and tight clothing reduced inhalation volume separately and synergistically, shoulder tension had a stronger effect.

Shaffer, F., Sponsel, M., Johnson, D., Schenck, C., Wehmeyer, T., *et al.* (1992). The sit-up effect: Acute sitting angles produce thoracic breathing [Abstract]. *Biofeedback and Self-Regulation, 17*(4), 344.

Previous researchers trained asthmatics to voluntarily wheeze by thrusting the head forward and drawing the shoulders in. This raised the question of how sitting posture affects respiration in healthy subjects. Forty-eight undergraduates were screened by questionnaire for epilepsy and obstructive respiratory disorders. They were randomly assigned to one of four posture orders (sit-good, sit-bad, stand-good, and stand-bad). Respiration rate and head and torso angles were measured during each five-minute posture condition. Inhalation volume was calculated immediately after each condition. We predicted that sitting slouched forward would produce greater accessory muscle EMG activity and smaller inhalation volumes than sitting upright. *A priori* mean contrasts supported our predictions. Bad sitting posture decreased torso angle, increased accessory EMG activity, reduced inhalation volume, and accelerated respiration. We have called acute torso angle production of thoracic breathing the *sit-up effect*, since it involves the abdominal compression observed during a sit-up.

Shaffer, F., Sponsel, M., Hollensbe, J., Belcher, J., Lewis, M., & Solomon, T. (1991). Maintenance of diaphragmatic breathing during experimental pain [Abstract]. *Biofeedback and Self-Regulation, 16*(3), 287-288.

Slow, diaphragmatic breathing involves regular excursion of the abdomen with minimal chest movement. Breathing instruction is often included in stress management programs since it counteracts sympathetic arousal produced by hyperventilation (Schwartz, 1987). In the present study, we examined whether a standard diaphragmatic breathing protocol could significantly increase abdominal excursion and reduce respiration rate. Further, we tested whether these changes could be maintained during the stress of experimental pain. Twenty-four undergraduates were matched on respiration rate and randomly assigned to abdominal-thoracic or thoracic-abdominal treatment conditions. Subjects were trained to breathe in abdominal and thoracic patterns during two, 60-minute sessions. During the second session, experimental pain was introduced as a stressor during both abdominal and thoracic breathing exercises. A one-tailed *t*-test revealed that diaphragmatic breathing instruction increased abdominal excursion and reduced respiration rate during breathing practice and experimental pain.

Shaffer, F., Sponsel, M., Kice, J., & Hollensbe, J. (1991). The Effect of auditory feedback on diaphragmatic breathing [Abstract]. *Biofeedback and Self-Regulation, 16*(3), 317.

Several authorities (Fried, 1990; Janis, Defares, & Grossman, 1988) have implicated disordered breathing patterns like hyperventilation in diverse psychophysiological disorders. Slow diaphragmatic breathing, which involves regular excursion of the abdomen with minimal chest movement, corrects abdominal breathing patterns. In the present study, we examined whether feedback of abdominal excursion during breathing instruction would increase excursion more than breathing instruction alone. Eighteen undergraduates, screened by questionnaire for obstructive respiratory or vasoconstrictive disorders, were matched on degree of abdominal excursion and respiration rate, and then randomly assigned to breathing instruction with auditory feedback for abdominal excursion or breathing instruction alone. Subjects were trained to increase the degree of abdominal excursion in two 1-hour sessions. A two-way analysis of variance with repeated measures revealed that diaphragmatic breathing instruction combined with auditory feedback produced significantly greater increases in abdominal excursion than unassisted breathing instruction. Further, only a single 1-hour training session was required in either condition to significantly increase abdominal excursion.

Shaffer, F., Sponsel, M., Kice, J., & Hollensbe, J. (1991). Test-retest reliability of resting baseline measurements [Abstract]. *Biofeedback and Self-Regulation, 16*(3), 317 318.

Behavior therapists monitor biological responses in research and the diagnosis and treatment of medical disorders. Psychophysiological measurements are often recorded during a *resting baseline* at the start of each training session to monitor patient progress within and across sessions. The practice of comparing baseline values across sessions assumes that resting baselines possess acceptable test-retest reliability. This study investigated the temporary stability of six psychophysiological responses (abdominal amplitude, respiration rate, blood volume pulse, hand surface temperature, heart rate, and skin conductance level) recorded over two sessions (days 1 and 8) using 21 undergraduate subjects. Measurement sessions consisted of a 15-min adaptation period, followed by a 5-minute resting baseline condition. Test-retest reliability coefficients were calculated on absolute score values. Five or six reliability coefficients (abdominal amplitude, respiration rate, hand surface temperature, heart rate, and skin conductance level) were statistically significant. These results show that resting baseline measurements can achieve satisfactory test-retest reliability over a standard interval of 1 week between measurement sessions.