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Self-regulatory biofeedback training: an intervention to reduce school burnout and improve cardiac functioning in college students

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ABSTRACT

With the detrimental relationship between school burnout and physiological and cognitive functioning now well documented, interventions to ameliorate school burnout symptomology are needed. This study examined the effectiveness of a self-regulatory biofeedback intervention program (Heart Rate Variability Coherence Biofeedback Training [HRVCB]) in contrast to a protocol demonstrated to produce cognitive and physiological improvements (a high intensity interval training protocol [HIIT]) as well as a wait-list control condition at decreasing school burnout in an American collegiate sample ($N = 90$). Intervention training was conducted over a 4-week span (three sessions per week) with accompanying baseline and post-intervention assessments. In addition to measurements of school burnout and negative affect (depression and anxiety), intervention influences on cognition (via a serial subtraction task) and physiology (hemodynamics, electrocardiography, and a submaximal cardiorespiratory fitness test) were explored. Findings indicate HRVCB training significantly decreased school burnout and increased mathematical performance from pre- to post-intervention measurement. These changes did not occur for HIIT or waitlist participants. Brachial and aortic systolic blood pressure decreased pre to post-intervention for HRVCB but not HIIT or waitlist participants. Cardiovascular fitness (VO_{2max}) improved pre to post-intervention for HIIT but not HRVCB or waitlist participants. Also, both HRVCB and HIIT training participants decreased heart rate from pre to post-intervention but not waitlist participants. Finally, all participants decreased cardiac sympathovagal tone from pre to post-intervention. These findings provide evidence that HRVCB training programs can decrease school burnout as well as improve components associated with cardiac health. Study limitations and directions for future research are discussed.

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Introduction

Although occupational burnout research has increased, reviews of the literature reveal few robust empirical evaluations of interventions designed specifically to alleviate burnout (Leiter & Maslach, 2014). In regard to *school burnout*, there appear to be no published intervention studies. Accordingly, this study reports a self-regulatory biofeedback training intervention aimed at decreasing school burnout symptomology in an American collegiate sample.

School burnout has been conceptualized as school-related strain and stress due to exhaustion from school work, cynicism toward the meaning of school, and a sense of inadequacy with school work (Salmela-Aro, Kiuru, Leskinen, & Nurmi, 2009). After accounting for stress, depression, and anxiety, research suggests school burnout to be a stronger indicator of not only poorer academic performance and absenteeism, but also general diminished cognitive and physiological functioning (May, Bauer, & Fincham, 2015; May, Sanchez-Gonzalez, Brown, Koutnik, & Fincham, 2014; May, Sanchez-Gonzalez, & Fincham, 2015). In the absence of data pertaining to school burnout interventions, work burnout interventions are informative. Most promising may be general, comprehensive interventions aimed at impacting both psychological and physiological mechanisms and outcomes; prior interventions to eliminate occupational burnout effects via only cognitive mechanisms have shown limited improvements (Diestel, Cosmar, & Schmidt, 2013; Maslach & Leiter, 2015).

In light of the above findings, we examined the effectiveness of a comprehensive intervention among college students in order to determine whether school burnout in this population is modifiable. The selected intervention, Heart Rate Variability Coherence Biofeedback (HRVCB) training, combines personalized emotional regulation training with biofeedback heartrate variability technology to induce synchronization in nervous system activity. Research has linked HRVCB training to increased emotional stability, improved heart rate variability and improved cognitive task performance in primary school students (Bradley et al., 2010; Light & Bincy, 2016). HRVCB training has yet to be evaluated in the context of ameliorating school burnout in collegiate students.

Additionally, in this study HRVCB training was evaluated in contrast to a high intensity interval training protocol (HIIT), as well as a wait-list control condition. The HIIT protocol has previously been demonstrated to produce improvements in cognition (e.g. increased selective attention, short-term memory, and executive functioning, Alves et al., 2014; Berryman

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et al., 2014; Costigan, Eather, Plotnikoff, Hillman, & Lubans, 2016), affect (lowering of depression and anxiety, Wu, Lee, Hsu, Chang, & Chen, 2015) and physiology (decreasing blood pressure, insulin sensitivity, and body fat; Boutcher, 2011; Gibala, Little, MacDonald, & Hawley, 2012). HIIT, therefore, serves as a strong comparison condition to evaluate any outcome changes attributed to HRVCB training.

Given HRVCB's attention to psychological and physiological mechanisms responsible for advantageous stress management, we hypothesized that HRVCB training would lead to a greater reduction in school burnout symptoms than participants engaged in HIIT or who were wait-listed. Intervention training was conducted over four weeks (three sessions per week) with accompanying baseline and post-intervention assessments. In addition to the measurement of school burnout and accompanying negative affect (depression and anxiety), intervention influences on changes in cognition (via a mathematics test), and physiology (heart rate, brachial and aortic blood pressures, cardiac sympathovagal tone, and submaximal cardiorespiratory fitness) were explored.

Method

Participants

A total of 90 participants ($M_{age} = 18.55$ years, $SD = 0.99$, 82% Female, 32% freshman, 23% sophomore, 24% junior, 21% senior) qualified for the study which was approved by the university's institutional review board. To avoid potential cardiovascular functioning confounds (as previously specified in May et al., 2014; May et al. 2015), participants were excluded from study participation through an online health screening assessment if they exercised regularly (>120 min/week) in the previous 6 months, used nicotine products, were hypertensive (BP >140/90 mmHg), were taking beta blockers, antidepressants, or stimulants, or had chronic diseases. Participants were asked to abstain from alcohol, caffeine, and strenuous physical activity for at least 24 h prior to testing. They were also instructed not to eat any food 4 h prior to baseline and post-test assessments. Female participants were tested in the early follicular phase of the menstrual cycle to avoid potential variations in pressure wave morphology and cardiac reactivity (Adkisson et al., 2010). The overall ethnic composition of the samples were 71% Caucasian, 13% African American, 8% Asian, and 7% endorsed either biracial or nondisclosed ethnicity. Students who completed at least one full academic semester were eligible for study participation. All participants were recruited from a major southeastern university in the United States, were informed of the nature of the study, and gave their written consent prior to study participation as approved by the university's institutional review board.

Measures and instruments

School burnout

School burnout was measured using the nine-item School Burnout Inventory (SBI; Salmela-Aro et al., 2009). The SBI consists of three first-order latent factors, school related exhaustion, cynicism toward the meaning of school, and a sense of inadequacy at school and an overarching second-order factor representing overall school burnout. Summed scores from the first-order factors comprise a second-order overall school burnout score. The overall school burnout composite score was used for analysis in this study. Items were rated on a 6-point Likert-scale ranging from 1 (completely disagree) to 6 (strongly agree). Example items include "I feel overwhelmed by my schoolwork," "I'm continually wondering whether my schoolwork has any meaning," and "I often have feelings of inadequacy in my schoolwork" for exhaustion, cynicism, and inadequacy, respectively. Higher composite scores indicate higher school burnout with a possible range of 45 (9–54). Reliability for the sample was $\alpha = .93$.

Negative affect

Negative affect was assessed through measurement of depression and anxiety symptoms. Depressive symptoms were measured using the 10-item Center for Epidemiologic Studies Depression Scale (CES-D; Santor & Coyne, 1997). The CES-D has been widely used to measure depressive symptoms in nonclinical samples. The CES-D has participant respond to a list of ways they may have felt or behaved during the previous week (0 = rarely or none of the time, 3 = most or all of the time). Items include "I felt depressed," "I felt fearful," and "I was happy." Responses were summed into an overall score with a possible range of 0–30. Higher scores are indicative of greater depressive symptoms. Reliability for the sample was $\alpha = .87$. Anxiety was measured using the 20-item State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970). Responses to items such as "I feel calm," "I am worried," and "I am tense" were scored on a 4-point Likert scale (1 = not at all, 4 = very much so). Items were summed to create a composite anxiety score with a possible range of 20–80 with higher scores indicating greater anxiety. Reliability for the sample was $\alpha = .92$.

Hemodynamics

Pulse wave analysis (PWA), which enables accurate evaluation of central aortic functioning via transfer functions from the brachial waveform (Hashimoto, Imai, & O'Rourke, 2007; Safar, Blacher, Protogerou, & Achimastos, 2008), was conducted with the SphygmoCor XCEL PWA system (SphygmoCor, AtCor Medical, Sydney, Australia). The SphygmoCor XCEL PWA system uses brachial pressure cuff inflation to provide a central aortic waveform using a validated generalized transfer function via a 20-s wave epoch. The specific pressure indices provided by SphygmoCor XCEL PWA include brachial systolic blood pressure (BSBP), brachial diastolic blood pressure (BDBP), aortic systolic blood pressure (ASBP), and aortic diastolic blood pressures (ADBP). Collection of PWA indices takes approximately 60 s to complete.

Electrocardiography

Through electrocardiography, the calculation of the time duration of intervals between heartbeats (RRI) was automatically detected using commercially available software (WinCPRS, Turku, Finland). The RRIs were inspected for artifacts, premature beats and ectopic episodes in order to calculate HRV parameters. The main spectral components of the HRV that we calculated, by means of Fast Fourier transformation, were the low-frequency (LF; 0.04–0.15 Hz) and the high-frequency (HF; 0.15–0.4 Hz) bands. LF and HF can be expressed in normalized units (nu). Calculation of nu is conducted by dividing the power of a given component by the total power from which the very low-frequency band has been subtracted (Sgoifo, Carnevali, Alfonso, & Amore, 2015). Due to structural algebraic redundancy inherent in the normalized spectral HRV measures with respect to each other (LFnu = 1 − HFnu), we only report LFnu and denote LFnu as an index of cardiac sympathovagal tone (Burr, 2007; Pagani et al., 1986; Task Force of the European Society of Cardiology & The North American Society of Pacing and Electrophysiology, 1996). Cardiac sympathovagal tone represents the contribution of the sympathetic influence on the balance of the autonomic state resulting from sympathetic and parasympathetic influences (May, Bamber, et al., 2016). Both heart rate (HR) and cardiac sympathovagal tone were collected via electrocardiography.

Heart rate variability coherence biofeedback (HRVCB) training

HRVCB training (Institute of HeartMath, 2014) combines stress reduction strategies and biofeedback technologies. Stress reduction strategies included interactive training pertaining to attention focusing, resonant frequency breathing, and positive emotion induction strategies for achieving and maintaining cardiac coherence. Biofeedback technologies assessed the degree of coherence in the HRV waveforms (e.g. PC desktop and mobile ambulatory software paired with pulse sensors for physiological measurement). Coherence occurs when electroencephalographic (ECG) rhythms synchronize with heart rhythms (McCraty, Atkinson, Tomasino, & Bradley, 2009). It is characterized by a heart rhythm pattern of elevated amplitude in low-frequency HRV. This coherence signal pattern is identified by a smooth, sinusoidal curve form in the heart rhythms (specifically the elevated low-frequency HRV band around 0.1 Hz, McCraty et al., 2009). Research demonstrates that this pattern indicates a balance between sympathetic and parasympathetic divisions of the autonomic nervous system (ANS) that is predictive of improved health (e.g. myocardial efficiency and output, vagal afferent traffic to inhibit sympathetic signal dominance, resetting of baroreceptor sensitivity to improve blood pressure regulation and respiratory efficiency, cognitive functioning, and emotional stability; Edwards, 2015; Berry et al., 2014; Mackinnon, Gevirtz, McCraty, & Brown, 2013; McCraty, 2016; McCraty & Atkinson, 2003; McCraty, Atkinson, & Tomasino, 2003; McCraty & Childre, 2002; McCraty et al., 2009; McCraty & Tomasino, 2004).

With practice, coherence can be self-induced to allow individuals to shift to a more coherent psychological state before, during and after challenging or adverse situations (McCraty et al., 2009). Participants practice shifting and sustaining heart rhythm coherence with an emWave device that signaled his/her coherence levels, which they were tasked to use on a regular basis in order to help them improve their self-regulation skills and physiological and psychological balance. The emWave2 biofeedback apparatus consists of an (1) earlobe pulse sensor, (2) USB connector cable, and (3) a 2 × 3 inch computer with LED screen for handheld physiological coherence biofeedback. The handheld device displays readings of HRV, time elapsed, as well as low, medium, and high levels of coherence. Feedback consists of red-, blue-, and green-colored bars with percentage indications and accompanying audio feedback for low, medium, and high coherence levels. Further feedback is provided by a cumulative coherence graph with a demarcated area for coherence indicating the zone of optimal ANS functioning. A feedback tone is provided when 100 coherence points accrue. Accompanying the emWave2 is online software that allows for coherence practice. In conjunction with the emWave2 device, the online software allows for real-time HRV chart displays, secure storage of all session information for future comparison and review, and four challenge levels including a challenging advanced user mode.

Training regarding the stress reduction strategies included interactive sessions of approximately 20 min pertaining to attention focusing, resonant frequency breathing, and positive emotion induction strategies for achieving and maintaining cardiac coherence by a certified HRVCB mentor. Resilience manuals which contained all the information were given to participants during each training session and they were then encouraged to practice their coherence techniques frequently in their own time.

High intensity interval training

The HIIT, adapted from Gillen, Percival, Ludzki, Tarnopolsky, and Gibala (2013) was comprised of brief bursts of intense exercise separated by short periods of recovery. The HIIT protocol involved three supervised cycling sessions per week over 4 weeks (e.g. Monday, Wednesday, and Friday each week). Each session comprised 10 × 60-s cycling bouts interspersed with 60-s recovery. Training was performed on an ergometer set in constant watt mode (fixed resistance) at a pedal cadence of 80–100 rpm. Individual workloads were selected to elicit a heart rate of approximately 90% of their age predicted maximum (220 − Age = maximum heart rate) or peak power output during the intervals. During the 60-s recovery, participants rested or pedaled slowly at a resistance of 50 W. Training sessions included a 3-min warm-up and a 2-min cool-down at 50 W, for a total time commitment of 25 min. Previous research has shown this method of exercise is a time-efficient stimulus to induce physiological adaptations normally associated with continuous moderate-intensity training (Babraj et al., 2009; Gibala & McGee, 2008; Rakobowchuk et al., 2008).

Control (waitlist non-training)

Non-training sessions consisted of visits to the laboratory to report the normal daily activities participants engaged in during the duration of the study. Non-training participants were encouraged to not change their normal daily routines during the duration of the study.

YMCA cycle ergometer test

The YMCA cycle ergometer test is a submaximal cardiorespiratory fitness test which uses the temporal linear relationship between cardiac output and oxygen consumption to calculate maximum oxygen consumption (VO_{2max}; Garatachea, Cavalcanti, García-López, González-Gallego, & de Paz, 2007). For this test, participants begin at a specific bike resistance (828E Monark Cycle Ergomedic Test Cycle; Vansbro, Sweden) determined by their resting heart rate (HR). HR was obtained by means of a validated wireless monitor (Polar 800CX; Polar Electro OY, Kempele, Finland) with a strap placed around the thoracic area at the level of the xyphoid process of the sternum (Nunan et al., 2009). The resistance is increased in stages in accordance with the participants rising HR. Prior to the increase of resistance, a steady state HR is ensured to maintain the relationship between cardiac output and oxygen consumption. When the participant's HR reached 85% of their age predicted max HR the test was terminated. VO_{2max} calculations were derived based on equations provided by the Canadian Society for Exercise Physiology (2010). Research indicates that VO_{2max} is one common indicator of cardiorespiratory fitness and a key measurement in predicting all-cause mortality (Blair et al., 1996).

Serial subtraction task

A 5-min serial subtraction arithmetic task was utilized via the DirectRT computer software program (see May et al., 2015). Instructions informed participants that the arithmetic task would involve subtracting 7 from a randomly selected number. Time related pressure was eliminated as a potential confound by not telling participants there was a task time limit of 5-min. Practice trials demonstrated how a number would appear (e.g. 1107) and how the correctly computed answer (1100) would be accepted through a keystroke response. This correct response would then be the base number for the next subtraction trial. The trial would repeat if an incorrect solution was provided. The program ended after 5 min. The total number of computation errors per attempts was calculated for use in analyses.

Academic performance

Academic performance was measured using students' self-report of grade point average (GPA). GPA is the total average of earned points accumulated by a student throughout their college career. Major universities in the United States use a scale ranging from 0.0 to 4.0 with higher GPA reflective of higher academic achievement.

Manipulation checks

Self-report questions assessed at post-intervention served as proxy manipulation checks. These questions pertained to absenteeism (0 = no classes missed during the semester, 4 = very many classes missed during the semester), perception of academic success ("how effective did you feel the intervention was at improving your overall academic success," 1 = highly ineffective, 6 = effective), perception of test anxiety ("How effective was the intervention at decreasing test anxiety," 1 = highly effective, 6 = highly ineffective), and mental concentration ("how did the intervention improve your ability to mentally concentrate on tasks at hand," 1 = highly ineffective, 6 = effective).

Procedure

Participants were recruited from undergraduate classrooms as an option for voluntary class credit and all data was collected in the middle (weeks 3–9) of the semester. Participants were sent an url link to an online survey containing an informed consent form, information on the nature of the study, and a questionnaire containing the following measures: Demographics (age, gender, ethnicity, GPA, class), physical health history questionnaire, and measurement scales (SBI, CES-D, and STAI). After completing the online survey participants were invited to attend a laboratory session which assessed hemodynamics (brachial and aortic blood pressure), electrocardiography (heart rate and cardiac sympathovagal tone), cognitive functioning via the serial subtraction task, and a physical fitness bike test to obtain VO_{2max} values (submaximal cardiorespiratory fitness).

At the laboratory, participants were first seated and given a 10-min rest before any measurements were performed. Following the resting period, measurements of hemodynamics via the SphygmoCor XCEL PWA system were taken. Then a 5-min electrocardiogram assessment was conducted. This was then followed by cognitive testing then the bike test. Participants were then randomly assigned to one of the following three interventions ($n = 30$/group): HRVCB training, HIIT training, or the non-training control condition. HRVCB and HIIT participants attended training sessions conducted by trained instructors three times per week over 4 weeks. The non-training control participants visited the laboratory to report the normal daily activities that they conducted during the duration of the study three times per week over 4 weeks. Groups were given the measurement scale, physiology, cognitive functioning, and physical fitness assessments before and after the 4-week intervention period. Additional questions serving as manipulation checks were given at the end of the post intervention assessment.

Statistical analyses

A univariate ANOVA was conducted to evaluate pre-intervention differences in student GPA between experimental conditions. Evaluating manipulation checks, univariate ANOVAs with Bonferroni pairwise alpha adjustments were conducted on indicators of academic success, test anxiety, and mental concentration. To evaluate measurement scale, cognitive functioning, physiology, and physical fitness difference before and after the 4-week intervention period by experimental condition, two (pre-intervention vs. post-intervention) × three (control, HRVCB, HIIT) factorial repeated measures ANOVAs with follow-up univariate contrasts were examined.

Results

Univariate ANOVA analyses of pre-intervention student GPA indicated no significant differences between study groups, $F(2, 87) = 0.02$, $p = .980$, partial $\eta^2 = 0.000$. Univariate ANOVA analyses of post-intervention manipulation checks indicated that in comparison to HIIT and control, HRVCB participants reported their intervention as being perceived as leading to greater overall academic success, $F(2, 87) = 4.74$, $p = .011$, partial $\eta^2 = 0.083$, decreasing test anxiety, $F(2, 87) = 35.74$, $p < .001$, partial $\eta^2 = 0.405$, and improving concentration, $F(2, 87) = 21.84$, $p < .001$, partial $\eta^2 = 0.294$. No differences between conditions emerged for class absenteeism, $F(2, 87) = 0.57$, $p = .567$, partial $\eta^2 = 0.010$.

Factorial repeated measures ANOVAs indicated no pre-post intervention by experimental condition interactions for depressive or anxiety scores, F's < 1, $p > .05$. However an interaction was found for school burnout scores, $F(2, 87) = 4.32$, $p = .016$, partial $\eta^2 = 0.076$, with only HRVCB training showing a decrease in burnout symptomology from pre to post intervention measurement, $F(1, 87) = 11.91$, $p < .001$, partial $\eta^2 = 0.102$. Similarly, an interaction was found for serial subtraction scores, $F(2, 87) = 4.50$, $p = .014$, partial $\eta^2 = 0.050$, with only HRVCB demonstrating less math errors from pre to post test, $F(1, 87) = 7.72$, $p = .014$, partial $\eta^2 = 0.090$ (see self-report response to training condition is Table 1).

Regarding physiology, significant interactions were found for brachial systolic blood pressure (BSBP), $F(2, 87) = 7.81$, $p < .001$, partial $\eta^2 = 0.192$, and aortic systolic blood pressure (ASBP), $F(2, 87) = 6.88$, $p = .001$, partial $\eta^2 = 0.179$. Follow-up contrasts indicate from pre to post-test that HRVCB, not HIIT or control, significantly decreased BSBP, $F(1, 87) = 40.02$, $p < .001$, partial $\eta^2 = 0.628$, and ASBP, $F(1, 87) = 35.42$, $p < .001$, partial $\eta^2 = 0.606$. No significant interactions were found for brachial or aortic diastolic blood pressures, F's < 1, $p > .05$. For heart rate (HR) values, a significant interaction was identified, $F(2, 87) = 6.60$, $p = .002$, partial $\eta^2 = 0.163$. Follow up contrasts showed both HRVCB training, $F(1, 87) = 28.48$, $p < .001$, partial $\eta^2 = 0.511$, and HIIT training, $F(1, 87) = 26.20$, $p < .001$, partial $\eta^2 = 0.500$, significantly decreased HR in comparison to control from pre to post-test. However, the reduction in HR values from pre to post-test did not significantly differ between HRVCB and HIIT conditions, F's < 1, $p > .05$. For cardiac sympathovagal tone values, while no pre-post intervention by experimental condition interaction was significant ($p > .05$), a main effect for pre to post-test change was significant, $F(1, 87) = 46.71$, $p < .001$, partial $\eta^2 = 0.702$ with contrasts showing each experimental condition to significantly decrease cardiac sympathovagal tone from pre to post-test, with F's > 40, $p < .001$, and partial $\eta^2{}_s > 0.700$. Finally for the results of the bike fitness test, an interaction was found for VO_{2max}, $F(2, 87) = 5.19$, $p = .007$, partial $\eta^2 = 0.131$, with follow-up contrasts showing that HIIT, but not HRVCB (or control), significantly improved VO_{2max} from pre to post test, $F(1, 87) = 19.39$, $p < .001$, partial $\eta^2 = 0.219$ (see physiological outcomes to training conditions in Table 2).

Discussion

School burnout is a critical, but often under-researched factor negatively impacting the mental and physical health of students. In light of this fact, the present study evaluated a comprehensive intervention program to improve the well-being of college students. The study investigated the efficacy of a 4-week self-regulatory biofeedback intervention program (Heart Rate Variability Coherence Biofeedback; HRVCB) in an attempt to reduce school burnout and explore changes in cognition and physiology among college students. Findings indicated that undergraduate students enrolled in a HRVCB program showed significant decreases in school burnout symptomology and brachial and aortic systolic blood pressure, as well as significant increases in cognitive performance (less mathematical errors) from pre- to post-intervention assessments. These changes were not found in comparison to an established exercise program (HIIT) or a waitlist control condition.

To date, research has not previously evaluated the ability of this new generation of biofeedback equipment at decreasing school burnout. These data demonstrate the effectiveness of a computer based self-regulatory biofeedback intervention

Table 1. Self-report responses to training conditions.

	Pre-intervention			Post-intervention		
Variable name	HRVCB $N = 30$	HIIT $N = 30$	Control $N = 30$	HRVCB	HIIT	Control
GPA	3.46 ± 0.42	3.43 ± 0.37	3.44 ± 0.39			
Academic success				3.00 ± 0.21[ab]	2.31 ± 0.22	2.29 ± 0.20
Test anxiety				2.29 ± 0.24[ab]	4.13 ± 0.18	4.01 ± 0.21
Concentration				3.86 ± 0.14[ab]	2.43 ± 0.27	2.55 ± 0.19
Absenteeism				0.08 ± 0.28	0.27 ± 0.50	0.17 ± 0.27
Math error ratio	0.051 ± 0.003[c]	0.054 ± 0.003	0.052 ± 0.003	0.042 ± 0.003[c]	0.049 ± 0.003	0.054 ± 0.003
SBI	26.92 ± 1.24[a]	27.44 ± 1.44	27.65 ± 1.13	22.39 ± 1.75	26.75 ± 1.02	26.26 ± 1.37
CES-D	14.46 ± 1.01	16.94 ± 1.02	16.01 ± 1.07	13.00 ± 1.13	15.38 ± 0.91	16.45 ± 1.01
STAI	17.39 ± 1.48	17.38 ± 1.33	17.22 ± 1.34	16.54 ± 1.14	16.63 ± 1.03	16.02 ± 1.11

Data are mean ± standard error.
[a] $p < .05$ HRVCB pretest vs. HRVCB posttest.
[b] $p < .05$ HRVCB vs. HIIT posttest.
[c] $p < .05$ HRVCB vs. Control.
HRVCB: heart rate variability coherence biofeedback; HIIT: high intensity interval training; GPA: grade point average; SBI: school burnout; CES-D: depression; STAI: anxiety.

Table 2. Physiological outcomes by training conditions.

	Pre-intervention			Post-intervention		
Variable name	HRVCB $N = 30$	HIIT $N = 30$	Control $N = 30$	HRVCB	HIIT	Control
VO_{2max}	30.50 ± 1.69	33.13 ± 1.09[b]	32.58 ± 1.40	30.36 ± 1.67	36.43 ± 1.12	31.25 ± 1.25
BSBP (mmHg)	118.60 ± 1.90[a]	116.13 ± 2.01	118.54 ± 2.11	113.70 ± 2.06	115.50 ± 2.21	117.13 ± 2.22
BDBP (mmHg)	69.40 ± 1.19	72.06 ± .85	71.98 ± 1.02	71.10 ± 1.06	70.18 ± .73	72.81 ± 1.06
HR (bpm)	70.90 ± 1.46[d]	72.52 ± 1.53[b]	73.11 ± 1.48	67.40 ± 1.09	69.10 ± 1.23	72.68 ± 1.31
ASBP (mmHg)	103.67 ± 1.81[a]	102.22 ± 1.71	104.87 ± 1.67	99.66 ± 1.71	100.83 ± 1.93	103.33 ± 1.89
ADBP (mmHg)	70.50 ± 1.36	73.49 ± 1.97	69.54 ± 1.80	71.11 ± 1.76	72.49 ± 1.95	70.87 ± 1.90
LFnu	0.76 ± .02[a]	0.79 ± .02[b]	0.74 ± .03[c]	0.43 ± .06	0.54 ± .02	0.60 ± .02

Data are mean ± standard error.
[a] $p < .05$ HRVCB pretest vs. HRVCB posttest.
[b] $p < .05$ HIIT pretest vs. HIIT posttest.
[c] $p < .05$ Control pretest vs. Control posttest.
[d] $p < .05$ HRVCB vs. HIIT posttest.
HRVCB: heart rate variability coherence biofeedback; HIIT: high intensity interval training; VO_{2max}: maximum oxygen consumption; HR: heart rate; BSBP: brachial systolic blood pressure; BDBP: brachial diastolic blood pressure; ASBP: aortic systolic blood pressure; ADBP: aortic diastolic blood pressures; LFnu: normalized low-frequency band.

program in reducing school burnout symptomology. The HRVCB intervention program evaluated in this research was particularly effective at decreasing school burnout symptoms (M_{change} pre- to post-test = 74.53) but was less effective at decreasing related negative affective symptoms (<1.5 point M_{change} for depression and anxiety symptoms). This intervention's ability to reduce school burnout is important to highlight, as the mean intervention change found is approximately one standard deviation of the mean school burnout values (SD of school burnout scores from this sample was 6.78). Thus, even though a clinical scoring cutoff for school burnout scores has yet to be established, this intervention seems promising in helping to reduce school burnout, potentially in both clinical and non-clinical samples.

The HRVCB training program also has the advantage of improving a core component involved in academic success, mathematical computation. Interestingly, the self-report findings show that the HRVCB intervention appears to the participants as an effective means of improving their academic success, reducing test anxiety, and improving concentration in comparison to the other condition's (see manipulation check scores). In combination, these findings might suggest that the HRVCB intervention may be an effective means of reducing the negative effects of stereotype threat, math phobia, and generalized motivated performance on mathematical performance (May, Sanchez-Gonzalez, Seibert, Samaan, & Fincham, 2016). This is especially true as the HRVCB training is not designed to be overtly oriented toward improving mathematical ability, thus not inducing conscious awareness of performance threats. While research needs to be done to evaluate this claim, the present study suggests that HRVCB might address poor mathematical performance more effectively than changes in environment and training protocols where the goal of improving math skill is more salient.

Regarding physiology, whereas most indices were improved by both HRVCB and HIIT training (e.g. HR and LFnu), some indices were only improved by HRVCB training (e.g. brachial and aortic systolic blood pressures). However, even though not statistically significant, it should be noted that there was a trend of decreasing blood pressures from pre- to post-intervention for the HIIT training. Finally and unsurprisingly given the rigorous exercise program, aerobic fitness (VO_{2max}) was improved only for students undergoing HIIT training.

Although these findings are promising and informative in regard to the utility of applying HRVCB training to the reduction of school burnout, the exact mechanism leading to these positive changes remain to be elucidated. This is particularly important as HRVCB training relies on both training of cognitive skills (e.g. resiliency and coping) and adaptive physiological functioning (e.g. resetting of HRV homeostasis). On the psychological side, additional measurements of self-control capacity or changes in emotional regulation strategies would greatly supplement these findings and provide a potential link (mediator) between skills learned in the training protocol and outcome measures pertaining to affect, cognition, and physiology. Moreover, HRVCB training theoretically involves a reset of baseline ANS homeostasis. Our data demonstrate that while cardiac sympathovagal tone does decrease pre to post-intervention for HRVCB training participants, it also does for HIIT and waitlist participants. Thus, whether through longitudinal laboratory or ambulatory assessments of HRV, additional data on HRV changes could greatly inform interventionists to the training's potential in relation to both school burnout and cardiac function, as improved HRV is related to a number of additional health benefits including decreased all-cause mortality (Priori et al., 2001). The search for mediators/mechanisms linking training based skill development and HRV realignment to outcomes indexing student well-being, both psychologically and physiologically, are vital for future research investigating HRVCB training programs.

Notwithstanding the current research's strength, several limitations deserve attention. The sample consists of a high percentage (82%) of females and caution is therefore needed when inferring the implications of study findings across gender. This is especially true given potential gender differences in physiology and affective symptomology. However, it should be noted that the U.S. Department of Education (U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System [IPEDS], 2016) reports that undergraduate studies are populated with a greater concentration of female students (56%) than males students (44%), with the percentage gap projected to continue to increase. Additionally, given our somewhat strict exclusion criteria aimed at eliminating confounds (e.g. the existence of diseases or medicated subjects would complicate our findings), our sample most likely consists of healthier than average students. Future examination of HRVCB training utilizing differing clinical populations (e.g. populations suffering from attentional, cognitive, or learning deficits, affective symptoms, etc.) would provide insight into the robustness of the training program's efficacy. In addition to the noted absence of potential mediators in the study, only one index of academic success (GPA) and cognition (serial subtraction task) was measured. A host of additional indicators of academic success and cognition should also be examined in future research, some of which may include in-class assessments (quizzes, tests), measures of absenteeism, standardized tests (GRE), measures of general cognition (Stroop task) or working memory capacity to name just a few. Finally, it would be beneficial for future research to pursue longitudinal studies investigating the developmental patterns associated with school burnout, cognition, and physiology over time to help better understand direction of effects.

In conclusion, even though research on school burnout in American universities is beginning to document its detrimental relationship with physiological and cognitive functioning, school burnout still waits to be recognized as a serious health concern (e.g. it does not appear in the National College Health Assessment II; American College Health Association, 2016). If the mental health of collegiate population is to be comprehensively addressed, school burnout needs to recognized and routinely assessed. This is especially true in terms of adapting efficient intervention strategies to decrease existing symptomology. The current study begins the investigation of school burnout interventions in educational settings but continued research on how best to reduce school burnout is needed.

Lay summary

This research demonstrates, over a 4-week span, the effectiveness of a biofeedback program at decreasing school burnout and blood pressure as well as improving mathematical computation. Similar changes were not found in comparison to an established exercise program (high intensity interval training) or a waitlist control condition. This research provides a needed evaluation of the ability of a new generation of computer based self-regulatory biofeedback training program at improving affect, cognition, and physiological functioning.

Disclosure statement

No potential conflict of interest was reported by the authors.

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