The effect of a portable biofeedback tool on physician stress: a randomized controlled clinical trial

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ABSTRACT

Background: Physicians often experience work related stress that may lead to personal harm and impaired professional performance. Biofeedback has been used to manage stress in various populations.

Objective: To demonstrate whether a portable biofeedback tool reduces physician stress.

Design: Randomized controlled trial measuring efficacy of a stress reduction intervention over 28 days, with a 28 day open label trial extension assessing effectiveness.

Setting: Urban tertiary care hospital.

Participants: Forty staff physicians (23 males and 17 females) from various medical specialties (1 from primary care, 30 from a medical specialty, and 9 from a surgical specialty) were recruited using electronic mail, mail outs and posters placed in the physicians' lounge and throughout the hospital.

Intervention: Intervention group instructed to use a biofeedback tool three times daily. Both control and intervention groups received twice weekly support visits from the research team over 28 days.

Main Outcome Measure: Stress was measured using a scale developed to capture short term changes in global perceptions of stress for physicians.

Results: During the randomized controlled trial (days 0-28), the intervention group demonstrated a significant mean stress score change of -14.7 (SD 23.8; p=0.01), versus -2.2 (SD 8.4; p=0.03) for the control group. The mean score change difference between the groups was 12.5 (p=0.05). The intervention group's lower mean stress scores were maintained during the trial extension to day 56. During days 28-56, the control group received the intervention without research team support, and showed a significant mean stress score change of -8.5 (SD 7.6; p=0.0002).

Interpretation: A portable biofeedback device may be a simple and effective stress reduction tool for physicians to add to their coping strategies.

Trial registered with Clinical Trials.Gov ID # E-22185, http://clinicaltrials.gov

INTRODUCTION

Given the nature of their occupational duties and environment, physicians often experience work related stress [1] that may lead to personal harm such as burnout, depression and substance abuse, as well as impaired professional performance such as medication errors and reduced attentiveness or caring behavior toward their patients [2]. Stress management refers to a range of processes that are intended to mitigate aspects of the psychobiology of stress. Biofeedback, an intervention that involves measuring a subject's quantifiable bodily functions (e.g. blood pressure, heart rate, muscle tension) and conveying the information to the subject in real-time, is a useful way of providing guidance and reinforcement for successful management of the physiological response to stress. Various biofeedback techniques have been used in differing populations for the treatment of, and to help deal with the stress caused by disorders such as, hypertension, migraine headaches, tinnitus, irritable bowel syndrome and fibromyalgia [3-6]. Stress and emotion have also been linked to heart rate variability (HRV), a measure of naturally occurring beat to beat changes in the heart rate reflecting vagal antagonism of sympathetic influences [7,8]. Biofeedback tools that incorporate measures of HRV enable the study of the linkage between HRV and both the psychology and biology of stress [9-12]. Physician wellness has been increasingly linked to quality of patient care yet there is suboptimal attention paid to self wellness by physicians due to individual, professional and health care organizational factors [2]. It is therefore important to explore practical and credible means of helping physicians contend with work related stress, with the ultimate goal of improving their overall performance.

The aim of this study was to determine whether a portable biofeedback tool measuring HRV, referred to herein as a personal stress management device (PSMD), reduces physician stress, as defined by their perceptions of how unpredictable, uncontrollable and overloaded they

find their lives [13]. We evaluated the PSMD's efficacy over a 28 day randomized controlled trial and, during a trial extension (days 28-56), its effectiveness by measuring whether any intervention group benefits were maintained. On day 28 we also introduced the control group to the intervention (training and instruction in the use of the PSMD) to then evaluated its effectiveness over days 28-56 in the absence of intensive research team support.

METHODS

Design

Figure 1 describes the study flow. During days 0-28, we conducted an open-label randomized controlled clinical trial with concealed allocation assessing the efficacy of a PSMD for reducing physician stress. An open label trial extension (days 28-56) applied to both arms assessed the intervention's effectiveness by measuring: 1) any sustained stress reduction effects where the intervention group cohort was instructed to continue to use the PSMD until day 56, and 2) stress reduction effects of the PSMD in a "real life" setting without intensive research team support where the physicians enrolled in the control arm over days 0-28 participated in a PSMD training session on or about day 28 and were instructed to use the device until day 56. Outcomes were measured at days 0, 28 and 56.

Setting, participants, and randomization

Eligible participants were staff physicians practicing in an urban tertiary care center. Recruitment occurred during March 2009, by electronic mail, mail outs, and posters placed in the physicians' lounge and throughout the hospital. Study execution was from April to June 2009. Potential participants who screened positive for major depression using the PHQ-9 depression scale [14] were excluded and referred to the provincial physician wellness support program. A random allocation sequence to either control or intervention group with stratification by sex to

ensure parity within groups was generated using a computer program. Participants' allocation to control or intervention group was concealed until after the research assistant and/or the co-investigators confirmed eligibility criteria and received informed consent. Given the intervention design and the outcome measures, blinding did not occur. Data collection occurred primarily at the hospital with participants occasionally completing the stress questionnaire by accessing the study website from an offsite location. Ethics approval was obtained from the Conjoint Health Ethics Review Board of the University of Calgary. Participants' written consent was obtained.

Intervention

The personal stress management device used in our study, the emWavePSR (Personal Stress Reliever) (HeartMath, LLC, Boulder Creek, California), is a lightweight battery operated device about the size of a small deck of cards that can be carried in a pocket or purse. The PSMD calculates beat to beat changes in the heart rate (heart rate variability or HRV), to produce a measure of physiological coherence, a state that may be achieved through the quick coherence technique (QCT) comprised of rhythmic breathing coupled with actively self-generated positive emotions such as appreciation for something or someone, or remembering a special place in nature. The device reads heart rate through a digit or ear lobe sensor, and provides reinforcement of successful implementation of the QTC through visual cues (e.g. a light that transitions from red, to blue, to green with increasing coherence and a another that pulses with the captured heart beat) and auditory cues (e.g. beeps that signal achieved coherence). An accompanying software application (emWavePC) performs these tasks within a Microsoft Windows environment for use on a laptop or desktop computer, providing a more detailed real time quantitative and graphical display of heart rhythm pattern. Participants received an emWavePSR to use throughout the pertinent study period and to keep thereafter (intervention group days 0-56, control group days

28-56) and attended a thirty minute standardized training session provided by personnel employed by the health region that had undergone formal training to be qualified as instructors. The study participants were taught the QTC, the principles of the biofeedback tool through demonstrations of both the emWavePSR and emwavePC, how to use their personal emWave PSR, and given contact information should questions arise. The research assistants also used the emWavePC version during their twice weekly encounters with the intervention group during days 0-28 in order to reinforce the visual display of coherence.

Randomized controlled trial days 0-28

Subjects allocated to the intervention group 1) received a brochure describing the provincial physician wellness support program, 2) were given a PSMD and participated in an individual training session with optional follow up instruction offered 3) were given a prescription to use the PSMD during study days 0-28 for five minutes at least three times daily, and 4) were contacted twice weekly by a research assistant in order to measure stress and well-being, heart rate, blood pressure, document their adherence to using the PSMD, and record a three minute biofeedback session using the emWavePC software. This encounter enabled the research assistant to reinforce the use of the PSMD and to further visually display the participants' ability to achieve coherence levels over the course of the study.

Subjects allocated to the control group 1) received a brochure describing the provincial physician wellness support program, 2) were contacted twice weekly by a research assistant in order to measure stress and well-being, heart rate and blood pressure.

Trial extension days 28-56

Subjects allocated to the intervention group 1) were told to continue to use their PSMD at their discretion, 2) were offered the opportunity to request and receive additional training and

support, and 3) were contacted by a research assistant on or about day 56 to gather outcome measures data.

Subjects allocated to the control group 1) received a PSMD and participated in a personal training session on or about day 28, 2) were given a prescription to use the PSMD during study days 28-56 for five minutes at least three times daily, 3) were offered the opportunity to request and receive additional training and support but were not otherwise supported by the research team, and 4) were contacted by a research assistant on or about day 56 to gather outcome measures data.

Outcome measures

The primary outcome of stress was measured using a multiple item scale developed by the research team intended to measure global perceptions of stress and also to capture occupation-specific stress that is particularly relevant to physicians (Appendix A). The survey included fifteen items from the Perceived Stress Scale (PSS), a reliable and valid psychological instrument designed to measure perceptions of stress (defined as how unpredictable, uncontrollable and overloaded respondents find their lives) over a short period of one to two months [13,15]. The PSS questions are general in nature, not specific to any sub population group and considered valid across sex and age categories. The survey also included twenty-five selected items from the Personal and Organizational Quality Assessment-Revised (POQA-R) questionnaire [16], an eighty-five item self-report inventory designed to reflect key psychological and workplace elements that indicate the overall quality of one's experiences within an organization. Specific items were chosen based upon the results of a pilot study of ten hospital-based physicians asked to provide a written response describing in their own words how they feel when they are busy or stressed at work. The twenty-five items represent three themes:

anxiety/anger, physical symptoms of stress, and work-related time pressures. The final forty item instrument was validated through confirmatory common factor analysis [17] with varimax rotation showing that all forty items loaded onto a single factor with an eigenvalue of 18.8 (results available upon request). The response set for all items included Never (coded 0), Almost Never (coded 1), Sometimes (coded 2), Often (coded 3), Very Often (coded 4) and Always (coded 5). Summing across all forty items was carried out for a maximum possible stress score of two hundred, where a higher score indicates greater feelings of stress. The inter-item reliability for the summated scale is .97 based on Cronbach's alpha that was calculated for all participants at day 0.

The secondary outcome measures included adherence, heart rate, blood pressure, and salivary cortisols. Good adherence was defined as at least fifteen minutes per day of self reported PSMD use, (based on the prescribed use instructions) as calculated by the daily mean during days 0-28. Baseline demographic data were collected at enrollment. Heart rate and blood pressure were measured using Physiologic Auto Blood Pressure Monitor Model 106-925 (AMG Medical Inc, Montreal). Salivary cortisols were collected according to manufacturer's instructions upon awakening (fasting) and at mid-day, supper and before bedtime on or about days 0 and 28 and analyzed by enzyme immunoassay (Salimetrics LLC).

Statistical analysis

A sample size calculation determined that we needed 17 participants per study arm to detect a between-group difference in stress score of 15 (with 80% power and an estimated common SD of 15). In conducting the study we targeted final enrolment of approximately 20 participants per group to account for possible loss to follow up. Measurements of participant's baseline characteristics were expressed as a mean plus standard deviation for continuous

variables (age, years in practice, heart rate, systolic and diastolic blood pressure, salivary cortisol) and as a proportion for categorical variables (sex, marital status, type of medicine, smoking status and exercise pattern). Stress scores at days 0, 28 and 56 were expressed as a group mean plus standard deviation. Within-group or between-group comparisons were performed using a paired t-test. Mean stress score change was limited to participants with complete data as it was calculated by subtracting the day 0 score from the day 28 score for each participant, and then reporting the mean of these differences. The same analysis was used for calculating the mean stress score change over days 0-56 and days 28-56. Daily mean adherence to prescribed use of the PSMD was calculated by summing daily total minutes of use divided by 28 for each intervention group participant during days 0-28. All statistical analyses were performed using Stata 10 (StataCorp LP, College Station, Texas USA).

Funding Source

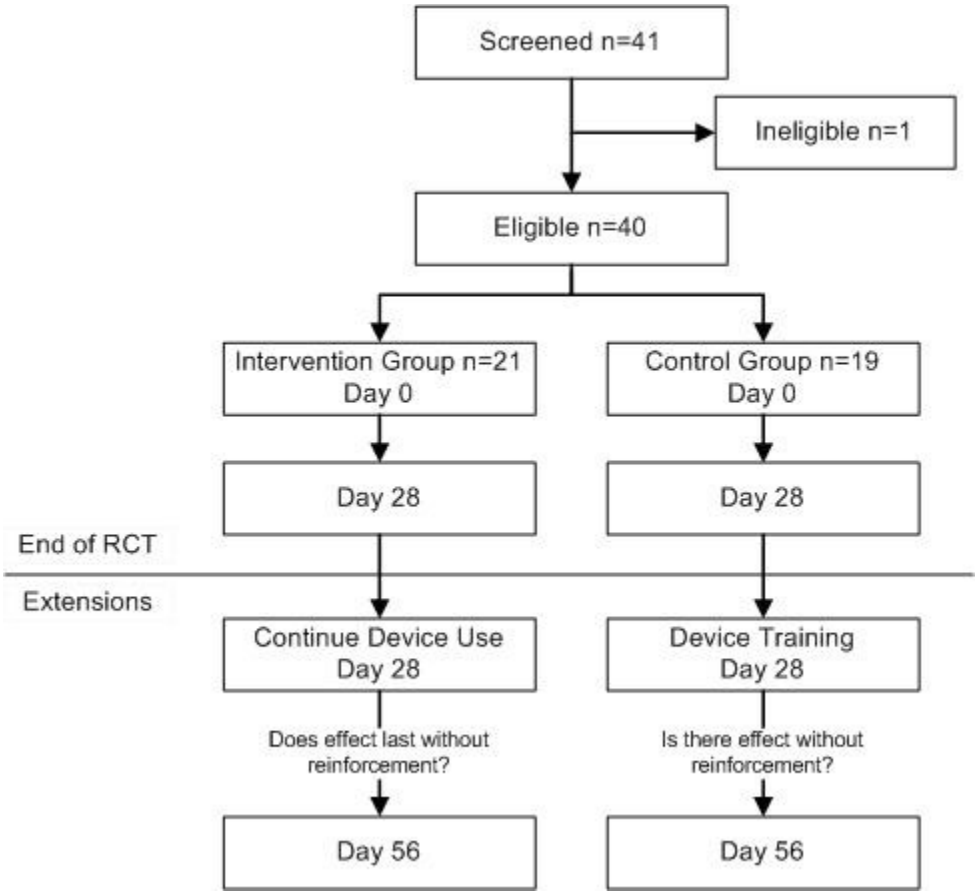
Support for this research was provided by a grant from the Alberta Health Services Wellness and Citizen Engagement portfolio, the Department of Medicine and the Faculty of Kinesiology University of Calgary. The researchers had total independence from the funders. The HeartMath trainers were employees of Alberta Health Services. Otherwise, the funding sources had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review or approval of the manuscript.

Ethics Approval

Ethics approval was obtained from the Conjoint Health Ethics Review Board of the University of Calgary. Participants' written consent was obtained. Informed consent was obtained from all participants.

RESULTS

Figure 1. Study flow chart



Participant characteristics

Forty-one potential participants were screened and 40 physicians from various medical specialties participated (19 in the control group and 21 in the intervention group), all of whom completed the study protocol (Figure 1). No intervention adverse effects were reported. Complete primary outcome data were available for all but one control group participant at day 0 and one person in each group at day 28. Table 1 outlines the participants' baseline characteristics. The eligible participants included 23 males (11 control and 12 intervention) and 17 females (8 control and 9 intervention). The mean age of the control group was 44.8 and the mean for the

intervention group was 47.8. 15% of the control group and 18% of the intervention group were married. The control and intervention group had been practicing medicine for a mean of 13.0 and 14.3 years respectively. Participants were from a variety of medical specialties (2.5% from primary care, 75% from a medical specialty and 22.5% from a surgical specialty). With the exception of mean baseline heart rate (67 beats per minute in the intervention group v.s. 74 beats per minute control group, p=0.03), there were no statistically significant differences across the two groups.

Table 1. Characteristics of study participants.

	Control n=19	**Intervention n=21**	**p-value**
Demographic			
Male (%)	11 (57.9)	12 (57.1)	0.96
Mean age in years (sd)	44.8 (8.2)	47.8 (8.5)	0.27
Married (%)	15 (79.0)	18 (85.7)	0.56
Mean years in practice (sd)	13.0 (8.1)	14.3 (9.8)	0.65
Type of medicine			0.46
Primary care (%)	1 (5.3)	0 (0)	
Medical specialty (%)	13 (68.4)	17 (81.0)	
Surgical specialty (%)	5 (26.3)	4 (19.1)	
Physiological			
Mean heart rate in beats per minute (sd)	74 (12)	67 (10)	0.03
Blood pressure in mmHg			
Mean systolic (sd)	123 (15)	123 (17)	0.98
Mean diastolic (sd)	77 (9)	77 (10)	0.78
Salivary cortisol first sample of day in ug/dL (sd)	0.42 (0.23)	0.43 (0.30)	0.874
Lifestyle			
Smoker (%)	0	1 (4.8)	0.34
Exercise pattern			0.28
<1x/week (%)	3 (15.8)	4 (19.1)	
1-2 times/week (%)	4 (21.1)	2 (9.5)	
2-4 days/week (%)	7 (36.8)	13 (61.9)	
>4 days/week (%)	5 (26.3)	2 (9.5)	

Table 2. Stress and physiological measurements, plus within group change and between group difference over days 0-28, by group.

STRESS MEASUREMENT			
	Control	**Intervention**	
	Mean (SD)	Mean (SD)	**p-value for between-group difference**
Stress score			
Baseline	74.1 (24.5) n=18	81.3 (29.5) n=21	
Day 28	69.8 (26.6) n=18	65.0 (26.6) n=20	
Within group change	-2.2 (8.4) n=17	-14.7 (23.8) n=20	0.05
p-value for within-group change	0.30	0.01	
PHYSIOLOGICAL MEASUREMENTS			
	Control	**Intervention**	
	Mean (SD)	Mean (SD)	**p-value for between-group difference**
Systolic BP (mmHg)	n=19	n=21	
Baseline	123 (15)	123 (17)	
Day 28	122 (12)	122 (14)	
Within group change	-1.5 (15.6)	-1.0 (15.9)	0.93
p-value for within-group change	0.68	0.76	
Diastolic BP (mmHg)	n=19	n=21	
Baseline	77 (9)	77(10)	
Day 28	77 (7)	79 (8)	
Within group change	+0.1 (10.4)	+1.9 (9.6)	0.58
p-value for within-group change	0.97	0.38	
Heart rate (beats/minute)	n=19	n=21	
Baseline	74 (12)	67 (10)	
Day 28	73 (13)	68 (11)	
Within group change	-1.1 (12.5)	+1.4 (8.9)	0.47
p-value for within-group change	0.70	0.48	
A.M. Salivary cortisol (ug/dL)	n=15	n=18	
Baseline	0.418 (0.23)	0.429 (0.31)	
Day 28	0.422 (0.23)	0.414 (0.19)	
Within group change	+0.004 (0.33)	-0.015 (0.27)	
p-value for within-group change	0.96	0.81	0.85

Stress

Randomized control trial days 0-28

Table 2 shows the mean stress scores, within group score changes and between group differences for the control and intervention groups over days 0-28. The baseline mean stress score of 81.3 (SD 29.5) for the intervention group dropped to 65.0 (SD 26.6) at day 28, a statistically significant change of -14.7 (SD 23.8; p=0.01). The baseline mean stress score of 74.1 (SD 24.5) for the control group dropped to 69.8 (SD 26.6) at day 28, a change of -2.2 (SD 8.4) that was not statistically significant (p=0.3). The mean score change difference between the groups was significant at 12.5 (p=0.05). A sensitivity analysis of the individual components of the stress score (PSS and POQA-R derived items) showed a statistically significant decrease in mean stress scores for the intervention group but not for the control group, mirroring the main study results (results available upon request). Figure 2 illustrates individual stress score changes over days 0-28 by group. 15/20 intervention group physicians (75%), compared with 10/17 (59%) of those in the control group had reduced stress scores at day 28 relative to day 0.

Trial extension days 28-56

For the intervention group, a reduction in the mean stress score was maintained through to day 56. The day 0 mean score of 81.3 (SD 29.5) dropped to 68.3 (SD 29.1) at day 56, a statistically significant change of -13.0 (SD 25.0; p=0.03). 14/21 physicians in the intervention group (67%) had a reduced stress score at day 56 relative to day 0 (Figure 3). For the control group whose participants were given a PSMD, underwent training, and used the device without intensive reinforcement and support during days 28-56, mean stress scores also dropped from 69.8 (SD 26.6) at day 28 to 61.3 (SD 25.1) at day 56, a statistically significant change of -8.5 (SD 7.6; p<0.001). 15/18 physicians in the control group (83%) had a reduced stress score at day 56 relative to day 28 (Figure 4).

The mean stress score change experienced by the intervention group in the randomized controlled trial (-14.7; 95% CI: -25.8 to -3.6) and that of the control group exposed to the intervention during the trial extension (-8.5; 95% CI: 12.3 to -4.7) were not significantly different (p=0.30). The mean stress score change experienced by the control group during the randomized controlled trial (-2.2; 95% CI: -6.5 to 2.1) and when exposed to the intervention during the trial extension (-8.5; 95% CI: 12.3 to -4.7) was significantly different (p=0.03).

Figure 2. Individual physician stress score changes over days 0-28 by group. The shaded region depicts those physicians that had a reduced stress score. The proportion of physicians with a reduced stress score is also shown.

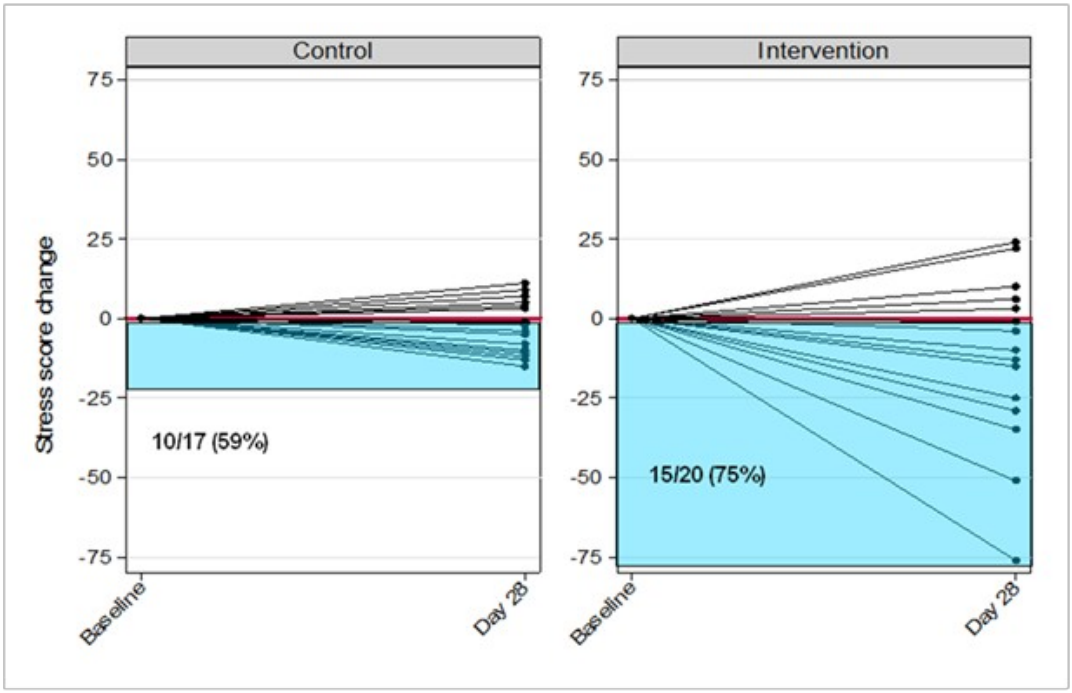


Figure 3. Individual physician stress score changes over days 0-56 for intervention group. The shaded region depicts those that had a reduced stress score. The proportion of physicians with a reduced stress score is also shown.

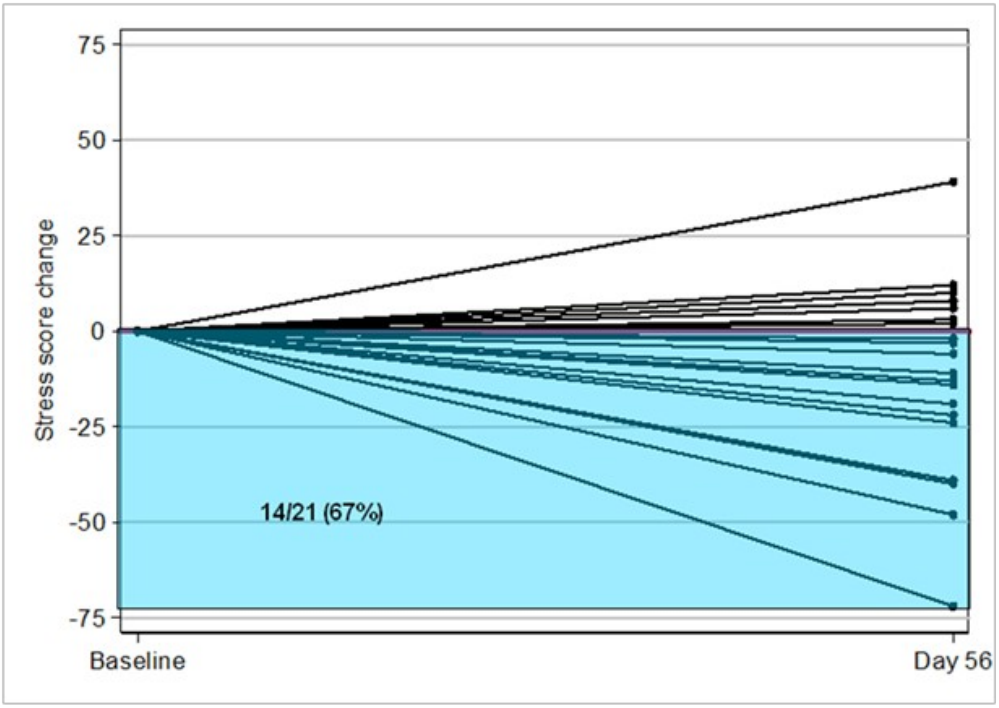
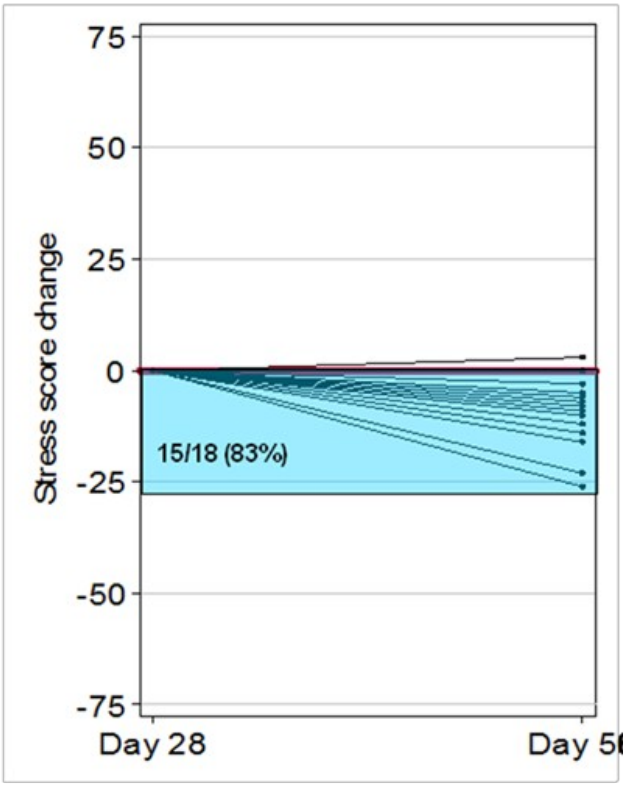


Figure 4. Individual physician stress score changes over days 28-56 for control group after introduction to intervention on day 28. The shaded region depicts those that had a reduced stress score. The proportion of physicians with a reduced stress score is also shown.



Adherence

Five intervention group participants met criteria for good adherence and fifteen had poor adherence (missing data n=1). Those with good adherence all showed a decrease in their stress score. Of those with poor adherence, 9/15 showed decreased stress scores and 6/15 showed increased stress scores.

The fifteen participants with decreased stress scores used the PSMD over a range of 2 to 40 minutes per day (mean 16, SD 11), with a total 28 day cumulative range of 47 to 1,120 minutes (mean 447, SD 325). The five participants with increased stress scores used the PSMD over a range of 5-12 minutes per day (mean 9, SD 3), with a total 28 day cumulative range of 151 to 347 minutes (mean 260, SD 76).

Physiological measurements

Over days 0-28, there were no statistically significant within group changes in blood pressure, heart rate, or salivary cortisol, nor any significant differences when comparing the control and intervention groups (Table 2). Across days 0-56, the intervention group showed no significant change in blood pressure or heart rate, nor did the control group when using the biofeedback device during days 29-56. Of note, there were only two people in the control group and three in the intervention group with a day 0 SBP >140 mm/Hg.

INTERPRETATION

An intervention of stress reduction training with biofeedback was associated with a significant decline in measured stress for physicians. The benefit of this to the intervention group was sustained over a prolonged period during an additional open label 28 days and the control group exposed to the intervention during this time without intensive reinforcement and support also showed a significant decrease in measured stress. Adherence data suggest that an average of fifteen minutes per day of PSMD use over a one month period is sufficient to provide benefit. The study did not show a change in any of the secondary outcome measures most likely related to the relatively short trial period. For heart rate and blood pressure, the starting values being in the normal range may have also contributed to this finding.

The practice of medicine is stressful for physicians with such demands as increasing workloads, emotionally charged situations, excessive cognitive requirements, and frequent organizational changes. The potential psychological and physical impacts of stress upon physicians have been well documented in a previous review [2]. A study by Cohen et al documents the basic physiology of stress facing medical students in which having to deliver bad news versus good news using a simulated patient encounter was associated with increased

cardiovascular responses, self-reported distress, and an increase in natural killer cell function for the bad news group [18]. Physicians may cope with stress using a variety of strategies including problem-focused coping which facilitates completion of work tasks (e.g. making a plan of action), emotional-focused coping that assists in managing the emotional reaction to stressors (e.g. using humor to lighten the situation), and seeking support from colleagues, family and friends, or maladaptive coping strategies (e.g. abusing alcohol and drug use) [19-22]. A literature search (Medline Search 1985 to present) found that health systems efforts to reduce occupational distress for physicians have included interventions such as alterations of the physical work schedule and environment, the establishment of support groups, programs that teach coping strategies, face-to-face counseling sessions, and mail-out self help interventions [23-27]. Although biofeedback of various types and those using HRV in particular have been used to enhance patient care, we found no evidence of research exploring biofeedback techniques as a stress management tool for physicians.

The intervention used in our study may have been associated with lower stress scores for several reasons. First, the concrete visualization of achieving “coherence” provided by the personal emWave use and the research assistant emWavePC sessions may have enhanced both physicians’ skill and the belief in their ability to manipulate psychobiological responses to stress, thus strengthening compliance and effort. Second, public admission or acknowledgement, prevention and/or treatment of stress are sometimes stigmatized within the medical profession and may be perceived as a sign of weakness and incompetence [2]. The technology and physiology based PSMD may help overcome these challenges by legitimizing the psychobiology of stress, and by providing a quantifiable and dynamic measure of stress. Third, the ease of portability and use of the PSMD were likely contributing factors. Fourth, as competency in

achieving coherence progressed, it is possible that physicians sometimes recruited the breathing technique and self-generating positive emotions effectively without enlisting biofeedback from the PSMD, thus further facilitating stress management even under conditions where using the PSMD may have been difficult (e.g. during surgical procedures).

Our study has some caveats and limitations. First, although the study results provide evidence in support of a portable biofeedback device as an effective stress reduction tool for physicians, an alternate explanation exists. It is possible that the higher random baseline mean stress score in the intervention group compared to the control group, although not statistically significant, did allow the possibility of a greater decline in stress scores, in particular is there is a "floor effect" where physician stress can only go so low. However, the suggestion of a true benefit from the intervention is further supported by the significant decrease in stress scores for the control group when they used the PSMD during the open-label trial extension. Second, our measure of stress, constructed using several sources, has not been validated and thus the clinical significance of the stress score changes is difficult to quantify. Weighing against this, the subscale factor and sensitivity analysis suggest that the questionnaire was a robust measure of stress and the study results consistently showed a decrease in stress scores for participants using the PSMD. In addition, the stress measure incorporated both a general stress scale as well as items chosen to tap into the medical profession's dimensions of stress based on physicians' descriptors of their stress experience. Third, the study was not designed to identify if the PSMD is more effective for coping with certain types of stress than for others. Fourth, the twice-weekly support from the research team may have contributed to stress reduction. However, the controlled study design should have attenuated this effect. It is also possible that these twice weekly visits increased stress due to the time commitments required from the physicians, thus

underestimating the stress reduction benefits shown. Fifth, given that the intervention group participants were not blinded, they may have been subject to the demand characteristics of the study and responded to the stress questionnaire so that their stress scores were lowered over time because they knew they were expected to. Lastly, given the study was of hospital-based physicians at a single center, the results may have limited generalizability. Future research could confirm that the impact of the PSMD upon stress reduction was maintained over an even longer time period and whether or not it is more effective for certain stressors than others.

Although it is likely that a variety of stress management tools are needed to meet the varying needs of physicians as individuals, this study suggests that a biofeedback device is both efficacious and effective for helping hospital based physicians manage their feelings of stress. From these findings, further discussion should ensue around models of implementation. One approach would be to leave it to physicians themselves to initiate personal stress reduction strategies such as using a PSMD. Alternatively, health care organizations could proactively offer stress reduction tools for health care providers or even assume greater accountability by introducing system wide interventions to promote and evaluate physician wellness. Given the growing body of evidence supporting the association between physician wellness and quality of patient care, a simple biofeedback device to manage stress may present a powerful tool.

ACKNOWLEDGEMENTS

Authorship contributions are as follows: JBL contributed to the study conception and design, analysis and interpretation of data, drafting of the manuscript, critical revision of the manuscript for important intellectual content, statistical analysis, and obtaining funding; JEW contributed to the study conception and design, critical revision of the manuscript for important intellectual content, and obtaining funding; AML contributed to the study conception and design,

analysis and interpretation of data, critical revision of the manuscript for important intellectual content, and statistical analysis; JdG contributed to the study conception and design, acquisition of data, revision of the manuscript for important intellectual content, administrative support; JPS contributed to the study conception and design, acquisition of data, critical revision of the manuscript for important intellectual content, and technical support. JBL had full access to all of the data in the study and as guarantor for the study takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors also had full access to the data and can take responsibility for the integrity of the data and the accuracy of the data analysis. Data sharing: no additional data available. The authors declare no potential conflicts of interest, including financial interests and relationships and affiliations relevant to the subject of this manuscript. All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that (1) none of the authors have support from HeartMath for the submitted work; (2) none of the authors have relationships with HeartMath that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) none of the authors have non-financial interests that may be relevant to the submitted work. We wish to thank Debbie Gray BHumEc, BSW, RSW, MSc for her assistance in coordinating the HeartMath instruction sessions, the AHS instructors in HeartMath for their valuable assistance, and W.A. Ghali MD MPH University of Calgary for his critical review of the manuscript. No compensation related to the study was received for these services. We are also indebted to the Ward of the 21st Century Medicine Unit and the Foothills Medical Staff Association, Foothills Medical Center for providing ongoing support of physician wellness research.

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Appendix 1 Stress Measure

Response Set: Never (coded 0), Almost Never (coded 1), Sometimes (coded 2), Often (coded 3), Very often (coded 4), Always (coded 5). An "R" indicates the item was reverse coded. Maximum score 200 where a higher score indicates greater feelings of stress.

Part A: Perceived Stress Scale

In the last month, how often have you…

1. Been upset because of something that happened unexpectedly?
2. Felt that you were unable to control the important things in your life?
3. Felt nervous?
4. Felt "stressed"?
5. Dealt successfully with irritating life hassles? (R)
6. Felt that you were effectively coping with important changes that were occurring in your life? (R)
7. Felt confident about your ability to handle your personal problems? (R)
8. Felt that things were going your way? (R)
9. Found that you could not cope with all the things that you had to do?
10. Been able to control irritations in your life? (R)
11. Felt that you were on top of things? (R)
12. Been angered because of things that happened that were outside of your control?
13. Found yourself thinking about things that you have to accomplish?
14. Been able to control the way you spend your time? (R)
15. Felt difficulties were piling up so high that you could not overcome them?

Part B: Selected items from the Personal and Organizational Quality Assessment-Revised

Following is a list of words and statements that describe feelings people sometimes have. Please fill in the number which best reflects how frequently you have felt the following during the last month.

Note: On the study questionnaire, these items were presented in random order and not grouped according to theme

Anxiety/anger: Resentful; Cynical; Angry; Anxious; Annoyed; Worried; I sometimes have a short fuse; I get upset easily; It's difficult for me to calm down after I've been upset; Uneasy; My sleep is inadequate; Calm (R); Relaxed (R); Peaceful (R)

Physical symptoms: Tired; Exhausted; Fatigued; Indigestion, heartburn or stomach upset; Rapid heartbeats; Headaches; Muscle tension; Body aches

Time pressure: I feel there is never enough time; I feel pressed for time; The pace of life is too fast and I can't keep up