Video Article

A Community-based Stress Management Program: Using Wearable Devices to Assess Whole Body Physiological Responses in Non-laboratory Settings

Robert Carter III¹, Kirtigandha Salwe Carter², John Holliday³, Alice Holliday³, Carlton Keith Harrison⁴

¹Department of Emergency Medicine, The University of Texas Health Science Center

²Department of Integrative Physiology, The University of North Texas Health Science Center

³Works of Wonder International

⁴DeVos Graduate Sports Business Management Program, University of Central Florida

Correspondence to: Robert Carter III at robert.carter422.mil@mail.mil

URL: <https://www.jove.com/video/55816>

DOI: [doi:10.3791/55816](https://doi.org/10.3791/55816)

Keywords: Behavior, Issue 131, physiology, wearable devices, brain function, photoplethysmography (PPG), field studies, Electroencephalography (EEG), stress management, compensatory reserve

Date Published: 1/22/2018

Citation: Carter III, R., Carter, K.S., Holliday, J., Holliday, A., Harrison, C.K. A Community-based Stress Management Program: Using Wearable Devices to Assess Whole Body Physiological Responses in Non-laboratory Settings. *J. Vis. Exp.* (131), e55816, doi:10.3791/55816 (2018).

Abstract

A pragmatic breath-based intervention to benefit human performance and stress management is timely and valuable to individuals seeking holistic approaches for emotional regulation and optimizing compensatory reserve mechanisms. This protocol is designed to not only teach mind-body awareness but also to provide feedback utilizing physiological data and survey results. The primary findings of this study showed that heart coherence and alpha variables were significantly correlated after four weeks of the breath-based meditation stress protocol. Meditation and rhythmic breathing produced significant increases in alpha brain activity. These brain physiological responses conformed to the Pleth Variability Index (PVI) changes, suggesting the ability of the human body to enter into a meditative state and effectively manage stress. When assessed after four weeks of daily practicing the techniques employed in the stress management protocol, based on the Five Facet Mindfulness Questionnaire, subjects improved in applying mindfulness skills. The overall mindfulness score, Pleth variability index (PVI), and perfusion index (PI) increased after the 4-week intervention period. Results from electroencephalography (brain waves) were consistent with a meditative state during the post-study follow-up session. This provides evidence that wearable devices are feasible for data collection during a breath-based stress management intervention. This protocol can be easily and efficiently implemented into any study design in which physiological data are desired in a non-laboratory-based setting.

Video Link

The video component of this article can be found at <https://www.jove.com/video/55816/>

Introduction

Although stress is an unavoidable and persistent component of life, alternative approaches for the management of physical and emotional stimuli are being considered^{1,2,3,4}. Uninterrupted stress is associated with the early onset and development of chronic conditions such as diabetes, obesity, cardiac, and cerebrovascular disease^{4,5}. In recent years, an increasing percentage of Americans have reported stress has a negative impact on their mental and physical health⁶, and a sizable proportion did not feel they were doing enough to manage their stress⁷. Furthermore, a recent study showed that when individuals perceived that stress is negatively impacting their physical health, there was an elevated risk of premature death⁸.

Traditionally, public health and medical professionals have focused on physical activity as a means to manage stress. However, a significant portion of the United States population develops unhealthy lifestyle habits (*i.e.*, smoking or excessive alcohol consumption) or unhealthy behaviors (*i.e.*, poor diet patterns) as a result of stressful lifestyles. Currently, more Americans are becoming aware of the potential use of various forms of yoga and breathing exercises for stress management^{4,6,9}. However, due to a lack of scientific validation, cultural appropriation, and the requisite physical environments (*i.e.*, yoga studios), a significant portion of the United States population are not considering these alternative approaches for stress management⁶.

In an attempt to deliver holistic stress management techniques such as yogic breathing and guided relaxation to a broader audience, a protocol was developed and delivered to a small group of individuals in a non-laboratory setting. Previous studies have shown that techniques such as alternate nostril breathing are effective in delivering a more relaxed state of mind and body⁴.

Until recently, scientific studies of complex physiological measurements such as brain activity, respiration, and tissue perfusion were limited to laboratory settings, and thus studies relied on less complex measures such as ambulatory arterial blood pressure (ABP), respiratory rate (RR), and heart rate (HR). However, with the development of more scientifically accurate, wearable devices, the physiological responses to stress management interventions can be studied in non-laboratory settings.

The goal of this project is to create an accessible, inexpensive management program for stress that is generalizable to both laboratory and non-laboratory settings. Additionally, this article provides the methodology for an evidence-based approach to investigating physiological responses during a stress management protocol in a non-laboratory setting while utilizing commercially available wearable devices.

Recommendations are made to allow investigators to study better stress management interventions, as well as the setup and utilization of the portable electroencephalogram (EEG) system in a systematic way that is easily adaptable to various settings. The details needed to replicate the program are specified.

Protocol

The protocol was approved by the Institutional Review Board (IRB) and all participants signed an informed consent form. Briefly, twelve healthy, normotensive, nonsmoking subjects (five men, seven women) aged between 31 and 65 years (mean age = 44 ± 12 years) volunteered to participate in this study. Brown and Gerbarg³ studied meditation and similar breathing techniques in individuals across a broad age range (14 - 85 years of age) for the management of anxiety, post-traumatic stress disorder, and overall wellness and lifestyle management.

1. Participant Selection

1. Perform the following for all participants: a telephone screening, a baseline visit (home), a 4-week intervention period, and an endpoint visit (same or similar setting as the baseline visit).
 1. Arrange telephone screenings with interested volunteers. During the call, determine eligibility by asking questions about medical history and medications.
 2. Schedule a baseline visit for eligible and interested volunteers (home or similar setting). Deliver consent forms for review before the visit.
NOTE: It is well described in the literature that a human undergoing study in a laboratory can be associated with environmental and cognitive stress due to their awareness of being observed (e.g., the Hawthorne effect). One of the primary advantages of the home-based protocol is the ability to minimize the potential impact of foreign environments, such as a clinical or laboratory setting, on the physiological measures. Additionally, investigators may be able to extend research protocols to community-based interventions without having to request participants come to a laboratory.
 3. Arrive at the home or pre-intervention setting and explain the purpose, procedures, risks and discomforts, benefits, confidentiality, and liability of the study both in writing and verbally before participants sign the consent form.
 4. Confirm inclusion and exclusion criteria.
 5. Have participant complete the subjective questionnaire on mindfulness¹⁰. Equip participant with physiological devices.
 6. Record baseline measurements for 10 min in a comfortable seated posture, for 10 min after the initial intervention, a 10 min baseline after the 4-week intervention, and a 10 min period after the individual completes the breathing and meditation protocol.
NOTE: The data collection setting was the same pre- and post-intervention within a given individual. The 10 min data recording periods were stored for further analysis and reported as a 10 min average.
 7. Immediately after completing the consenting procedures, teach three breathing techniques immediately followed by listening to pre-recorded audio of the 20 min guided relaxation^{3,11,12}. Repeat four times to establish a baseline.
 8. Report only the final breathing and meditation protocol data as the initial intervention time point. Give all participants a compact disc (CD) with the breathing technique instructions and 20 min guided relaxation audio.
 9. Provide each person with detailed instructions for the four weeks of self-guided daily breathing techniques and instruct him or her to complete the breathing exercises, along with the 20 min of guided relaxation, each morning for four weeks.
 10. Have a member of the study team follow up with each person to ensure that the protocol was being followed and to assist with any instructional issues.
 11. After the 4-week intervention period, return to the participant's home to complete the endpoint visit, proceeding in the same manner as the baseline visit. Also, have participants complete the 39-item Five Facet Mindfulness Questionnaire.
NOTE: The purpose of this paper was to describe the methodology of the breathing protocol and the use of physiological monitoring in a non-laboratory setting. Investigators utilizing the breath-based meditation stress management protocol and physiological monitoring devices described in this paper may need to employ a control group for internal validity. Previous studies examining the benefit of meditation and controlled breathing have utilized a variety of control groups such as a time-matched aerobic exercise, other meditation practices, biofeedback techniques, serious gaming along with guided meditation yoga routines, and a time control without intervention.

2. Setup for Research Grade Wireless Electroencephalography (EEG) System

1. To export, evaluate, and analyze the data, provide/equip a personal laptop with a serial port to participants.
 1. Set up an EEG Control Panel that allows the user to monitor the status and features of the headset EEG, including facial expressions and emotions¹³. Data collection will take place in real time, while the subject wears the EEG headset.
 2. Before starting the recording of EEG data, switch on the EEG headset and ensure that the battery is fully charged. The device can now be set up for the user.
2. Before recording an EEG session, perform the following steps.
 1. Hydrate the twelve sensors. Assemble the headset. Thoroughly saturate the felt pads using 0.5% saline solution. When the headset is placed on the scalp, the pads should feel wet.
 2. Put on the headset. Place the headset on the user's head and make sure that the EEG electrodes make good contact (defined as below five k Ω) on the scalp of the operator. Adjust the headset until each sensor impedance is below five k Ω .
 3. Position the reference sensors to touch the skin behind the ear. It is critical that the reference sensors make contact with the skin behind the ear with a sensor impedance of below five k Ω .

4. Plug the dongle into the device's USB port. When a headset is paired, the indicator light should flicker rapidly. If this is not the situation, reinsert the dongle and try again.
 3. Launch the software on the laptop.
 4. Turn on the headset. The power switch is at the rear of the headset. A light indicates when the headset is on.
 5. Verify signal quality by examining the engine status on the control panel.
- NOTE: Because EEG data is being recorded, it is possible to utilize a software platform for additional research quality analysis on emotional states and facial expression^{13,14,15}.

3. Setup of the Bluetooth-Enabled Pulse Oximeter

1. Capture and record the pulse oximetry using a pulse oximeter, attached to a right or left ring finger, which is activated when connected.
 1. Ensure that the volunteer is in the upright position with both feet on the floor. Place the hand with the pulse oximeter comfortably on the thigh.
 2. Expose the interior of pulse oximeter sensor and insert a non-dominant finger. Position the finger so that the fingertip approaches the sensor's end. Close the device gently so that the finger contacts with the sensor pad.
- NOTE: Once the portable pulse oximeter is closed on the finger, the device should show heart rate (HR), respiratory rate (RR), perfusion index (PI), and the Pleth variability index (PVI)^{16,17}. HR, RR, PI, and PVI are displayed on the pulse oximeter device and can be displayed via Bluetooth on a smart tablet or computer.

4. Overview Five Facet Mindfulness Questionnaire

Note: This questionnaire is available in both paper and electronic format for administration¹⁰. The paper form is provided in Appendix A. Each of the five facets are based on a scale of mindfulness from 1 to 5. There is no cutoff score for being mindful or not mindful; rather it is a continuum from low to high. Each of the subscales related to the five facets of mindfulness is below.

1. Observe the ability to stay and be present and not be preoccupied with body sensations, feelings, and thoughts on a scale from 1 to 5, with five being the easiest to accomplish this task and one being the most difficult to accomplish this task.
2. Assess the ability to define emotions and expectations, past or present on a scale from 1 to 5, with five being the easiest to accomplish this task and one being the most difficult to accomplish this task.
3. Assess the ability to stay present with whatever is going on physically or mentally without disturbance, on a scale from 1 to 5, with five being the easiest to accomplish this task and one being the most difficult to accomplish this task.
4. Assess the ability to remain nonjudgmental of any past experiences or attempt to cognitively criticize the present experience, on a scale from 1 to 5, with five being the easiest to accomplish this task and one being the most difficult to accomplish this task.
5. Assess the ability to recognize the presence of emotions and thoughts without responding to them physically or mentally, on a scale from 1 to 5, with five being the easiest to accomplish this task and one being the most difficult to accomplish this task.

5. Alternate Nostril Breath Protocol (5 min)

1. Sit comfortably with the spine erect, the left hand on the left knee and the eyes closed.
2. Bring the right hand to the face. Place the index and middle fingers between the eyebrows. Place the ring and little fingers gently on the left nostril, and place the thumb on the right nostril.
3. Take a deep breath in.
4. Press the thumb down on the right nostril to close it off and exhale through the left. Inhale through the left side of the nose.
5. After that, by pressing the nostril with the ring finger, close that side of the nose. Release the thumb and breathe out through the right side. Then, inhale using the right nostril.
6. Repeat 5.4 - 5.5, continually alternating inhalations and exhalations, for 5 min.
7. Recognize the presence of emotions and thoughts without responding to them in a physical or mental manner and continue to bring your attention to the air entering and exiting the nose.

6. Victorious Breath Protocol (5 min)

1. Sit comfortably with the spine erect.
2. Take a long, deep breath in slowly.
3. With the mouth closed, breathe out through the nose, constricting the back of the throat. This mild constriction of the throat creates resistance to the passage of air.
4. Breathe in gently, pushing the breath in against the resistance produced by constricting the back of the throat.
5. Gently inhaling and exhaling slowly and deeply against this constriction at the back of the throat creates a soothing sound like ocean waves rising and falling.
6. Continue this breathing cycle for 5 min while in a seated posture.
7. Recognize the presence of emotions and thoughts without responding to them physically or mentally and continue to bring your attention to the air entering and exiting the nose.

7. Bellows Breath Protocol (5 min)

1. Sit up tall with relaxed shoulders.

2. Breathe in slowly and deeply through the nose.
3. Breath in and out from the nose with the eyes closed.
4. Flex the arms to bring elbows close to the rib cage and loose fists close to the shoulders.
5. With active inhalation, raise the arms up above the head while opening the fists.
6. With vigorous exhalation, bring the arms down to bring the elbows close to the rib cage and the fists by the shoulders.
7. Repeat steps 7.1 to 7.3 consecutively 15 to 20 times, making one set.
8. Do 3 sets with a pause of 10 to 15 s between each set.

8. Guided Relaxation Body Scan (8 - 10 min)

NOTE: Read these instructions to the participants: "The purpose of this guided relaxation is to bring the attention to different areas of the body and may assist with better awareness of physical sensations in various areas of the body. Drawing attention to various regions of the body trains the mind to be more attentive to these feelings."

1. Have a seat in a comfortable chair or the floor and after 15 seconds close the eyes. Be sure that the environment is safe, quiet, and free of distractions.
2. Observe how the mind and body are feeling right now. Observe any sensations in the body or any thoughts in mind. Continue to notice how the body is feeling and observe any thoughts on the mind.
3. Start to scan the body: With the eyes closed, mentally scan the body. Remember to take a deep breath in and let it go periodically. Recognize the presence of emotions and thoughts without responding to them physically or mentally and continue to bring your attention to the air entering and exiting the nose.
 1. Start scanning with the right foot; move to the right leg and right hip. Repeat scanning with the left foot, leg, and hip. Move slowly through each part of the body. Repeat this again starting with the right side and moving to the left side.
 2. Continue scanning the body by moving slowly to the stomach, the left aspect of the body, the right aspect of the body, the upper to the lower back and finally to the chest, starting at the neck and moving down to the stomach.
 3. Continue to mentally scan the left hand, left arm and left shoulder; continue by examining the right hand, right arm, and right shoulder.
 4. Slowly scan the head, starting with the face and moving to the neck, back of the head, and top of the head.
 5. Observe any tension in the body and bring the mental attention to that region and rescan it.
 6. Finally, before opening the eyes, take a moment to observe thoughts, feelings, and sensations. What are the thoughts right now about the body scan? Try not to judge the scan; just observe the breath and body.
 7. Take one final deep breath in, hold it for 4 seconds and let it go. Now slowly open the eyes.

Representative Results

The primary findings of this study showed that heart coherence and alpha variables were significantly correlated after the primary endpoint, the baseline after four weeks, and the endpoint after four weeks of the breath-based meditation stress protocol, but not during the baseline measurement (**Figure 1**). Based on these findings, it was concluded that this protocol produced significant increases in alpha brain activity consistent with meditative states. These brain physiological changes were in line with the PVI changes (**Figure 2**), suggesting the ability of the human body to enter into a meditative state and effectively manage stress. When assessed after four weeks of daily practice of the techniques employed in the stress management protocol, based on the Five Facet Mindfulness Questionnaire, improvements in using mindfulness skills were achieved. All of the five facets—observing, describing, acting with awareness, non-judging of inner experience, and nonreactivity to inner experience—increased on average by 0.9 to 1.3 points on a scale of 1 (never) to 5 (often).

From a methodological perspective, the study confirmed that this home-based stress management program could be conducted and could capture useable data with wearable devices. The measurements of these whole-body physiological changes are practical in a non-clinical or laboratory setting. Evidence-based stress management programs are needed, and the participants' ability to observe their own physiological data after the study can be valuable.

Figure 1. Alpha activity data captured with the EEG headset during four time periods over the course of the 4-week stress management protocol.

Significant changes in alpha activity were observed by the end of the 4-week period, suggesting a meditative state was achieved. [Please click here to view a larger version of this figure.](#)

Figure 2. Pleth variability index (PVI) data captured with a pulse oximeter during four time periods over the course of the 4-week stress management protocol.

Significant changes in PVI were observed by the end of the 4-week period, which may be consistent with more responsive physiologic factors in vascular tone and circulating blood volume. [Please click here to view a larger version of this figure.](#)

Discussion

The evolution of wearable technology and its ability to accurately track physiological responses can revolutionize the daily management of stress and monitor physical and cognitive performance across a range of interventions¹⁸. There has already been a host of clinical applications involving stress interventions that have been analyzed, including but not limited to blood pressure, heart rate, and motion or activity prediction. These technologies are continuously being improved upon by machine learning algorithms such as the Pleth variability index (PVI) and the compensatory reserve index (CRI) and can extend into any academic research field of study or community-based intervention¹⁹. However, wireless sensing technologies must demonstrate reliability, validity, and physiological responsiveness to a range of clinical and human performance-related activities.

One constraint of delivering a protocol in a non-laboratory setting is the need to ensure that environmental factors such as noise, ambient temperature, lighting, and unexpected visitors are minimized. This research successfully illustrates the feasibility and effectiveness of the implementation of breathing exercises with wearable technology within the confines of the unique constraints and characteristics of a non-laboratory environment.

Teaching the specifics of how to cultivate more adaptive ways of responding to life stressors is a critical piece of any instructor–student relationship. The opportunity to review their physiological data gives participants a way to quantify the effectiveness of stress management and progression in an unconventional approach to managing stress as they become increasingly aware of the attentiveness, alertness, and respiratory rates that are all reflective of stress levels. A key feature of this breathing protocol is the flexibility to deploy it in various populations and meet the needs of chronically stressed individuals and communities and improve their human performance.

There are important technical considerations to consider for users of the portal EEG system and PVI pulse oximetry. The EEG electrodes may shift along the scalp due to the spring-loaded system affixed to the plastic headset. Furthermore, the impedance of electrodes is based on maintaining appropriate saline, so investigators must ensure the electrodes have the appropriate amount of saline to reduce the likelihood of drying during the investigation. It may be necessary to replace the loss of the saline solution to some of the electrodes over the course of longer recording sessions.

It is essential for the investigators to minimize any external distractions during the EEG and PVI pulse oximeter recording as the devices may produce unwanted results and excessive noise to the EEG and PVI recordings.

Some individuals have reported moderate discomfort from wearing the EEG headset during extended periods of time (more than 2 hours). During this investigation, the recording sessions were limited to less than 2 hours to reduce the likelihood of any extreme discomfort associated with pressure from the electrodes and the headset.

Previous studies have reported volunteers getting bored during meditation and breathing protocols, while others have reported utilizing several biofeedback techniques to make the breathing tasks more enjoyable. The protocol described in this paper is associated with high compliance. It is essential that the participants are very comfortable with the guided meditation and breathing tasks. Most individuals reported that the CD with the guided audio of the breathing functions and meditation were of significant value.

Investigators interested in employing this technology and stress management protocol will need to identify an appropriate control group for the population being studied. Although this paper focused on the physiological monitoring and the stress management protocol, it is recognized that a control group is needed to validate any potential benefits of this protocol. Rather, the scope of this paper was to report the stress management protocol, associated wireless physiological monitoring devices, and stress reaction questionnaire.

Disclosures

The authors declare that they have no competing interests.

Acknowledgements

The authors would like to thank Dr. Harpreet Dhanoa for her generous insights toward the design of the breathing and meditation program so that it was safe, therapeutic, and impactful for individuals with stress management issues.

KC, RC, and JH conceived the project. RC and KC performed a literature search, study selection, and data extraction. All authors participated in the development of the manuscript and provided input into the final version.

References

1. Sperduti, M., Martinelli, P., Piolino, P. A neurocognitive model of meditation based on activation likelihood estimation (ALE) meta-analysis. *Conscious Cogn.*, **21** (1), 269-276 (2012).
2. Seppälä, E.M., et al. Breathing-based meditation decreases posttraumatic stress disorder symptoms in US Military Veterans: A randomized controlled longitudinal study. *J Trauma Stress*. **27** (4), 397-405 (2014).
3. Brown, R.P., Gerbarg, P.L. Yoga breathing, meditation, and longevity. *Ann N Y Acad Sci.*, **1172** (1), 54-62 (2009).
4. Carter, K.S., Carter III, R. Breath-based meditation: A mechanism to restore the physiological and cognitive reserves for optimal human performance. *World J Clin Cases.*, **4** (4), 99-102 (2016).
5. Mohan, A., Sharma, R., Bijlani, R.L. Effect of meditation on stress-induced changes in cognitive functions. *J Altern Complement Med.*, **17** (3), 207-212 (2011).
6. Astin, J.A. Stress reduction through mindfulness meditation. *Psychother Psychosom.*, **66** (2), 97-106, (1997).
7. Hahn, R.G., Rundgren, M. Vasopressin and amino acid concentrations in serum following absorption of irrigating fluid containing glycine and ethanol. *Br J Anaesth.*, **63** (3), 337-9 (1989).
8. Keller, A., et al. Does the perception that stress affects health matter? The association with health and mortality. *Health Psychol.*, **31** (5), 677-84 (2012).
9. Gaylord, C., Orme-Johnson, D., Travis, F. The effects of the transcendental meditation technique and progressive muscle relaxation on EEG coherence, stress reactivity, and mental health in black adults. *Int J Neurosci.*, **46** (1-2), 77-86, (1989).
10. Baer, R.A., Smith, G.T., Hopkins, J., Krietemeyer, J., Toney, L. Using self-report assessment methods to explore facets of mindfulness. *Assessment.*, **13** (1), 27- 45, (2006).
11. Brown, R.P., Gerbarg, P.L. Sudarshan Kriya yogic breathing in the treatment of stress, anxiety, and depression: part I-neurophysiologic model. *J Altern Complement Med.*, **11** (1), 189-201, (2005).
12. Bhatia, M., Kumar, A., Kumar, N., Pandey, R.M., Kochupillai, V. Electrophysiologic evaluation of Sudarshan Kriya: an EEG, BAER, P300 study. *Indian J Physiol Pharmacol.*, **47** (2), 157-163, (2003).
13. Lievesley, R., Wozencroft, M., Ewins, D. The Emotiv EPOC neuroheadset: an inexpensive method of controlling assistive technologies using facial expressions and thoughts? *J Assist Technol.*, **5** (2), 67-82 (2011).
14. Badcock, N.A., et al. Validation of the Emotiv EPOC(R) EEG gaming system for measuring research quality auditory ERPs. *Peer J.*, **1**, e38 (2013).
15. Duvinage, M., et al. Performance of the Emotiv EPOC headset for P300-based applications. *Biomed Eng Online.*, **12** (1), 1 (2013).
16. Cannesson, M., et al. Pleth variability index to monitor the respiratory variations in the pulse oximeter plethysmographic waveform amplitude and predict fluid responsiveness in the operating theatre. *Br J Anaesth.*, **101** (2), 200-206 (2008).
17. Cannesson, M., et al. Does the Pleth variability index indicate the respiratory-induced variation in the plethysmogram and arterial pressure waveforms?. *Anesth Analg.*, **106** (4), 1189-1194 (2008).
18. Lin, Y., Fisher, M.E., Roberts, S.M. and Moser, J.S. Deconstructing the Emotion Regulatory Properties of Mindfulness: An Electrophysiological Investigation. *Front Hum Neurosci.*, **10**, (2016).
19. Poh, P.Y., et al. Respiratory pump contributes to increased physiological reserve for compensation during simulated haemorrhage. *Exp Physiol.*, **99** (10), 1421-1426 (2014).