International Journal of Emergency Mental Health and Human Resilience,Vol.23, No.7, pp 101-107 © 2021 OMICS International ISSN 1522-4821

A Biological Approach to Building Resilience and Wellness Capacity among Public Safety Personnel Exposed to Post-traumatic Stress Injuries

Judith P. Andersen

Department of Psychology & Affiliated Temerty Faculty of Medicine, University of Toronto, Mississauga, Ontario, Canada

Joseph Arpaia

Private Practice, Psychiatry and Behavioral Medicine, Eugene, USA

Harri Gustafsberg

Police University College, Tampere, Finland

AbSTRACT: *To review core biological processes that underlie psychophysiological dysfunction following trauma that have not been adequately addressed in prior resilience intervention research and propose a novel way to improve intervention outcomes.* ***Methods:*** *The authors present a theoretical and methodological approach to building resilience among PSP tested and refined across six, grant-funded, multi-method studies with over 300 police participants measuring objective psychophysiological and behavioral data.* ***Results:*** *Modifying cardiorespiratory function through autonomic modulation training utilizing heart rate variability biofeedback techniques has been identified as one evidence-based method of improving wellness and performance outcomes among PSP.* ***Conclusions:*** *Policy implications include directing research efforts and funding support for biologically based resilience interventions among PSP.*

Keywords: *Biological Resilience, Post Traumatic Stress Injury; Autonomic Modulation; Heart Rate Variability; Respiratory Sinus Arrhythmia; Police; Public Safety Personnel; Mental Health; Intervention; Heart Rate Variability Biofeedback*

INTRODUCTION

Police officers are routinely exposed to hazardous, disturbing events that can impose severe stress and long-term trauma. Upwards of 15-26% of public safety personnel (PSP) report one or more mental health symptoms. (Carleton et al., 2018) Accumulated stress and posttraumatic stress injuries (PTSI) result in chronic physical and mental health disorders including anxiety, depression, substance abuse, and cardiovascular disease. (Arpaia & Andersen, 2019; Violanti et al., 2006) PTSI are also related to reduced occupational performance, absenteeism, and risky behaviour, with implications for both police and public safety. (Austin-Ketch et al., 2012; Ruotsalainen et al., 2014) Recent empirical evidence and government reports have highlighted a mental health and suicide crisis among from various PSP sectors in North America. (Carleton et al., 2018; Suicide, 2019) The research above forms an urgent call for evidence-based programs that build resilience and wellness capacity in order to prevent PTSI symptoms before they manifest as severe, chronic, diagnosable disorders. However, existing prevention and resilience interventions for PTSI tailored to PSP show limited effectiveness. (Ruotsalainen et al., 2014; Carleton et al., 2018; Smith et al., 2018).

Advances in physiology and neuroscience demonstrate that resilience is maintained by the healthy functioning of psychophysiological systems within the body. Objective biological measures have shown that chronic stress and trauma disrupt both psychological and physiological functioning, eroding resilience and reducing wellness capacity. Traditional interventions to build resilience among PSP have not adequately addressed the physiological underpinnings that lead to mental and physical health conditions, as well as burnout and fatigue following trauma. (Lehrer, 2018; Rogala et al., 2014; Maslach et al., 2001; Morse et al., 2012; Violanti & Gehrke, 2004) In this paper we posit that, to date, there has been a missing piece in intervention research for PSP exposed to trauma. Specifically, the consideration of psychophysiology. We propose a biological approach to building resilience and wellness capacity among PSP exposed to PTSI. Prior research shows that autonomic modulation techniques, such as heart rate variability biofeedback, effectively reduce psychophysiological stress and mental health symptoms in

*Correspondence regarding this article should be directed to: judith.andersen@utoronto.ca

clinical and non-clinical populations. (Lehrer et al., 2020; Lin et al., 2018; Goessl et al., 2017; Tan et al., 2011) We also present examples from intervention research in the field of policing that demonstrate that autonomic modulation techniques improve police health and occupational performance when completed during scenario-based, in-person training (Andersen et al., 2018; Andersen & Gustafsberg, 2016; Andersen et al., 2016).

BIOLOGICAL RESILIENCE: THE MISSING PIECE

Traditional interventions to build resilience or relieve symptoms of PTSI are focused on addressing cognitive, emotional, and behavioural components without addressing underlying neurological and physiological mechanisms that erode resilience, maintain pathology, and cause symptoms to resurface following treatment. (LeDoux & Pine, 2016; Minassian et al., 2015) For example, research and clinical practice have shown that directing patients to apply effortful, consciously deployed strategies like reappraisal are not helpful when either subcortical circuitry (e.g., brainstem) or peripheral (e.g., nervous system) physiology is dysregulated. (Arpaia & Andersen, 2019; Lehrer, 2018; LeDoux & Pine, 2016) Theoretical models and recent research indicate that biological resilience is maintained by the psychophysiological feedback network (PFN, Figure 1), comprised of bidirectional signals between a) higher order cognitive and emotional processing regions of the brain (e.g., prefrontal cortex (PFC) and limbic system), b) subcortical regions of the central autonomic network (e.g., brainstem), and c) the peripheral autonomic nervous system (ANS) (e.g., parasympathetic and sympathetic), including the heart and lungs (Lehrer, 2018; Porges, 2003; Smith et al., 2017; Thayer et al., 2009).

In other words, healthy functioning of the bi-directional signals between the brain and the central and peripheral nervous systems maintains resilience, defined as adaptive emotion regulation, cognition, and the physical capacity to function in the face of stress. (Porges, 2003; Smith et al., 2017; Mather & Thayer, 2018) Typically, when a person encounters stress (either real or imagined) they will experience characteristic changes in the nervous system, including increased sympathetic nervous system (SNS) activation that elevates heart rate (HR) and respiration, and a withdrawal of parasympathetic nervous system (PNS) activation. When stress has abated, PNS activation will lower heart and breathing rates and blood pressure, helping the body returns to reparative and restorative functioning (Porges, 2003).

Exposure to chronic stress and PTSI is strongly associated with disruption in the function of individual PFN system components and the signals between systems, which can lead to a reduction in an individual's short- and long-term reserves to maintain wellness. (Arpaia & Andersen 2019; LeDoux & Pine, 2016; Gillie & Thayer, 2014; Glover et al., 2006; McEwen, 2002) afferent connections from the heart and lungs to the brain indicate that dysregulation in breathing and cardiac dynamics directly influence brain physiology and cognitive processing in ways that exacerbate acute and chronic stress. (Holzman & Bridgett, 2017) For example, upon exposure to a traumatic event an individual may feel threatened (i.e., PFC, limbic system activation) and experience dramatic changes in ANS activation causing a rapid rise in HR (i.e., enhanced SNS and PNS withdrawal) and respiration (i.e., hyperventilation). At a later date, changes in respiration unrelated to threat (e.g., resulting from physical exertion) may trigger dysfunctional cognitive processes (e.g., appraisal of a non-threatening situation as dangerous) resulting in maladaptive behavior (e.g., avoiding situations they should be attending to). Chronic stress and trauma are associated with a 'rewiring' of the PFN, such that a person may experience the withdrawal of PNS activity, or increases in SNS, even when they are at rest (Holzman & Bridgett, 2017). Given that the ANS plays an essential role in the PFN, linking visceral organs such as the heart and lungs with higher order brain regions like the PFC, when the balance between SNS and PNS activity is disrupted, the individual becomes vulnerable to mental and physical health conditions (Thayer et al., 2009; Ginty et al., 2017).

The good news is that the function of the PFN, thus the level of resilience, can be objectively measured and strengthened using cardiorespiratory biometric indices such as heart rate

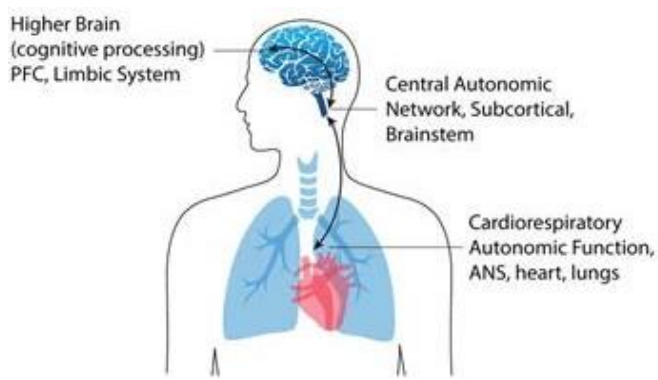

Figure 1. The Psychophysiological Feedback Network, PFN.

variability (HRV) and respiratory sinus arrhythmia (RSA). (Holzman & Bridgett, 2017; Lehrer & Gevirtz, 2014) Prior research indicates that each of these indices can be targeted by autonomic modulation training to improve resilience and wellness capacity.

METHODS

CARDIORESPIRATORY INDICES OF WELLNESS CAPACITY

HRV has been characterized as an index of autonomic resilience. (Hildebrandt et al., 2016) HRV is the variation in the time between successive heart beats and depends primarily on the extrinsic regulation of HR by the balance between SNS and PNS branches of the ANS. (Acharya et al., 2006; Laborde et al., 2017) If the time between heart beats is rather constant, HRV will be low, whereas if the time varies, HRV will be higher. When a person is at rest, high HRV signals good health because it represents a physical indicator of autonomic flexibility in responding to challenges. (Acharya et al., 2006; Shaffer & Ginsberg, 2017) In contrast, low resting HRV signals an imbalance in autonomic function, such as in clinical cases of anxiety and psychopathology where there is an overactivation of the sympathetic branch and a weakening of parasympathetic influence over the heart. (Beauchaine & Thayer, 2015) As mentioned, parasympathetic function is associated with restorative and regulatory processes in the body (e.g., immune functioning, growth, and repair), and a lack of PNS function is associated with both physical (e.g., cardiovascular disease) and mental health problems. (Beauchaine & Thayer, 2015; Ginsberg, 2016) There are a variety of HRV parameters that indicate autonomic resilience (e.g., time- and frequency-domain measures, RSA). (Laborde et al., 2017) and may be targeted to rewire maladaptive functioning in the PFN.

Respiratory Sinus Arrhythmia (RSA) refers to heart rate variability that is in phase with breathing such that HR speeds up during inhalation (shortening the time between heart beats) and slows during exhalation (lengthening the time between heart beats). (Lehrer & Gevirtz, 2014; Yasuma & Hayano, 2004) As noted in Figure 1, the lungs and respiratory system play a key role in the PFN. Increasing RSA builds physical wellness capacity by strengthening an individual's long-term reserves, theorized to occur via multiple pathways (i.e., baroreflex control, blood pressure regulation, and efficiency of pulmonary gas exchange). (Lehrer, 2018; Lehrer & Gevirtz, 2014) RSA is also associated with stimulation of the vagus nerve, a principle nerve of the PNS. (Brodal, 2004) Thus, RSA can be measured to examine the functional state of the PNS. Porges (2003) Research reveals a connection between respiration, arousal, and emotional control, such that the manner by which a person breathes sends signals to regions in the brainstem and forebrain that modulate arousal. (Mather & Thayer, 2018) For example, periods of slow breathing are associated with SNS suppression and PNS stimulation, which may underlie the anxiety and stress-reducing effects of RSA. (Mather & Thayer, 2018).

The authors have expanded the use of RSA as a micro-intervention during acute stress to assist patients (Arpaia) and police officers (Andersen & Gustafsberg) to regain focus, shift attention, and select responses that better match the demands of the situation at hand. For example, when a person's HR is high due to mental stress, they can change the pattern of a single breath, causing a rapid drop in HR due to vagal outflow. This drop in HR is then communicated via vagal afferents to the solitary nucleus in the brainstem, Browning & Travagli (2011) activating feedback loops in the PFN via secondary connections from the solitary nucleus to widespread brain areas involved in perceptual, cognitive, and emotional processing (Figure 1). Browning & Travagli (2011) The drop in HR lasts a few seconds and provides a brief temporal window during which these changes in brain processing enable the person to reassess the environment and direct attention to more helpful behavioral, cognitive, and / or emotional responses (Arpaia, personal communication, 2019) (Lehrer, 2018; Vlemincx et al., 2013). The authors have used autonomic modulation techniques teach individuals to modify both short- and long-term RSA, an objective indicator of the ability to recover more quickly following stress, and has been shown to effectively do so in clinical samples and police officers (Lehrer et al., 2020; Andersen et al., 2018).

Below we describe the particular methods and autonomic modulation techniques that we have used with clinical patients and PSP to test our biological approach to building resilience.

Autonomic Modulation Training: Strengthening Resilience and Wellness Capacity

In order to teach individuals how to modulate autonomic processes and signals between networks in the PFN, we have utilized heart rate variability biofeedback (HRVB), a methodology that enables an individual to manipulate cardiorespiratory function. Heart rate variability biofeedback is a technique that has been developed and refined by Lehrer and colleagues over the past three decades. (Lehrer & Gevirtz, 2014) During HRVB, a person is shown visual feedback of their beat-by-beat heart rate data while engaging in slow breathing with the goal of maximizing RSA. The optimal slow breathing pace differs from person to person, is not intuitive, and does not occur naturally in waking states. Therefore, training is required to gradually develop comfort with breathing at a pace that maximizes RSA, with the eventual goal of being performed unconsciously through rewiring of the PFN. (Lehrer et al., 2000) For clinically effective treatment, it is not sufficient to simply instruct a person to breathe slowly. Rather, HRVB training is required to identify the precise breathing rate for maximizing RSA to the individual, and to condition this rate through practice. (Lehrer et al., 2000) There is promising empirical support for the effectiveness of HRVB for modifying symptoms associated with PTSI, such as anxiety (Goessl et al., 2017), depression (Beckham et al., 2013; Caldwell, 2015; Karavidas et al., 2007), insomnia (Lin et al., 2019) and PTSD (Tan et al., 2011).When people practice HRVB daily over a period of time, RSA is improved even during periods outside of daily practice (Lehrer et al., 2003).

To provide context for the biological tools described above, the authors also use psychological tools that have been shown to effectively reduce clinical symptoms and build resilience and wellness capacity among individuals Arpaia & Andersen (2019). Specifically, these meta-cognitive skills, defined as the awareness and understanding of one's own thought processes, assist individuals in learning to correctly identify psychophysiological demands and resources and regulate the appraisal of experience using attentional and cognitive techniques. Arpaia & Andersen (2019) Meta-cognitive skills combined with HRVB and short term RSA provides individuals with a more comprehensive way to rewire the PFN. We call this 'autonomic modulation training.' In line with prior work, our biologically focused approach of teaching individuals to modify autonomic processes as a way to change higher order cognitive functioning appears to help individuals feel more in control of physiological, behavioral and emotional functioning all around (Lehrer et al., 2000; Mizener et al., 1988; Nanke & Rief, 2000; Wilson, 2017). Below we outline the research that supports our proposed biological approach to building resilience and wellness capacity among police.

RESULTS

The proposed approach to building resilience and wellness capacity among PSP is the culmination the authors extensive experience working with soldiers, veterans, police, and trauma survivors over the past 20 years. In a research context, Andersen has worked with civilian and military personnel exposed to mass trauma, acute stress disorder, and PTSD (Pizarro, 2006; Silver et al., 2006; Pizarro, 2004; Silver et al., 2005; Holman et al., 2008; Andersen et al., 2010; Possemato et al., 2010; Silver et al., 2013; Andersen et al., 2013; Andersen & Silver 2020). In a clinical context, Arpaia has developed and refined autonomic modulation techniques in his psychiatry clinical practice for the past 20 years with over 700 patients Arpaia & Andersen (2019). Gustafsberg, an academic and retired commander and trainer of elite federal Special Forces units in Europe, has been developing and refining autonomic modulation in the field with active duty officers. (Gustafsberg, 2014; Åhman & Gustafsberg, 2017; Gustafsberg, 2018) The authors combined experience and expertise have laid the foundation for the proposed theoretical and practical approach to building resilience and wellness capacity among PSP exposed to post traumatic stress injury.

In collaboration and with advisement from expert police practitioners, medical and academic experts in psychophysiological risk and resilience, the authors developed the International Performance Resilience and Efficiency Program (iPREP) an intensive resilience program to address the unique acute and chronic stressors that police officers face and to improve occupational health and performance. (Andersen et al., 2018; Andersen & Gustafsberg, 2016, Andersen et al., 2016) This program has been refined across six, grant-funded, multi-method studies with over 300 police participants measuring objective psychophysiological and behavioral data. (Andersen & Collins, 2020; Planche et al., 2019; Andersen et al., 2017; Andersen & Papazoglou, 2015; Andersen et al., 2016; Andersen et al., 2016; Andersen et al., 2016; Andersen et al., 2015; Andersen et al., 2015; Andersen et al., 2015; Andersen et al., 2015; Andersen et al., 2015; Andersen & Papazoglou, 2014; Papazoglou & Andersen, 2014) the most recent i PREP validation study repeatedly tracked police officers up to 18 months post-training, showing significant, long-term reductions in occupational errors, and improvements in their ability to recover quickly from acutely stressful events (Andersen et al., 2018).

DISCUSSION

Taken together, the research and clinical evidence above demonstrates how psychophysiological dysfunction results from chronic and traumatic stress. Additionally, the evidence reviewed provides insight into the necessary biological components of relieving current distress and preventing future suffering following trauma exposure. We propose that autonomic modulation training (AMT) fills an existing gap in the applied research literature supporting capacity-building prevention and intervention programs for PSP exposed to PTSI, such that AMT measures and strengthens objective biological resilience. This paper serves as a 'call to action' inviting other researchers and practitioners to explore and test our proposed approach in basic and applied settings.

FUNDING

A grant from the Government of Ontario Ministry of Labour (ROP 15-R-021) funded partial data collection. Dr. Andersen is now funded by the Canadian Institutes of Health Research to continue with this research (Grant #433650). However, the funding agencies do not have any other involvement in the conceptualization, design, analysis, decision to publish, or preparation of this manuscript.

AUTHORS CONFLICT OF INTEREST

The authors declare no competing or conflicting interests in the publication of this manuscript.

REFERENCES

Acharya, U. R., Joseph, K. P., Kannathal, N., Lim, C. M., & Suri, J. S. (2006). Heart rate variability: a review. *Med bio eng comput*, *44*(12), 1031-1051.

Åhman, H., & Gustafsberg, H. (2017). Tilannetaju, päätä paremmin. *Alma Talent Pro. Helsinki*.

Andersen JP, Gustafsberg H, Collins P, Poplawski S. (2017). Performing under stress: Evidence-based training for police resilience. *In. RCMP Gazette*. Vol 79.

Andersen JP, Gustafsberg H, Nyman M, Koskelainen M, Papazoglou K.(2015). The Essential Role of Mental Preparedness in Optimal Functioning among the Police: Opening a Dialogue on an Understudied Topic. National Defence University, Department of Leadership and Military Pedagogy Series. 16:21-32.

Andersen JP, Papazoglou K, Gustafsberg H, Collins PI, Arnetz BB. (2016). Mental Preparedness Training. In. FBI Law *Enforc Bull*.

Andersen, J. P., & Collins, P. I. (2020). *A longitudinal, within-subjects intervention study to reduce lethal force errors: psychophysiological research with police officers*. SAGE Publications Ltd.

Andersen, J. P., & Gustafsberg, H. (2016). A training method to improve police use of force decision making: a randomized controlled trial. *Sage Open*, *6*(2), 2158244016638708.

Andersen, J. P., & Papazoglou, K. (2014). Friends under fire: Cross-cultural relationships and trauma exposure among police officers. *Traumatol*, *20*(3), 182.

Andersen, J. P., & Papazoglou, K. (2015). Police health professionals' knowledge and practices in educating officers about trauma and health.

Andersen, J. P., Di Nota, P. M., Beston, B., Boychuk, E. C., Gustafsberg, H., Poplawski, S.et al. (2018). Reducing lethal force errors by modulating police physiology. *J Occup Environ Med*, *60*(10), 867.

Andersen, J. P., Dorai, M., Papazoglou, K., & Arnetz, B. B. (2016). Diurnal and reactivity measures of cortisol in response to intensive resilience and tactical training among special forces police. *J Occup Environ Med e*, *58*(7), e242-e248.

Andersen, J. P., Papazoglou, K., & Collins, P. (2016). Reducing robust health-relevant cardiovascular stress responses among active-duty special forces police. *Gen Med: Open Access*.

Andersen, J. P., Papazoglou, K., Arnetz, B. B., & Collins, P. (2015). Mental preparedness as a pathway to police resilience and optimal functioning in the line of duty.

Andersen, J. P., Papazoglou, K., Koskelainen, M., Nyman, M., Gustafsberg, H., & Arnetz, B. B. (2015). Applying resilience promotion training among special forces police officers. *Sage Open*, *5*(2), 2158244015590446.

Andersen, J. P., Papazoglou, K., Nyman, M., Koskelainen, M., & Gustafsberg, H. (2015). Fostering resilience among police.

Andersen, J. P., Pitel, M., Weerasinghe, A., & Papazoglou, K. (2016). Highly realistic scenario based training simulates the psychophysiology of real world use of force encounters: implications for improved police officer performance.

Andersen, J. P., Silver, R. C., Stewart, B., Koperwas, B., & Kirschbaum, C. (2013). Psychological and physiological responses following repeated peer death. *PloS one*, *8*(9), e75881.

Andersen, J., & Silver, R. C. (2020). Health Effects of Traumatic Events. *Wiley Encyclo Health Psychol*, 255-260.

Andersen, J., Wade, M., Possemato, K., & Ouimette, P. (2010). Association between posttraumatic stress disorder and primary care provider-diagnosed disease among Iraq and Afghanistan veterans. *Psychosom Med*, *72*(5), 498-504.

Arpaia, J., & Andersen, J. P. (2019). The Unease Modulation Model: An Experiential Model of Stress With Implications for Health, Stress Management, and Public Policy. *Front psychiatry*, *10*, 379.

Austin-Ketch, T. L., Violanti, J., Fekedulegn, D., Andrew, M. E., Burchfield, C. M., & Hartley, T. A. (2012). Addictions and the criminal justice system, what happens on the other side? Post-traumatic stress symptoms and cortisol measures in a police cohort. *J Addict Nurs*, *23*(1), 22-29.

Beauchaine, T. P., & Thayer, J. F. (2015). Heart rate variability as a transdiagnostic biomarker of psychopathology. *Int J psycho*, *98*(2), 338-350.

Beckham, A. J., Greene, T. B., & Meltzer-Brody, S. (2013). A pilot study of heart rate variability biofeedback therapy in the treatment of perinatal depression on a specialized perinatal psychiatry inpatient unit. *Arc women's ment health*, *16*(1), 59-65.

Brodal, P. (2004). *The central nervous system: structure and function*. oxford university Press.

Browning, K. N., & Travagli, R. A. (2011). Plasticity of vagal brainstem circuits in the control of gastrointestinal function. *Auton Neurosci*, *161*(1-2), 6-13.

Caldwell, H. W. (2015). *Impact of heart-rate variability biofeedback on major depression disorder in resting-state fMRI*. Brigham Young University.

Carleton, R. N., Afifi, T. O., Turner, S., Taillieu, T., Duranceau, S., LeBouthillier, D. M et al. (2018). Mental disorder symptoms among public safety personnel in Canada. *Can J Psychiatry*, *63*(1), 54-64.

Carleton, R. N., Afifi, T. O., Turner, S., Taillieu, T., LeBouthillier, D. M., Duranceau, S et al. (2018). Suicidal ideation, plans, and attempts among public safety personnel in Canada. *Can Psychol Psycholog can*, *59*(3), 220.

Carleton, R. N., Korol, S., Mason, J. E., Hozempa, K., Anderson, G. S., Jones, N. A. et al. (2018). A longitudinal assessment of the road to mental readiness training among municipal police. *Cogn Behav Ther 47*(6), 508-528.

Gillie, B. L., & Thayer, J. F. (2014). Individual differences in resting heart rate variability and cognitive control in posttraumatic stress disorder. *Fron psychol*, *5*, 758.

Ginsberg, J. P. (2016). Dysregulation of autonomic cardiac control by traumatic stress and anxiety. *Front psychol*, *7*, 945.

Ginty, A. T., Kraynak, T. E., Fisher, J. P., & Gianaros, P. J. (2017). Cardiovascular and autonomic reactivity to psychological stress: neurophysiological substrates and links to cardiovascular disease. *Auton Neurosci*, *207*, 2-9.

Glover, D. A., Stuber, M., & Poland, R. E. (2006). Allostatic load in women with and without PTSD symptoms. *Psychiatry: Int bio pro*, *69*(3), 191-203.

Goessl, V. C., Curtiss, J. E., & Hofmann, S. G. (2017). The effect of heart rate variability biofeedback training on stress and anxiety: a meta-analysis. *Psychol med*, *47*(15), 2578-2586.

Gustafsberg, H. (2014). Mielen valmentamisella optimaaliseen suoritukseen. *Vimpeli: Kustannus Siipipyörä*.

Gustafsberg, H. (2018). "DO PEOPLE GET SHOT BECAUSE SOME COPS PANIC?": Enhancement of individual resilience through a police resilience and efficiency training program.

Hildebrandt, L. K., McCall, C., Engen, H. G., & Singer, T. (2016). Cognitive flexibility, heart rate variability, and resilience predict fine-grained regulation of arousal during prolonged threat. *Psychophysiol*, *53*(6), 880-890.

Holman, E. A., Silver, R. C., Poulin, M., Andersen, J., Gil-Rivas, V., & McIntosh, D. N. (2008). Terrorism, acute stress, and cardiovascular health: A 3-year national study following the September 11th attacks. *Arc gen psychiatry*, *65*(1), 73-80.

Holzman, J. B., & Bridgett, D. J. (2017). Heart rate variability indices as bio-markers of top-down self-regulatory mechanisms: A meta-analytic review. *Neurosci Biobehav reviews*, *74*, 233-255.

Karavidas, M. K., Lehrer, P. M., Vaschillo, E., Vaschillo, B., Marin, H., Buyske, S. et al. (2007). Preliminary results of an open label study of heart rate variability biofeedback for the treatment of major depression. *App psychophysiol biofeedbac*, *32*(1), 19-30.

Laborde, S., Mosley, E., & Thayer, J. F. (2017). Heart rate variability and cardiac vagal tone in psychophysiological research–recommendations for experiment planning, data analysis, and data reporting. *Front psychology*, *8*, 213.

LeDoux, J. E., & Pine, D. S. (2016). Using neuroscience to help understand fear and anxiety: a two-system framework. *Am J psychiatry*.

Lehrer, P. M. (2018). Heart rate variability biofeedback and other psychophysiological procedures as important elements in psychotherapy. *Int J Psychophysiolo*, *131*, 89-95.

Lehrer, P. M., & Gevirtz, R. (2014). Heart rate variability biofeedback: how and why does it work?. *Frontiers in psychology*, *5*, 756.

Lehrer, P. M., Vaschillo, E., & Vaschillo, B. (2000). Resonant frequency biofeedback training to increase cardiac variability: Rationale and manual for training. *App psychophysiol biofeedbac*, *25*(3), 177-191.

Lehrer, P. M., Vaschillo, E., Vaschillo, B., Lu, S. E., Eckberg, D. L., Edelberg, R. et al. (2003). Heart rate variability biofeedback increases baroreflex gain and peak expiratory flow. *Psychosom med*, *65*(5), 796-805.

Lehrer, P., Kaur, K., Sharma, A., Shah, K., Huseby, R., Bhavsar, J.et al. (2020). Heart rate variability biofeedback improves emotional and physical health and performance: a systematic review and meta analysis. *App psychophysiol and biofeedbac*, *45*(3), 109-129.

Lin, I. M., Fan, S. Y., Yen, C. F., Yeh, Y. C., Tang, T. C., Huang, M. F. et al. (2019). Heart rate variability biofeedback increased autonomic activation and improved symptoms of depression and insomnia among patients with major depression disorder. *Clin Psychopharmacol Neurosci*, *17*(2), 222.

Maslach C, Schaufeli WB, Leiter MP. Job Burnout. *Ann Rev Psychol*. 2001;52(1):397-422.

Mather, M., & Thayer, J. F. (2018). How heart rate variability affects emotion regulation brain networks. *Cur op behav sci*, *19*, 98-104.

McEwen, B. S. (2002). The neurobiology and neuroendocrinology of stress: Implications for post-traumatic stress disorder from a basic science perspective. *Psychiatric Clinics*, *25*(2), 469-494.

Minassian, A., Maihofer, A. X., Baker, D. G., Nievergelt, C. M., Geyer, M. A., Risbrough, V. B.et al.. (2015). Association of predeployment heart rate variability with risk of postdeployment posttraumatic stress disorder in active-duty marines. *JAMA psychiatry*, *72*(10), 979-986.

Mizener, D., Thomas, M., & Billings, R. (1988). Cognitive changes of migraineurs receiving biofeedback training. *Headache: J Head Face Pain*, *28*(5), 339-343.

Morse, G., Salyers, M. P., Rollins, A. L., Monroe-DeVita, M., & Pfahler, C. (2012). Burnout in mental health services: A review of the problem and its remediation. *Adm Pol Mental Health Mental Health Ser Research*, *39*(5), 341-352.

Nanke, A., & Rief, W. (2000). Biofeedback-Therapie bei somatoformen Störungen. *VETERINARIA*, *10*(4), 238-248.

Papazoglou, K., & Andersen, J. P. (2014). A guide to utilizing police training as a tool to promote resilience and improve health outcomes among police officers. *Traumatol Int J*, *20*(2), 103.

Pizarro, J. (2004). The efficacy of art and writing therapy: Increasing positive mental health outcomes and participant retention after exposure to traumatic experience. *Art Therap*, *21*(1), 5-12.

Pizarro, J., Silver, R. C., & Prause, J. (2006). Physical and mental health costs of traumatic war experiences among Civil War veterans. *Arch Gen Psychiatry*, *63*(2), 193-200.

Planche, K., Chan, J. F., Di Nota, P. M., Beston, B., Boychuk, E., Collins, P. I. et al. (2019). Diurnal cortisol variation according to high-risk occupational specialty within police: comparisons between frontline, tactical officers, and the general population. *J occup env med*. *61*(6), e260-e265.

Porges, S. W. (2003). The polyvagal theory: Phylogenetic contributions to social behavior. *Physiol behav*, *79*(3), 503-513.

Possemato, K., Wade, M., Andersen, J., & Ouimette, P. (2010). The impact of PTSD, depression, and substance use disorders on disease burden and health care utilization among OEF/OIF veterans. *Psychol Trauma: Theory, Research, Pract, Pol*, *2*(3), 218.

Rogala, A., Shoji, K., Luszczynska, A., Kuna, A., Yeager, C., Benight, C. C et al. (2016). From exhaustion to disengagement via self-efficacy change: Findings from two longitudinal studies among human services workers. *Front Psychol*, *6*, 2032.

Ruotsalainen, J. H., Verbeek, J. H., Mariné, A., & Serra, C. (2014). Preventing occupational stress in healthcare workers. *Coch Database System Reviews,* (11).

Shaffer, F., & Ginsberg, J. P. (2017). An overview of heart rate variability metrics and norms. *Front pub health*, *5*, 258.

Silver, R. C., Holman, E. A., Andersen, J. P., Poulin, M., McIntosh, D. N., & Gil-Rivas, V. (2013). Mental-and physical-health effects of acute exposure to media images of the September 11, 2001, attacks and the Iraq War. *Psychol sci*, *24*(9), 1623-1634.

Silver, R. C., Holman, E. A., McIntosh, D. N., Poulin, M., Gil-Rivas, V., & Pizarro, J. (2006). Coping with a national trauma: A nationwide longitudinal study of responses to the terrorist attacks of September 11.

Silver, R. C., Poulin, M., Holman, E. A., McIntosh, D. N., Gilrivas, V., & Pizarro, J. (2005). Exploring the myths of coping with a national trauma: A longitudinal study of responses to the September 11th terrorist attacks. *J Aggr, Maltreat Trauma*, *9*(1-2), 129-141.

Smith, B., Shatté, A., Perlman, A., Siers, M., & Lynch, W. D. (2018). Improvements in resilience, stress, and somatic symptoms following online resilience training: A dose–response effect. *J occup environ med*, *60*(1), 1.

Smith, R., Thayer, J. F., Khalsa, S. S., & Lane, R. D. (2017). The hierarchical basis of neurovisceral integration. *Neurosci biobehav rev*, *75*, 274-296.

Suicide OCCsEPoPODb. Staying Visible, Staying Connected for Life. Ontario2019.

Tan, G., Dao, T. K., Farmer, L., Sutherland, R. J., & Gevirtz, R. (2011). Heart rate variability (HRV) and posttraumatic stress disorder (PTSD): a pilot study. *App psychophysio biofeedbac*, *36*(1), 27-35.

Thayer, J. F., Hansen, A. L., Saus-Rose, E., & Johnsen, B. H. (2009). Heart rate variability, prefrontal neural function, and cognitive performance: the neurovisceral integration perspective on self-regulation, adaptation, and health. *Ann Behav Med*, *37*(2), 141-153.

Violanti, J. M., & Gehrke, A. (2004). Police trauma encounters: precursors of compassion fatigue. *Int J emerg mental health*.

Violanti, J. M., Fekedulegn, D., Hartley, T. A., Andrew, M. E., Charles, L. E., Mnatsakanova, A et al. (2006). Police trauma and cardiovascular disease: association between PTSD symptoms and metabolic syndrome. *Int J emerg mental health*.

Vlemincx, E., Abelson, J. L., Lehrer, P. M., Davenport, P. W., Van Diest, I., & Van den Bergh, O. (2013). Respiratory variability and sighing: a psychophysiological reset model. *Bio psychol*, *93*(1), 24-32.

Wilson, A. M. (2017). *Heart rate variability biofeedback training as an intervention for chronic pain* (Doctoral dissertation, Marquette University).

Yasuma, F., & Hayano, J. I. (2004). Respiratory sinus arrhythmia: why does the heartbeat synchronize with respiratory rhythm?. *Chest*, *125*(2), 683-690.