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Individuals with tension and migraine headaches exhibit increased heart rate variability during post-stress mindfulness meditation practice but a decrease during a post-stress control condition – A randomized, controlled experiment

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ABSTRACT

Background: Current research suggests that associations between headache conditions (migraine, tension) and imbalances in the autonomic nervous system (ANS) are due to stress-related dysregulation in the activity of the parasympathetic-sympathetic branches. Mindfulness meditation has demonstrated effectiveness in reducing pain-related distress, and in enhancing heart rate variability—a vagal-mediated marker of ANS balance. This study examined HRV during cognitive stress and mindfulness meditation in individuals with migraine and tension headaches.

Methods: Undergraduate students with tension and migraine headaches ($n = 36$) and headache-free students ($n = 39$) were recruited for an experiment involving HRV measurement during baseline, cognitive stress-induction, and after randomization to post-stress conditions of audio-guided mindfulness meditation practice (MMP) or mindfulness meditation description (MMD). HRV was derived using electrocardiograms as the absolute power in the high frequency bandwidth (ms^2). A three-way ANOVA tested the effects of Group (headache vs. headache-free), Phase (baseline, stress, & post-stress), and Condition (MMP vs. MMD) on HRV.

Results: ANOVA revealed a significant three-way interaction. Simple effects tests indicated: 1) HRV increased significantly from stress to MMP for headache and headache-free groups ($p < 0.001$), 2) significantly greater HRV for headache ($p < 0.001$) and headache-free ($p < 0.05$) groups during MMP compared to MMD, and 3) significantly lower HRV in the headache vs. headache-free group during the post-stress MMD condition ($p < 0.05$).

Discussion: Results suggest mindfulness practice can promote effective heart rate regulation, and thereby promote effective recovery after a stressful event for individuals with headache conditions. Moreover, headache conditions may be associated with dysregulated stress recovery, thus more research is needed on the cardiovascular health and stress resilience of headache sufferers.

1. Introduction

Tension and migraine headache conditions are neurovascular disorders that lead to severe pain and disability, and can be resistant to pharmacological treatment (Leandri et al., 2001; Leone et al., 2010). Recent estimates indicate migraine and tension-type headache conditions have a lifetime prevalence of 18–22% (Vos et al., 2013), and headache disorders are the 3rd ranked cause of disability worldwide (Steiner et al., 2015). Etiological research indicates that stress-related dysregulation of the autonomic nervous system (ANS) is a contributing factor to headache condition onset and maintenance (Elmenshawy and Sakr, 2009; Koenig et al., 2015). Mindfulness meditation is a stress regulation practice that has demonstrated effectiveness for a wide range of chronic health conditions (Eisendrath et al., 2014; Murphy et al., 2012; Ospina et al., 2008; Paswani et al., 2013) and for treatment outcomes assessed by means of physiological markers (Chiesa and Serretti, 2010; Nyklíček et al., 2013). The purpose of the current study was to assess the effectiveness of mindfulness meditation for regulating stress in individuals reporting tension and migraine headache pain.

Heart rate variability (HRV) measures variations in beat-to-beat heart rate (HR), and indexes the activity of sympathetic (decreased HRV) and vagal parasympathetic (increased HRV) subsystems in the ANS (Allen et al., 2007; Beauchaine and Thayer, 2015; Koenig et al., 2015). Reduced vagal tone has been observed in several chronic pain conditions (Koenig et al., 2015; Tracy et al., 2016) and psychopathologies (Kemp et al., 2012; Lyonfields et al., 1995; Pittig et al., 2013; Thayer et al., 1998). Furthermore, exposures to cognitive stressors can

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lead to sympatho-excitatory elevations in HR, and reductions in HRV and vagal tone (Boonnithi and Phongsuphap, 2011; Porges, 1995; Verkuil et al., 2010). A healthy and flexible ANS adapts to stressor demands when stress is present, and serves a restorative function with parasympathetic (vagal) activation to return to ANS balance after stressful periods conclude (Porges, 2011; Thayer et al., 2012). For example, it is adaptive to have sympathetic reactivity (HR elevation) to unintentionally placing one's hand on a hot stove as this generates the arousal level that triggers one to attenuate the acute pain and physical threat by quickly removing their hand. In the aftermath of the hand being removed from the pain stimulus, a vagal-mediated recovery to resting levels (baseline HR) is adaptive and situationally appropriate given the pain and threat has subsided. Accordingly, it is useful to measure HRV markers of stress and recovery to examine possible deficiencies in parasympathetic regulation, as prolonged post-stress HRV reduction and delay in returning to resting vagal tone can indicate elevated risk of psychological and physical pathologies (Blascovich and Edward, 1993; Brosschot et al., 2006; Thayer et al., 2012; Verkuil et al., 2010).

Several studies have found evidence of sympathetic hyperactivity and reduced vagal tone in individuals with tension and migraine headaches (Elmenshawy and Sakr, 2009; Gass and Glaros, 2013; Grosu et al., 2013; Koenig et al., 2015; Matei et al., 2015; Nilsen and Tronvik, 2009). However, despite evidence that individuals with headache conditions are more psychologically sensitive towards stressors (Holm et al., 1997; Huss et al., 2009), few studies have assessed HRV in these individuals in response to and after stressful periods. In the present study, we hypothesized individuals with tension and migraine headaches would exhibit significantly reduced HRV after cognitive stress exposure, reflecting dysregulation in their parasympathetic recovery.

Associations between decreased HRV and headache conditions suggest increasing vagal-mediated HRV is a potential target of therapeutic intervention. Stress is considered a trigger of headache episodes (Hashizume et al., 2008; Nash and Thebarge, 2006; Wöber et al., 2006) and stress reduction is central to the psychological-behavioural management of headaches (Cathcart and Pritchard, 2008; Nash and Thebarge, 2006; Schramm et al., 2014). Psychophysiology studies have found that in the aftermath of experimental stressors, individuals with headache conditions report significantly higher subjective stress sensitivity (Rojahn and Gerhards, 1986; Stronks et al., 1999), and exhibit significantly delayed cardiovascular recovery (Holm et al., 1997). Koenig et al. (2015) conducted a systematic review and meta-analysis and found several studies reporting sympathetic hyperactivity associated with migraines and tension-type headaches. Seven studies ($n = 122$) were included in the meta-analysis, and significantly decreased time and frequency-domain metrics of HRV (representing a medium effect size) were found to be associated with headache disorders while controlling for respiration rate, a confounding variable in HRV analyses. Vagal-mediated HRV reflects respiratory sinus arrhythmia, characterized by synchronized increases and decreases in HR during cycles of inhalation and exhalation, respectively (Allen et al., 2007; Porges and Byrne, 1992; Yasuma and Hayano, 2004). It is well documented that paced and relaxed breathing increases HRV (Bernardi et al., 2000; Peng et al., 2004; Perakakis et al., 2009; Yasuma and Hayano, 2004), and recently, breath-focused techniques such as mindfulness meditation have demonstrated effectiveness in elevating HRV (Azam et al., 2015; Burg and Wolf, 2012; Krygier et al., 2013; Lumma et al., 2015). The purpose of this study was to determine the effectiveness of a post-stress mindfulness meditation condition in enhancing HRV in individuals with tension and migraine headache pain.

Mindfulness practices elicit nonreactive awareness and acceptance of present sensory, emotional, and cognitive experiences (Didonna, 2009; Kabat-Zinn et al., 1985). Brief and sustained mindfulness meditation practice is known to have beneficial physiological effects on autonomic indices of blood pressure (Abbott et al., 2014), HR (Ditto et al., 2006; Nyklíček et al., 2013), and HRV (Azam et al., 2015; Burg and Wolf, 2012; Krygier et al., 2013; Lumma et al., 2015). Breath-focused mindfulness meditation primarily instructs one to complete their breathing cycles while being aware of breathing sensations, and non-judgmentally noticing other sensory, cognitive, and emotional experiences arising in the present moment (Ritvo et al., 2013; Stahl and Goldstein, 2011). Recent evidence shows this practice can promote respiratory sinus arrhythmia, the term for restful and healthy synchronization of HR and breathing rates reflected in increased HRV (Appelhans and Luecken, 2006; Berntson et al., 1993). These findings reflect the potential of mindfulness-based interventions in increasing HRV and reducing the stress-related physiological response in individuals suffering from headaches. Accordingly, several studies have demonstrated the effectiveness of mindfulness-based interventions in helping to manage headache pain and pain-related cognitive stressors. Wells et al. (2014) conducted a randomized-control trial (RCT) comparing 8 weeks of mindfulness-based stress reduction (MBSR) delivered to episodic migraineurs ($n = 19$) vs. usual care ($n = 9$). Results indicated fewer and less severe migraines per month and significant between-group reductions on the Migraine Disability Assessment ($p < 0.05$) and Headache Impact Test ($p < 0.05$) for MBSR participants (Wells et al., 2014). In a similar study, Day et al. (2014) evaluated mindfulness-based cognitive therapy (MBCT) by comparing headache participants classified as treatment responders (≥50% improvement in pain intensity and/or pain interference) and non-responders (<50% improvement). They found 14 treatment responders among the 21 intervention participants, with large effect size differences (between responders and non-responders) for pre-to post-treatment change in standardized measures of pain acceptance and catastrophizing (Day et al., 2014), reflecting the importance of targeting cognitive stress factors in the treatment of headache patients.

The present study assessed HRV in participants with tension and migraine headache pain and headache-free controls using a 3-phase experiment consisting of baseline, stress, and random allocation to one of two post-stress conditions. The stress phase involved performing a pattern-recognition task covertly providing falsified real-time performance feedback to elicit cardiac elevation (Azam et al., 2015). Ratings were obtained after the stress phase with regards to the degree of subjective stress experienced during the task. The post-stress conditions were either audio-guided “mindfulness of breathing” instructions or an audio description of mindfulness meditation (each 10 min in duration). The following hypotheses were tested:

1) A greater proportion of headache group participants would report moderate-high subjective stress after the stress task compared to headache-free.

2) Significant increases in HRV would be observed during the post-stress mindfulness meditation exposure for both groups.

3) Significantly lower HRV would be observed in the headache group in the post-stress control condition.

2. Methods

This study was conducted at York University, a large public institution based in Toronto, Canada, and recruited undergraduate students of all years of study and majors. Recruitment was facilitated through an online system of research participation that grants course credits.

3. Participants

Online pre-screens selected for individuals self-reporting experiencing recurrent migraines or headaches. To recruit control participants, pre-screens selected for individuals not reporting experiencing recurrent migraines or headaches. Exclusion criteria for the study included current diagnoses of any anxiety disorder, major depressive disorder, and cardiovascular disease (hypertension, coronary artery disease, and arrhythmias). These conditions are known to involve ANS dysfunction (Chalmers et al., 2014; Haensel et al., 2008; Kemp et al., 2012; Miu et