



Physiology of school burnout in medical students: Hemodynamic and autonomic functioning



Ross W. May^{a,*}, Gregory S. Seibert^a, Marcos A. Sanchez-Gonzalez^b, Frank D. Fincham^a

^a Family Institute, The Florida State University, Tallahassee, FL, USA

^b Division of Clinical and Translational Research, Larkin Community Hospital, South Miami, FL, USA

ARTICLE INFO

Article history:

Received 19 November 2015

Received in revised form 10 February 2016

Accepted 19 May 2016

Keywords:

Ambulatory
Autonomic
Blood pressure
Cardiovascular
School burnout

ABSTRACT

This study investigated the relationship between burnout and hemodynamic and autonomic functioning in both medical students (N=55) and premedical undergraduate students (N=77). Questionnaires screened for health related issues and assessed school burnout and negative affect symptomatology (anxiety and depression). Continuous beat-to-beat blood pressure (BP) through finger plethysmography and electrocardiogram (ECG) monitoring was conducted during conditions of baseline and cardiac stress induced via the cold pressor task to produce hemodynamic, heart rate variability, and blood pressure variability indices. Independent sample *t*-tests demonstrated that medical students had significantly higher school burnout scores compared to their undergraduate counterparts. Controlling for age, BMI, anxiety and depressive symptoms, multiple regression analyses indicated that school burnout was a stronger predictor of elevated hemodynamics (blood pressure), decreased heart rate variability, decreased markers of vagal activity and increased markers of sympathetic tone at baseline for medical students than for undergraduates. Analyses of physiological values collected during the cold pressor task indicated greater cardiac hyperactivity for medical students than for undergraduates. The present study supports previous research linking medical school burnout to hemodynamic and autonomic functioning, suggests biomarkers for medical school burnout, and provides evidence that burnout may be implicated as a physiological risk factor in medical students. Study limitations and potential intervention avenues are discussed.

© 2016 The Authors. Published by Elsevier GmbH. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Data from the American College Health Association-National College Health Assessment II (ACHA-NCHA II), pooling from 108 universities and including over 93,000 college students indicates that maladaptive affective functioning is the most prevalent psychological impediment to successful academic performance among US college students (ACHA-NCHA II, 2015). In fact, students overwhelmingly ranked the negative impact of stress as the leading factor affecting their individual academic performance during the last 12 months. Accordingly, considerable resources (both research and public policy based) have been allocated toward identifying, understanding, and decreasing affective symptomatology that diminishes the mental and physical health of collegiate populations (Regeher, Glancy, & Pitts, 2013).

A growing concern regarding affective symptomatology in academic populations is school burnout. School burnout is school-related stress conceptualized as chronic exhaustion from school-related work, cynicism toward the meaning of school and a belief of inadequacy in school related accomplishment (Salmela-Aro, Kiuru, Leskinen, & Nurmi, 2009). Prior research shows that school burnout is associated with an imbalance of hemodynamic functioning. *Hemodynamics* is the study of blood movement or blood flow and how physical forces affect circulation (Guyton & Hall, 1996). Specifically, school burnout (a) is associated with cardiac hyperactivity during conditions of cardiac stress and recovery via a cold pressor task (CPT; submersion of one's hand in water of 4°C for a specified amount of time) and (b) predicts arterial stiffness and blunted diurnal blood pressure variability as assessed through ambulatory blood pressure monitoring (see May, Sanchez-Gonzalez, Brown, Koutnik, & Fincham, 2014; May, Sanchez-Gonzalez, & Fincham, 2014). All the above findings relating school burnout to physiological functioning were independent of affective symptomatology (i.e., anxiety and depression). Moreover, the cardiovascular responses of individuals suffering from

* Corresponding author at: 310 Longmire, Florida State University, Tallahassee, FL 32306-1491, USA.

E-mail addresses: rossmay00@gmail.com, rmay@fsu.edu (R.W. May).

higher levels of burnout have been identified as risk factors for the future development of cardiovascular disease (Bajko et al., 2012; FitzGerald, Ottaviani, Goldstein, & Shapiro, 2012; Matthews et al., 2004). Arguably these findings make school burnout a potential public health issue of particular concern to educators and health care policy makers.

School burnout is pervasive at multiple educational levels: it has been found in high school students (Salmela-Aro et al., 2009; Walburg, 2014), undergraduate students (May, Sanchez-Gonzalez, Brown et al., 2014; May, Sanchez-Gonzalez, & Fincham, 2014), and graduate students (Dahlin & Runeson, 2007; Dyrbye, Thomas, & Massie et al., 2008; Dyrbye et al., 2011). Current research suggests that burnout may be particularly deleterious in medical students as various forms of burnout in this population have been associated with numerous negative professional and physical health issues, including depressive symptoms and suicidal ideation (Dahlin & Runeson, 2007; Dyrbye et al., 2008, 2011), unprofessional behavior (Brazeau, Schroeder, Rovi, & Boyd, 2010; Dyrbye, Massie et al., 2010), medical school dropout contemplation, (Dyrbye et al., 2011; Dyrbye, Thomas et al., 2010) lower empathy (Brazeau et al., 2010; Thomas et al., 2007), sleep disorders (Pagnin et al., 2014) and lower performance-based self-esteem (Dahlin, Joneborg, & Runeson, 2007).

The prevalence of medical school burnout is high. IsHak et al. (2009) showed that across 51 studies the prevalence of burnout ranged from 28 to 45% in medical students (Dyrbye, Thomas, & Huntington, 2006; Willcock, Daly, Tennant, & Allard, 2004) and 27% to 75% (averaged 50%) in residents (Martini, Arfken, Churchill, & Balon, 2004). In a more recent literature review of 9 studies, medical student burnout ranged from 45% to 71% (IsHak et al., 2013). Thus nearly half of all medical students experience burnout during their medical education making this an at-risk population.

Given the many negative professional and wellness issues associated with school burnout, it is surprising that the physiological effects of burnout in medical school populations remains relatively underexplored. Accordingly, we examined the relationship between medical school burnout and physiology through analysis of cardiovascular reactivity (CVR) induced by the cold pressor task (CPT). CVR is defined as the magnitude or pattern of hemodynamic responses to stressors (Manuck, 1994; Treiber et al., 2003). Research indicates that only through inducing states of CVR may some individuals be identified as at risk of deteriorated cardiovascular functioning (Manuck, 1994; May, Sanchez-Gonzalez, Brown et al., 2014; Treiber et al., 2003). Thus through CVR, cardiac anomalies undetectable at resting states may be better identified. For example, CVR has been shown to be both a marker and a mechanism in the pathogenesis of cardiovascular disease (Manuck, 1994; Treiber et al., 2003). A research review investigating CVR and the development of subclinical and clinical CVD states, found that blood pressure responses to the CPT were predictive of future hypertension in longitudinal epidemiological studies in initially normotensive samples (Treiber et al., 2003).

Physiological parameters of interest in this study include typical hemodynamic (e.g. blood pressure and heart rate) and autonomic nervous system indices (vagal modulation) as well as more progressive cardiac indicators of autonomic functioning: cardiac sympathovagal tone (through heart rate variability analysis) and sympathetic vasomotor tone (through blood pressure variability analysis). Cardiac sympathovagal tone produces an index denoting the contribution of sympathetic influence on the balance of the autonomic state resulting from sympathetic and parasympathetic influences (Goldberger, 1999; Goldstein, 1983). Elevated cardiac sympathovagal tone has been identified as an important marker of cardiovascular morbidity and mortality (Goldberger, 1999; Goldstein, 1983). Unlike cardiac sympathovagal tone which

is predominately a vagal driven (parasympathetic) autonomic nervous system indicator, sympathetic vasomotor tone provides a more robust index of the sympathetic autonomic nervous system influence on the vasculature (Malliani, Pagani, Lombardi, & Cerutti, 1991). In more general terms, sympathetic vasomotor tone describes the level of nervous system stimulation on smooth muscles in the blood vessel walls which contributes to their level of contraction (i.e. *vasoconstriction*). Elevated sympathetic vasomotor tone has been associated with a variety of negative wellness indicators (e.g. affective disorders, hypertension, autonomic nervous system disorders, Izdebska, Cybulska, Izdebskir, Makowiecka-Ciesla, & Trzebski, 2004; Okamoto et al., 2012; Sanchez-Gonzalez, May, Koutnik, Kabbaj, & Fincham, 2013). Collectively, cardiac sympathovagal tone and sympathetic vasomotor tone are referred to as indicators of cardiac autonomic modulation.

Therefore, we examined the relationship between medical school burnout and CVR using indices of hemodynamics and cardiac autonomic modulation. We also explored this relationship at both the graduate and undergraduate levels of medical education. We expected medical school burnout to be associated with suboptimal cardiovascular functioning as indicated by elevated hemodynamics and imbalanced cardiac autonomic modulation (i.e. higher cardiac sympathovagal tone and sympathetic vasomotor tone). We also expected burnout to be implicated as a cardiovascular risk factor in students at both the graduate and undergraduate medical educational level. Furthermore, given the greater professional and educational burden placed on medical students in graduate programs compared to undergraduate programs (IsHak et al., 2013), we expected graduate student burnout to have stronger relationships with impaired cardiac functioning than undergraduate student burnout.

2. Methods

2.1. Participants

Fifty-five first year medical students (41 females) and 77 undergraduate university students majoring in premedical studies (61 females; 72% Seniors) qualified for study inclusion. In an attempt to avoid potential cardiovascular functioning confounds, participants were excluded from study participation through an online health screening assessment if they smoked, exercised regularly (defined as >120 min per week in the previous 6 months), were hypertensive (blood pressure $\geq 140/90$ mmHg), had chronic diseases, or were taking beta blockers, antidepressants, or stimulants (as previously specified in May, Sanchez-Gonzalez, Brown et al., 2014, May, Sanchez-Gonzalez, & Fincham, 2014). Participants were asked to abstain from caffeine, alcohol, and strenuous physical activity for at least 24 h prior to testing and were asked not to eat any food 4 h prior to testing. Female participants were tested in the early follicular phase of the menstrual cycle to avoid potential variations in pressure wave morphology and cardiac reactivity (Adkisson et al., 2010). The graduate medical student sample was 76% Caucasian, 7% African American, 9% Hispanic, 5% Asian, and 3% endorsed either biracial or non-disclosed ethnicity. The premedical undergraduate sample was 73% Caucasian, 10% African American, 8% Hispanic, 7% Asian, and 2% endorsed either biracial or non-disclosed ethnicity. Participants were recruited through campus advertisements and from classrooms as an option for voluntary class credit with all data collected in the middle (weeks 3–9) of the fall semester. All participants gave their written consent prior to study participation as approved by The Florida State University Institutional Review Board.

2.2. Measures

2.2.1. Anthropometrics

Height was measured using a stadiometer, body weight was measured using a Seca scale (Sunbeam Products Inc., Boca Raton, FL), and body mass index (BMI) was calculated as kg/m^2 .

2.2.2. Blood pressure

Continuous beat-to-beat blood pressure (BP) and electrocardiogram (ECG) monitoring was conducted for this study. Beat-to-beat assessment allows for the incorporation of psychophysiological markers of autonomic nervous system (ANS) functioning via power spectral analysis of heart rate variability (HRV) and blood pressure variability indices (BPV). Blood pressure (BP), heart rate (HR), systolic BP (SBP), and diastolic BP (DBP) were recorded through finger plethysmography (NIBP-100 Bio-pac Inc., Goleta, California).

2.2.3. Heart rate variability

The BP peaks were used to calculate the time duration of intervals between heartbeats (R wave to R wave interval, RRI) and were automatically detected using WinCPRS software (WinCPRS, Turku, Finland). The RRIs were inspected for artifacts, premature beats, and ectopic episodes before calculation of heart rate variability (HRV) parameters. The HRV was calculated through the time domain statistics percentage of adjacent R-R intervals that differ by 50 ms (pNN50), root mean square of successive R-R differences (RMSSD), and total power or variance in RRI. These are considered standard markers of cardiac vagal modulation and are elevated during states of relaxation or physiological wellbeing (Task Force, 1996).

The main spectral components of the HRV that were calculated, by means of Fast Fourier transformation, were the low frequency (LF; 0.04–0.15 Hz) and the high frequency (HF; 0.15–0.4 Hz). To exclude the influence of very low frequency (VLF) and to control for changes in total power during the intervention induction, it is more appropriate to report these spectral components in normalized units (nu; Pagani et al., 1986). Due to structural algebraic redundancy inherent in the normalized spectral HRV measures with respect to each other ($nLF = 1 - nHF$), we only report LFnu and denote LFnu as an index of cardiac sympathovagal tone (Task Force, 1996; Burr, 2007; Pagani et al., 1986). Increased LFnu is associated with states of increased cardiovascular stress such as that induced by the cold pressor test (Sanchez-Gonzalez et al., 2013).

2.2.4. Blood pressure variability

ECG measurement produced BPV indices by having the SBP time series resampled at 5 Hz and the continuous data stream passed through a low pass impulse response filter with a cutoff frequency of 0.5 Hz. The data were then subjected to Fast Fourier transform algorithms using a Hanning spectral window and subsequently smoothed using a triangular averaging function to produce a spectrum. The power was calculated by measuring the area under the peak of the power spectra density curve. Power spectra within the 0.04–0.15 Hz range were defined as LFSBP and taken as an estimate of sympathetic vasomotor modulation (Malliani et al., 1991). Reductions in short term BPV including increased LFSBP have been associated with adverse cardiovascular outcomes (Manios et al., 2014; Parati, Ochoa, Lombardi, & Bilo, 2015).

2.2.5. School burnout

School burnout was measured using the School Burnout Inventory (SBI; Salmela-Aro et al., 2009). The SBI closely mirrors the work-related conceptualization of burnout as measured by the Maslach Burnout Inventory (MBI; Maslach, Jackson, & Leiter, 1996). The SBI consists of three first-order latent factors, exhaustion at school (four items), cynicism toward the meaning of school (three

items), a sense of inadequacy at school (two items) and an overarching second-order factor representing overall school burnout. Thus summed scores from the first-order factors comprise a second-order overall school burnout score. The overall school burnout composite score was used for analysis in this study. As in Salmela-Aro et al., 2009, all the items were rated on a 6-point Likert-type scale ranging from 1 (completely disagree) to 6 (strongly agree). Higher composite scores indicate higher burnout. Reliability for the sample was $\alpha = 0.93$. In a reliability and validity study, Salmela-Aro et al. (2009) demonstrated that this SBI model demonstrated good model fit with depressive symptoms, school engagement, and academic achievement predictive of SBI scores in high school students.

2.2.6. Depression

Depression was measured using the 10-item Center for Epidemiologic Studies Depression Scale (CES-D; Santor & Coyne, 1997). The CES-D has been widely used to measure depressive symptoms in nonclinical samples. It asks participants to respond to a list of ways they may have felt or behaved during the previous week. Responses ranged from 0 (rarely or none of the time) to 3 (most or all of the time). Responses were summed into one overall score with a possible range of 0–30. Higher scores are indicative of greater depressive symptoms. Reliability for the sample was $\alpha = 0.87$.

2.2.7. Anxiety

Anxiety was measured using the 20-item State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970). Responses were scored on a 4-point Likert scale 1 (not at all) to 4 (very much so). Items were then summed to create a composite anxiety score with a possible range of 20–80 with higher scores indicating greater anxiety. Reliability for the sample was $\alpha = 0.92$.

2.3. Procedure

After laboratory familiarization, height and weight measurements were taken of participants. Participants then completed an online self-report questionnaire containing health and demographic information as well as scale measurements including the SBI, CES-D, and STAI. After instrument calibration and a 10-min resting period in a seated position, 5 min of baseline beat-to-beat finger hemodynamic data (including BP, HR, HRV, BPV) were recorded. This was followed by a 3 min cold pressor test (CPT) in which continuous beat-to-beat finger hemodynamic data was recorded. The CPT is used to assess cardiovascular reactivity to a stressor by measuring a participant's cardiovascular status before and during the submersion of their hand in cold ($<4^\circ\text{C}$) water. All data collection was conducted in the afternoon in a quiet, dimly lit, temperature-controlled room ($23 \pm 1^\circ\text{C}$) at the same time of the day (± 2 h) to minimize potential diurnal variations in cardiovascular reactivity.

3. Results

Independent sample *t*-tests comparing graduate and undergraduate student health demographics and scale measurements (SBI, CES-D, STAI) scores indicated that graduate medical students had significantly ($p < 0.05$) higher school burnout scores than pre-medical undergraduates, $t(130) = 2.02$, $p = 0.045$, Cohen's $d = 0.370$. Age was the only demographic significantly different between graduate and undergraduate students, $t(130) = 18.53$, $p < 0.001$, Cohen's $d = 0.311$, with graduate students older than undergraduates. No other group differences were found on scores of CES-D, STAI, height, weight, or BMI (r 's < 1 , $p > 0.05$). Table 1 displays descriptive statistics. Multiple regression analyses (controlling for age, BMI, anxiety, and depression) and follow-up simple slope

Table 1
Descriptive statistics of health demographics and scale measurements.

Variable	Medical (n = 55)	Undergraduate (n = 72)
	M ± SD	M ± SD
1. SBI	24.09 ± 6.79	20.92 ± 10.02
2. CES-D	8.91 ± 4.58	7.67 ± 8.11
3. STAI	25.09 ± 6.96	24.00 ± 8.54
4. Height (cm)	165.66 ± 10.66	161.11 ± 6.81
5. Weight (kg)	65.03 ± 15.39	63.54 ± 13.70
6. BMI (kg/m ²)	23.38 ± 3.35	24.53 ± 3.50
7. Age (yrs)	24.76 ± 2.05	19.57 ± 1.15

Note: Study N = 127. SBI = School Burnout Inventory, CES-D = Center for Epidemiologic Studies Depression Scale, STAI = State-Trait Anxiety Inventory, BMI = body mass index.

analyses evaluated the relationship between SBI scores and student class (graduate vs. undergraduate students) in predicting variance in physiological outcomes (see Table 2). Analyses examining interactions between student class category (graduate vs. undergraduate students) and SBI scores on baseline cardiovascular outcomes indicate that graduate medical students had higher baseline hemodynamic parameters (heart rate, blood pressures) as well as elevated sympathetic nervous system activity (higher LFnu, lower pNN50 and lower RMSSD) in comparison to undergraduates. Of note is vasomotor tone (LFSBP). Although no interaction (student class X SBI) was found for LFSBP, LFSBP was significantly associated with increased SBI for graduate students but not for undergraduates. Although LFSBP was indeed higher for undergraduates in comparison to graduate students, the large amount of variance in the LFSBP undergraduate measurement prevented significant statistical association (see Table 2, panel A).

Change scores (Δ) were calculated for CPT task analysis as CPT task values minus baseline values (see Table 2, panel B). Regression analyses indicated that during sympatho-stimulation (CPT task), graduate medical students' demonstrated greater cardiac hyperactivity than premedical undergraduate students as indicated by increased heart rate, blood pressures (SBP, DBP) and sympathetic activity (LFnu, but not pNN50 or RMSSD).

4. Discussion

This study evaluated novel relationships between burnout and cardiovascular and autonomic nervous system functioning in medical and premedical student samples. As expected, graduate medical

students suffer from higher burnout than premedical undergraduates. Furthermore, the associations between school burnout and indices of poorer cardiovascular functioning were stronger for the graduate medical students than the premedical undergraduates. In particular, we observed that school burnout was associated with decreased markers of vagal activity (pNN50, RMSSD) and increased markers of sympathetic tone (LFnu, LFSBP) to a greater degree in graduate medical students. Thus the novel findings of the present study include identifying potential biomarkers of school burnout which provide initial evidence to suggest that school burnout, especially in the medical student population, may be cardiotoxic and hence may predispose individuals with high school burnout scores to cardiovascular disease.

This research extends previous investigations into physiological links to school burnout (May, Sanchez-Gonzalez, Brown et al., 2014; May, Sanchez-Gonzalez, & Fincham, 2014) by evaluating a specific, at-risk population, namely, medical students. Furthermore, and of concern, is the comparison of mean school burnout values between this research and the previous research utilizing the SBI in US samples. School burnout was higher for both the graduate and undergraduate medical samples in this study ($M = 24.09$, $M = 20.92$, respectively) than in all of the undergraduate samples using the SBI ($M = 20.19$ in May, Sanchez-Gonzalez, Brown et al. (2014); $M = 17.76$ in sample 1 and $M = 18.09$ in sample 2 in May, Sanchez-Gonzalez, and Fincham (2014); $M = 17.11$ in sample 1, $M = 17.53$ in sample 2, $M = 17.01$ in sample 3 and $M = 17.39$ in sample 4 in May, Bauer, & Fincham, 2015). This comparison highlights the prevalence of burnout in undergraduate and graduate medical school populations. It also provides novel insight into the cardiovascular and autonomic functioning potentially responsible for the deleterious health associations with school burnout.

Regarding limitations, this study was constrained by a largely female sample. Future research should aim for sampling that more accurately reflects the gender proportions in medical school especially given the predominance of males in graduate medical programs (see Association of American Medical Colleges (AAMC, 2015). Additionally, while this study (76%) and national averages (54%) report Caucasians (non-Hispanic) as the predominate ethnicity enrolled in graduate medical schools, Asian student participation was lower in this sample (5%) than what would be expected given national enrollment rates (21%). Future research should seek to reflect student samples more proportional to current national enrollment rates (AAMC, 2015). Furthermore, this study

Table 2
Regression analyses displaying interaction statistic and simple slope analysis of physiological indices on school burnout scores by class at baseline (Panel A) and during cold pressor task (Panel B).

Criterion	Interaction	Medical (n = 55) M ± SD	Beta	Undergrad (n = 72) M ± SD	Beta
Panel A					
SBP	$t = 5.15^{**}$	123.90 ± 12.26	0.91 ^{**}	120.35 ± 15.53	-0.08
DBP	$t = 4.43^{**}$	77.17 ± 5.43	0.98 ^{**}	72.32 ± 8.75	-0.05
HR	$t = 7.12^{**}$	68.74 ± 7.56	0.55 ^{**}	67.00 ± 12.36	-0.52 ^{**}
RMSSD	$t = 3.67^{**}$	43.33 ± 0.95	-0.38 ^{**}	46.00 ± 30.29	-0.98 ^{**}
pNN50	$t = 4.72^{**}$	20.40 ± 5.93	-0.42 ^{**}	22.91 ± 21.84	0.28 [*]
LFnu	$t = 5.74^{**}$.71 ± 0.07	0.33 [*]	.67 ± 0.19	0.62 ^{**}
LFSBP	$t = 1.17$, $p = 0.246$	1.20 ± 0.44	-0.94 ^{**}	2.91 ± 4.18	-0.19
Panel B					
Δ SBP	$t = 2.16^*$	5.13 ± 4.78	-0.85 ^{**}	4.51 ± 14.33	-0.42 [*]
Δ DBP	$t = 2.12^*$	12.37 ± 5.46	0.69 ^{**}	9.29 ± 5.44	0.19
Δ HR	$t = 2.46^*$	8.48 ± 0.80	0.90 ^{**}	5.75 ± 2.85	-0.09
Δ RMSSD	$t = 0.58$, $p = 0.561$	-6.67 ± 5.83	0.00	3.90 ± 19.40	-0.07
Δ pNN50	$t = 0.04$, $p = 0.966$	-6.87 ± 8.12	-0.11	-1.00 ± 8.83	-0.08
Δ LFnu	$t = 4.94^{**}$	-0.18 ± 0.05	0.77 ^{**}	-0.004 ± 0.14	-0.34 [*]
Δ LFSBP	$t = 2.63^*$	0.57 ± 1.19	0.76 ^{**}	0.20 ± 1.25	0.16

Predictor: School burnout inventory. * $p < 0.05$, ** $p < 0.001$. Δ = baseline—cold pressor task, SBP = systolic blood pressure, DBP = diastolic blood pressure, HR = heart rate; RMSSD = root mean square of successive differences, pNN50 = the proportion of NN50 divided by total number of NNs, LFnu = normalized low frequency heart rate variability, LFSBP = low-frequency component of systolic blood pressure variability.

was laboratory based and utilized only one physiological stressor (cold pressor task) which might be influenced by fitness and other physiological characteristics. However, our study methodology attempted to minimize this fitness influence via use of a study exclusion criterion regarding exercise frequency (defined as >120 of exercise minutes per week during the previous 6 months).

Future research may find it beneficial to incorporate ambulatory cardiovascular assessments to more accurately evaluate stress in one's natural environment as well as fitness measures such as oxygen consumption (VO_{2max}). Lastly, it should be noted that this study is observational and demonstrates association only and is silent on causation. We interpreted this study's findings as medical school enrollment being associated with increased levels of burnout and adverse hemodynamic findings. However, an alternate explanation could be that students with these characteristics are more likely to be admitted to medical school. This could be clarified in the future by longitudinal studies following medical students from admission to college through medical school or following undergraduates as they transition into medical school.

As this research provides evidence that school burnout is linked with suboptimal physiological functioning and could potentially increase cardiovascular risk in medical students, it behooves medical school policy makers to investigate potential wellness interventions to attenuate school burnout's negative influences on students' well-being. This is especially important given that data suggest burnout is socially contagious. As with research on the socially contagious nature of mood and negative affect (see Giletta et al., 2011; Joiner & Katz, 1999; Kiuru, Aunola, Nurmi, Leskinen, & Salmela-Aro, 2008; Kiuru, Burk, Laursen, Nurmi, & Salmela-Aro, 2012; Neumann & Strack, 2000; Van Zalk, Kerr, Branje, & Stattin, 2010; Van Zalk, Branje, Kerr, & Stattin, 2010), the symptomatology associated with work burnout can transfer both with and without direct or close contact among employees (Bakker, Demerouti, & Schaufeli, 2006; Gonzalez-Morales, Peiro, Rodriguez, & Bliese, 2012). Although it remains to be evaluated in an educational context, we believe it highly likely that school burnout functions similarly as a social contagion.

In addition to efforts to develop burnout reduction interventions aimed at systematic factors which induce burnout in the learning environment, promising interventions may also be aimed at both psychological and physiological mechanisms and outcomes (Bradley et al., 2010). For example, emWave personal resilience training combines personalized stress reduction training with biofeedback heart rate variability technology to induce psychophysiological coherence (www.heartmath.org/research/e-books; McCraty, 2010). Initial research demonstrates that emWave training increases synchronization of nervous system activity, increases emotional stability, and improves cognitive and task performance (McCraty, 2010). This appears to be a promising burnout intervention that awaits evaluation in future research.

Conflict of interest

The authors declare that there are no conflicts of interest.

References

- Association of American Medical Colleges. (2015). *FACTS: applicants, matriculants, enrollment, graduates, MD/PhD, and residency applicants data—data and analysis*. Retrieved February 08, 2016, from <https://www.aamc.org/data/facts/>
- American College Health Association. (2015). *American College Health Association—National College Health Assessment II: Reference Group Executive Summary Spring 2015*. Hanover, MD: American College Health Association.
- Addikson, E. J., Casey, D. P., Beck, D. T., Gurovich, A. N., Martin, J. S., & Braith, R. W. (2010). Central, peripheral and resistance arterial reactivity: fluctuates during the phases of the menstrual cycle. *Experimental Biology and Medicine (Maywood)*, 235(1), 111–118. <http://dx.doi.org/10.1258/ebm.2009.009186>, 235/1/111 [pii]
- Bajko, Z., Szekeres, C. C., Kovacs, K. R., Csapo, K., Molnar, S., Soltesz, P., . . . & Csiba, L. (2012). Anxiety, depression and autonomic nervous system dysfunction in hypertension. *Journal of the Neurological Sciences*, 317, 112–116.
- Bakker, A. B., Demerouti, E., & Schaufel, W. (2006). Crossover of burnout and engagement in work teams. *Work and Occupations*, 33, 464–489.
- Bradley, R. T., McCraty, R., Atkinson, M., Tomasino, D., Daugherty, A., & Arguelles, L. (2010). Emotion self-regulation, psychophysiological coherence, and test anxiety: results from an experiment using electrophysiological measures. *Applied Psychophysiology and Biofeedback*, 35, 261–283.
- Brazeau, C. M., Schroeder, R., Rovi, S., & Boyd, L. (2010). Relationships between medical student burnout, empathy and professionalism climate. *Academic Medicine*, 85, 33–36.
- Burr, R. L. (2007). Interpretation of normalized spectral heart rate variability indices in sleep research: a critical review. *Sleep*, 30(7), 913–919.
- Dahlin, M. E., & Runeson, B. (2007). Burnout and psychiatric morbidity among medical students entering clinical training: a three year prospective questionnaire and interview-based study. *BMC Medical Education*, 7, 6.
- Dahlin, M. E., Joneborg, N., & Runeson, B. (2007). Performance-based self-esteem and burnout in a cross-sectional study of medical students. *Medical Teacher*, 29(1), 43–48.
- Dyrbye, L. N., Thomas, M. R., & Huntington, J. L. (2006). Personal life events and medical student burnout: a multicenter study. *Academic Medicine*, 81(4), 374–384.
- Dyrbye, L. N., Thomas, M. R., Massie, F. S., Power, D. V., Eacker, A., Harper, W., . . . & Sloan, J. A. (2008). Burnout and suicidal ideation among U.S. medical students. *Annals of Internal Medicine*, 149(5), 334–341.
- Dyrbye, L. N., Massie, F. S., Jr., Eacker, A., Harper, W., Power, D., Durning, S. J., . . . & Shanafelt, T. D. (2010). Relationship between burnout and professional conduct and attitudes among US medical students. *JAMA*, 304(11), 1173–1180.
- Dyrbye, L. N., Thomas, M. R., Power, D. V., Durning, S., Moutier, C., Massie, F. S., Jr., . . . & Shanafelt, T. D. (2010). Burnout and serious thoughts of dropping out of medical school: a multi-institutional study. *Academic Medicine*, 85(1), 94–102.
- Dyrbye, L. N., Harper, W., Durning, S. J., Moutier, C., Thomas, M. R., Massie, F. S., Jr., . . . & Shanafelt, T. D. (2011). Patterns of distress in US medical students. *Medical Teacher*, 33(10), 834–839.
- FitzGerald, L., Ottaviani, C., Goldstein, I. B., & Shapiro, D. (2012). Effects of dipping and psychological traits on morning surge in blood pressure in healthy people. *Journal of Human Hypertension*, 26(4), 228–235.
- Giletta, M., Scholte, R. H. J., Burk, W. J., Engels, R. C. M. E., Larsen, J. K., Prinstein, M. J., & Clairano, S. (2011). Similarity in depressive symptoms in adolescents' friendship dyads: selection or socialization. *Developmental Psychology*, 47, 1804–1814.
- Goldberger, J. J. (1999). Sympathovagal balance: how should we measure it? *American Journal of Physiology. Heart and Circulatory Physiology*, 276, 1273–1280.
- Goldstein, D. S. (1983). Plasma catecholamines and essential hypertension: an analytical review. *Hypertens*, 5(1), 86–99.
- Gonzalez-Morales, M. G., Peiro, J. M., Rodriguez, I., & Bliese, P. D. (2012). Perceived collective burnout. A multilevel explanation of burnout. *Anxiety, Stress, and Coping*, 25, 43–61.
- Guyton, A. C., & Hall, J. E. (1996). *Textbook of medical physiology* (9 ed.). Philadelphia, PA: W.B. Saunders Company.
- IsHak, W. W., Lederer, S., Mandili, C., Nikravesh, R., Seligman, L., Vasa, M., . . . & Bernstein, C. A. (2009). Burnout during residency training: a literature review. *The Journal of Graduate Medical Education*, 1(2), 236–242. <http://dx.doi.org/10.4300/JGME-D-09-00054.1>
- IsHak, W., Nikravesh, R., Lederer, S., Perry, R., Ogunyemi, D., & Bernstein, C. (2013). Burnout in medical students: a systematic review. *Clinical Teacher*, 10, 242–245.
- Izdebska, E., Cybulska, I., Izdebskir, J., Makowiecka-Ciesla, M., & Trzebski, A. (2004). Effects of moderate physical training on blood pressure variability and hemodynamic pattern in mildly hypertensive subjects. *Journal of Physiology and Pharmacology*, 55(4), 713–724.
- Joiner, T. E., & Katz, J. (1999). Contagion of depressive symptoms and mood: meta-analytic review and explanations from cognitive, behavioral, and interpersonal viewpoints. *Clinical Psychology: Science and Practice*, 1999(6), 149–164.
- Kiuru, N., Aunola, K., Nurmi, J.-E., Leskinen, E., & Salmela-Aro, K. (2008). Peer group influence and selection in adolescents' school burnout: a longitudinal study. *Merrill-Palmer Quarterly*, 54, 23–55.
- Kiuru, N., Burk, W. J., Laursen, B., Nurmi, J.-E., & Salmela-Aro, K. (2012). Is depression contagious? A test of alternative peer socialization mechanisms of depressive symptoms in adolescent peer networks. *Journal of Adolescent Health*, 50, 250–255.
- Malliani, A., Pagani, M., Lombardi, F., & Cerutti, S. (1991). Cardiovascular neural regulation explored in the frequency domain. *Circulation*, 84(2), 482–492.
- Manios, E., Michas, F., Stamatelopoulos, K., Barlas, G., Koroboki, E., Tsouma, I., & Zakopoulos, N. (2014). Short-term beat-to-beat but not ambulatory blood pressure variability is correlated to carotid intima-media thickness. *Blood Pressure Monitoring*, 19(5), 288–293. <http://dx.doi.org/10.1097/mbp.000000000000062>
- Manuck, S. B. (1994). Cardiovascular reactivity in cardiovascular disease: "once more unto the breach". *International Journal of Behavioral Medicine*, 1(1), 4–31.
- Martini, S., Arfken, C. L., Churchill, A., & Balon, R. (2004). Burnout comparison among residents in different medical specialties. *Academic Psychiatry*, 28(3), 240–242.

- Maslach, C., Jackson, S. E., & Leiter, M. P. (1996). *Maslach burnout inventory* (3rd ed.). Palo Alto, CA: Consulting Psychologists Press.
- Matthews, K. A., Katholi, C. R., McCreath, H., Whooley, M. A., Williams, D. R., Zhu, S., & Markovitz, J. H. (2004). Blood pressure reactivity to psycho-logical stress predicts hypertension in the CARDIA study. *Circulation, 110*(1), 74–78.
- May, R. W., Sanchez-Gonzalez, M. A., Brown, P. C., Koutnik, A. P., & Fincham, F. D. (2014). School burnout and cardiovascular functioning in young adult males: a hemodynamic perspective. *Stress, 1*, 79–87.
- May, R. W., Sanchez-Gonzalez, M. A., & Fincham, F. D. (2014). School burnout: increased sympathetic vasomotor tone and attenuated ambulatory diurnal blood pressure variability in young adult women. *Stress, 18*(1), 11–19.
- May, R. W., Bauer, K. N., & Fincham, F. D. (2015). School burnout: diminished academic and cognitive performance. *Learning and Individual Differences, 42*, 126–131.
- McCraty, R. (2010). Coherence: bridging personal, social, and global health. *Doc Children Alternative Therapies, 16*, 10–24.
- Neumann, R., & Strack, F. (2000). Mood contagion: the automatic transfer of mood between persons. *Journal of Personality and Social Psychology, 79*, 211–223.
- Okamoto, L. E., Raj, S. R., Peltier, A., Gamboa, A., Shiba, C., & Diedrich, A. (2012). Neurohumoral and haemodynamic profile in postural tachycardia and chronic fatigue syndromes. *Clinical Science (London), 122*(4), 183–192.
- Pagani, M., Lombardi, F., Guzzetti, S., Rimoldi, O., Furlan, R., Pizzinelli, P., . . . & Piccaluga, E. (1986). Power spectral analysis of heart rate and arterial pressure variabilities as a marker of sympatho-vagal interaction in man and conscious dog. *Circulation Research, 59*(2), 178–193.
- Pagnin, D., de Queiroz, V., Carvalho, Y. T., Dutra, A. S., Amaral, M. B., & Queiroz, T. T. (2014). The relation between burnout and sleep disorders in medical students. *Academic Psychiatry, 38*(4), 438–444.
- Parati, G., Ochoa, J. E., Lombardi, C., & Bilo, G. (2015). Blood pressure variability: assessment, predictive value, and potential as a therapeutic target. *Current Hypertension Reports, 17*(4), 537. <http://dx.doi.org/10.1007/s11906-015-0537-1>
- Regeher, C., Glancy, D., & Pitts, A. (2013). Interventions to reduce stress in university students: a review and meta-analysis. *Journal of Affective Disorders, 148*, 1–11. <http://dx.doi.org/10.1016/j.jad.2012.11.026>
- Salmela-Aro, K., Kiuru, N., Leskinen, E., & Nurmi, J. E. (2009). School burnout inventory (SBI): reliability and validity. *European Journal of Psychological Assessment, 25*, 48–57.
- Sanchez-Gonzalez, M. A., May, R. W., Koutnik, A. P., Kabbaj, M., & Fincham, F. D. (2013). Sympathetic vasomotor tone is associated with depressive symptoms in young females: a potential link between depression and cardiovascular disease. *American Journal of Hypertension, 26*(12), 1389–1397. <http://dx.doi.org/10.1093/ajh/hpt131>
- Santor, D. A., & Coyne, J. C. (1997). Shortening the CES-D to improve its ability to detect cases of depression. *Psychological Assessment, 9*(3), 233–243.
- Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *Manual for the state-trait anxiety inventory*. Palo Alto, CA: Consulting Psychologists Press.
- Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. (1996). Heart rate variability: standards of measurement, physiological interpretation and clinical use. *Circulation, 93*(5), 1043–1065.
- Thomas, M. R., Dyrbye, L. N., Huntington, J. L., Lawson, K. L., Novotny, P. J., Sloan, J. A., & Shanafelt, T. D. (2007). How do distress and well-being relate to medical student empathy? A multicenter study. *Journal of General Internal Medicine, 22*(2), 177–183.
- Treiber, F. A., Kamarck, T., Schneiderman, N., Sheffield, D., Kapuku, G., & Taylor, T. (2003). Cardiovascular reactivity and development of preclinical and clinical disease states. *Psychosomatic Medicine, 65*(1), 46–62.
- Van Zalk, M. H. W., Kerr, M., Branje, S., & Stattin, H. (2010). Peer contagion and adolescent depression: the role of failure anticipation. *Journal of Clinical Child & Adolescent Psychology, 39*, 837–848.
- Van Zalk, M. H. W., Branje, S., Kerr, M., & Stattin, H. (2010). It takes three: selection, influence, and de-selection processes of depression in adolescent peer networks. *Developmental Psychology, 46*, 927–938.
- Walburg, V. (2014). Burnout among high school students: a literature review. *Children & Youth Services Review, 42*, 4228–4233.
- Willcock, S. M., Daly, M. G., Tennant, C. C., & Allard, B. J. (2004). Burnout and psychiatric morbidity in new medical graduates. *Medical Journal of Australia, 181*, 357–360.