Biological Psychology 83 (2010) 84–92

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Psychophysiological and neuroendocrine responses to laboratory stressors in women: Implications of menstrual cycle phase and stressor type☆

M. Kathleen B. Lustyk [a,b,*], Karen C. Olson [c,1], Winslow G. Gerrish [a,2], Ashley Holder [a,2], Laura Widman [d]

[a] Lustyk Women's Health Lab, School of Psychology, Family, and Community, Seattle Pacific University, 3307 Third Ave. West, Watson B-47, Seattle, WA 98119, United States
[b] Biobehavioral Nursing and Health Systems, University of Washington School of Nursing, United States
[c] Center for Transitional Neurorehabilitation, St. Joseph's Hospital and Medical Center, 222W. Thomas Rd, Ste. 401, Phoenix, AZ 85013, United States
[d] University of Tennessee, Department of Psychology, Knoxville, TN 37996, United States

ARTICLE INFO

Article history:
Received 16 March 2009
Accepted 9 November 2009
Available online 14 November 2009

Keywords:
Women
Psychophysiology reactivity
Cardiovascular recovery
Neuroendocrine reactivity
State anxiety
Menstrual cycle
PASAT
Cold pressor
Salivary cortisol

ABSTRACT

This study assessed stressor and menstrual phase effects on psychophysiological and neuroendocrine responses to laboratory stressors in freely cycling women ($N = 78$, ages 18–45). Participants performed counterbalanced stressors [Paced Auditory Serial Addition Test (PASAT) or cold pressor test (CP)] during their follicular and luteal menstrual cycle phases between 1:00 and 3:00 p.m. to control for cortisol rhythm. Participants rested 30-min, performed the stressor, and then recovered 30-min while electrocardiography continuously monitored heart rate (HR). Systolic (SBP) and diastolic blood pressure (DBP), salivary cortisol, and state anxiety were assessed at timed intervals. HR, SBP, and cortisol varied more over the course of luteal than follicular phase testing. A three-way interaction revealed state anxiety reactivity was greater with the PASAT during the follicular phase. DBP showed equal and persistent reactivity with both stressors during both cycle phases. Results extend the stressor-specific HPAA hypothesis and have important methodological implications for women's biopsychology research.

Understanding the intricacies of cardiovascular reactivity remains a critical area of women's health research given the links between cardiovascular reactivity and heart disease; the latter being the leading cause of death among American women (Centers for Disease Control and Prevention [CDC], 2004). One pathway through which the cumulative effects of cardiovascular reactivity lead to heart disease is hypertension (Carroll et al., 2001; Manuck et al., 1990), a condition worsened by frequent cortisol exposure (McEwen and Stellar, 1993). Given the presence of estrogen receptors in the heart and the direct influences of steroid hormones on the cardiovascular system (Hirshoren et al., 2002), researchers have explored the effects of the menstrual cycle on women's stress-induced cardiovascular reactivity (Miller and Sita, 1994; Sato et al., 1995; Sita and Miller, 1996; Stoney et al., 1990; Tersman et al., 1991). Yet, despite several attempts to explicate menstrual cycle phase effects on psychophysiological and neuroendocrine responses to laboratory stressors in women, findings remain equivocal, with some studies reporting greater cardiovascular reactivity during the luteal cycle phase compared to the follicular phase (e.g., Manhem et al., 1991; Sato et al., 1995; Tersman et al., 1991), and others reporting greater reactivity during the follicular cycle phase (Miller and Sita, 1994). Still other studies reveal no evidence of cycle phase effects (Stoney et al., 1990; Weidner and Helmig, 1990).

Our ability to effectively draw conclusions from these discrepant findings is limited by methodological variations among studies. One such variant is the means by which cycle phase is determined. In some studies, cycle phase is estimated from a participant's subjective report of the first day of their last menses (Polefrone and Manuck, 1988). This calendar method is problematic given the inter- and intra-individual variability of follicular phase duration. Other studies assess cycle phase through measured progesterone and/or estrogen levels (Manhem et al., 1991; Miller and Sita, 1994; Pollard et al., 2007). Although very

☆ This research was carried out in the Lustyk Women's Health Lab at Seattle Pacific University: http://www.spu.edu/LustykLab.

* Corresponding author at: Seattle Pacific University, 3307 Third Ave. West, Suite 107, Seattle, WA 98119, United States. Tel.: +1 206 281 2893; fax: +1 206 281 2695.
E-mail addresses: klustyk@spu.edu (M. Kathleen B. Lustyk), kcosarah@spu.edu (K.C. Olson), winslow@spu.edu (W.G. Gerrish), holdea@spu.edu (A. Holder), lwidman@utk.edu (L. Widman).
[1] Tel.: +1 206 353 1393.
[2] Tel.: +1 206 281 2541.

0301-0511/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.biopsycho.2009.11.003

precise, this method is costly and has contributed to small sample sizes and reduced statistical power for assessing cycle phase effects.

Collective interpretation of results is also limited by inconsistent operational definitions and measurement of physiological and psychological responses to laboratory stressors in women. For example, when assessing physiological reactivity, some researchers use direct measures of heart rate (HR) and blood pressure (BP; Weidner and Helmig, 1990), while others use assessments of underlying hemodynamics (Sita and Miller, 1996) or HR variability (Sato et al., 1995) to operationally define reactivity. Neuroendocrine assessments also vary with some studies adding catecholamine changes to the operational definition of stress reactivity (Litschauer et al., 1998; Stoney et al., 1990), while others measure hypothalamic–pituitary–adrenal axis activity (HPAA) via changes in cortisol levels (Kirschbaum et al., 1999). Assessments of psychological responses to laboratory stressors are similarly inconsistent. For example, Miller and Sita (1994) included questionnaires to assess post-stressor state anxiety and anger reports, though much of the research in this area has neglected to assess this psychological response to a stressor.

A third problem that plagues research on reactivity to laboratory stressors is the varied nature and number of the stressor tasks employed. Laboratory stressors have included well-validated cognitive challenges (e.g., math calculations) and physical tasks (e.g., cold pressor test), but they have also included study-specific stressors with no known psychometric properties (Sato et al., 1995). Further, some researchers use only one stressor type repeated over multiple tests introducing the potential confound of habituation (Collins et al., 1985), while other researchers use multiple stressors (Miller and Sita, 1994). The varied nature of stressor tasks may explain why the literature to date does not evince clear cycle phase effects on psychophysiological or neuroendocrine responses to laboratory stressors; responses may be specific to the kind of stressor that is utilized (e.g., cognitive vs. physiological). Non-significant findings may be the result of an inadequate stressor task rather than non-reactivity. For example, recent evidence suggests that among the many acute psychological stressors utilized in research, those involving a motivated performance task characterized by an evaluative and/or uncontrollability component produce significant cortisol responses (Dickerson and Kemeny, 2004), and this HPAA responsivity may be affected by menstrual cycle phase (Kajantie and Phillips, 2006). However, systematic evaluations of this stressor-specific HPAA hypothesis in studies accounting for menstrual phase effects on stress reactivity and recovery in freely cycling women are scant.

Considering the aforementioned limitations, our purpose was to systematically investigate women's psychophysiological and neuroendocrine reactivity and physiological recovery during the follicular and luteal menstrual cycle phases using two well-validated and counterbalanced laboratory stressors of similar duration in a repeated measures design. Further, we used an endocrine assessment of ovulation to determine cycle phase, and tested enough healthy and freely cycling women to exceed power requirements. Given the equivocal findings reported in the extant literature, we did not test directional hypotheses but rather posited three research questions. First, in response to laboratory stressors, does psychophysiological reactivity measured by HR, BP, and state anxiety reports differ by cycle phase or stressor type? Second, in response to laboratory stressors, does neuroendocrine stress reactivity measured by salivary cortisol differ by cycle phase or stressor type? Third, after laboratory stressors, does HR and BP recovery differ by cycle phase or stressor type?

1. Method

1.1. Power analyses

Power analyses were performed with G-Power 3.0.3 (Faul et al., 2007). Given the inconsistent findings reported in the literature, we set our effect size input parameters as small-moderate with $f^2 = .15$, $\alpha = .05$, and $1 - \beta = .80$. For two groups and five repetitions (detailed below) a sample size of 56 was needed. For these same analyses with three repetitions for cortisol reactivity, the sample size needed to achieve the same power was 74.

1.2. Participants

Following approval from the University Institutional Review Board, participants were recruited via local advertisements. Eligible participants self-identified as: (a) 18–45 years of age (not premenarcheal or menopausal); (b) non-smokers; (c) not taking hormones, medications, or having undergone a medical procedure known to affect the natural menstrual cycle; (d) not pregnant, nursing, or amenorrheic and reported having a cycle length of 21–40 days; (e) not taking medications known to affect the stress response (including psychotropics); (f) free from chronic physical and mental health conditions (e.g., hypertension, known arrhythmias, obesity, major depression); (g) not wearing braces or dental apparatuses that might affect salivary sampling; (h) able to read and write English; and (i) able to come to our lab for two, one-hour research sessions. Interested participants were instructed to call our lab for screening, which involved confirming eligibility criteria and assessing if a traumatic event had occurred in the participants life in the past 2 months. Since upward of 10% of cycles may be anovulatory (Swain et al., 1974), we incorporated planned missingness strategies (Schafer and Olsen, 1998) into our study, which included pulsing our advertising throughout the study and screening continuously until our projected sample size was met. Participants were paid $75.00 for completing all parts of the study; otherwise, partial remuneration was issued commensurate with level of completion.

1.3. Apparatus and measures

1.3.1. Cardiovascular measures

BP was measured with an automatically inflated sphygmomanometer (Dinamap, 1846: Critikon, Inc., Tampa, FL). HR was continuously measured with electrocardiography via the online chart recorder system Powerlab (Powerlab 800; ADinstruments, Boulder, CO).

1.3.2. Salivary cortisol

HPAA reactivity was measured by salivary cortisol. Saliva samples were collected at three time points throughout the laboratory session (see Fig. 1 for timing) with a 10 mm × 37 mm cotton pledget (Salimetrics, LLC, State College, PA) following the collection advice offered by Salimetrics (2009a) and described by Granger et al. (2007). Samples were kept on ice throughout the laboratory session and subsequently frozen at −20 °C until shipped on dry ice via over-night mail to the Salimetrics Lab for assay. Samples were analyzed using high sensitivity enzyme immunoassay specifically designed and validated by Salimetrics for the quantitative measurement of salivary cortisol. The inter-assay coefficient of variation (CV) was 3.75–6.41%, the intra-assay CV was 2.9%, and the lower limit of sensitivity was <0.003 μg/dl for our samples.

1.3.3. State anxiety

To be consistent with other studies that measured psychological aspects of stress reactivity in response to laboratory or naturalistic stressors (e.g., Choi and Salmon, 1995; Dimitriev et al., 2008; Lewis et al., 2007; O'Donovan and Hughes, 2008; Renaud and Blondin, 1997; Summer et al., 1999), we employed a measure of state anxiety. Self-reported state anxiety was assessed pre and post stressor task via the state portion of the Spielberger State/Trait Anxiety Inventory (STAI-S; Spielberger et al., 1983). In completing this assessment, women rated their present moment feelings including tension, upset, and nervousness on a 4-point scale ranging from (1) *not at all* to (4) *very much so*. Spielberger et al. (1983) reported acceptable internal reliability for the state measure (alpha = .86–.95), and test–retest reliability coefficients for time intervals of one hour to 104 days that were moderate ($r = .16$–.62), as expected with transitory emotional states.

1.3.4. Demographic and health information

Participants provided information on their age, ethnicity, perceived cycle normality and length, cigarette and alcohol use, as well as height and weight for calculation of body mass index. Participants were also queried on their past and current level of regular physical activity and if they had ever received a diagnosis of premenstrual syndrome or premenstrual dysphoric disorder (PMS/PMDD). The US Public Health Service definition of regular physical activity was provided to participants, which states that people are regularly active if they do either of the following: (a) moderate-intensity activities for at least 30 min on at least five days of the week, or (b) vigorous-intensity activities for at least 20 min on at least three days of the week. Moderate-intensity physical activity includes such things as brisk walking (as if you are going some place, 3–4.5 mph or 14.3–20 min per mile), lawn