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The Influence of High Intensity Interval Training on the Salivary Cortisol Response to a Psychological Stressor and Mood State in Non-Sedentary College Students

Michael J. Ormsbee[1], Amber W. Kinsey[1], Minwook Chong[2], Heather S. Friedman[2], Tonya Dodge[2,3], and Patricia C. Fehling[2]

[1]Department of Nutrition, Food and Exercise Sciences, The Florida State University, Tallahassee, FL, [2]Health and Exercise Sciences Department, Skidmore College, Saratoga Springs, NY, USA; [3]Department of Psychology, The George Washington University, Washington, DC, USA.

ABSTRACT

Ormsbee MJ, Kinsey AW, Chong M, Friedman HS, Dodge T, Fehling PC. The Influence of High Intensity Interval Training on the Salivary Cortisol Response to a Psychological Stressor and Mood State in Non-Sedentary College Students. **JEPonline** 2013;16(1):105-116. High-intensity interval training (HIIT) has been reported to induce similar physiological adaptations associated with endurance training but in less time. However, the influence of short-term HIIT on salivary cortisol (in response to a psychological stress) and mood state has not been evaluated. The present study examined the effects of progressive HIIT (10 days of training over 2 wks, progressing from 0 to 8 HIIT intervals) on a cycle ergometer on salivary cortisol (in response to stress) and mood state. Twenty two, non-sedentary, college students were randomly assigned to either a HIIT group (n=12) or a no exercise control group (n=10). Psychological stress was induced by a public speaking task (5-min speech) before and after the training intervention. No significant changes in salivary cortisol concentrations (in response to the stressor) or mood state were present after progressive HIIT. Ten sessions of progressive HIIT is an insufficient amount of time to observe changes in salivary cortisol concentrations in response to psychological stress or mood state in non-sedentary, college students. Future studies should address different types of populations including sedentary and highly active individuals to understand if HIIT can effectively improve stress responses and mood state similarly to other types of training.

Key Words: Cycle Ergometer, Hypothalamic-Pituitary-Adrenal Axis

INTRODUCTION

Endurance exercise training is an effective intervention for improving autonomic function and hypothalamic-pituitary-adrenal (HPA) axis reactivity (27,31). High-intensity interval training (HIIT) has been reported to induce similar physiological adaptations associated with endurance training, but in less time (5,15,26). Previously, physiological improvements were observed after only six (4,15,17) or eight (24,26) days of HIIT. Gibala et al. (15) compared HIIT (4-6 x 30 sec 'all out' cycling sprints) to endurance training (90-120 min of cycling at 65% VO_2 peak) and reported similar training adaptations albeit total training time commitment for HIIT was ~7.5 hrs less than endurance training. While improvements in some performance variables have been observed with this type of training, the influence of short-term HIIT on salivary cortisol in response to a psychological stress and mood state have not been evaluated.

Cortisol is secreted in response to psychological and physiological stress. Maintaining physiologically relevant cortisol levels is important because chronically elevated cortisol levels, such as those in patients with Cushing's syndrome, have been reported to increase cardiovascular risk factors and negatively impact psychological state (3). Salivary cortisol correlates positively with serum cortisol (29) and is reported to increase following exposure to stressful social events (9,19,22). Moreover, in response to psychosocial stress endurance-trained men exhibited lower cortisol concentrations compared to untrained men, without any baseline differences between groups (31). While endurance training (31) has been shown to alter the cortisol response to stress the impact of the very popular HIIT style of training needs further evaluation. It is plausible that the short duration of HIIT compared to traditional type endurance exercise would allow for a relatively quick way for people under high-stress or experiencing acute high stress levels to alleviate some of the potential negative effects of elevated cortisol in the body and mind. However, the ability of HIIT to alter salivary cortisol concentrations in response to stress or mood state has not been investigated.

Exercise training, in general, has been shown to improve psychological mood state (8,27,31). For example, improved depression symptoms were reported in college-aged females with mild to moderate depression completing 50-min jogging sessions 5 $d \cdot wk^{-1}$ (27). Similarly, endurance trained men reported better mood and increased self-efficacy in response to stressor compared to their untrained counterparts (31). These data demonstrate that endurance exercise training improves mood state but whether HIIT elicits the same effect on mood state is unknown.

Therefore, the primary purpose of this study was to investigate the effect of progressive HIIT (10 days of training over 2 wks, progressing from 0 to 8 HIIT intervals) on salivary cortisol concentrations in response to psychological stress and mood state compared to a no exercise control (C) group. It was hypothesized that progressive HIIT would lead to reduced salivary cortisol concentrations in response to psychological stress and an improved mood state (i.e. increased feelings of vigor with decreased feelings of depression) compared to C.

METHODS

Subjects

Twenty-two healthy, non-sedentary (~600 $kcal \cdot d^{-1}$ expended with physical activity as determined by accelerometers for the duration of the study), college-aged subjects were randomly assigned to a HIIT group or (n = 12; 7 women, 5 men) or a no exercise control group (C; n = 10; 8 women, 2 men) (Table 1). The sample size was chosen from previously published work using interval training (15). A list of subject identification numbers (IDs) and conditions (HIIT vs. control) were randomly generated using the program randomizer.org prior to the start of the study. There were two versions of the consent form, one for the HIT group and one for the control group. A consent form that matched experimental condition was placed in a folder, and the folder was marked with a randomly generated ID. These folders were placed in the order that was randomly generated, and research assistants were instructed to pull the next available folder from the cabinet. Thus, when a subject arrived to the lab s/he would receive the next available randomly generated ID and condition. Research assistants were blind to experimental condition until subjects were presented with the consent form (which explicitly stated whether the participant would be part of the HIIT or control group). Furthermore, the research assistants for the HIIT group were different than the research assistants for the control group. Subjects were all naïve to HIIT prior to the study. Subjects were included if they were at least 18 yrs of age, had no known cardiorespiratory or metabolic conditions, were non-athletes, and had no injuries affecting their ability to exercise. This study was approved by the Skidmore College Institutional Review Board and all subjects completed an informed consent prior to participation. Subjects were required to attend 10 laboratory sessions within a 14-day period to be included. All testing was completed in a fasted state between 07:00-10:00 AM. The HIIT group reported to the human performance lab for all training sessions while the C group reported to the psychology lab to complete passive benign filler tasks (see intervention section for details) for the duration of the 10-day intervention (Figure 1). Laboratory time invested was matched between groups.

Table 1. Descriptive Data of the Subjects.

	HIIT N=12 (5 men)	Control N=10 (2 men)
Age (yrs)	19.3 ± 0.4	19.5 ± 0.4
Height (m)	1.67 ± 0.03	1.67 ± 0.02
Body Mass (kg)	66.3 ± 4.0	63.7 ± 7.2
Body fat (%)	21.8 ± 2.8	22.1 ± 2.9

Values are means ± SE. Abbreviations: HIIT, high intensity interval training group. p> 0.05 for all variables

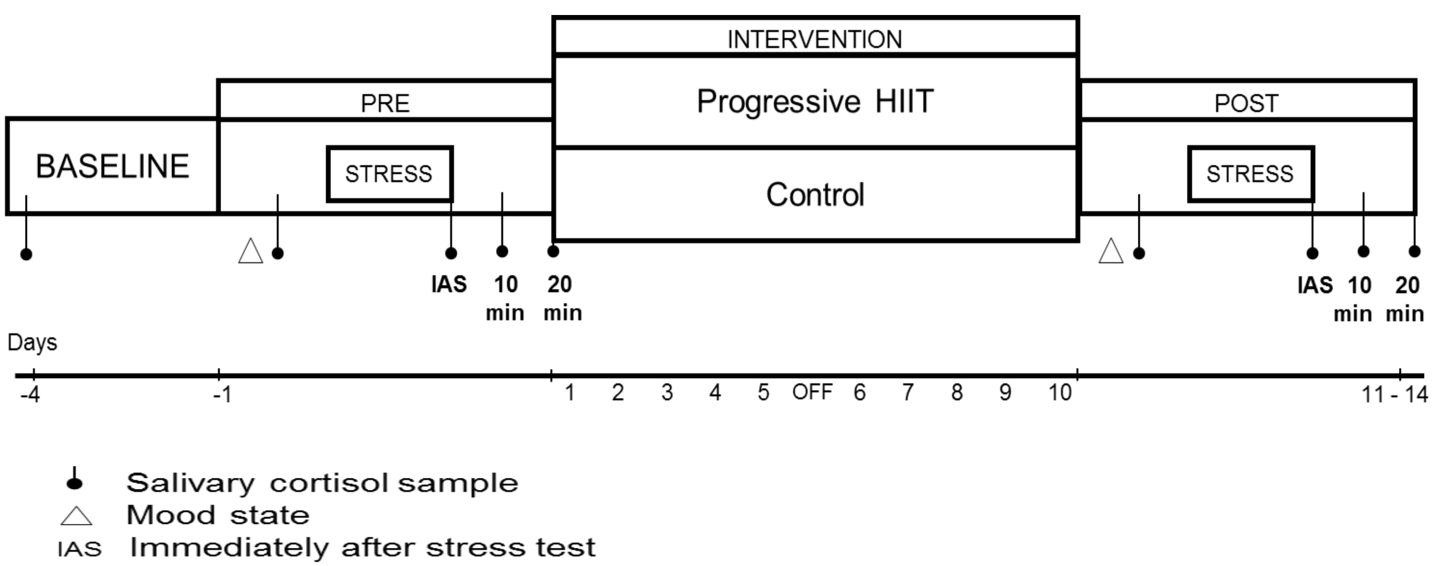

Figure 1. Experimental Design and Timeline. HIIT = high intensity interval training.

Procedures

Baseline

Height, mass, and body composition measurements were obtained using a calibrated stadiometer (QuickMedical, Issaquah, WA), digital scale (Befour Inc, Cedarburg, WI), and air-displacement plethysmography (Bod Pod, Concord, PA), respectively. Salivary cortisol was collected in a fasted state (see salivary cortisol collection and analysis).

Pre Intervention

Psychological Stress. To elicit psychological stress, the subjects were required to write and deliver a 5-min speech on eating behaviors among college students. Subjects were informed their speech would be video recorded and sent to experts in persuasive communication for evaluation. The speeches would be evaluated using the following dimensions: warmth, knowledge, defensiveness, logic, and clarity. The subjects were given 10 min to prepare the speech. The experimenter was in the room while the subjects delivered their speeches and a video camera was placed approximately 4 ft from the subjects. If the subjects finished speaking before 5 min was reached, they were informed that there was time remaining and prompted to continue speaking about the topic. This protocol is similar to other methods used to induce and assess psychological stress (1,11). Studies have demonstrated that socially-evaluative tasks like public speaking bring about psychological stress as demonstrated by changes in cortisol pre-post speech (1,11,12).

Salivary (Free) Cortisol Collection and Analysis. Salivary cortisol samples were collected at approximately the same time during baseline, pre-intervention, and post-intervention analyses. The subjects consumed water 10 min prior to sample collection to rid the mouth of food particulate. At collection time, Salimetrics™ oral cotton swabs were placed under the tongue for 2 min to ensure full saturation, then, immediately placed into swab collection tubes and placed on ice and stored at -80°C within 30 min as prescribed by the manufacture (Salimetrics™, State College, PA). Saliva collection via cotton swabs has been illustrated as a reliable technique for predicting total and free serum cortisol concentrations compared to collection via passive drooling (28), and it is more convenient for handling. Salivary cortisol was collected a total of 9 times: at baseline (n = 1), pre-intervention (n = 4) and post-intervention (n = 4). The four salivary cortisol collections pre- and post-intervention were obtained prior to heart rate variability and taken immediately, 10 and 20 min after the psychological stress task. Cortisol assays were performed on all samples at the conclusion of the study for batch analysis to limit day-to-day assay variability. Samples were thawed and centrifuged (Hettich Rotina 46R5, Buckinghamshire, England) at 3000 rpm for 15 min to extract the saliva from the collection tubes. Cortisol was measured in duplicate using an enzyme linked immunosorbent assay (ELISA) kit according to the manufacturer's instructions (Salimetrics™, State College, PA, United States; sensitivity 0.003 $\mu g \cdot dL^{-1}$) using a standard plate reader (BioRad 680, Hercules, CA). Intra-assay coefficient of variation was 3.46%.

Mood State. Mood state was evaluated with the Positive and Negative Affect Scale (PANAS); a 20-item self-report measure of positive and negative affect (32) and this measure has been used with college samples (7,14,32). Both positive and negative affect were assessed with 10-items each. Positive items included: interested, excited, strong, enthusiastic, proud, alert, attentive, inspired, determined, and active. Negative items included: distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery, and afraid. The subjects were asked to report the extent to which they felt each way in the past 2 wks on a 5-point scale with 1 representing "very slightly or not at all" and 5 representing "extremely." The ability for the PANAS to indicate changes in mood state over 2 wks was specifically chosen in order to detect changes in mood as a result of the HIIT intervention and not only the last exercise bout. The PANAS was completed prior to first cortisol sample.

High Intensity Interval Training (HIIT). The 10 exercise sessions were completed on a Monark cycle ergometer (Denmark, Sweden). Target heart rates to meet the exercise training intensity were determined using the Karvonen method: Heart rate reserve (HRR) = [(HR max – HR rest) x % training intensity] + HR rest (2), where HR max = 220 - age (Table 2). Heart rate was measured using a Polar FS1 Heart Rate Monitor (New York, United States) and recorded every 2 min to ensure intensity was properly maintained. The resistance on the cycle ergometer was self-selected but was adjusted to a resistance that would enable the subjects to meet and maintain their target heart rate ranges. The first, 5 days of the progressive HIIT consisted of up to three, 30-sec cycling bouts at >90% HRR during a 30-min ride at 60-85% of HRR. The second 5 days of progressive HIIT consisted of 8, 30-sec cycling bouts at >90% HRR alternated with 2 min of active recovery for a total of 20 min of cycling (a 5-min cool-down period was allowed). This protocol was designed to progressively allow subjects to become accustomed to the HIIT training in order to avoid injury and maintain retention and compliance. The subjects were allowed 1 day of rest following the first, 5 days of training. During all training sessions, technicians provided water ad libitum, and consistent verbal encouragement and music in order to bring about the necessary heart rate response.

Table 2. Exercise Training Protocol.

Day	High Intensity Interval Training (HIIT)	HIIT interval Target Heart Rate as a Percent of Heart Rate Reserve (THR)	Recovery THR
1	0	> 90 %	60 – 70 %
2	2		60 – 70 %
3	2		70 – 80 %
4	2		70 – 80 %
5	3		70 – 85 %
	OFF		
6	8	> 90 %	50 - 60 %
7	8		
8	8		
9	8		
10	8		

Control. The C group maintained normal lifestyle but refrained from planned physical activity for the duration of the study, which was monitored by Acticals physical activity monitors (see section below). The subjects reported to the PL to complete benign filler tasks, consisting of questionnaires, word finds, Sudoku games and evaluating and reading passages, to match the laboratory time invested by the HIIT group as well as to prevent boredom and fatigue.

Post Intervention
Approximately 12-48 hrs following the last day of the intervention all pre-intervention procedures with a new speech topic were repeated for post-intervention testing.

***Dietary Recall and Physical Activity*.** Nutritional intake was assessed with a 3-day dietary recall for the first, 3 days prior to and during the last 3 days of the intervention. All dietary analyses were performed by the same laboratory technician using Food Processor version 10.6 (ESHA Research, Salem, OR). In addition to the dietary recall, all subjects were fitted with an Actical physical activity monitor (Actical®, Philips Respironics, Bend, Oregon) to measure physical activity at baseline and throughout the duration of the intervention. The Actical is a small (29 mm x 27 mm x 11mm) device that quantifies whole body movements. It was worn on the hip, and its validity has been established (13,16). All subjects were instructed to refrain from exercise during the intervention, with the exception of the training sessions for the HIIT group and the Actical was used to ensure compliance. Actical data was downloaded on the off day of the intervention for both groups and compliance to the exercise guidelines were met in the C group if activity was less than or equal to baseline. For the HIIT group compliance was met if activity was equal to baseline since there is minimal whole body movement during stationary cycling.

Statistical Analyses
Repeated measures analysis of variance was used to analyze within and between group differences between all variables with group (HIIT vs. C) and time (baseline, pre, and post for salivary cortisol; pre vs. post for mood state) as factors. When necessary, a Tukey post-hoc analysis was used to determine where significance was located. All statistics were analyzed using SPSS version 18.0 (SPSS Inc., Chicago, IL). Significance was set at P<0.05 and all values are reported as means ± standard error, unless otherwise noted.

RESULTS
Salivary Cortisol. Salivary cortisol data are presented in Table 3. Statistical analysis revealed no difference for cortisol concentrations measured immediately, 10 and 20 min after the psychological stress task. Therefore, these three time points were averaged to yield one sample (AST, after stress test) both before and after the intervention period. There was no significant group or group x time interaction observed, however, there was a significant main effect of time (P=0.0002) with preintervention AST being significantly lower than baseline.

Table 3. Salivary Cortisol Concentrations.

	Baseline	Pre Intervention		Post Intervention	
		BST	AST	BST	AST
HIIT ($\mu g \cdot dL^{-1}$)	0.78 ± 0.32	0.64 ± 0.31	0.39 ± 0.14*	0.74 ± 0.36	0.49 ± 0.19
Control ($\mu g \cdot dL^{-1}$)	0.82 ± 0.27	0.55 ± 0.17	0.57 ± 0.23	0.76 ± 0.40	0.65 ± 0.34

Values are mean ± SD; Abbreviations: BST, before stress test; AST, after stress test (average of immediate, 10-min, and 20-min post-exercise); Main time effect of P=0.0002 was observed for pre intervention compared to baseline. *, P<0.05 compared to baseline salivary cortisol concentrations.

Mood State. Mood did not change among or between groups as a result of HIIT training (P>0.05; Table 4).

Table 4. Positive and Negative Affect Scores (PANAS).

	Positive Affect		Negative affect	
	HIIT	Control	HIIT	Control
Pre Intervention	3.2 ± 0.2	3.5 ± 0.1	2.5 ± 0.1	2.3 ± 0.2
Post Intervention	3.0 ± 0.2	3.2 ± 0.2	2.3 ± 0.2	2.1 ± 0.2

Values are means ± SE; Abbreviations: HIIT, high-intensity interval training group; P>0.05 for all variables.

Dietary Recall and Physical Activity. Macronutrient intake remained unchanged from baseline to the end of the intervention among and between groups (Table 5; P>0.05). Analysis was unable to be completed on three subjects (HIIT, n=1; C, n=2) due to lack of information on the dietary recall. Energy expenditure (EE) as a direct result of physical activity was not different between groups at baseline (P=0.46). For the HIIT group, there were no significant differences in EE from baseline to the end of the intervention (baseline, 505.8 ± 75.5 $kcal \cdot d^{-1}$; end of intervention, 554.2 ± 75.9 $kcal \cdot d^{-1}$; P=0.49; data not shown). Although not statistically significant P=0.054), there was a decline in physical activity in the C group from baseline to the end of the intervention (baseline, 622.3 ± 140.5 $kcal \cdot d^{-1}$; end of intervention, 354.2 ± 51.7 $kcal \cdot d^{-1}$). Between groups, as expected, EE was significantly greater in HIIT compared to C during the intervention (HIIT, 554.2 ± 75.9 $kcal \cdot d^{-1}$; C, 354.2 ± 51.7 $kcal \cdot d^{-1}$; P=0.048). Physical activity data for three participants (HIIT, n=2; C, n=1) were unable to be analyzed.

Table 5. Macronutrient Composition by Group

	HIIT	Control
Protein (g)		
Baseline	109.5 ± 9.1	94.5 ± 12.0
End of Intervention	104.4 ± 20.9	163.4 ± 10.8
Carbohydrate (g)		
Baseline	335.4 ± 83.1	337.5 ± 27.9
End of Intervention	364.0 ± 10.5	378.9 ± 48.7
Fat (g)		
Baseline	78.4 ± 9.2	85.7 ± 10.6
End of Intervention	85.1 ± 10.5	73.4 ± 12.3
Total ($kcal \cdot d^{-1}$)		
Baseline	2485.2 ± 173.3	2449.3 ± 191.9
End of Intervention	2639.5 ± 12.1	2829.8 ± 327.2

Values are mean ± SE and based off of 3-day dietary recall at baseline and at the end of the intervention. Abbreviations: HIIT, high-intensity interval training group. P>0.05 for all variables.

DISCUSSION

Previous research has shown that in college-aged individuals endurance training results in lower cortisol concentrations in response to psychosocial stress (31), and can improve mood state (8,27). Interestingly, HIIT has been reported to induce similar skeletal muscle (i.e., oxidative capacity) and exercise performance (i.e., time trial) adaptations to endurance training (5,15,26). It remains unknown, however, whether HIIT elicits the same effect as endurance exercise with respect to cortisol concentrations and psychological mood state. Therefore, the purpose of the present study was to determine if progressive HIIT over 2 wks could elicit alterations in cortisol concentrations in response to a psychological stressor and improvements in mood state. Our data indicate that 10 sessions of progressive HIIT performed over 2 wks was safe (no health or safety complications), but does not influence salivary cortisol concentrations in response to psychological stressor or mood state in non-sedentary, college-aged men and women.

Salivary Cortisol in Response to Stress

Salivary cortisol concentrations in response to a psychological stressor did not change after 10 sessions of progressive HIIT in the present study (Table 3). Kirschbaum et al. (20,22) and others (9,19) have demonstrated elevations in salivary cortisol in response to psychological stress. Johansson et al. (18) measured plasma cortisol levels in male students before and after a medical examination. Compared to control values taken on separate days before the start of the study, cortisol was elevated immediately prior to the start of the medical examination and remained elevated thereafter. However, blunted salivary cortisol concentrations have been observed in exercise trained individuals in response to psychological stressors compared to their untrained counterparts (30,31). The subjects in the present study were non-sedentary and expended roughly 600 $kcal \cdot d^{-1}$ from physical activity, which may have attenuated a larger response that may have been observed with sedentary people. In addition, it is possible that the intermittent nature of HIIT results in a different HPA response than traditional endurance exercise. We recognize that the majority of our subjects were women (n=15 of 22) and that menstrual cycle phase, oral contraceptive use, and gender were not accounted for and may have played a role in HPA axis reactivity (10,20,21). Unfortunately, our small sample size precluded analysis based upon gender and future studies must address this issue.

Mood State Response

Moderate intensity endurance exercise has been demonstrated to improve mood state (8,27). However, the effect of progressive HIIT on mood state has not been reported. In the present study, mood state was unaffected by our progressive HIIT intervention. It is likely that the short duration of our training program or the timing of PANAS administration may have influenced the results. While the PANAS questionnaire was administered within approximately 24 hrs post-training, our range of time to administer was 12-48 hrs after the intervention. Others have observed significant differences when mood state questionnaires were administered during or immediately after an acute bout of exercise (23,33). However, the PANAS is designed to take into account the previous 2 wks rather than just the previous few hours. Therefore, because our exercise duration was 10 days in length, we used the PANAS to reflect measures of mood state over the duration of the study rather than the last exercise bout.

Limitations

Several limitations exist and need to be addressed, which may have introduced a type-II error into our findings. Traditionally, HIIT is defined as 4-6, 30-sec maximal intensity sprints separated by 4-min of rest between each bout (15). Unfortunately, HIIT is quantified via different methods in published trials and each study uses various durations (e.g., 30 sec vs. 1 min) and individual intensity protocols (e.g., heart rate vs. watts) for HIIT (17,25). This complicates comparing our results to other published findings in this area. It is also possible that the psychological stressor was not a true stressor to some individuals who may have enjoyed public speaking tasks. However, previous studies have reported using this technique with success (1,11,12). We also did not measure heart rate during the benign filler tasks for the control group, although the tasks involved seated, quiet, reading and writing tasks. Subjects in the present study were expending ~600 $kcal \cdot d^{-1}$ based upon physical activity energy expenditure recorded prior to the intervention and all subjects were unfamiliar to HIIT training. Therefore, we believe that our results do reflect accurate physiological changes due to our protocol.

CONCLUSIONS

Ten sessions of progressive HIIT (0 to 8 intervals/session) on a cycle ergometer is an insufficient amount of time to observe changes in salivary cortisol concentrations in response to psychological stress or mood state in non-sedentary, college-aged, men and women. HIIT has clearly been shown to alter physiological processes similarly to traditional endurance exercise (5,15,26). However, the scope of the hormonal and psychological changes that may arise from HIIT are not well understood. Due to the popularity of HIIT, more research in this area is warranted. Future studies should address different types of populations including sedentary and highly active individuals to understand if HIIT can effectively improve stress responses and mood state similarly to other types of training.

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Address for correspondence: Michael J. Ormsbee, Department of Nutrition, Food, and Exercise Sciences, Florida State University, Tallahassee, FL 32306-1493. Phone (850)-644-4793. Fax (850)-645-5000, Email: mormsbee@fsu.edu

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