Physiology & Behavior xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Physiology & Behavior

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

Female breakfast skippers display a disrupted cortisol rhythm and elevated blood pressure

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HIGHLIGHTS

- Breakfast skipping is associated with increased concentrations of free cortisol.
- Chronic breakfast skippers also displayed elevations in blood pressure.
- Changes in cortisol metabolism may lead to deleterious metabolic outcomes.

ARTICLE INFO

Article history:
Received 15 September 2014
Received in revised form 12 December 2014
Accepted 24 December 2014
Available online xxxx

Keywords:
Cortisol
Breakfast skipping
Blood pressure
Cardiometabolic health

ABSTRACT

Chronic stress and over-activity in the hypothalamic–pituitary–adrenal (HPA) axis may link breakfast skipping and poor cardiometabolic health. Missing the first major meal of the day in rodents prolongs elevated circulating corticosterone at a time when it's normally decreasing. To extend these findings to humans, we hypothesized that habitual breakfast skippers would display a similar pattern of circulating cortisol and alterations in meal and stress-induced cortisol reactions. Normal weight to obese women aged 18–45 years old who were strictly defined as either breakfast skippers ($n = 30$) or breakfast eaters ($n = 35$) were invited to participate in our study. Normal breakfast habits were maintained for the entire study period and each participant attended 4 lab visits. Over the first 2 lab visits, body composition, fasting clinical chemistries, and self-reports of chronic stress were assessed. On each of 2 additional days (lab visits 3 and 4), salivary free cortisol was measured at home upon waking and at bedtime, and in the lab in response to a standard lunch, ad libitum afternoon snack buffet, and stress and control (relaxation) tasks. The order of the control and stress test visits was randomized. While body weight, body composition, HOMA-IR, total and HDL cholesterol did not statistically differ ($p > 0.05$), both diastolic and systolic blood pressure was elevated ($p < 0.01$) and LDL cholesterol was lower ($p = 0.04$) in the breakfast skipper group. Compared to the breakfast eaters and on the control task visit only, breakfast skippers had higher circulating cortisol from arrival to midafternoon ($p < 0.01$) and during the snack buffet ($p < 0.05$). Furthermore, the lunch-induced cortisol reaction was larger in the 'skippers' ($p = 0.03$). On both stress and control visit days, the diurnal cortisol amplitude was significantly ($p = 0.02$) blunted in breakfast skippers. Self-reports of chronic stress did not differ between the groups. These data indicate that habitually skipping breakfast is associated with stress-independent over-activity in the HPA axis which, if prolonged, may increase risk (e.g., hypertension) for cardiometabolic disease in some people.

1. Introduction

Breakfast skipping is prevalent and occurs regularly in 20% of US adults [1]. Among young men, minorities and the economically disadvantaged, this phenomenon is even higher [2,3]. Habitual breakfast skipping may be detrimental to health [4] and has been linked to elevated blood pressure [5], insulin resistance [6], and dyslipidemia [7]. While associations between breakfast skipping and BMI, or increased energy intake have been reported [1,8–10], recent evidence disputes these claims [11,12]. Differences in the physiological response to skipping breakfast may explain the apparent discrepancies. However, a physiological basis connecting regular breakfast skipping and poor metabolic health is unclear. Given the negative effects of chronically elevated cortisol on metabolic health [13–16], cortisol increases in response to skipping breakfast may, over time, promote risk for metabolic dysfunction. Persistent increases in cortisol are linked to

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http://dx.doi.org/10.1016/j.physbeh.2014.12.044
0031-9384/

hyperglycemia [17], insulin resistance [15], abdominal obesity [18], and high blood pressure [19].

In one of the few human studies looking at the frequency of breakfast intake and circulating cortisol concentrations, individuals eating breakfast every day had lower daytime mean salivary cortisol than those individuals who never ate breakfast [20]. In another study, breakfast skipping accounted for 22% of the inverse association between socioeconomic status and salivary cortisol [21]. In rodents, preventing consumption of the first meal of the day (lights off) significantly elevates corticosterone, which resolves when the animals are allowed to eat [22]. This phenomenon has not been well documented in humans.

We hypothesized that self-reported breakfast skippers would have elevated circulating cortisol, particularly during the morning and up until lunch. Secondly, we hypothesized cardiometabolic disease risk factors including insulin sensitivity, lipid profile, waist to hip circumference, and blood pressure will be higher in breakfast skippers, relative to breakfast eaters. Thirdly, we hypothesized that ongoing (chronic) stress may be more prominent in breakfast skippers and may contribute to elevated cortisol.

2. Materials and methods

2.1. Participants and recruitment

The Institutional Review Board at the University of California, Davis, approved the protocol. Based on the following criteria, women were invited to participate in a cross sectional observational study. Participants were premenopausal aged 18 to 45 years with a BMI of less than 40 kg/m^2, weight stable, maintained a typical diurnal schedule and were classified as either being "breakfast eaters" or "breakfast skippers." A breakfast eater was defined as someone who consumed at least 15% of their estimated total daily energy needs in solid food between the hours of 4 am and 10 am, at least 6 days per week. A breakfast skipper was defined as someone who did not eat any solid food between the hours of 4 am and 10 am at least 4 days per week. Breakfast consumption is poorly defined in the literature therefore a strict set of criteria was developed to clearly separate the "skipper" group from the "eater" group [23–26]. A registered dietitian confirmed breakfast eating status using 3, 24-hour recalls administered over the phone. Women were excluded if they used tobacco or chronic medications outside of oral contraceptives, were pregnant or lactating, or had a current diagnosis of any endocrine, metabolic or digestive disorders. Women were also excluded if they reported any past or current diagnosis of adrenal or pituitary specific disorders.

2.2. Experimental procedures

Eligible women were invited to participate in 4 visits at the Western Human Nutrition Research Center. At the first visit, a fasting blood sample was collected using standard phlebotomy, and height, weight and blood pressure were collected. Approximately 2 weeks later at visit 2, height and weight measurements were repeated and body composition was measured. Subjects were also instructed on proper technique for saliva collection before completing several questionnaires related to stress and eating behavior. At the final two visits, which occurred approximately two months after visit 1, volunteers participated in 6-hour lab protocols. These visits included a standard lunch which was designed to provide 35% of daily energy needs for each subject; an afternoon snack buffet and either a validated social stress test designed to elicit a cortisol response, or a similarly timed period of relaxation that functioned as control to the social stress test (Table 1). For the final two visits, order was randomized and each volunteer participated in both control and stress visits. Menstrual cycle was tracked throughout the study because cycle phase has been shown to affect the cortisol response to a stressor [27]. When possible, subjects participated in visits 3 and 4 during the follicular phase of their cycle.

Table 1
Test day[a] timeline schematic for a protocol administered twice[b] to a group of breakfast eaters and a group of breakfast skippers.

Time	Saliva	Meals	Task
Waking	✓		
Waking + 30 min	✓		
Variable		Maintain usual breakfast habit	
1200 h	✓		POMS
1230 h	✓		
1235 h–1250 h		Standard lunch[c]	
1315 h	✓		
1330 h	✓		PSS
1400 h	✓		POMS
1450 h	✓		
1500 h–1520 h			TSST or Control
1525 h	✓		POMS
1555 h	✓		
1600–1630 h		Snack buffet	
1630 h	✓		POMS
1700 h	✓		
Variable		Maintain usual dinner/snack habit[c]	
Bedtime	✓		

[a] The time interval between the first visit and the TSST or the Control test day visit was 60 days.
[b] The two test day visits varied only in the type of task administered at 1500 h. Subjects were randomized to receive either the TSST or the control relaxation task first and a cross-over design was implemented.
[c] Lunch menu items included a cheese quesadilla (full fat cheese, low fat cheese, tortilla), potato chips, canned peaches, maraschino cherries, tomato salsa and water; TERTER was determined using the Dietary Reference Intakes for adult women with a sedentary physical activity level assumed. Test meal energy and macronutrient composition were adjusted in 100 kilocalorie increments and consisted of 55% kcal from carbohydrates, 15% kcal from protein, and 30% kcal from fat. PSS, Perceived Stress Scale; POMS Profile of Mood States; TER Total Energy Requirement; TSST Trier Social Stress Test.

2.2.1. Blood pressure

Diastolic and systolic blood pressure was measured twice, 1 min apart, using the automated Dinamap 1846 (Critikon/GE). Measurements were taken after a 5-minute rest period, on the non-dominant arm while participants were seated.

2.2.2. Anthropometry and body composition

Height and weight were measured using a wall mounted stadiometer (Ayrton Stadiometer model S100; Prior Lake, MN) and an electronic scale (Scale-tronic model 6002; Wheaton, IL), respectively. Body mass index was calculated as kg/m^2. Hip and waist circumference was measured in the standing position against bare skin with the abdomen relaxed and the arms hanging at the sides using a spring-loaded non-metallic tape. Hip circumference was measured at the maximum protuberance of the buttocks while waist circumference was measured midway between the lateral lower rib margin and the iliac crest. Total fat mass and percent of total body lean and fat mass were assessed using air-displacement plethysomography by the Bod-Pod (Life Measurement Systems; Concord CA) with participants wearing tight fitting clothing and a swim cap.

2.2.3. Questionnaires

The Perceived Stress Scale (PSS) and the Wheaton Chronic Stress Inventory (WCS) were used to quantify the magnitude of chronic stress and loss of control experienced outside of the lab (e.g., at work and home) while the Profile of Mood States (POMS) was used to capture acute changes in mood and perceived stress at 4 times during the social stress test and the control day visit (Table 2) [28–30]. The PSS is a 10-item questionnaire designed to assess the frequency (from "never" to "very often") of various general stressful experiences over the previous month period. The WCS Inventory evaluates the presence of specific, personal, financial and work-related stressors using a 3 point scale (from "not at all true" to "very true") for 51 items. The POMS questionnaires use 65 unique terms defining an emotional, or emotion related

Please cite this article as: M. Witbracht, et al., Female breakfast skippers display a disrupted cortisol rhythm and elevated blood pressure, Physiol Behav (2014), http://dx.doi.org/10.1016/j.physbeh.2014.12.044