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Research report

Two-day fasting evokes stress, but does not affect mood, brain activity, cognitive, psychomotor, and motor performance in overweight women

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ABSTRACT

The physiological, cognitive state, and motor behavior changes that occur during acute fasting are not completely understood. Thus, the aim of this study was to estimate the effect of 2-day total fasting on evoked stress, mood, brain activity, and cognitive, psychomotor, and motor function in overweight women. Eleven overweight women (body mass index above 25 kg/m^2) aged 20–30 years were tested under two conditions allocated randomly: 2-day zero-calorie diet with water provided *ad libitum* and 2-day usual diet. One week before the experiment, aerobic fitness was evaluated. Subjective stress ratings in relation to the diet, autonomic function, prefrontal cortex activity, cognitive performance, psychomotor coordination, and grip strength were evaluated before and after each diet. The study demonstrated that fasting decreased log-transformed high-frequency (HF) power, without affecting heart rate. The relative maximum oxygen uptake was negatively correlated with subjective stress rating and changes in log-transformed HF. Fasting did not affect mood, brain activity, and cognitive, motor, and psychomotor performance. Thus, 2-day total fasting evoked moderate stress with a shift of the autonomic nervous system balance toward sympathetic activity in overweight women. Better aerobic endurance is likely to facilitate the capacity for dealing with acute fasting. Regardless of the evoked stress, cognitive state and motor behavior remained intact.

1. Introduction

With an increasing prevalence of excessive weight and obesity worldwide, researchers have been focusing on the development of effective and safe weight-loss methods [1–3]. Recently, 5:2 intermittent fasting has been popularized, in which a very-low-calorie diet is allowed 2 days a week and “normal” eating is resumed on non-diet days [2]. However, individuals may find it easier to follow a diet with no calorie counting and may choose a zero-calorie diet with water provided ad libitum [4]. Moreover, under the conditions of a zero-calorie diet, more ketones are produced in response to a lower glucose level [5] and greater energy restriction [6]; increased ketosis can burn stored fat to a greater extent, to produce the energy needed by the brain [7,8] and muscles [8]. Nevertheless, it has been suggested that a critical transition period of 3–6 weeks during which the brain adapts to intermittent fasting is needed [9], and the responses to acute 2-day fasting are not well understood [10–13].

Limited and equivocal information is available regarding the effect of acute short-duration fasting on cognitive state. There is evidence of adverse effects [13,14] or no effects [10] of total or near-total calorie deprivation on mood state. We are not aware of any previous studies on the effect of acute fasting on mood state in overweight individuals. However, it has been established that appetite sensations, such as a feeling of fullness and hunger, are associated with a dysphoric mood [13,15]. A recent study reported by Huh et al. [16] observed that a higher body mass index (BMI) is positively associated with perceived hunger. Thus, it might be expected that a 2-day zero-calorie diet would adversely affect the mood state in overweight individuals.

Contradictory results regarding cognitive performance have also been reported, which showed deteriorated [17], unaffected [10,18], or even improved cognition [13] in response total or near-total calorie deprivation. In addition, Chechko et al. [19] observed that overnight fasting can decrease performance-associated brain activity even in the absence of differences in cognitive performance. The relationship between stress intensity and cognitive performance following an inverted U-shaped curve has been well established [20,21]. Moreover, higher perceived hunger is positively associated with perceived stress [16,22], and obesity is associated with an altered autonomic nervous system response showing sympathetic dominance [23]. We are not aware of any previous studies of the effect of an acute 2-day zero-calorie diet on cognitive performance and associated brain activity in overweight individuals; however, it can be expected that a greater increase in hunger

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perception would evoke greater subjective and physiological stress responses, which would shift cognitive performance to the far end of inverted U-shaped curve. Consequently, it would deteriorate the performance of most stress-sensitive prefrontal cortex (PFC) functioning-related tasks (*i.e.*, mental flexibility, inhibitory control, and working memory) [24,20,13] and decrease PFC activity in overweight individuals.

It is worth mentioning that the PFC has connections with the motor cortices [20]. Recent studies have shown that mental fatigue after the performance of prolonged cognitively demanding tasks deteriorates psychomotor function, as indicated by slowed fast and accurate reaching movement performance [25]; however, maximal force production capacity [26] and corticospinal excitability were not altered [25]. Accordingly, fasting studies showed that the two-finger tapping rate, as a measure of psychomotor speed, was decreased after 1-day fasting [27,18], and that grip strength, as a predictor of total muscle strength, was not affected by 3-day fasting [28,29]. Furthermore, it has been suggested that stress can modulate motor system function. It reduces skilled movement accuracy in reaching and walking [30,31] and decreases muscle endurance [32]. Moreover, a recent study by Mehta [32] observed that motor function deterioration is accelerated in obese individuals. Thus, it can be expected that acute-fasting-evoked stress and cognitive degradation would adversely affect psychomotor task performance, whereas grip strength capacity would not be altered.

It is well known that dieting is a more common practice among women than men [2]. Thus, the aim of the present study was to estimate the effect of a 2-day zero-calorie diet with water provided ad libitum on physiological and subjective stress responses, mood state, cognition-related brain activity, and cognitive, psychomotor, and motor function in overweight women. There is also a need to identify specific ways of increasing stress resilience and tolerability in acute 2-day fasting for overweight individuals. Recent studies have shown that regular physical activity and a greater aerobic fitness level may decrease stress levels [33–36]. However, to the best of our knowledge, no studies of fasting have considered this; therefore, we deemed it important to evaluate the relationship between the aerobic fitness level and fasting-evoked stress responses.

2. Materials and methods

2.1. Participants

Twenty-one women were assessed for eligibility. The inclusion criteria were as follows: women with a BMI greater than 25 kg/m^2, aged 20–30 years, and not pregnant and not undergoing lactation. Participants were excluded if they smoked; were in a weight reduction program; were involved in excessive regular moderate or vigorous physical activity, *i.e.*, ≥3 times per week; had a history of chronic disease; had irregular menses; or used medications regularly (including oral contraceptives) that might affect experimental variables. In total, 11 women aged 24.3 ± 3.3 years with a BMI in the overweight range (from 25.0 to 29.9 kg/m^2) met the inclusion criteria and agreed to participate in this study. Participants were not engaged in any physical exercise or sports program. Their physical characteristics are presented in Table 1. All participants had normal or corrected-to-normal vision and were right-handed as determined by the Edinburgh Handedness Inventory [37]. Written informed consent was obtained from all participants. All procedures were approved by the Human Research Ethics Committee and were conducted according to the guidelines of the Declaration of Helsinki.

2.2. Experimental procedures

The volunteers were familiarized with the procedures over 3 days. One week before the experiment, all women attended a familiarization session during which they were introduced to the experimental measurements for cognitive, psychomotor, and motor function evaluation. On each day, the participants performed the cognitive and psychomotor tasks, and on day 3 they learned to achieve and maintain a maximal voluntary handgrip contraction, and their physical fitness was assessed.

Table 1
The effect of 2-day diets on the anthropometric characteristics and glucose level.

	Fed state		Fasting state	
	Before	After	Before	After
Mass, kg [a, b, axb]	80.1 (8.0)	80.1 (7.8)	80.3 (7.8)	78. (7.7)[*, #]
BMI, kg/m^2 [a, b, axb]	27.2 (2.5)	27.4 (2.2)	27.5 (2.2)	26.7 (2.2)[*, #]
Glucose, mmol/l [a, b, axb]	5.51 (0.65)	5.38 (0.45)	5.36 (0.53)	4.37 (0.47)[*, #]

Data are presented as mean (standard deviation). BMI, body mass index.
[a] P < 0.05, time effect.
[b] P < 0.05, state effect.
[axb] P < 0.05, time × state interaction effect.
[*] P < 0.05, compared with before fasting.
[#] P < 0.05, compared with fed state.

The study consisted of two experimental parts. Women participated in both a 2-day fasting and a 2-day feeding study in a randomized fashion. Before the start of each part, the participants were instructed to sleep for at least 7 h the night before the experiment and to refrain from intense physical and mental work for at least 24 h and from ingesting alcoholic beverages, caffeine, and sedating antihistamines for at least 48 h before the experimental measurements. Both experimental parts were separated from one another, and all women were tested during the two early follicular phases (days 3–5) of their menstrual cycle. To control for circadian and diurnal rhythm, both experiments began at 8:00 a.m [38]. The participant arrived at the laboratory after overnight fasting (8–10 h), to complete baseline measurements. Upon arrival at the laboratory, anthropometric measurements were performed. The participant was then asked to rest in a sitting position for 15 min. The autonomic nervous system response and resting PFC activity were recorded during the last 5 min of the resting period. Subsequently, a measurement of blood glucose level was performed and the participants rated their current mood and appetite sensations. The participant was then seated at a table, cognitive testing was performed, and PFC activity during cognitive tasks was recorded. Subsequently, a psychomotor task and three attempts of maximal voluntary handgrip contraction interspaced with a 1 min rest interval were performed. The best of three attempts was recorded. The participants then rested 1 day before starting the 2-day zero-calorie diet with water provided *ad libitum* or the 2-day usual diet. During the usual diet, participants were requested to make no changes in their daily diet. Both diets were followed by the performance of experimental measurements in the same order as that described for the period before dieting. In addition, the participants were asked to rate perceived stress level in relation to the diet.

2.3. Experimental measurements

2.3.1. Anthropometric measurements

The participant's weight (TBF-300 body composition scale, Tanita, UK) and height (Leicester Height Metre; Invicta Plastics, UK) were estimated while the subjects were wearing only underwear and barefoot. BMI was calculated as body weight in kilograms divided by squared height in meters.

2.3.2. Measurement of aerobic fitness

Aerobic fitness was assessed by a ramp incremental exercise test on an electronically braked cycle ergometer (Ergometrics-800s, Ergoline Medical Measurement Systems, Germany). Standardized verbal encouragement was provided throughout the test to stimulate maximal