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Review

Relationship between stress, eating behavior, and obesity

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Abstract Stress is thought to influence human eating behavior and has been examined in animal and human studies. Our understanding of the stress-eating relation is confounded by limitations inherent in the study designs; however, we can make some tentative conclusions that support the notion that stress can influence eating patterns in humans. Stress appears to alter overall food intake in two ways, resulting in under- or overeating, which may be influenced by stressor severity. Chronic life stress seems to be associated with a greater preference for energy- and nutrient-dense foods, namely those that are high in sugar and fat. Evidence from longitudinal studies suggests that chronic life stress may be causally linked to weight gain, with a greater effect seen in men. Stress-induced eating may be one factor contributing to the development of obesity. Future studies that measure biological markers of stress will assist our understanding of the physiologic mechanism underlying the stress-eating relation and how stress might be linked to neurotransmitters and hormones that control appetite.

Keywords: Stress; Eating behavior; Sucrose; Fat; Rat; Weight gain; Obesity

Introduction

A complex array of internal and external factors influences appetite and consequently the amount and types of food consumed by humans. Internal factors include physiologic mechanisms that regulate appetite, with hormones such as neuropeptide-Y stimulating food intake [1] and leptin reducing food intake [2]. Many external factors can also influence food intake and include environmental factors (e.g., economic, food availability) [3], social factors (e.g., influence of others) [4], and the palatability of foods [4]. It is a commonly held belief that stress can alter eating patterns [5]. When an acute stress is experienced, such as a threat to personal safety, there is an instant physiologic response, the "flight or fight" response [6], which results in the suppression of appetite [7]. Exposure to chronic psychological stressors, e.g., job pressures, is one of many mental health disorders that contribute to the global burden of disease [8]. For many, the typical response to these chronic stressful situations is not to avoid food but may be to seek out and consume energy-dense foods [9,10]. Obesity is a global epidemic and is increasing at an alarming rate, and can be attributed to a myriad of genetic and environmental factors [11]. If stress causes some individuals to consume food in excess of requirements, then this may culminate in weight gain and obesity.

Our aim is to review the evidence from animal and human studies on the effect of acute and chronic stress on eating behavior, and how stress-induced eating may contribute to the development of obesity. First, we describe how stress can alter total food intake. Second, we discuss how stress can promote consumption of nutrient-dense foods, specifically a preference for sweet foods, which has been the recent focus of our research work. Third, we present evidence to support the hypothesis that stress-induced eating may result in future weight gain and ultimately obesity. Fourth, we discuss how the physiologic responses to stress may interact with processes involved in appetite regulation.

Stress response

Stress can be defined as "the generalized, non-specific response of the body to any factor that overwhelms, or threatens to overwhelm, the body's compensatory abilities

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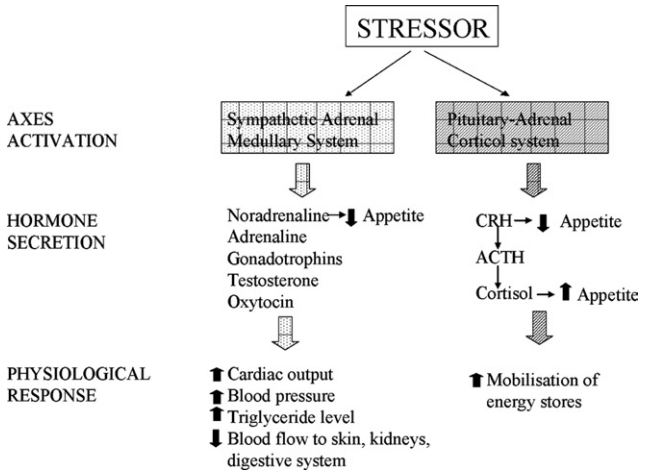

Fig. 1. Physiologic response to stress. ACTH, adrenocorticotropic hormone; CRH, corticotropin-releasing hormone.

to maintain homeostasis" [6]. The following stressors can induce a stress response: physical stressors (trauma, surgery, intense heat or cold); chemical stressors (reduced oxygen supply, acid-base imbalance); physiologic stressors (heavy exercise, hemorrhagic shock, pain); psychological or emotional stressors (anxiety, fear, sorrow); and social stressors (personal conflicts, change in lifestyle) [6]. Stressors can be short term (acute stress) or occur on a daily basis (chronic stress). Reactions to stressors have been suggested to be of several types [12], and those of most importance are the "active fight-or-flight" pattern (sympathetic adrenal medullary system) and the "passive" pattern (pituitary-adrenal cortical system involving the hypothalamic-pituitary-adrenal [HPA] axis; Fig. 1). Activation of the sympathetic adrenal medullary system, with release of catecholamines (adrenaline and noradrenaline), is typical during periods of acute stress [13]. Hyperactivation of the HPA axis, with release of corticosteroids (cortisol), has been associated with individuals who are chronically stressed [14]. Furthermore, it has been proposed that a hyperactive HPA axis may be programmed during the prenatal period as a result of fetal growth retardation [15]. Responses to acute or chronic stress can lead to physiologic changes that include slowed gastric emptying [16], elevation of blood pressure, increase in heart rate, mobilization of energy stores, and decrease in blood flow to non-essential organs, e.g., the digestive system, kidneys, and skin [13]. Hormones released in response to stress can specifically affect appetite. Noradrenaline [17] and corticotropin-releasing hormone [18] have been reported to suppress appetite during stress, whereas cortisol is known to stimulate appetite during recovery from stress [18]. Anxiety, depression, uneasiness, anger, apathy, and alienation are emotions that commonly accompany chronic stress [13]. The responses to acute or chronic stress also include a number of modifying behaviors such as alcohol consumption [19], smoking [20], and eating [5].

Stress can alter food consumption: effect of stressor severity

Greeno and Wing [21] outlined the individual-difference model, which suggests there are two ways in which stress may influence eating, resulting in eating or not eating. These opposing responses may be explained by the severity of stress that is encountered.

Animal studies

Animal studies provide a convenient way to measure the effect of stress on food intake. Rats can be subjected to different stressors in a controlled laboratory setting with close monitoring of food intake. In addition, there is evidence that animal models can provide valuable information about the interplay between stress and psychological/emotional processes that drive humans to eat [22,23].

The severity of the stressor seems to influence food intake in the rat model. Immobilization, a severe stressor, consistently reduced ordinary food (rat chow) intake in rats when administered chronically [24–27] and even acutely [27]. Moderate stressors (restraint, noise stress) administered chronically have also been reported to reduce ordinary food intake [26,28–30]. This stress-induced inhibition of feeding behavior may have a physiological basis. As corticotropin-releasing factor levels increase in response to stress, food intake decreases [31]. Furthermore, this was confirmed by a study in rats that found corticotropin-releasing factor inhibited the hyperphagia induced by neuropeptide-Y [32].

A mild stressor (tail pinch) increased intake of sweetened condensed milk in two studies [33,34] but did not alter intake of chow [35], and another mild stressor (handling) in rats had no effect on chow intake [26]. Therefore, mild stressors appear to have no effect on food intake when the foods available have limited hedonic characteristics but may increase food consumption when the foods offered are highly palatable. This is supported by studies in rats that have demonstrated that exposure to a cafeteria diet (highly palatable, high-fat diet) causes a greater increase in calorie intake and body weight when compared with rats offered ordinary chow [36,37].

Human studies

Human studies have also found decreased and increased eating in response to stress and this may also be related to the severity of the stressor. A retrospective survey of United States Marine's food intake during combat provided an opportunity to examine the effect of a severely stressful situation on eating behavior [38]. During the first day of combat, 68% of marines reported eating less than usual. The main reason for eating less was lack of time, followed by fear, which included being nervous, tense, and scared. In a prospective study, 158 male and female subjects completed