Review Article

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THE PHYSIOLOGY BEHIND HOW WE EAT DURING STRESS.

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ABSTRACT Stress is a part and parcel of our daily lives. One vital life process that is affected by stress in multiple ways is food intake. Stress when acute suppresses food intake and when persistent or chronic increases it. This narrative review is intended to provide a lucid understanding of how the different hypothalamic centres affect our food intake and satiety and how stress fits into this neural circuitry. It also discusses the physiology behind the feeding pattern of "emotional eaters."

KEYWORDS :

INTRODUCTION

Stress has been an integral part of human lives from the primitive times. With the advancements in various fields of life, the quantum of stress hasn't come down. Only its forms have changed. It tries to offset the homeostasis of the human body in the same way. One vital aspect of our daily lives that is affected by stress is the feeding behaviour which in turn, determines the balance of our calorie expenditure and also influences the metabolism of the body is remarkably modified during periods of stress.

THE TERMS: HUNGER OR APPETITE?

Feeding behaviour commonly refers to the act of eating or consuming food. It has two broad components: "hunger" and "appetite". Hunger has been described as the conscious urge to eat in order to fulfil the caloric requirements of the body. It is the homeostatic component of the feeding behaviour. Appetite, on the other hand, is the hedonic counterpart of hunger which refers to the seeking of food with particular preferences depending on its palatability, past experiences, mood etc. [1] The fundamental difference in the nature of both these behaviours is while the former is a compulsive need, appetite is a pleasant desire to consume food. The third term that comes in conjunction with this discussion is "satiety". It refers to the state of feeling sated, satisfied or full after having a meal. The primary goal towards which all these behaviours act is maintenance of energy homeostasis.

BRAIN CENTRES REGULATING THE FOOD INTAKE AND ENERGY HOMEOSTASIS

It was initially thought that food intake is controlled from two centres in the hypothalamus, the ventromedial nucleus (the satiety centre) and the lateral hypothalamus (the feeding centre). Much of this work is credited to experiments by John Brobeck in the 1950s at the John Fulton's laboratory, Yale where he produced small lesions in different areas of hypothalamus of rats and observed the effects. The work was later expanded by pioneering Indian scientist, B.K. Anand who discovered the satiety centre. Subsequent work postulated that the feeding centre is tonically active, which is periodically inhibited by the satiety centre. Further experiments in this field have found that this two-centre model is rather too simplistic and food intake and energy expenditure is controlled from multiple centres in the hypothalamus, involving different neural circuits and neuropeptides. [2,3] The arcuate nucleus (ARC) of the hypothalamus has emerged as the critical site for regulation of feeding and metabolism. [4] The most important aspect of ARC is its strategic location near the median eminence, a circumventricular organ (areas where blood-brain-barrier is deficient) that is rich in fenestrated capillaries. It thus allows the hypothalamus to sample blood carrying all the nutrient and chemical signals from the periphery. [5,6] The ARC also projects to other hypothalamic areas to produce a response. These areas include: Paraventricular Nucleus (PVN) which has inhibits food intake [7] and also controls central sympathetic outflow [8], Dorsomedial Nucleus (DMN) and Ventromedial Hypothalamus which reduces food intake, (VMN) and Lateral hypothalamus (LH) which stimulates food intake.[5,9] Apart from these, the perifornical area is also a sensitive site for stimulation of food intake. [10]

REGULATION OF FEEDING BEHAVIOUR

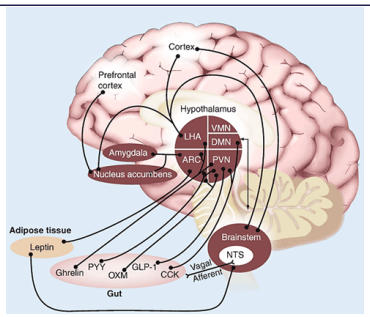
Physiologically, the feeding behaviour is controlled by a complex and intricate matrix of signals from both the periphery and the central nervous system, which include vagal afferents conveying the physical sensation of stretch or distension of the stomach for example and peptides & hormones, many of which are also released from the gut.

Role of the hypothalamus

The arcuate nucleus is considered to be the master of this orchestra because of its excellent location and its extensive neuronal projections. There are two major neuronal populations in the ARC implicated in the regulation of feeding. One population increases food intake and co-expresses neuropeptide Y (NPY) and agouti-related protein (AgRP). The second population of neurons co-expresses cocaine-and amphetamine-related transcript (CART) and pro-opiomelanocortin (POMC) and inhibits food intake. Neuronal projections from these two populations then communicate with other hypothalamic areas involved in appetite regulation such as the PVN, DMN and LHA. [5] The second-order neurons arising from these centres further connect with various circuits both inside and outside the hypothalamus, leading to an integrated response on energy intake and expenditure, respectively. [11] These include regions outside the hypothalamus like the nucleus of the solitary tract (NTS) which is a vital integrating centre for afferent signal processing like inputs from stomach, taste pathways, etc. [12]

Other influences

Food intake is also greatly influenced and modulated by higher functions like "wanting" or "craving" for a particular food, its taste and smell, emotional state, previous memories pertaining to the consumption of the food item, as well as external factors like the presence of stress. [13] These hedonic aspects utilize the central reward pathways. [13,14] This occurs by dopamine (DA) transmission within the mesocortico-limbic network, which includes dopaminergic neuronal projections of the ventral tegmental area (VTA) in the midbrain to the ventral striatum (nucleus accumbens) and parts of the limbic circuit like amygdala, hippocampus and prefrontal cortex. [15] Endogenous opioids acting at the ventral tegmentum also play an important role in the reward pathways. [16] Food intake is also influenced by various hormones released from the gut which include Cholecystokinin, Glucagon like peptide-1, Oxyntomodulin and Peptide YY, all of which suppress intake. [17] Thus, an orchestrated response on feeding, metabolism and energy homeostasis is generated. The cellular cross-talk in these circuits occurs with the help of various peptides. The chief anorexigenic peptides (which inhibit feeding and induce satiety) are leptin, insulin, pro-opiomelanocortin (POMC), cocaine- and amphetamine regulated transcript (CART) and Corticotropin Releasing Hormone (CRH). The various orexigenic factors are Neuropeptide Y (NPY), Agouti-Related Peptide (AgRP) Orexin-A, Endocannabinoids and Ghrelin. All of these factors act at various centres in the hypothalamus. [13]



Source: Google images. Simpson KA, Martin NM, Bloom SR. Hypothalamic Regulation of Appetite. Expert Rev Endocrinol Metab. 2008; 3(5):577-592.(Alsoavailableat:https://neuwritesd.org/2016/08/25/to-diet-or-not-to-diet-what-does-your-brain-think/)

HOW DOES STRESS INFLUENCE THESE CIRCUITS?

Stress may be described as a challenge to the natural homeostasis of an organism. Depending on whether the stress is acute or chronic, the responses of the human body can be different. Acute stress activates adaptive responses to overcome the period of difficulty or challenge, but prolonged stress leads to "wear-and-tear" (allostatic load) of the regulatory systems of the body, [18] resulting in many biological alterations.

Food intake in acute stress

Stress may affect the feeding behaviour by multiple mechanisms and has the potency of both increasing as well as decreasing food intake and energy expenditure. Stress resets the Hypothalamo-Pituitary-Adrenal axis leading to an immediate increase in the release of Corticotrophin Releasing Hormone (CRH). [14] Hypothalamus is the critical concurring point of the stress-response circuit as well as the feeding and energy-balance circuit. CRH inhibits neuropeptide Y (NPY)/agouti-related peptide (AGRP) neurons in the arcuate nucleus of the hypothalamus and thereby suppresses food intake. One more member of the CRH family, urocortins – Urocortin 1, 2 and 3 have been shown to inhibit appetite in acute stress by acting on CRHR2 receptors in hypothalamus. [19,20] It is also well known that the "fight-or-flight" type of response in acute stress takes precedence over activities such as eating. Yet another portal by which food intake regulated by the higher influences could be inhibited by stress is because of the role of endogenous opioids which can vary with the affective mood of the subject.

Food intake in chronic or persistent stress

When the stress is sustained or chronic or excessive, the persistent activation of the Hypothalamo-Pituitary-Adrenal (HPA) axis leads to the release of glucocorticoids into the blood stream from the adrenal cortex. They up-regulate expression of NPY and AGRP and increase appetite by acting directly. The role of glucose and insulin in inducing satiety was proposed by the "Glucostat" hypothesis which stated that specific glucosensitive-neurons in the ventromedial hypothalamus respond to the level of glucose utilization inside them. [2,3] This was all the more intriguing because the brain doesn't depend on insulin for utilization of glucose as its fuel, with the neurons of the VMN being an exception. Insulin also reduces food intake by acting at the ventral tegmental area (VTA) by reducing the dopaminergic neuron-mediated rewarding nature of food. Glucocorticoids released during stress work antagonistic to insulin and attenuate its signalling thereby increasing food intake. The insulin resistance also reduces the ability of insulin to inhibit NPY/AGRP neurons in the Arcuate Nucleus. [21] Further, insulin's suppressive effect on the reward pathways implies that the same food needs to be more "rewarding" to achieve the same level of satiety. [22] And accordingly, there is a preference for calorie-dense, high-fat and high-sugar food, as evidenced in various studies on animal models. [23] Humans similarly turn to hyper-palatable items such as fast food, snacks, etc which have been described as "comfort" foods. And this occurs even in the absence of hunger and lack of homeostatic need for calories. Some studies have documented that individuals in depression or negative affective states have a tendency consumption of hedonically rewarding foods high in sugar and/or fat, whereas intake during happy states were more in favour of less-palatable dried fruits.[24] An interesting observation was also made by Grogan S et al with regard to gender differences. The authors found that women had contradictory feelings towards eating sweet food than men, perceiving eating sweet snacks to be significantly less healthy ($p < 0.02$) and also to be more pleasant ($p < 0.01$). They concluded that social pressure was a critical factor that influences this behavioural difference. [25]

"emotional eaters" and the role of ghrelin

It has been known that circulating ghrelin levels are increased in during stress [26], which being an orexigenic naturally increases food intake. But ghrelin appears to have an ambivalent role in "emotional eaters", those who consume more highly palatable food during stress. It is interesting to note that in these individuals basal ghrelin have been actually found to be less than "non-emotional eaters" (those whose food intake is suppressed or unchanged by stress) and their ghrelin levels remain unaltered by food intake [27] which should normally come down when the subject is sated. This implies that emotional eaters may require relatively more palatable food to suppress stress-induced ghrelin to the same degree as non-emotional eaters. Lower basal ghrelin levels have also been associated with binge-eating, an emotional eating disorder. [28]

Food addiction: a myth or an emerging reality?

Stress has long been considered a critical risk factor in the development of addictive disorders and recent research has led to a broad notion that highly palatable and energy-rich foods could act analogous to drugs in a scenario of substance abuse. Both food and drugs of abuse may exploit similar pathways in the brain including the dopaminergic and opioidergic systems. [29, 30] High-fat diets alter CRF, Cortisol and noradrenergic activity to increase sensitization of reward pathways which in turn could trigger neurobiological remodelling towards compulsiveness in behaviour. This manifests as preference for addictive substances and hyper-palatable foods and increases "craving" and intake. [31] Over a period of time, this type of overeating could induce metabolic changes that promote weight and body fat mass which could then itself lead to stress, ensuing a vicious cycle. Studies show that these neurobiological changes are more in overweight or obese individuals as compared to lean individuals, underlining that stress can cause irregular eating patterns and strengthen neural networks towards hedonic overeating. [32]

CONCLUSION

Stress is ubiquitous and unavoidable in today's life. The pre-historic cave man had a singular source of stress-the pursuit of food. In today's modern world, accessibility to food is not as grave a concern as it was in those ages. But with different forms of stress creeping into our lives, interestingly and ironically, food intake and appetite are themselves markedly affected which has obvious negative impact on the long-term health of the individual. A clear understanding of the multiple ways by which different factors interplay in these neural circuits is crucial in properly acknowledging and addressing this scenario.

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