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Research Idea

The energy-rush and insulin model of obesity

Hangxing Jia ‡

‡ Key Laboratory of Zoological Systematics and Evolution & State Key Laboratory of Integrated Management of Pest Insects and Rodents, Institute of Zoology, Chinese Academy of Sciences, Beijing, China

Corresponding author: Hangxing Jia (jiahangxing@163.com)

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Abstract

Obesity has been a global health problem since the twentieth century. Despite the intensive research, there is no scientific consensus on the onset of obesity. The energy balance model (EBM) and the carbohydrate-insulin model (CIM) are two competing obesity theories, each with supporting and conflicting evidence. In this essay, I propose a new model, the energy-rush and insulin model (ERIM) which integrates not only the energy intake and expenditure, but also the food composition and digestibility, to explain how the high energy-rush and insulin secretion contribute to the development of obesity. The ERIM offers a novel framework to explain how obesity occurs and proposes new recommendations which may reverse the obesity epidemic in the future.

Keywords

EBM, CIM, ERIM, energy-rush, insulin secretion, obesity, food digestibility, GLP-1

Overview and background

Obesity can induce and increase the risk of many diseases (Ghaus et al. 2021, Kivimaki et al. 2022). Until 2016, approximately 40% of adults worldwide were classified as overweight or obese, accounting for approximately 1.9 billion individuals (OECD and WHO 2020). The rapid prevalence of obesity and recent studies suggest that environmental factors, rather

than genetic factors, are primarily to blame for the obesity epidemic (Blüher 2019). Although many environmental factors, including overeating, the type of food, lack of physical activity, alcohol consumption, lack of sleep, intestinal microbiota, soft drinks and so on, have been reported to be associated with the obesity epidemic (Safaei et al. 2021), the question of how obesity occurs remain unresolved. There are currently two mainstream theoretical models that attempt to explain the onset of obesity. The energy balance model (EBM) attributes the onset of obesity to excessive energy intake (Hall et al. 2022) and the carbohydrate-insulin model (CIM) claims that obesity is induced by excessive carbohydrate intake which can induce the hypersecretion of insulin (Ludwig and Ebbeling 2018, Ludwig et al. 2021).

However, there are several conflicts between the EBM and CIM (Ludwig and Ebbeling 2018, Ludwig et al. 2021, Ludwig et al. 2022, Hall et al. 2022). Firstly, the EBM claims that excessive energy intake drives additional fat deposition, while the CIM suggests that excessive fat accumulation causes additional energy intake; secondly, the EBM emphasises "a calorie is a calorie" without considering food composition, whereas the CIM underlines that a high intake of carbohydrates is the leading cause of obesity; thirdly, the EBM recommends a low-fat diet to reduce the consumption of energy-dense foods for weight loss, yet the CIM advocates a low-carbohydrate diet to reduce fat deposition.

Recent studies have shown that both low-fat and low-carbohydrate diets can effectively lose weight (Chawla et al. 2020, Ge et al. 2020). These findings both support and contradict the claims of the EBM and CIM. Additionally, the CIM claims that a high-carbohydrate diet can lead to cellular internal starvation and a decrease in metabolic rate (Ludwig and Ebbeling 2018), which is not supported by recent studies (Speakman and Hall 2021). Hence, the EBM and CIM can be seen as complementary perspectives, just like the two sides of the same coin, each shedding light on certain aspects of obesity while not encompassing the entire truth. To rationalise the onset of obesity, a new model is needed.

The energy-rush and insulin model

Here, I propose the energy-rush and insulin model (ERIM) to explain that obesity can emerge only when both energy-rush and insulin secretion increase concurrently (Fig. 1a).

Excessive energy intake is crucial for the onset of obesity (Hall et al. 2022). The term "energy-rush" in the ERIM, however, does not refer to the total amount of energy consumed, but rather to the total amount of energy in the blood, which is determined by how quickly the energy is absorbed and exhausted. This means that various physiological processes, such as food ingestion, digestion, absorption, basic metabolism and physical activity, have an impact on the energy-rush. Therefore, the energy-rush is not solely determined by energy intake and expenditure, but also by the food composition and digestibility. Due to differences in food digestibility, which determines how easily the food is digested and how quickly the energy is absorbed into the blood, two meals with the same calorie and food composition may lead to a quite different energy-rush. For example, the energy-rush of easy-to-digest white bread is much higher than that of spaghetti, as the

energy-rush mentioned here is mainly contributed by the increased blood glucose (Ludwig 2002).

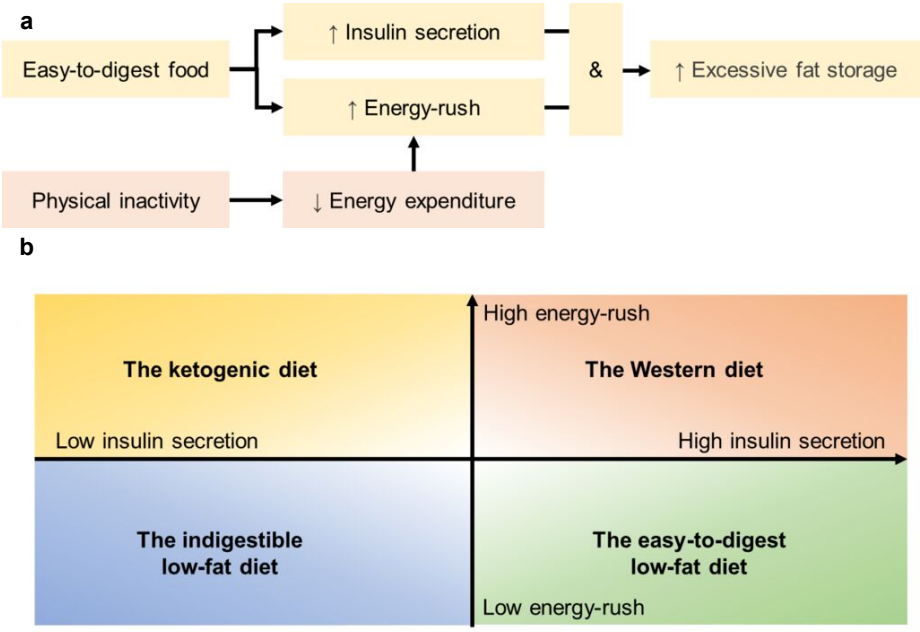

Figure 1.

The energy-rush and insulin model of obesity.

a: The energy-rush and insulin model claims that easy-to-digest food, which can lead to both high energy-rush and insulin secretion, is the leading cause of obesity; doi

b: Diets with varying food composition and digestibility result in different energy-rush and insulin secretion. doi

Insulin also plays a critical role in obesity development. Reducing insulin secretion can lead to weight loss, while injecting additional insulin can cause weight gain (Ludwig and Ebbeling 2018, Ludwig et al. 2021). Insulin has been reported to lower blood glucose, facilitate fat deposition, promote glycogen and protein synthesis, inhibit the lysis of glycogen and fat and suppress gluconeogenesis (Dimitriadis et al. 2021). In addition to these reported features, the ERIM claims that the major function of insulin is to enhance the processing of high energy-rush caused by food digestion and absorption, since insulin not only promotes the elimination of glucose and amino acids in the blood, but also enhances free fatty acids reduction during the postprandial stage. By facilitating fat storage and inhibiting lipolysis, insulin can contribute to the onset of obesity.

Thus, the ERIM claims that any diet, which can increase both the energy-rush and insulin secretion, will drive additional fat deposition and obesity development (Fig. 1a). For example, the most fattening Western diet (Kopp 2019), which is typically full of easy-to-digest carbohydrates and fats, rich in sugar and low in fibre (Ludwig et al. 2021, Hall et al.

2022), induces a dramatic increase in both the energy-rush and insulin secretion to drive the additional fat storage (Fig. 1b).

After consuming an easy-to-digest low-fat diet (Fig. 1b), the carbohydrates, fats and proteins in food are rapidly absorbed in the intestine, inducing a rapid rise in postprandial insulin secretion which further leads to a significant decrease in circulatory free fatty acids within half an hour, as well as the inhibition of fat lysis and enhanced glucose and fat storage (Dimitriadis et al. 2021, Hall et al. 2021). Such rapid digestion and processing of nutrients in blood will cause an increased likelihood of hunger, prompting individuals to consume more food to prevent hunger from reoccurring, which would ultimately contribute to the onset of obesity (Ludwig et al. 2022, Hall et al. 2022).

In contrast, consuming a low-sugar, high-fibre, low-fat and indigestible high-carbohydrate diet leads to slow nutrient digestion and absorption (Fig. 1b), resulting in a smoother rise and fall of the energy-rush and insulin secretion. As a result, hunger onset is delayed and the total energy intake is reduced in the long term, preventing excessive fat storage and obesity development.

On the other hand, a high-fat and low-carbohydrate ketogenic diet does not stimulate massive insulin secretion due to slow digestion and a lack of glucose and amino acids (Fig. 1b). Although the intake of high-fat food may result in a high energy-rush, there is no insulin to drive excessive fat accumulation in the adipose tissues and can prevent obesity development or even help with weight loss (Ludwig and Ebbeling 2018, Ludwig et al. 2021).

Unlike the EBM supporting low-fat diets and the CIM advocating low-carbohydrate diets (Ludwig and Ebbeling 2018, Ludwig et al. 2021, Ludwig et al. 2022, Hall et al. 2022), the ERIM supports any diet that can prevent additional fat storage by limiting either or both the energy-rush and insulin secretion. This is also consistent with the existing studies that find both low-fat and low-carbohydrate diets can help with weight loss (Chawla et al. 2020, Ge et al. 2020). Therefore, the ERIM provides a more comprehensive and evidence-based explanation of obesity development than that of the EBM and CIM.

Factors affecting energy-rush and insulin secretion

Most people are currently following an easy-to-digest high-carbohydrate diet with both high energy-rush and insulin secretion, which can accelerate the development of obesity. Studies have found that excessive salt intake, alcohol consumption and lack of sleep all lead to overeating and increased energy intake (Cappuccio et al. 2008, Moosavian et al. 2017, Covassin et al. 2022), which will further lead to high energy-rush and insulin secretion. Physical inactivity is also associated with the obesity epidemic (Safaei et al. 2021), as it can reduce the energy expenditure which, in turn, will increase the energy-rush and more energy will be stored as fat to induce obesity development (Fig. 1a).

Food composition is another important factor that determines insulin secretion and the energy-rush. When consumed alone, carbohydrates induce the strongest insulin secretion,

followed by proteins, while fat ingestion barely affects insulin secretion (Holt et al. 1997, Bao et al. 2009, Ludwig and Ebbeling 2018). The ERIM emphasises the importance of easy-to-digest carbohydrates because of their strong insulin secretion effect. Meanwhile, the increase in easy-to-digest fat will raise the energy-rush, which is also crucial for the onset of obesity (Hall et al. 2022). Additionally, in the context of a high-carbohydrate diet, increasing fat ingestion not only significantly increases the energy-rush, but also promotes insulin secretion (Jones et al. 1989, Bao et al. 2009), which will further inhibit lipolysis and increase fat deposition. Therefore, the ERIM acknowledges the contribution of both fat and carbohydrates in the development of obesity.

Food digestibility also affects insulin secretion and the energy-rush, especially for high-carbohydrate foods. Easy-to-digest foods, such as white bread, induce much higher levels of blood glucose and insulin secretion than slow-digesting foods like spaghetti with the same calories (Ludwig 2002). Moreover, when the same amount of glucose is infused into the intestine, the faster glucose enters the intestine, the higher blood glucose and insulin secretion it triggers (Ma et al. 2012). Thus, easy-to-digest foods tend to be more fattening, while slow-digesting foods can help with weight loss.

Slowing food digestion and absorption aids in weight loss

Food digestion and absorption, which determines the energy-rush and insulin secretion, are influenced by various factors, such as gastric emptying and medications. Gastric emptying is regulated by the enteric nervous system, the vagus nerve system and numerous endocrine hormones (Kuo et al. 2007). It is reported that more than 30% of the variance in postprandial blood glucose levels can be affected by the gastric emptying process (Dimitriadis et al. 2021).

Glucagon-like peptide-1 (GLP-1) is a hormone that has been extensively studied for its ability to delay gastric emptying (Nauck et al. 1997). GLP-1 is secreted from L-cells present in the distal ileum and colon of the intestinal tract (Baggio and Drucker 2007, Dimitriadis et al. 2021). When there are too many nutrients for the small intestine to absorb, the extra glucose, amino acids or fatty acids can reach the distal ileum and stimulate the secretion of GLP-1 which, in turn, helps to inhibit gastric emptying and slow down the food digestion and absorption (Nauck et al. 1997).

Several weight-loss approaches and medications work by increasing GLP-1 secretion or enhancing its effectiveness to slow down food digestion and absorption for reducing energy intake in the long run (Drucker 2022). GLP-1 receptor agonists, such as liraglutide, dulaglutide, semaglutide and tirzepatide are currently highly effective drugs for obesity treatment. Semaglutide and tirzepatide have demonstrated weight loss capabilities of 14.9% and 20.9% of body weight, respectively (Wilding et al. 2021, Drucker 2022, Jastreboff et al. 2022). Metformin has also been reported to increase GLP-1 secretion and help with weight loss in the long term (Bauer et al. 2018).

Bariatric surgeries, such as Sleeve Gastrectomy (SG), robotic Roux-en-Y Gastric Bypass (RYGB) and Gastric banding, are widely used for weight loss and can increase GLP-1 secretion (Meek et al. 2016). The bariatric effect is stronger in RYGB than in SG and the GLP-1 secretion is more upregulated in RYGB than in SG (Pucci and Batterham 2019). Those who lose more weight after RYGB surgery also have higher levels of GLP-1 secretion (Dirksen et al. 2013). GLP-1 receptor agonists have also been shown to reduce total insulin secretion in the long run (Rosenstock et al. 2014, van Can et al. 2014). In addition to GLP-1, bariatric surgery increases the secretion of many hormones that inhibit gastric emptying, such as cholecystokinin (CCK) and peptide-tyrosine-tyrosine (PYY), while decreasing the secretion of ghrelin, which promotes gastric emptying (Meek et al. 2016, Pucci and Batterham 2019).

In summary, GLP-1 and other hormones can delay gastric emptying to slow food digestion and absorption, which decreases both the energy-rush and insulin secretion, can reduce total energy intake in the long term and further aid in weight loss.

As previously mentioned, both the EBM and CIM advocate for non-refined foods that are rich in fibre and low in sugar, which can help slow down food digestion and absorption (Reynolds et al. 2019). Additionally, protein and fat-rich foods have longer gastric emptying times and solid foods also have longer gastric emptying times than liquid foods (Phillips et al. 2015, Goyal et al. 2019). This explains why nuts are helpful for weight loss and obesity prevention (Nishi et al. 2021).

Direct inhibition of food digestion and nutrient absorption can also help with weight loss. A combination of orlistat, which inhibits fat absorption and acarbose, which inhibits carbohydrate digestion, has also been shown to facilitate weight loss (Holmback et al. 2020).

Together, current studies support the claims of the ERIM that limiting food digestion and absorption through diet, medication and surgery can aid in weight loss by reducing the energy rush and insulin secretion.

Conclusions

The ERIM introduces a novel theoretical framework, which claims that an easy-to-digest diet with both high energy-rush and high insulin secretion is the leading cause of obesity, to explain the onset of obesity. The ERIM not only resolves the conflicts between the EBM and CIM, but also provides insights to control obesity by slowing down food digestion and absorption. People who want to stay slim or lose weight, for example, should eat fewer processed easy-to-digest foods like bread and chips and intake more vegetables and foods that are inherently slower to digest and absorb, whether it is low-fat or high-fat. In the future, the ERIM may assist in the prevention of obesity and reverse the obesity pandemic.

Conflicts of interest

The authors have declared that no competing interests exist.

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