Contributions of Appetite, Metabolism and Taste Sensitivities In Human Obesity: A Review of Richard D. Mattes's Research

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Fall 2006

A critical literature review submitted in partial fulfillment of the requirements for the senior research thesis.

Abstract

Richard Mattes has done considerable research in an attempt to discover the mechanisms contributing to obesity and weight loss. Obesity is a growing trend in America that leads to health problems and death. The research of Richard Mattes offers insight into the contributing factors of obesity, and possible preventative and intervening techniques.

Mattes exposes cultural increases in food portions, individual food units, and snacking behaviors that may lead to increased energy intake. Increasing energy intake without increasing physical activity can lead to positive energy balance, which leads to weight gain. Mattes also looks at different food forms, such as solids versus liquids, and their effects on satiety. As solids had more satietal value, and chewing was a hypothesized reason, Mattes also investigated the effects of chewing gum on satiety. He also experimented with various macronutrient contents of food items, as well as with effects of glycemic index on the glycemic response.

Richard Mattes's research also examined metabolic responses that affect weight. He compared fructose and glucose and their utilization after exercise. He also studied the use of peanuts and peanut oil as monounsaturated fat sources to improve lipid profiles in the blood and decrease risks for cardiovascular disease. In the area of taste sensitivities, Mattes researched taste sensations as a possible predictor of salt sensitivity, which can lead to high blood pressure. He also tested the effects of oral fat stimulation on the postprandial lipid response and cholesterol. Mattes's research has helped to create a vast understanding of the body's utilization and regulation of consumed substances.

Contributions of Appetite, Metabolism and Taste Sensitivities in Human Obesity: A Review of Richard D. Mattes's Research.

Introduction

Richard D. Mattes received a Masters of Public Health in Public Health Nutrition at the University of Michigan in 1978. He earned a Ph.D. in Human Nutrition at Cornell University in 1981. He became a Registered Dietician in Dietetics in 1982. He has received numerous awards for his research, and now is a professor of Foods and Nutrition at Purdue University. Dr. Mattes's ongoing research aims to discover the various influences on human dietary behavior, nutrient utilization, and energy balance. Some of these influences include neural, genetic, metabolic, hormonal, cognitive, cultural and sensory factors. All of these factors are being studied as possible contributing factors to obesity. In order to better understand Dr. Mattes's research, a more comprehensive explanation of obesity and its purported contributors must be given (Mattes, 2006).

According to the American Obesity Association, there are approximately 127 million overweight, 60 million obese, and 9 million severely obese adults in the United States today, according to measurements of the Body Mass Index (BMI). The BMI determines excess body weight. Overweight individuals are classified as having a BMI of 25 or higher. A BMI of 30 or higher constitutes an obese individual, while a BMI of 40 or higher signals severe obesity. The number of individuals that fall into these categories has been steadily increasing, and has several health and social implications. Obesity increases the chance of death, decreases mobility, and is associated with stigmatization and discrimination in many situations. Research that identifies possible contributing factors for obesity is valuable because of the high impact that obesity is having on the United States population. (AOA, 2006).

Dietary intake is one factor that may contribute to obesity when a positive energy balance is reached. Energy balance refers to the gross energy intake after energy (calorie) consumption, expenditure, and storage. By increasing energy intake without increasing physical activity, a positive energy balance is reached. Several factors may contribute to feeding behaviors that increase dietary intake.

The culture in which an individual grew up or now lives can affect feeding behaviors. Food portions, size of individual food units, and convenience of packaging and availability are culturally specific characteristics that may increase positive energy balance (Devitt and Mattes, 2004). Characteristics of individual food items may also promote positive energy balance. For example, liquids have been shown to have less impact on satiety than solid foods, in some studies (Mattes, 2005). The macronutrient content and Glycemic Index, a property of foods that helps to predict the postprandial blood glucose response, are also factors that affect hunger and satiety, which in turn corresponds with dietary intake (Alfenas and Mattes, 2005).

Besides studying appetitive variables that contribute to positive energy balance, Richard Mattes has also researched the influence of metabolism and taste sensitivities on intake. One area that Dr. Mattes has particularly explored is the effect of peanut consumption on lowering cholesterol and heart disease. He also has researched the substrate utilization of different sugars. In order to more completely understand metabolic effects on intake, metabolic processes must be explained.

Thermogenesis is the process of generating energy, or heat, by increasing the metabolic rate above normal. This can occur in response to exercise, specific nutrition, or nutritional supplements. It also occurs when the body is exposed to cold temperatures. Different macronutrients affect thermogenesis at varying rates. Proteins have a higher thermogenic rate than fats and carbohydrates, meaning that they increase metabolism more.

Another concept of metabolism related to positive energy balance is the Glycemic Response. The Glycemic Response occurs after the ingestion of foods, and is determined by the Glycemic Index of the food, a property of carbohydrate containing foods. The Glycemic Response refers to how quickly the body is able to increase blood glucose levels. If a food can quickly raise blood glucose levels, it has a high Glycemic Response. Richard Mattes has proposed and researched the ability of foods with a lower Glycemic Response to maintain satiety longer and thus decrease intake (Alfenas and Mattes, 2005).

Richard Mattes is perhaps most interested in intake as it related to sensory characteristics of foods. More specifically, his research focuses on taste sensitivities that affect feeding behaviors. The gustatory system is a chemical sensory system. The process of taste begins when a chemical tastant on the tongue enters the outer taste pore of a taste bud and interacts with the apical end of a taste receptor cell to stimulate neurotransmitter release onto afferent taste nerves. These nerves collectively represent three cranial nerves that innervate different sections of the tongue and carry signals to the brain.

While there are five identified tastes: salty, sour, bitter, sweet, and umami, Dr. Mattes has done considerable research examining a possible taste of fat. He has also explored the effect of oral fat exposure, as well as other types of tastants, on metabolic changes, hunger and fullness changes, and intake.

Richard Mattes's research utilizes human subjects, a method that has both advantages and disadvantages. Research using human subjects does not encounter the issue of generalization that animal research involves, as a rule. Human subjects are also able to self-report, whereas animal research must rely on behavioral or physiological measurements for data. Research with human subjects can generate self-reports that will supplement behavioral and/or physiological data. However, self-reporting can be faulty, as people tend to underreport about dietary intake. Mattes has explored, and sought to eradicate, this issue in his own research by creating measures that draw subjects' attention to their hunger sensations and intake (Mattes and Bormann, 2001). Human subjects also bring many other, possibly confounding, variables into any experiment, and cannot be manipulated as well as animal subjects. They also have the option of dropping out of the study at any time. Despite these disadvantages, Richard Mattes's research is best suited for human subjects because of their ability to self report.

Appetite

Appetite is one possible contributing factor to increased dietary intake and positive energy balance. Many of Richard Mattes's research projects have examined the effects of different types of food and food schedules on hunger, fullness, and desire to eat. These factors subsequently contribute to food intake.

Glycemic load is the product of a food's glycemic index and carbohydrate content, divided by 100. Previous studies have indicated that consuming a meal with a high glycemic load may result in increased intake at the next meal, when compared to a meal with a low glycemic load. Richard Mattes, along with Rita C.G. Alfenas P.h.D., (2005), sought to repeat these results, while also controlling for macronutrient composition of the meals, meal duration, energy density, rheology, and palatability, which are all possible confounds of previous studies. However, a more natural setting was also sought, as lack of generalization of lab settings has inhibited other studies. Rather than presenting either all low or all high glycemic loads, Mattes and Alfenas presented mixed meals. They also presented foods with different nutrient content, such as high protein, different types of fats, and varying levels of carbohydrates, to note effects of different nutrients on the glycemic response, and subsequently on food intake. In addition, the study consisted of two 8-day experimental periods, which is longer than previous studies, in order to examine any adaptation effects to multiple low or high glycemic load meals (Alfenas and Mattes, 2005).

Seventy-nine foods were selected for similar micronutrient composition and published glycemic index values. These values were then confirmed with non-study subjects by testing the glycemic responses to each food. Forty-eight foods remained in the study. Subjects were placed into either low or high glycemic index groups. Before each 8-day session, each group had a variety session where they ate a combination of three foods for each meal, all of which corresponded to their glycemic index group. They then selected their favorite food from each meal, and ate only that food for their meals during the experimental sessions. They were allowed to eat as much as they wanted, and amount eaten was covertly measured. Blood sampling and appetite questionnaires were completed before eating, as well as 30, 60, and 120 minutes after breakfast and lunch.

The appetite questionnaires consisted of labeled magnitude scales inquiring about hunger, desire to eat, and fullness. Blood glucose levels were measured using capillary blood as oppose to venous blood, because glucose changes are more reliable in the capillaries. Nutrient content, palatability, and energy density were similar between groups (Alfenas and Mattes, 2005).

The results did not show a significant difference in glycemic or insulin responses after breakfast or lunch, between groups or over the 8 day time period. There was also no significant difference in hunger, fullness, or desire to eat. Therefore, Mattes's and Alfenas's data does not support a difference in appetite resulting from a high or low glycemic load meal, even over a long period of time. Mattes and Alfenas attribute the lack of results to the possible confound of meal duration, which can affect the glycemic and insulin responses. However, if this were to be controlled, ecological relevance would be lessened. (Alfenas and Mattes, 2005)

In this study, Richard Mattes attempted to improve upon previous studies, but reproduce their findings. However, when he controlled for confounding variables, the results did not support the glycemic load of meals as a predictor for appetite and food intake. His results show that appetite, although only one possible factor of weight gain, is difficult to predict as a means of increased intake. Self-reporting as a means of collecting data can also be faulty, and create varying results, as seen here. Mattes explores this issue in another study.

Richard Mattes examined the problem of self-reporting in humans in a study designed to discover why people tend to under record their dietary intake during research studies. Other studies have shown that under recording occurs because people underestimate the portion of food they have eaten, possibly because of indiscriminate portion sizes. They also often forget food items eaten. Mattes, along with Leslie Bormann (2001), sought to reduce under-recording by requiring hourly food logging. Subjects were moderately overweight women, who were given weight loss aids, or a placebo, as well as a restrictive diet. Two 24-hour journals of intake records were kept by each subject at baseline, as well as at weeks 4, 8, and 12. Hunger and appetite logs were also kept, involving questions similar to those in the previous study (Mattes and Bormann, 2001).

Energy intake was more accurately recorded when subjects completed hunger and appetite logs. Therefore, it is likely that recording hunger and food intake simultaneously increases the accuracy of food intake records. This is likely due to the fact that hunger logs increase awareness of recent consumption, which makes recall of food items and portions easier (Mattes and Bormann, 2001).

In studies that involve self-reports or food journals, this should be taken into account, as incorrect data records could lead to a Type 1 or Type 2 error. This study also raises a possible research question. If awareness of hunger and fullness increases awareness of recently consumed items, might it also increase a subsequent desire to eat?

Along with studying methods of improving diet recording, Richard Mattes, M.I. Frieman, and P. Ulrich (1999) also examined another way to improve data collection from human subjects by creating a new scale on which to measure hunger sensations. This study also relates to the idea of heightening awareness of hunger and fullness sensations through questionnaires. Typical measurements of hunger involve rating feelings of desire to eat, stomach growling, and potential portions of food, and may also include placing an X on a figure of a human body in the areas where pain is felt during hunger. These methods create population data for hunger experiences, but do not produce data for the individual. Mattes and his colleagues sought to create a more finely tuned scale to more accurately measure the subjective feeling of hunger among individuals (Friedman et al, 1999).

The study was divided into 2 experiments. The first experiment asked subjects to specifically describe feelings of hunger. The subjects were not food deprived, but rather were asked to imagine hunger. They then outlined on a human figure the areas that were associated with hunger pains. The second experiment asked subjects to fast for 22 hours and to complete hunger questionnaires at various times throughout the day, as well as the body outline. They were then given either a low or high fat meal and given the questionnaires and body outline again. After eating a meal of their own choice later, they repeated the data collection process once more. The outlined areas from the figures were cut out and weighed for both groups (Friedman et al, 1999).

The first group, who had imagined hunger sensations, reported abdominal pains and headaches for extreme hunger. The second group did not vary after either low or high fat meals, implying that nutrient content does not affect satiety after fasting. The hunger pains as reported in the questionnaires did not change significantly throughout the day of fasting. However, the area of body circled increased throughout the day, implying that hunger questionnaires may not provide complete data on hunger sensations. The scale utilized in this experiment could improve data that relies on hunger questionnaires, and hunger questionnaires should not be used alone as sources of data (Friedman et al, 1999).

Along with the effects of glycemic load on appetite and intake, Richard Mattes, along with Amy A. Devitt (2004), has studied the effects of the size of food units and energy density. Portion sizes have been continuously rising since the 1970's, and along with them, energy intake. This suggests that positive energy balance occurs because of intake, a voluntary action, and not solely on physiological, metabolic processes. Food packaging has also become more convenient, with hand held items increasing. The size of the individual food unit is a likely determinant of the size of the portion that the individual will ingest. Therefore, if the food unit sizes were to decrease culturally in the United States, portion size and intake might decrease as well. However, smaller food units could potentially increase intake. For example, a person may only consume one customary-portioned cheeseburger, even if several are presented, but if several small-sized cheeseburgers, the individual may feel that they can eat more, and consume more than if they had eaten the larger food unit. In addition, food unit size could have little to do with positive energy balance. Some studies show that individuals tend to consume consistent gram weights of food. Therefore, positive energy balance could be a result of the energy density of certain foods, eaten in similar portion sizes to less energy dense foods (Devitt and Mattes, 2004).

Devitt and Mattes used smaller than customary portion sizes to study portion effects on gram weight intake and energy consumption. They hoped to discover whether intake was monitored physiologically, by gram weight of intake, or culturally, by food unit size and fat content. Meals were given to subjects over a four-day time period. Each day meals varied on energy density and food unite size. Appetite and desire to eat were measured after each meal, as well as the amount consumed. However, the results were inconclusive. No significant effects were found for energy density or food unit size on intake. Appetite questionnaires were used to collect data on hunger and fullness, which has already been shown to be less effective than when combined with other methods, such as the body diagram. Also, it is possible that there is a threshold for increasing the portion size of a food to increase intake. Too much food could have been provided, producing a ceiling effect. However, high energy dense foods caused more calories to be eaten, because the body did not regulate intake according to energy density. The same amount was eaten for low and high energy dense foods. Intake could be more culturally defined than by physiological processes, and increased awareness of portion sizes could aid in weight loss and management (Devitt and Mattes, 2004).

Because the amount of food eaten during meals and snacking is increasing culturally, daily caloric intake has increased. Dietary compensation to an increased or decreased amount of food, relative to normal intake, refers to an increase or decrease in post-meal intake to account for the added or lost calories. Many studies have been conducted to study the phenomenon of dietary compensation, but have varied the energy density of test meals by such a small amount that differences have been difficult to discern. This is illogical considering that the amount of food eaten daily fluctuates significantly. Dietary compensation, if it truly exists, would therefore most likely only occur when intake is changed significantly (Mattes et al, 1988).

Richard Mattes (1998) developed an experiment that consisted of a lunch meal that was either high calories or low in calories. He then measured the amount of food eaten after each lunch meal by examining subjects' food journals. If intake remained stable during periods of diet manipulation, when compared to baseline levels, then dietary compensation was estimated to have taken place (Mattes et al, 1988).

The most significant compensation occurred for caloric dilution as opposed to supplementation. In other words, when subjects were given low calorie meals, they compensated by eating more throughout the day, despite being unaware of the type of meal they were ingesting. When subjects ingested the high calorie meal, they usually did not compensate by ingesting fewer calories throughout the day, but rather ate the same amount that they consumed during baseline. If subjects had continued in this pattern, weight gain would most likely have occurred, because subjects ingested more calories, per day, than at baseline (Mattes et al, 1988).

This study appears to show that people tend to eat as much as they can. When they do not have enough calories, they will eat more, but when they do have enough calories, they still eat more. For some foods, nutritional value is difficult to assess, and this study shows that the body does not have a foolproof physiological mechanism to assess energy intake. The increased compensation during caloric dilution emphasizes the survival technique involved in dietary compensation as well. In times of hunger or energy need, the body can discern differences in caloric content. In times when ingestion is unimportant, perhaps this mechanism becomes inactive because it is not needed.

While food unit size and portion size are culturally determined factors that may predict intake, different fat sources are nutritional factors that may affect satiety, and consequently, intake. While fat has high energy density (i.e. calorie content) and palatability, it has weak satiety impact and a small oxidative response, resulting in its tendency to be stored. However, individual fatty acids may have different oxidative rates and satiety effects. The saturation of fat may also affect satiety. Mattes and Alfenas (2003) conducted an experiment to discover the different satietal properties of fat sources high in monounsaturated fatty acids (MUFA's) and those high in polyunsaturated fatty acids. Subjects ate muffins similar in taste and appearance, but containing different types of fat. Appetite questionnaires and feeding records were kept and used as data. While Mattes's previous research has shown the inaccuracies of these methods, this study involved plastic containers and detailed instructions on how to measure food intake, to increase the accuracy of the feeding records (Alfenas and Mattes, 2003).

When the fat free muffins were consumed, higher hunger ratings were found than for the muffins containing the various fats, suggesting that fat has a satietal impact. However, the fat free muffins contained less total energy, which could have decreased satiety. No significant differences were found between the different types of fats, although the predicted impact on satiety was PUFAs > MUFAs > SFAs (saturated fatty acids). Mattes's study challenges the notion that different fatty acids have different satietal impacts, although fat free foods should still result in less energy consumption due to having fewer total calories than fat containing muffins. The effects of fat content on satiety are still unclear, but appear not to be an adequate predictor for hunger or fullness (Alfenas and Mattes, 2003).

Another physical aspect of a food item that could affect satiety is whether or not the ingested substance is a solid food or a liquid, such as a beverage. Solid foods have been shown to satisfy the appetite more than liquids, possibly due to the action of chewing. However, beverages such as sodas, beer, wine, and milk are consumed often, are high in calories, and have little satiety value. The increased consumption of these drinks may be a cause of positive energy balance. Richard Mattes recognizes soup as a unique substance, because of its classification as a liquid while still containing higher appetitive value than beverages. Although it could be due to nutrient content, liquid and solid forms of the same foods (and therefore similar nutrient content) have different effects on satiety. Mattes sought to discover the effects on appetite of solid, liquid, and 'soup' forms of the same foods (Mattes, 2005).

Mattes's techniques in this study are particularly interesting because he is able to create three forms of food from one main ingredient. For example, a solid apple, apple soup and apple juice are compared for their satietal values. Apple juice produced a significantly smaller hunger reduction. The juice is the only substance that has a significantly different satiety value, suggesting that the soups and solid foods have similar effects on appetite. It is therefore not simply chewing that causes solid foods to be more satiable, than beverages. Soups are not chewed, and are still satiable. The benefits of soup therefore are that they satisfy the appetite more than a beverage, but are usually less energy dense. Therefore, calories can be consumed and hunger can be decreased at the same time, as opposed to calorie consumption without a hunger decrease, which will lead to more energy consumption, and more likely weight gain. This phenomenon could be related to cultural classifications of beverages as a meal supplement, rather than a meal replacement (Mattes, 2005).

Liquid meal replacers are often used in dieting regimes. In fact, several of Richard Mattes's research studies have been funded by SlimFast, most likely in hopes of discovering a way to create a liquid with higher satiety value. In order to do this, the mechanisms that prevent satiety after the consumption of a beverage must be discovered. It is also important to know if low satiety of a liquid meal replacer or beverage may promote increased energy intake, in an attempt to become satiated.

Richard Mattes examined this topic in his research on the satietal effects of ethanol. Ethanol makes up about 4-6% of U.S. per capita energy consumption. (Mattes, 1996) Its satietal effects, and the dietary compensation that occurs in response to its ingestion, will help in the understanding of yet another factor of the obesity epidemic as it related to ingestion.

Previous studies have shown small decreases in intake when ethanol is consumed, even though dietary compensation to alcoholic beverages is low. This effect is generally only seen in moderate drinkers though. For the most part, people do not decrease the amount that they eat to compensate for the amount of calories that they have consumed with alcohol. Richard Mattes investigated this phenomenon, while controlling for confounding variables, such as sensory properties, macronutrient response, and fluid volume effects by presenting beer along with nonalcoholic beer, cola, and carbonated water. (Mattes, 1996)

Diet journals and urine samples were taken 24 hours before and after ingestion. A beverage was given, along with crackers and cheese. Total energy intake increased from baseline for all beverages except carbonated water. The 5% alcoholic beer increased intake the most. The study did not show a dietary compensation effect, but rather the opposite, Subjects ingested more when given a beverage than baseline. The reason for this increase has not been researched, but several hypotheses for why beverages do not affect satiety have been formed. Beverages could bypass the postingestive satiety signals because they are ingested so quickly. They also reduce gastric fill more quickly than solid foods. Finally, chewing has been implicated as a possible satietal influence, and is lacking in beverages. Alcohol, similar to other beverages, does not decrease the amount eaten, and even increases it, a possible problem for the liquid meal replacement industry. (Mattes, 1996)

Richard Mattes conducted further research involving the behavior of chewing as it relates to appetite, while also relating it to cultural phenomena such as increased snacking. In the previous study, Mattes examined high calorie, low satiety characteristics of beverages. However, an answer to the problem of increased beverage consumption would be to introduce an item with high oral satiety, or ability to satisfy the desire to eat, with minimum calories. Sweetened chewing gum was his item of choice. Sweetened chewing gum provides early oral satiety, and studies using unflavored gum show that chewing gum increases satiety in general. Other studies have also shown sweet chewing gum's potential to reduce the desire to eat something sweet. Mattes sought to discover an influence of chewing gum on overall appetite and intake (Julis and Mattes, 2006).

Subjects were divided into two group. One group was allowed to chew gum for 20 minutes when they experienced a craving for something sweet. They could not have a sweet item until another craving occurred. The second group had a fixed time for chewing their gum, set at 2 hours after a meal. They then waited for a craving to occur, and could not eat anything until they had waited for 20 minutes. Regular hunger logs were kept in each group (Julis and Mattes, 2006).

Chewing gum did not significantly alter appetite or intake within either group. Therefore, sweetened chewing gum does not appear to have an effect on satiety or the amount of energy consumed. Chewing gum most likely cannot be utilized as a diet restricting technique, although other brands, flavors, and textures of gum could be tested for different effects. For example, a chewing gum that is meant to mimic the taste of a food, such as strawberry, may have a different effect than a bubblegum flavor (Julis and Mattes, 2006).

Because appetite seems to be a major deterrent for adherence to restrictive diets, substances that promote fullness and curb appetite are of a high value. While many such substances have been shown to have an effect on appetite, most have negative side effects. For example, substances that act on serotonergic neurotransmittion have been linked to cardiac problems. Hormone manipulation has been ineffective. As a result, herbal supplements have been increasingly popular and sought after. While fat sources, food portions, and food consistancy are aspects of most foods and meals, herbal supplements are additions to a diet, and are therefore a more active step towards appetite and intake reduction (Mattes and Bormann, 2000).

Garcinia Cambogia is an herb from southeast Asia that contains of 30% by weight -(-) hydroxycitric acid (HCA), and is purported to reduce appetite. HCA may suppress de novo fatty acid synthesis, and expedite lipid oxidation, and therefore reduce intake. However, it is also hypothesized to create inefficient oxidation, and therefore produce ketones, which supposedly suppress appetite (Mattes and Bormann, 2000).

Richard Mattes, along with Leslie Bormann (2000), designed an experiment to discover the effects of Garcinia Cambogia, as well as HCA, on appetite suppression as a means of weight loss. G. Cambogia pills and placebos were administered to different groups, and both were placed on mildly restrictive diets. Diet records, hunger logs, and activity logs were kept. Both groups lost significant amounts of weight. The difference between groups was significant as well, but only moderately. Both groups lost weight, but both were also placed on restrictive diets. Because their weight loss was congruent with their dieting, HCA can not be concluded to have affected satiety or weight loss. Instead, it is likely that the subjects simply adhered to their diets, perhaps because they were subjects in a study and had heightened awareness of their eating behaviors. The effects of HCA cannot be expunged though, because it was not tested at varying levels or on varying individuals. Subjects were moderately overweight, and HCA has been shown to affect obese individuals more than lean individuals. Low doses have also been shown to be more effective than high doses, and so more research involving different levels of HCA might yield more conclusive results. (Mattes and Bormann, 2000)

In addition to his research concerning possible appetitive variables of weight loss, Richard Mattes has also studied weight management after a period of weight loss as it relates to appetite. The issue of sustained weight loss is of high importance due to the tendency of individual who have lost weight to regain the weight after a period of time. One reason for this may be individual differences in responses to a sustained decrease in energy intake. Mattes attempts to determine characteristics of individuals that may help to predict sustained weight maintenance after the initial weight loss period. Such characteristics include time spent in food acquisition, preparation, and consumption, in an attempt to draw conclusions about an individual's preoccupation with food. Other factors include dietary motivation and concern over health (Mattes, 2002).

The study involved a weight loss period followed by a maintenance period. If weight gain occurred, return to the weight loss regimen was required. It took place over a period of 64 months, during which time questionnaires regarding the aforementioned variables were administered. Subjects were classified as maintainers, rebounders, and nonresponders in accordance with their weight loss and maintenance (Mattes, 2002).

Nonresponders spent significantly more time shopping for food and eating. They also spent less time preparing their food, so they could have been eating more convenience foods. Finally, nonresponders ate with fewer people than the other two groups. Rebounders exhibited less dietary restraint than maintainers, while maintainers showed more flexibility in their eating behaviors. Maintainers also appear to have more awareness of sensory cues relating to fullness and satiety than rebounders. These findings are important to the study of obesity because they reflect individual characteristics that may affect a person's ability to lose and/or maintain weight. By increasing knowledge of individual differences as related to weight loss, research can become more accurate as it accounts for these differences in subjects (Mattes, 2002).

Richard Mattes's research has focused heavily on appetitve variables as a purported factor of weight gain. Nutritional aspects of foods and beverages were examined, as well as physical aspects of foods, such as solids vs. liquids. Mattes's hypotheses were formed from previous research studies and knowledge in his field. The inconclusive nature of many of his findings is representative of the many variables that determine satiety, and on an even bigger scale, weight loss and maintenance.

Metabolism

In addition to researching appetite and its relation to obesity, Richard Mattes has also done considerable research into metabolic processes. Sometimes, these processes are described in their relation to appetite. Other times, his research focuses on the effects of certain foods and substances on the body, and the subsequent relation to weight gain.

One such study examined the difference of glucose versus fructose utilization after negative energy balance in obese individuals. Fructose has been used increasingly as a sweetener, and studies have suggested that it increases thermogenesis and carbohydrate oxidation, decreases the glycemic and insulin responses, and suppresses food intake. However, previous studies have only studied fructose in subjects consuming normal diets. This study sought to discover its effects in subjects who are obese, and undergoing conditions for weight loss involving reduced diet and increased exercise. These conditions may alter the metabolic response to fructose, which is metabolized by the liver. When the amount of fructose consumed exceeds the amount that can be oxidized by the liver, it becomes metabolized through other pathways. Reducing glycogen stores by negative energy balance may reduce the amount of fructose that must be metabolized in other pathways after a meal. This may increase thermogenesis and carbohydrate oxidation. Negative energy balance could therefore get rid of differences in utilization of different carbohydrates, and lead to weight loss (Tittelbach et al, 2000).

Subjects were divided into an energy balanced group and a negative energy balanced group. Subjects got both conditions (at different times) after exercising on a treadmill by consuming either a high fructose or high glucose liquid meal. Negative energy balanced individuals lost significant amounts of weight. Carbohydrate oxidation was higher after fructose ingestions than glucose ingestion in the energy balanced group, but the fat oxidation rates were lowered significantly in the energy balanced, high fructose group than either glucose group. Therefore, high glucose meals may provide a metabolic response that is favorable to that of fructose. The glucose meal increased the storage of carbohydrates and fat oxidation. However, both fructose and glucose were utilized similarly after exercise, and more studies would have to be completed to understand which one is more desirable. Current beliefs hold that fructose is ideal for obese and diabetic individuals because it has a low glycemic index and a high sweetening capacity per kilocalorie (Tittelbach et al, 2000).

The study of glucose versus fructose conducted by Mattes is highly tuned for his overall research goal, to study obesity and its possible contributing factors. He combined obese individuals with a weight loss program and observed the differences in their reactions to different nutrients. His research in this study is pointedly attempting to not only find a cause of obesity, but to also study variables that may aid obese individuals in losing weight.

A serious side effect of obesity is Cardiovascular Disease. Richard Mattes has conducted research relating to factors thought to be cause, or improve, heart disease. The consumption of nuts has been shown to reduce heart disease because they have properties that lower lipid levels. The property thought to be responsible is the fatty acid composition of nuts, which are high in unsaturated fats, especially monounsaturated fats (MUFAs). MUFAs are thought to lower the mortality rate from cardiovascular disease by reducing LDL (low-density lipoprotein) cholesterol. In addition to the data that supports these beliefs about the benefits of nuts is the fact that Americans consume more peanuts than any other nut combined. Mattes therefore chose the peanut as the nut of choice in his research design, in order to see the effects of peanut consumption on blood lipid profile, diet composition and intake (Alper and Mattes, 2003).

Peanuts had a considerable effect on intake. Subjects reported having difficulty consuming the prescribed diets because of the high satiety of peanuts. Peanut consumption also decreased the serum TAG (triacylglycerol) by replacing carbohydrates with fats. This effect was seen even when saturated fat levels were not altered, so the results can be attributed to the increased monounsaturated fat. More nutrients were consumed in regular diet as well, including folate, fiber, magnesium, and copper. However, the peanuts were not sufficient to lower LDL cholesterol. Regular peanut consumption can still be concluded to cause changes that are related to reduced cardiovascular disease (Alper and Mattes, 2003).

Mattes did another study on the effects of nuts on risk factors for heart disease, diabetes and high blood pressure. However, he utilized peanut oil as opposed to whole peanuts. Nuts are not digested as easily because of their shell, and so all of their contents to not get utilized. Peanut oil helps to get rid of this problem. Mattes also compared lean and overweight individuals in this study (Coelho et al, 2006).

Peanut oil increased body weight in overweight individuals, which was a hypothesized result because the peanut oil was consumed in milkshakes. However, more weight gain was expected than was observed. This could be because of the satiable nature of the unsaturated fats in nuts. Obese subjects' resting energy expenditure was increased during the study, and could have also led to decreased weight gain. Overall, the peanut oil had a favorable effect on weight gain (Coelho et al, 2006).

The peanut oil also had positive effects on the blood lipid profile. HDL cholesterol was raised, which reportedly decreases the risk of cardiovascular disease. While LDL and TAG levels were not reduced, they might have been if saturated fats had been limited in the study, instead of simply supplemented by unsaturated fat. Peanut oil supplements in a diet, as well as decreased saturated fats, could therefore have beneficial effects in preventing heart disease in obese individuals, and may even be more beneficial than whole nuts (Coelho et al, 2006).

Another study that also examined heart disease and its risk factors focused on lipid storage in humans. Elevated Triacylglycerol (TAG) is also a risk factor associated with cardiovascular disease. After eating, TAG concentration becomes elevated in phases. The first phase of elevation occurs 1-2 hours after meal consumption. The second, broader peak occurs 2-4 hours after the meal, and the 3rd, more rare peak occurs 6-7 hours after ingestion. The sources of these lipids has been disputed, but data shows that some could be from previous meals, and is stored in what is known as the "residual pool". Understanding how this residual lipid store is controlled and how it contributes to later TAG levels will have a beneficial effect on public health (Mattes, 2002).

Mattes presented almond meals with known fatty acid content (high oleic acid) to subjects. After blood had been taken and a considerable wait period undergone, subjects ingested safflower oil, which is high in linoleic acid. More blood sampling was done, and then subjects chewed either a cracker or a cracker with cream cheese, and spit it out. Blood was taken repeatedly at intervals after the oral stimulation (Mattes, 2002).

All subjects had at least one peak in TAG concentrations. Many experienced a second peak, and a few experienced a third. The levels of TAG at each peak were highly correlated after mastication of the cream cheese cracker. This indicates that even the small amount of oral fat stimulation provided by the cream cheese was enough to elevate the TAG levels significantly at each phase. This could be a predictor of heart disease.

The first peak of TAG was also largely comprised of oleic acid after ingestion of the cream cheese cracker. Oleic acid was highly present in earliest meal, indicating that the lipid peak comes from residual lipids from previous meals, and is stimulated to be released from the "residual pool" by oral fat stimulation (Mattes, 2002).

This study suggests that when fat is recognized, even orally, previously stored lipids are released into the blood, causing an increase in TAG serum, in order to be ready for the reception and digestion of more fat. This response could increase after continually ingesting a high fat diet if the body compensates by releasing even more of the residual pool of lipids into the blood. More research is needed to discover a long-term compensatory effect, but would show increased need for a balanced diet.

Mattes's studies regarding metabolic processes provide supplemental evidence that supports his research regarding appetite. Aspects that contribute to weight gain through appetite also contribute to weight gain, as well as cardiovascular disease, through metabolism. For example, Mattes explored the effects of fat sources on satiety, as well as their effects on TAG serum levels and cholesterol. Mattes's metabolic research uses many of the same techniques of his appetitive research, utilizing questionnaires and dietary journals. Appetite and metabolism are interconnected aspects of weight management, and therefore are usually both studied to some extent in research investigating obesity. Mattes's research on metabolic features of weight gain and cardiovascular disease substantiate the fact that weight manipulation is a complex process without a single, all encompassing factor.

Taste Sensitivities

A final area of investigation into the process of weight gain and obesity is that of taste sensitivities. Mattes's research in this area focuses on specific aspects of taste and oral stimulation that may lead to obesity, both through increased intake and metabolic processes that affect nutrient absorption and utilization. Mattes's studies examine taste sensitivities to different tastants and how it affects obesity.

High dietary sodium has been suggested to be a contributor to high blood pressure in people termed "salt-sensitive". These individuals experience blood pressure changes that are congruent to increases and decreases in sodium intake. Low sodium diets are recommended, but are almost impossible to adhere to, especially since salt-sensitivity status is not known by individuals. Mattes sought to assess a diagnostic procedure for salt sensitive individuals and to test the power of certain symptoms to predict salt sensitivity (Mattes and Falkner, 1999).

Mattes determined systolic and diastolic blood pressure values on four occasions during a 2 week period. Body weight, urine osmolality after an oral saline load, and taste sensations to sweet, sour, salty, and bitter stimuli were measured, as well as sodium concentration in the saliva. Then subjects were placed on a sodium restrictive diet. All of these factors had been previously shown to predict salt sensitivity. However, Mattes and Falkner were unable to find reliability in these measures. Salt sensitivity classification is important for cardiovascular health, but the metabolic and taste screening measures outlined above are insufficient in determining this feature (Mattes and Falkner, 1999).

Taste sensitivities can affect consumption, which can lead to weight gain. Fat intake has been discouraged for years by health care institutions and the media, However, fat consumption has not decreased. Although fat is usually mentioned with a negative connotation, there are may benefits or dietary fat, such as its contribution to cell structure and blood clotting factors. Because dietary fat is useful to the human body, some argue that it has an adaptive value. Thus, it is likely that a sensory device has evolved to increase fat intake. This device could be taste or oral stimulation that is pleasing to the individual. This could then send a signal to the brain that would cause bodily responses to increase ingestion, known as cephalic phase responses. This was demonstrated in Mattes's study involving oral fat stimulation with a cracker and cream cheese, which caused lipid serum levels to increase. Tasting of fat had an immediate digestive effect (Mattes, 2005).

This theory is reinforced by research that has shown fatty acids to be 'tasted' in the gastrointestinal tract, meaning that potassium channels linked to fat detection in the mouth are also in the intestines. The effects of the same lipids on these channels vary in different regions of the body. In the mouth, they may increase ingestion because they are pleasurable. Once they reach the intestine, they may increase satiety and reduce ingestion (Mattes 2005).

Discussion

The fact that oral fat sensation can cause metabolic responses that also affect appetite is indicative of the interrelated nature of the contributing factors of obesity. Controlling this process is therefore complex and difficult, with no single formula to solve the growing problem that is obesity. Richard Mattes's research has assisted in increasing knowledge of the elusive nature of weight management, and his findings contribute to the search for a solution to obesity.

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