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The effect of mastication on food intake, satiety and body weight

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ABSTRACT

As mastication is the major component of the oral processing of solid foods a better understanding of its influence on ingestion, digestion and metabolism may lead to new approaches to improve health. A growing number of studies provide evidence that mastication may influence energy balance through several routes: activation of histaminergic neurons, reducing eating rate, altered digestion kinetics, and changes in macronutrient availability. Indeed, accumulating evidence indicates that increasing the number of masticatory cycles before swallowing reduces food intake and increases satiety. However, while slowing eating rate has been shown to limit weight gain in children and adolescents it is not clear that slowing eating rate by increasing the number of masticatory cycles or slowing mastication rate is a viable method to aid weight management ([10], [15]). Further research is required to determine the influence of mastication on energy balance and how it could be manipulated to aid weight management. This narrative review will provide a brief overview of the effect of mastication on food intake, satiety and body weight.

1. Introduction

Oral processing of food starts the process of food digestion. Arguably, mastication of food is the most important aspect of food oral processing and will be the focus of this brief review. The primary goal of mastication is to reduce the particle size of an ingested food and mix these particles with saliva to form a bolus that is safe to swallow [28]. To be safe to swallow, the food bolus must be smooth, plastic and cohesive [35]. Mastication has a major role in food ingestion and digestion and has the potential to influence satiation (food intake), the postprandial satiety response, or body weight through several different mechanisms. First, it has been demonstrated in rodent models that mastication activates histaminergic neurons in the paraventricular nucleus and ventromedial hypothalamus [41]. Activation of these neurons reduces food intake while antagonists increase food intake [14,39,40]. However, at this time it is not clear that this pathway operates in humans. Second, the number of masticatory cycles used to prepare a food for swallowing is a strong predictor of eating rate [48,49,51,52]. As accumulating evidence indicates that a slower eating rate is associated with reduced food intake [38] and increased satiety [2,37] it is possible that prolonged mastication could influence these processes through a decreased eating rate. Third, as mastication increases the surface area per unit volume of a solid food it is likely that increasing the number of mastication cycles before swallowing increases the effective surface area of the swallowed bolus. As the rate of action of enzymes is proportional to the surface area that act upon difference in the particle size of the swallowed bolus may alter digestive kinetics and the post-prandial metabolic or endocrine response [6]. Fourth, mastication mechanically ruptures the cell wall of plant foods which liberates macronutrients that may not have been accessible to the body [16]. For instance, Ellis et al. [7] found that unless the cell wall of almonds was disrupted by mastication a proportion of the lipids in the almonds was not accessible to be digested and absorbed. Consequently, greater breakdown of the food bolus through increased mastication could increase the energy available from the diet and promote a positive energy balance [5]. Alternatively, the increased liberation of macronutrients may augment satiety by increasing the secretion of appetite-related hormones [22].

Despite having a major role in food ingestion, the influence of mastication on food intake, satiety and body weight is not clear and several questions remain to be answered. The role of inter-individual differences in masticatory parameters influence aspects on energy balance (e.g., satiation, satiety or metabolizable energy) requires elucidation. Moreover, it is not clear that masticatory parameters (e.g., number of chewing cycles, chewing rate) can be manipulated to augment satiation or satiety without deleterious consequences. While a recent study found that changing the texture of a food could increases masticatory activity without reducing the hedonic quality of the food [3,26] further research is required to determine if manipulation of mastication is acceptable to participants over the long-term. This paper will provide a brief overview of the evidence regarding mastication and its effect on food intake, satiety and body weight.

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1.1. Inter-individual differences in masticatory parameters

Masticatory parameters (e.g., number of chewing cycles, bite force, particle size of the swallowed bolus) are strongly influenced by the characteristics of the food being eaten, such as bite size, hardness or number of food pieces, and physiological factors such as dentition [47]. Foods that are harder to break down require a higher number of masticatory cycles before swallowing and are eaten at a slower rate [46]. Consequently, selecting a diet that requires greater masticatory effort may be a natural a way to manipulate eating rate, energy intake and impact body weigh over time.

A number of studies, using different test foods, indicate there is substantial inter-individual variation in the number of masticatory cycles required to prepare a food for swallowing. For instance, the number of chewing cycles required before swallowing peanuts ranged from 17 to 110 [8], 9 to 65 for carrots [23] or 14–44 for brazil nuts [23]. However, there appears to be less intra-individual variation in the number of masticatory cycles used to prepare a food for swallowing and individuals can be characterized as slow or fast chewers regardless of the test food being used [9]. Moreover, recent research indicates that faster eating is associated with a larger bite size, fewer chewing cycles per bite and a greater number of total bites during the meal [11,12]. Measures of oral processing have been found to be consistent across several eating occasions suggesting that individuals have a characteristic eating style [25]. While food texture may alter eating parameters (e.g., number of chewing cycles before swallowing or chewing rate) they change in a consistent manner (e.g., fast eaters remain fast eaters). While studies have reported an association between eating rate and food intake [46] further research is required to determine if inter-individual differences in mastication parameters influence food intake or satiety. For instance, do fast and slow eaters both respond to efforts to increase their masticatory activity by reducing food intake or experiencing increased satiety?

Studies generally conclude that in healthy, fully dentate individuals there are small inter-individual differences in the particle size of the swallowed bolus [13,33,47]. It is suggested the lack of variation is due to the importance of producing a fully masticated bolus that can be safely swallowed. However, studies of the particle size of the swallowed bolus are often limited by small sample sizes, difficulties in accurately measuring the particle size distribution of a swallowed bolus and a limited number of test foods used. Consequently, further research over a wide range of different foods is required to determine the magnitude of inter-individual differences in the particle size of the swallowed bolus and whether any differences are sufficiently large to significantly influence the satiety response.

The characteristics of the swallowed bolus may be markedly changed by aging, tooth loss or denture use. Older adults form a bolus that contains a larger proportion of smaller particles and fewer larger ones [47]. Dentures reduce masticatory efficiency and denture wearers form a bolus that contains a much larger percentage of larger particles and fewer small particles [47]. The influence of swallowing a bolus containing different proportions or small or large particles on digestive kinetics and the post-prandial appetitive, metabolic or endocrine response requires elucidation to better understand the contribution of suboptimal mastication to poor health.

1.2. Mastication and body weight

There is currently limited data regarding an influence of mastication on body weight. Indirect evidence is provided by studies that have examined the relationship between food hardness (harder foods generally require greater masticatory effort to break down) and body weight or composition. A rodent study found that the consumption of harder chow resulted in lower food intake and less weight gain compared to rats consuming powdered chow [30]. It is not clear if the lower food intake was due to mastication of or other factors such as lower palatability of the harder chow or a reduced eating rate. Another rodent study also noted that rodents fed a soft chow had a higher body weight and increased adiposity despite energy intake being the same [31]. A possible explanation for these results was that body temperature was higher in rats fed a hard chow. Consequently, food texture may influence body composition through an effect on post-prandial thermogenesis. Interestingly, it has been shown that increased masticatory effort also increases post-prandial thermogenesis in humans [17]. An explanation for these observations is still required but may involve changes in post-prandial digestion and absorption kinetics.

Data from studies of humans is currently lacking. An observational study found that food hardness was related to waist circumference but not body weight [29]. Other observational studies have observed an association between self-reported eating rate and body mass index [45] or bite size and BMI [24]. While several laboratory studies have investigated the relationship between masticatory parameters and body weight they do not generally identify a unique obese masticatory style. ([13,19,32,44]. However, the study by Isabel et al. [19] found that obese individuals swallowed a bolus with the largest median particle size indicating poorer masticatory performance. In contrast, a study of 64 fully dentate adults found a modest but statistically significant correlation between number of chewing cycles before swallowing (~0.3) or chewing duration (~0.35) and body weight [50].

While the currently available evidence does not provide strong evidence of a link between mastication and body weight these studies have used relatively small sample sizes that are likely not representative of the wider population. Moreover, the laboratory studies have used a limited number of test foods to characterize masticatory parameters. While there is currently no strong evidence to suggest that inter-individual differences in mastication influences body weight larger studies are required to better characterize the link between masticatory parameters and body weight

1.3. Mastication and food intake

While there is little information regarding the influence of inter-individual differences in masticatory parameters on food intake several studies have examined the effect of manipulating the number of masticatory cycles before swallowing on food intake. As increasing the number of masticatory cycles before swallowing changes the characteristics of the swallowed bolus and may also be uncomfortable for the participant these studies tell us little about how normal differences in masticatory parameters influence food intake.

In a study by Li et al. [21], it was found that increasing the number of chewing cycles from 15 to 40 reduced food intake by 12%. Similar results were reported by a preliminary study that found participants reduced food intake by 13% when they chewed pasta 35 times before swallowing compared to 10 [43]. A study using a different study design which required participants to chew pizza 100%, 150% or 200% of their normal number of chewing cycles [48,49] It was found that increasing the number of chewing cycles reduced food intake by 9.5% and 14.8% respectively. Despite the reduction in food intake there was no difference in subjective appetite at the termination of the meal or for the 60 min post ingestion. In contrast to these results, older adults do not reduce their food intake when required to increase the number of masticatory cycles before swallowing [48,49]. It is possible this result is due to age-related changes in appetite [34].

While these studies provide evidence that increasing the number of masticatory cycles reduces food intake it is not clear that mastication is directly responsible for this effect. Increasing the number of masticatory cycles also reduced eating rate which may influence food intake independent of mastication [1,38,42]. It is also possible that chewing past the point where swallowing would normally occur is uncomfortable for the participant and this resulted in premature cessation of the eating episode. Studies are required to unambiguously demonstrate the role of mastication in satiation.