The Impact of Eating Rate on Energy Intake, Body Composition, and Health 35

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Abstract

The modern food environment is often characterized by an increasingly assessable diet of inexpensive, energy-dense, and highly palatable foods. Extensive evidence indicates the eating rate of foods (g/min or kcal/min) is associated with energy intake, body composition, and the associated risk of food-based non-communicable diseases. Moderating eating rate during food intake offers a simple but effective strategy to regulate energy consumption and body weight. Research evidence from population and experimental studies demonstrates that eating at a slower rate can produce sustained changes in *ad libitum* energy intake, influence body composition, and moderate our metabolic response to ingested nutrients. Understanding which factors combine to influence eating rates affords new opportunities to design “slower” foods that can reduce the risk of over-consumption and support better long-term energy control. This chapter summarizes the role of eating rate in energy intake and body composition, provides an overview of development of eating behaviors in infancy and childhood, and describes the individual and food-based factors that can influence eating rate and its metabolic impact. The chapter provides a summary of research that has intervened to slow eating rate and demonstrates opportunities to support energy intake reductions using texture-led changes to eating rate.

Introduction: Impact of Eating Rate on Energy Intake and Body Composition

Obesity is a disorder of energy balance that is driven by overconsumption of calories relative to energy expenditure (Hall and Guo 2017) and is associated with a range of metabolic disorders responsible for much of the food based non-communicable diseases and ill-health that burden our society (Hruby et al. 2016). The increasing prevalence of obesity has led many to speculate that the food environment may be promoting greater energy intakes through the increased availability of inexpensive, energy-dense, and highly palatable foods. Attention has been focused on educating people to regulate their food intake by promoting healthy eating alongside re-shaping the food environment. Interventions focused on eating rate have attracted attention as a simple and effective strategy to better regulate food intake and body weight (Bellack 1975). The rate of eating can be summarized as the g/min or kcal/min of energy consumption during a meal and has been suggested to act as an indicator of appetite avidity and satiety sensitivity (Llewellyn et al. 2008), wherein a slower eating rate results in reduced food intake within a meal. Previous research has demonstrated the efficacy of slower eating to reduce food intake (Bolhuis et al. 2014a; Forde et al. 2013b; McCrickerd et al. 2017). The rate a person eats is thought to be the result of the combination of their internal drive to eat and the food texture environment they choose to consume (Forde et al. 2019). This is supported by extensive reports from epidemiological research which consistently show that faster self-reported eating rates are associated with increased food intake, increased body weight (Maruyama et al. 2008; Sasaki et al. 2003), and a higher risk of obesity and cardio-metabolic disease (Lee et al. 2013; Mochizuki et al. 2012; Nagahama et al. 2014; Sasaki et al. 2003). Therefore, understanding what drives faster eating rates creates opportunities to identify moderators of this behavior and the potential to support long-term changes to energy intake and body weight.

This chapter summarizes the evidence supporting the role of eating rate in promoting energy intake and higher body weight and its association with non-communicable diseases. The chapter will provide an overview of the individual and food-based factors that can influence eating rate and describe the metabolic impact of faster eating rates on health and body composition. Finally, we summarize research that has demonstrated opportunities to intervene on eating rate at both the individual and food environment level to support reductions in energy intake.

Relationship Between Eating Rate, Energy Intake, Obesity, and Non-communicable Diseases

Epidemiological Evidence for an Association Between Eating Rate, Body Composition, and Health

In population research the rate of eating is often self-reported as slow, medium, or fast. This self-reported eating rate measure has been widely reported in the epidemiological literature (Sasaki et al. 2003), and shown to have good reliability (Maruyama et al. 2008). Epidemiological studies have consistently shown that individuals that self-report a higher eating rate are at greater risk of overweight and obesity (Maruyama et al. 2008; Sasaki et al. 2003; van den Boer et al. 2017a). For instance, compared with adults who report slower eating, those who ate at a faster rate were 1.8- to 2.1-fold more likely to be overweight or obese in a large Japanese cohort (Maruyama et al. 2008). Longitudinal studies have shown that self-reported faster eating can also predict long-term weight gain and obesity (Gerace and George 1996; Tanihara et al. 2011). For example, those reporting faster eating gained 9.9 pounds over 7 years compared to 6.8 pounds among those consistently reporting a slower eating rate (Gerace and George 1996). In a separate population, faster eaters gained 1.1 kg more over an 8-year period than those self-reporting as slow to medium-eaters (Tanihara et al. 2011) suggesting an association between eating at a faster rate and greater prospective weight gain. Faster eating rate has also been positively associated with a greater incidence of type-2-diabetes biomarkers including interleukin-1β and interleuin-6 (Mochizuki et al. 2012), and the onset of type-2-diabetes (Sakurai et al. 2012), among otherwise healthy men even after adjusting for energy intake and BMI (Mochizuki et al. 2012). These findings indicate that insulin resistance (Otsuka et al. 2008) and weight gain may stem from consistently consuming greater energy by eating at a faster rate. Individuals that self-report eating faster have also been shown to have a higher risk of metabolic syndrome (Zhu et al. 2015), and non-alcoholic fatty liver disease (Lee et al. 2016). Faster eating is also strongly associated with markers of the metabolic syndrome including higher blood lipid profiles and greater waist circumference (Lee et al. 2013; Nagahama et al. 2014). These associations have been observed in both Asian and non-Asian populations, despite differences in diet and ethnicity.

Empirical Evidence of an Association Between Eating Rate, Body Composition, and Health

Across studies there is a large variation in the strength of associations between faster eating rates and noncommunicable diseases. Many of these discrepancies may be dependent on the accuracy of self-reported eating rate, and whether this accurately reflects observed differences in real life. Recent studies have confirmed that self-reported eating rate reflects differences in measured eating rates at an individual rather than a group level, indicating the findings from epidemiological comparisons of eating rate would hold true when measured (Petty et al. 2013; van den Boer et al. 2017a).

In laboratory studies eating rate has been objectively measured using a range of approaches including behavioral coding of video recordings, timers, bite counting devices or computerized software to track food disappearance from the plate (i.e., Universal eating pattern monitor). A large body of laboratory-based evidence supports a link between faster eating rate and an increased acute energy intake (Andrade et al. 2008; Forde et al. 2013b; Martin et al. 2007; Scisco et al. 2011; Zijlstra et al. 2009). Eating faster has been associated with increased food intake by increasing the rate of energy ingestion (kcals/min) during a meal (Spiegel and Jordan 1978). Individuals consume greater energy when instructed verbally to eat at a faster rate (Andrade et al. 2008) or when guided by a computerized task to increase their rate of intake (Martin et al. 2007; Scisco et al. 2011). In both cases, verbal or visual instructions that slow the rate of eating also led to a reduction in energy intake. Participants that were instructed to eat for an extended duration of 21-minutes decreased their *ad libitum* meal intake by an average of 67 kcals compared to a faster eating comparison group (Andrade et al. 2008). A meta-analysis of 21 studies confirmed that when participants eat at a faster rate they increase their overall energy intake, with a small- to medium-sized effect of 0.45 (Robinson et al. 2014).

Differences in Eating Rate and Microstructure by Weight Status

Whether eating rate is a cause or consequence of higher body weight has been a research question for many years, with numerous studies exploring whether people with a higher body weight eat with a distinctive microstructure to support faster eating rates. Eating microstructure encompasses behaviors such as average bite size (g/bite), chews per bite, total oral exposure (minutes), and total bites, and is best summarized as overall eating rate by weight (g/min) or energy intake rate (kcals/min). Results from some early comparative work by Ferster and colleagues showed that individuals with obesity tended to take larger bites and eat at a faster rate than a control group of lean individuals. The conclusion was that individuals with obesity would consume less if they slowed their intake by taking smaller bites (Ferster et al. 1962). Subsequent experimental studies however have been equivocal in their findings, with some confirming these observed differences in eating styles (Gaul et al. 1975; Park and Shin 2015), while others have found no differences in eating styles between individuals from different weight status subgroups (Spiegel 2000; Spiegel et al. 1993). Part of the lack of agreement in these results can be attributed to differences in the measures of eating rate, but it is also likely that if differences exist, they are likely to be nominal and may be partially due to the higher energy needs associated with increased body weight. Normal eating microstructure is typically characterized by a deceleration in eating rate towards the end of a meal, characterized by longer gaps between bites which signal the onset of satiation. Previous research has suggested that individuals with obesity retain a constant linear eating speed of eating throughout the meal which has been proposed to reflect an absence or distorted perception of satiety (Zandian et al. 2009).

Based on extensive evidence from both epidemiological and empirical studies, faster eating rates appear to have a significant role in promoting greater energy intakes acutely and have been associated with increased prospective weight gain over time. To date there is little consistent evidence to support the idea that faster eating rate is solely linked to a higher weight status, and wide variations in eating rate have been observed across all weight classes.

Factors that Can Influence an Individual's Eating Rate

The rate at which a meal is consumed has been described as a combination of an individual's drive to eat and the properties of the foods they choose to consume (Forde et al. 2019). Here we summarize the development of eating behaviors during childhood, and the main factors that have been reported to influence eating rate, summarizing factors related to the (i) person, (ii) food properties, and (iii) food environment, and the interaction between these factors.

Development of Eating Behaviors During Childhood

Eating rate is a heritable phenotypic with a heritability index of 0.62, making it one of the highest heritability estimates reported among appetitive traits, with a greater score than disinhibition, palatability, or neophobia (Llewellyn et al. 2008). From an early age, infants from 2 to 4 weeks old that were observed to have a greater sucking voracity later had a faster eating rate and greater prospective weight gain over time (Agras et al. 1987, 1990). Eating at a faster or slower rate may reflect both an individual's drive to eat and their early life experience with foods. Pre-weaning parental feeding practices such as breast feeding have been shown to stimulate better early life orofacial muscle and skeletal development in the developing infant when compared to bottle feeding (Viggiano et al. 2004), though no clear longer-term impact on orofacial muscle and skeletal development was found between breast or bottle feeding.

Early life exposure to a wide variety of food textures is important to promote diversity in food preference and a broader texture acceptance (Coulthard et al. 2009). In the development of eating behaviors both bite force and mastication abilities are influenced by early-life texture experiences (Wang and Ge 2015) which in turn support the consumption of harder and more complex textures in later childhood (Gisel 1988). One recent study tracked infant texture acceptance longitudinally alongside oral development between 6 and 18 months (Demonteil et al. 2019). This study demonstrated that chewing behavior begins to emerge and stabilize at approximately 8 months and is well established by 10 months, coinciding with the acceptance of harder and more complex textures. However, it remains unclear which elements of early life texture experiences and oral development influence the emergence of differences in eating rate, or how differences observed during infancy track from later childhood and adulthood.

Infants with greater sucking voracity gain weight at a faster rate, and in a similar way children that tend to eat faster have also been shown to gain weight at a faster rate over time (Berkowitz et al. 2010). These differences in eating rate and the associated microstructural patterns of eating may track into later childhood, and have been shown to have a sustained impact on the energy intake and prospective weight gain over time (Berkowitz et al. 2010; Okubo et al. 2017). Recent findings from the Growing up in Singapore to Healthy Outcomes birth cohort (GUSTO) demonstrate that among 4.5-year-old children, those that eat at a faster rate and for a longer duration consumed an average of 75% more energy within an *ad libitum* meal, than those that ate slower. Children who ate faster had a consistently higher energy intake and this was associated with increased BMI z-score and indices of whole-body adiposity (Fogel et al. 2017b). Those children that showed a faster rate of eating at 4.5 years still had a faster eating rate and greater increases in BMI z-scores and adiposity at 6 years, indicating the stability of this behavior and links to prospective weight changes (Forde et al. 2019). In this study, children that ate at a faster rate did so by taking larger bite size, chewing less *per* gram with a reduced oro-sensory exposure time *per* bite (Fogel et al. 2017a). This has been described as an "obesogenic" eating style that strongly associates with increased energy intake and not exclusively limited to children with overweight or obesity, but was also seen among children with BMI z-scores in the upper normal range (Fogel et al. 2017a, b). Taken together, these findings highlight the early emergence and consistency of eating rates in childhood, which associate with both increased energy intake and more rapid weight and adiposity gains during the preschool years.

Throughout childhood, parents often use feeding practices during meal time to encourage or restrict a child's food intake (Faith et al. 2004). Research has shown that within-meal frequency of parental feeding practices is associated with faster eating rates and greater energy intakes (Drucker et al. 1999; Fogel et al. 2018a). Longitudinal data also show that within-meal parental feeding practices, such as instructions to speed up or slowdown, restrictions around food choice, encouragement and coercive prompts to eat, have also been associated with faster eating rates and a higher BMI z-score suggesting a bidirectional relationship between the parent's feeding practices and child's eating behaviors (Fogel et al. 2018a; Fries et al. 2019; Quah et al. 2019). Faster eating rates have also been associated with stronger appetitive traits, enjoyment of food, food responsiveness and lower satiety responsiveness and slowness of eating, possibly reflecting a heightened responsivity to the food environment and a decreased sensitivity to satiety cues. Eating faster has been shown to mediate associations between greater food enjoyment, lower slowness in eating, lower food fussiness, and higher energy intakes, suggesting that eating rates associated with increased obesity risk may be underpinned by appetitive traits, and may be one of the behavioral pathways through which these appetitive traits promote greater energy intakes (Fogel et al. 2018b). More broadly, children with lower inhibitory control also tend to select multiple food servings, served themselves more and consume their meal at a faster rate, indicating that eating rate may be an important behavioral manifestation of this trait which can increase the risk of overweight or obesity (Fogel et al. 2019).

The early feeding practices and the food environment a child is exposed to play an important role in shaping their eating behaviors, and may exacerbate a stronger appetite response and poorer inhibitory control in an energy rich food environment. This can manifest through the early emergence of habitually faster eating rates that can exert a sustained influence on energy intake and increase prospective weight and adiposity gains during childhood, increasing the risk of obesity and metabolic dysfunction in later life.

Individual Factors that Can Influence Eating Rate

Eating rate has been shown to consistent at an individual level, across several different food products such that a tendency to eat faster for one meal is often generalized to faster eating across many other products (Guy-Grand et al. 1994). A recent study measured eating rate in participants who consumed the same meal during four separate *ad libitum* test sessions, and repeated this comparison across four separate feeding trials with a similar design (McCrickerd and Forde 2017). Results show that eating rate meal to meal was highly stable for each individual, with a person's eating rate during their first meal significantly predicting both their eating rate and energy intake during subsequent meals (McCrickerd and Forde 2017) (Fig. 1). This suggests that eating rate is a consistent and "automatic" behavior that is stable over time (Ioakimidis et al. 2011) and predictive of within-meal energy intake. Eating rate within an individual tends to be consistent but varies considerably between individuals (Ketel et al. 2019), with wide variations in eating rate have been observed among young children (Fogel et al. 2017b), and adults (Devezeaux de Lavergne et al. 2015; Zijlstra et al. 2010). Children described as faster eaters (9.33 g/min) were reported to eat approximately twice as fast as those children described as slower eaters (4.43 g/min), independently of the foods being consumed (Fogel et al. 2017b). Similarly, adults described as faster eaters (17.4 g/min) consumed about twice as fast as those described as slower

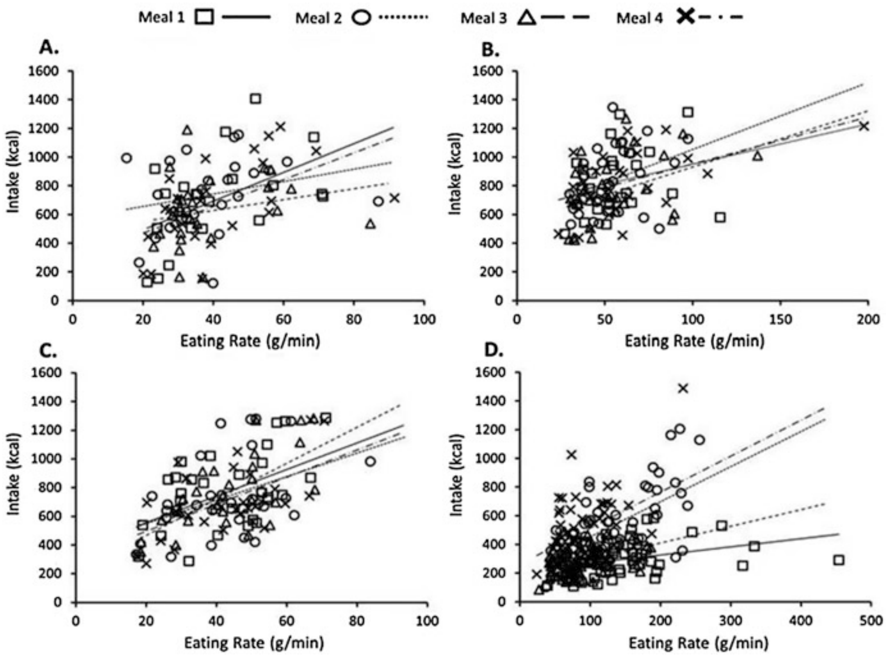

Fig. 1 Scatter plots of individual eating rates and energy intake across each of the four test meals consumed in (**A**) Study 1, (**B**) Study 2, (**C**) Study 3, and (**D**) Study 4. The lines represent the regression line of best fit for each meal. (From McCrickerd and Forde 2017)

eaters (7.8 g/min), for both hard and soft versions of the same test food (sausages) (Devezeaux de Lavergne et al. 2015).

Large differences in eating rate are consistently observed across genders, with one early study showing that independently of body size, females take more frequent bites with a smaller average bite size compared to men when consuming the same test food (Hill and McCutcheon 1984). Males have a larger average bite size for liquid, semisolid, and solid foods, and eat at a faster rate for solid foods, compared to women (Ketel et al. 2019; Park and Shin 2015). Males also have a higher maximal bite force (Palinkas et al. 2010), saliva flow rate (Percival et al. 1994), and cheek and lip compression strength (Clark and Solomon 2012), compared to women. These gender differences in oral anatomy and masticatory performance are plausible due to male's larger energy requirements which are linked to a higher lean muscle mass and resting metabolic rate. A recent study showed that across both genders, adults with higher lean muscle mass and basal metabolic rate had a higher eating rate (Henry et al. 2018), suggesting that eating faster may be an adaptive behavioral response to greater energy requirements.

Changes in oral health and dentition may also influence masticatory performance and studies have shown that older consumers tend to chew solid foods for longer, with more chews per bite compared to the young adults (Ketel et al. 2019; Mioche et al. 2004). Older consumers may experience a decline in their masticatory performance including oral health, dental status, jaw muscle strength, and bite force which, in turn, can lead to a lowering of their eating rate, changes in food choice, and the requirement for more chews *per* bite (Ketel et al. 2019). Masticatory performance and oral health status can therefore have a significant impact on food choice, enjoyment, and nutritional status (Schwahn et al. 2013). The total number of functional teeth has been suggested to affect masticatory efficiency (Boretti et al. 1995; Van der Bilt 2011). In adults, the loss of teeth posterior to the canines is significantly correlated with a reduction of masticatory efficiency (Hatch et al. 2001). Dental rehabilitation has been shown to be effective in reducing oral pain and can enhance chewing ability, and masticatory performance has been shown to improve following restorative dental treatment and prostheses (Allen and McMillan 2002).

In addition to age and gender, ethnic differences in cultural feeding practices may influence habitual oral processing behaviors. In one study Chinese participants were observed to have a lower average bite size and slower eating rate when compared to Dutch participants of a similar age across a range of different test foods (Ketel et al. 2019). Differences in eating behavior between the two ethnicities may be due to the differences in oral physiology and anatomy, with some reports suggesting differences in oral cavity volume (Xue and Hao 2006). Cultural differences in eating habits and food consumption contexts can also influence microstructural patterns of eating, with one study observing a smaller bite size and slower eating rate when the same test food was consumed using chopsticks compared to eating with a spoon or hands (Sun et al. 2015). These findings highlight that differences in eating rate can be influenced by individual differences in age, ethnicity, gender, and metabolic energy requirements in addition to cultural eating practices and textures encountered by consumers in their food environment.

The Influence of Food Texture on Eating Rate and Energy Intake

Texture is the dynamic sensation that arises from the combination of structural, mechanical, and surface properties of foods and beverages detected through the senses of vision, hearing, and touch. In addition to its contribution to sensory perception, a food's texture can also influence the oral processing behaviors required to form a swallowable bolus (Wee et al. 2018) and in this way can play an important role in moderating eating rate and regulating energy intake during a meal. We eat at a slower rate and consume less energy to satiation when provided with more textured versions of the same foods and this has been demonstrated for solid, semisolid, and liquid food textures (Bolhuis et al. 2014a; Forde et al. 2013b; Zijlstra et al. 2008, 2010).

The relationship between food and eating rate can be further explained by the oral breakdown path (Hutchings and Lillford 1988), which summarizes the breakdown process of a food into a swallowable bolus along three dimensions of degree of structure, lubrication, and time (Hutchings and Lillford 1988). When a food is consumed, it has to be first broken down in oral cavity to smaller particle sizes, lubricated with saliva, and agglomerated into a bolus before it becomes safe to swallow (Campbell et al. 2017). Several studies have shown that instrumental measures of food structure are directly linked to degree of oral processing, and differences in eating rate (Wee et al. 2018). Of all the macronutrients, proteinaceous foods have been reported to more often have a stiffer structure than the carbohydrate- and fat-rich foods; prolonging oro-sensory exposure time and reducing eating rate (Wee et al. 2018). Foods with greater innate lubrication, such as water and/ or fat content, tend to have faster eating rates and a faster time to swallow (Forde et al. 2017; van den Boer et al. 2017b; Viskaal-van Dongen et al. 2011).

Numerous recent studies have compared the eating rates of foods across a wide variety of different textures, macronutrient and energy contents (Forde et al. 2013a, 2017; Viskaal-van Dongen et al. 2011; van den Boer et al. 2017b). Harder (stiffer structure), thicker and chewier (less lubricated) foods (e.g., Tok, a Korean rice cake) require more chews and take a longer oro-sensory exposure time to form a swallowable bolus, producing a slower rate of eating than softer, thinner, and less chewy foods (e.g., cooked white rice). Eating rates of many solid foods have been observed in the range of <10–120 g/min, whereas for semisolids and liquids this range extends up to 600 g/min (Forde et al. 2013a, 2017; van den Boer et al. 2017b). Previous findings have shown that average bite size, chews per bite, and oro-sensory exposure time are strongly correlated with *ad libitum* energy intake (Bolhuis et al. 2014a, b). Slowing eating rate using food texture can be used to support a reduction in energy intake, though not all approaches to slowing eating rate have demonstrated this effect. Slowing down overall eating rate by increasing the pauses between bites was shown to be ineffective as a mean to reduce energy intake (Hermans et al. 2017). This suggests food structure manipulations which slow down eating rate naturally are likely to be more effective than approaches that require consumers to consciously adjust their natural eating habits to include prolonged pauses between bites.

Across a series of studies, researchers have explored the potential for texture-based differences in eating rate to reduce *ad libitum* energy intake while maintaining meal liking and post-meal fullness (Bolhuis et al. 2014a; Forde et al. 2013b; McCrickerd et al. 2017). In one example energy intake was compared across pureed and whole versions of the same savory meal with greater energy intake observed in the pureed meal condition and no significant difference in meal liking or post-meal appetite feelings (Forde et al. 2013b). Texture differences in meal components were used to produce a natural reduction in eating rate of approximately 20% to produce an average reduction in *ad libitum* energy intake of 12%. In a follow up study, slightly harder and softer versions of a hamburger and rice salad meal were served to participants in a cross-over design and intake at lunch and later energy compensation at dinner was recorded (Bolhuis et al. 2014a). Results showed participants consumed on average 13% less energy at lunch, and tended not to compensate for this reduced meal size later in the day to produce a total energy reduction of approximately 11% over the course of a full day, directly as a result textures differences served at lunch. More recently, across two studies researchers have explored the impact of texture-based reductions in eating rate in moderating energy consumption at breakfast when combined with reductions in energy density (study 1) and portion size (study 2).

Results again showed that the least energy was consumed when the thicker ("slow") meal was consumed at a lower energy density and in a smaller portion size (McCrickerd et al. 2017). These findings highlight opportunities to apply texture-based reductions in eating rate to support reductions in energy intake, which can be further enhanced when combined with reductions in energy density and portion size (McCrickerd et al. 2017). Importantly, across all studies, participants reported feeling equally full despite the decrease in energy intake and all foods were rated as hedonically equivalent as study participants ate in response to the textures served. Findings to date suggest that a 20% reduction of eating rate can lower *ad libitum* energy intake by between 10% and 15%, while sustaining food liking and post-meal satisfaction (McCrickerd and Forde 2017; McCrickerd et al. 2017). Further research is needed to establish whether such texture-based reductions in eating rate and energy intake persist over time to support sustained energy reductions and subsequent weight loss (Forde 2018a).

Harder food textures can be applied to reduce intake, but the reverse is also true as softer food textures that are easier to consume can promote greater consumption within and across meals. A texture- and energy density-modified "cottage pie" was shown to enhance energy intake in a crossover trial and proposed as an effective "food first" approach to support for individuals who struggle to meet their required energy needs (Pritchard et al. 2014). In a recent in-patient randomized controlled crossover study, Hall and colleagues found that when given 2 diets matched for total calories, macronutrients, and fiber, adults consumed significantly more energy *ad libitum* (~500 kcal/day) and gained more weight when consuming an ultraprocessed versus a less processed diet. Both diets were iso-energetic and matched for macronutrients; however, eating rate was significantly slower when participants were on the less processed diet, consuming 17 fewer calories *per* minute compared to ultraprocessed diet (Hall et al. 2019). These findings indicate that differences in food texture moderated participants eating rate and had a sustained impact on daily energy intakes that was sufficient to effect a change in body weight. The texture of industrially produced ultraprocessed foods was consistently softer and easier to chew and swallow, thereby increasing both eating rate and the overall energy consumed within and across meals. Future studies are required to better evaluate whether modern food processing can also be applied to enhance food texture in ways that can slow eating rate and support reductions in energy intake over time.

A food's flavor represents the integrated response to the smell, taste, and texture cues that emerge during consumption, and has also been shown to influence the rate of food intake within a meal. In one example, odor quality and intensity has been shown to influence the average bite size taken when consuming a semi-solid food (de Wijk et al. 2012). Flavor intensity may also indicate a higher nutrient content and influence eating microstructure (Forde 2016). Food palatability has also been shown to stimulate appetite, and enhance initial eating rate and through this facilitate greater food intake (Yeomans 1996). During the early stages of a meal, people tend to eat at a faster rate and can sometimes eat more when a food is perceived to have greater palatability (Bellisle and Le Magnen 1980). Palatability can influence intake by stimulating appetite and increasing the desire to consume a food through what is termed “appetition,” and through this promote faster eating rates and intake. This effect has primarily been observed during the first phases of a meal (Bellisle and Le Magnen 1980; Yeomans 1996). However, not all studies have shown an effect of increased palatability on food intake via faster eating, and it is likely this effect is dependent on meal context and the type of food consumed (Guy-Grand et al. 1994).

Elements of the Food Environment that Interact with Eating Rate to Promote Energy Intake

Portion size acts as a visual reference for the appropriate consumption amount (Marchiori et al. 2014), and larger portions have been shown to promote a larger average bite size and promote faster eating rates. Previous studies show that increased portion size is associated with a liner increase in bite size (Almiron-Roig et al. 2015; Burger et al. 2011), and larger bite sizes have been shown to increase eating rate and food intake (Forde et al. 2013a; Spiegel et al. 1993). In small-portion conditions, eating rate is reduced more quickly over a shorter period, whereas eating rate is faster and more consistent in larger portion conditions, up to an estimated threshold of approximately ~540 g (Almiron-Roig et al. 2015). This may be due in part to a natural tendency for “plate-cleaning” behavior where individuals plan to consume the full portion served. Seeing a larger portion may therefore prime the consumers and trigger individuals to maintain their initial eating rate for a longer duration within a meal in an effort to finish the portion and satisfy a predefined hunger goal (Burger et al. 2011). Interestingly, foods that are perceived as thicker and chewier are also often believed to be more filling (Forde et al. 2013a; Hogenkamp et al. 2011) which has been shown to result in the selection of smaller portions (McCrickerd et al. 2014). Texture cues such as increased viscosity have also been shown to slow the rate of consumption for semisolid foods (Zijlstra et al. 2009), suggesting this texture can influence both portion selection and eating rate during consumption (McCrickerd and Forde 2016). In this way, sensory cues pre-consumption such as texture or flavor may act as a cue to reduce portion selection and meal size due to their association with greater satiety. In a similar way, the well-established portion size effect whereby people consume more food in the presence of larger portions, has been shown to be larger for softly textured foods (Roe et al. 2016). Others have shown that energy intake is higher for high energy density foods that are eaten at a faster rate (Karl et al. 2013; McCrickerd et al. 2017). This further confirms that a food’s texture can interact with other elements of the meal (energy density/portion size) to impact both the rate of intake and the total amount of energy consumed to satiation.

Social facilitation can influence food intake by extending the duration of a meal (de Castro 1994), and through this may also influence eating rate. Individuals tend to eat faster and consume more when eating with multiple people and when their companions eat at a faster rate (Herman et al. 2003). People have been shown to replicate the eating behaviors of their eating companions, for example mimicking bite frequency by taking a bite within 5 s of their eating companion (Hermans et al. 2012).

This can influence eating rate when both eating speed, duration and overall intake speed become synchronized through a process of behavioral mimicry. The early meal termination of an eating companion has also been shown to indirectly alter the food intake of others (van den Boer and Mars 2015). In this way individuals often adjust their eating speed and food intake to that of their eating companions where their eating behaviors are triggered not by their desire to eat or the properties of the foods, but by cues from their eating environment.

What Is the Impact of Eating Rate on Metabolism?

As described earlier, eating at a slower rate has been shown to lower energy intake within a meal, but further studies have also demonstrated the impact of eating speed on post-meal fullness and hunger (Andrade et al. 2008; Zijlstra et al. 2009). The satiety response is defined as the intensity and duration of the absence of hunger post-meal and is mediated by the complex interplay between gastric emptying and a cascade of postprandial hormonal responses to the ingested food (Forde 2018b). In the hours' post-meal, there is a steady increase in the concentration of the orexigenic hormone ghrelin which produces sensations of hunger which when coupled with low levels of anorexigenic peptides that promote fullness such as peptide YY (PYY) and glucagon-like peptide-1 (GLP-1) (Benelam 2009). Research has shown that intravenous infusion of ghrelin in humans enhances appetite and increases the energy intake by 28% (Wren et al. 2001), whereas the intravenous infusion of PYY (the biologically active form) has been reported to inhibit food intake (Batterham et al. 2002). In a similar way, rate of eating has been shown to influence the excursion of satiety hormones when a longer chewing duration can stimulate greater anorectic hormone production. When food is chewed 40 times instead of 15 times, participants report feeling greater fullness and the additional chewing stimulates a longer postprandial suppression of ghrelin and reduced later energy intake. By contrast, the excursion of postprandial GLP-1 and cholecystokinin (CKK) levels were increased when the same quantity of food was chewed 40 times, though these responses were somewhat blunted among participants with obesity suggesting that extending chewing time may not have the same beneficial effect on satiety across all populations (Li et al. 2011). In another study, PYY and GLP-1 responses were increased during the early to mid-postprandial period when a fixed portion meal was consumed over 30 min compared to consumption of the same meal in a 5 min period (Kokkinos et al. 2010). Together, these findings indicate that eating more slowly and with more chews *per* bite both extends the meal duration and can promote an increased subjective experience of satiety which is supported by hormonal signaling of satiety producing less hunger and more fullness *per* calorie consumed. This effect seems to be primarily driven by the extended oral processing time as simply spacing the meal out for longer does not seem to produce the same impact on satiety. To test this, participants were asked to consume a meal normally or split into seven smaller equal meals that were consumed at intervals within a fixed time. There was a large variation in eating duration but little variation in eating rate when consuming the same fixed-portion meal and the result shows that spacing the meal for longer did not alter subjective feelings of satiety, though there were small differences in CKK and pancreatic polypeptide (PP) response (Karl et al. 2011). The finding illustrates the important contribution mastication makes to both the onset of satiation and the subsequent feeling of fullness post-meal for an equivalent calorie load.

Another important contribution to post-meal satiety comes from gastrointestinal transit time between meals (Juvonen et al. 2009). Foods with higher viscosity tend to be require a longer oro-sensory exposure time and slower eating rate, which has been suggested to stimulate a stronger cephalic phase response (de Graaf 2012). The putative mechanism is that a higher food viscosity stimulates a prolonged oro-sensory exposure time and lower eating rate and could also contribute to delayed gastric emptying and through this contribute to a greater satiety response (Juvonen et al. 2009; Marciani et al. 2001). An early example of the impact of food form and eating rate on post-meal satiety showed that 500 g of apple juice can be consumed 11 times faster than a calorie-equivalent 500 g of apples (~2 vs. 17 min), and post-meal satiety was significantly higher from apples in the solid form (Haber et al. 1977). Recent studies have shown that despite reductions of 10–15% in *ad libitum* energy intake, people feel equally full after a harder (slower) version of a food was consumed compared to the softer (faster) food equivalent (Bolhuis et al. 2014a; Karl et al. 2013; Zhu et al. 2013a; Zijlstra et al. 2008). In one study, Zhu and coworkers showed that a high viscosity semisolid meal produced a slower eating rate compared to a standard viscosity version of the same semisolid meal, with reductions in post-meal appetite and delayed gastric emptying following the high viscosity meal (Zhu et al. 2013a). Results suggest that relatively subtle but perceptible increases in viscosity can stimulate a stronger satiety response *per* calorie consumed. Consistent with this finding, participants report a greater expected and perceived "fullness" following consumption of equi-calorie meals that were naturally consumed at a slower eating rate (Ferriday et al. 2016) (Fig. 2). Slowing the eating rate of food intake is therefore likely to contribute to a stronger satiety response for an equivalent calorie load, and may be a simple but effective way to add fullness to meals without the necessity to add further energy.

The impact of a slower eating rate seems to be predominantly driven by the extended oro-sensory exposure time a food spends in mouth during consumption. One study has compared the oral and gastric contributions to post-meal satiety and concluded that longer oro-sensory exposure which was produced by modified sham feeding exerted a larger impact on inhibiting later appetite and intake compared to an equivalent increase in gastric volume delivered through nasogastric infusion (Wijlens et al. 2012). This highlights the importance of eating rate and the oro-sensory contribution to food intake, which plays an important role in signaling the arrival of calories and the associated perception of post-meal fullness. Eating rate can also be considered as the speed of transition of calories through the oral cavity and is the product of both the eating rate and energy density of the food being consumed (Stubbs et al. 1995). This combined measure has been referred to as the energy intake rate (EIR) (kcal/min) of a food (Forde et al. 2013a) and can act as an indicator of consumption rate of calories within a meal (van den Boer et al. 2017b). A

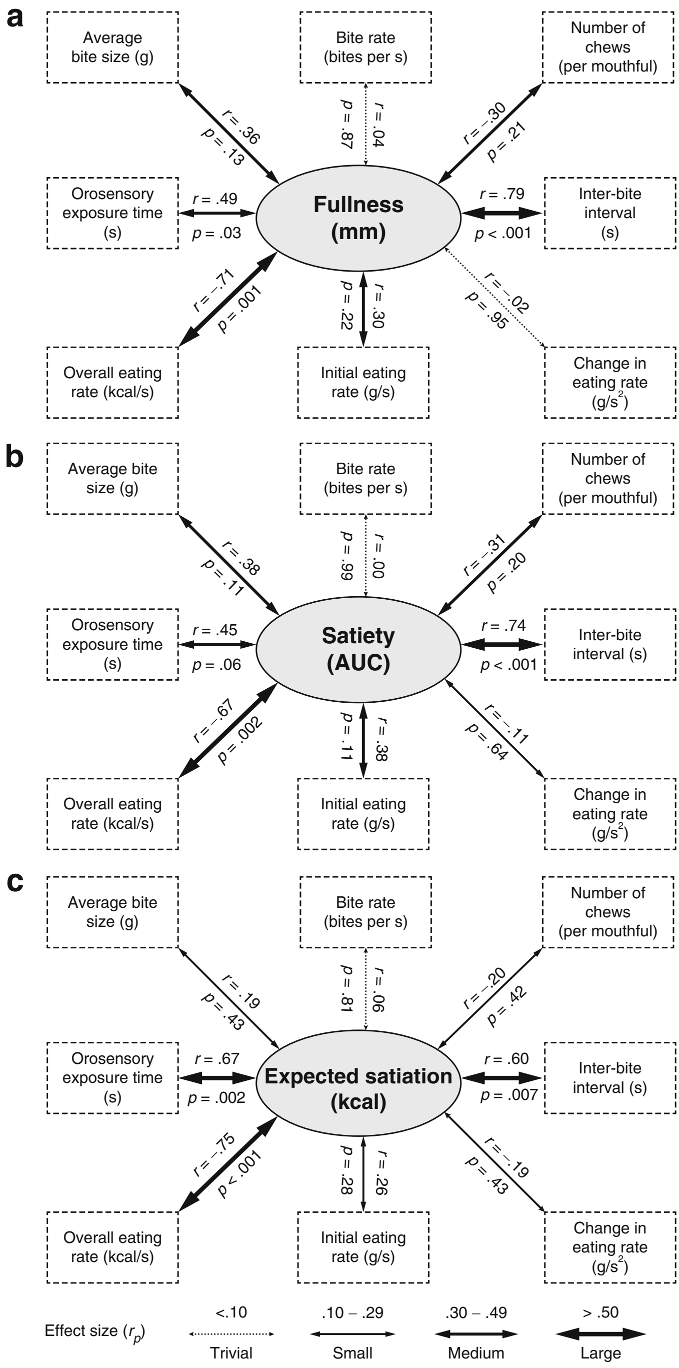

Fig. 2 Partial correlations between oral processing behaviors and (**a**) perceived fullness, (**b**) satiety, and (**c**) expected "fullness" after controlling for baseline composite fullness (r_p). Effect sizes are denoted by the width of each arrow. (From Ferriday et al. 2016)

comparison of the energy intake rate of a wide range of foods demonstrates there is a large natural variation in the rate of calorie intake across commonly consumed foods, with potential to significantly reduce energy consumption rate by considering both the energy density and eating rate of a food. Future research is needed to demonstrate the potential for lower energy intake rate foods to support sustained and meaningful reductions in dietary energy intakes over an extended period, as most studies to date have only measured acute energy intake.

In addition to effects on appetite, eating rate has also been shown to influence postprandial glycemic and insulin responses (Sun et al. 2015). The postprandial glycemic response is the change in blood glucose concentration induced by a food for the first 120-min post-ingestion. When the same carbohydrate source (rice) was chewed 30 instead of 15 times, the postprandial glycemic response was shown to increase by approximately 18% (Ranawana et al. 2014). Significantly higher plasma glucose, insulin, and glucose-dependent insulinotropic peptide (GIP) concentrations were reported when the same food (pizza) was chewed 40 rather than 15 times *per* mouthful (Zhu et al. 2013b). A longer chewing duration may support reductions in energy intake but can also produce a larger glycemic and insulin response. Eating rates impact on post-ingestive metabolism is likely mediated by the degree of oral breakdown, where longer chewing produces a reduced bolus particle size and offers a greater substrate surface area for digestive enzymes to produce a heightened metabolic response. The impact of bolus particle size on glycemic response has previously been reported in both *in vitro* (performed outside of a living organism) (Ranawana et al. 2010b), and *in vivo* (performed on or in a living organism) studies (Ranawana et al. 2010a) and demonstrated that smaller particle size produces an increased surface area for enzymatic saliva and a faster glucose absorption rate and higher glycemic response. When the oral phase of digestion is skipped and carbohydrates are consumed without chewing, blood glucose responses are attenuated, highlighting the importance of eating rate and degree of chewing in moderating the metabolic response to ingested carbohydrates (Read et al. 1986).

Another important metabolic effect of eating rate is its contribution to the thermic effect of food intake through what is termed “diet-induced thermogenesis” (DIT). DIT is defined as the increase in energy expenditure associated with the digestion, absorption, and storage of foods, which accounts for 10–15% of the total daily energy expenditure (Levine 2004). The extent of diet-induced thermogenesis (DIT) is dependent on the speed of meal consumption and research has shown that small changes in DIT (10-20 kcal/day) can result in 0.5–1 kg of weight gain over the course of a year (Lean and Malkova 2016). A higher DIT response was recorded when the same meal was eaten more slowly compared to when it was eaten rapidly (Hamada et al. 2014), whereas others have noted an increase in oxygen uptake and splanchnic blood flow following the slower consumption of a meal (Madsen et al. 2006; Hamada et al. 2014). Eating the same calories slower has been shown to induce an increase of 15 kcal in DIT (Hamada et al. 2016) although others have failed to replicate this effect (Laboure et al. 2002). As with satiety and glycaemia, DIT was larger following oral feeding compared to intra-gastric feeding (Jonge et al. 1991).

Eating Rate as Target for Intervention

Given the extensive evidence supporting the impact of eating rate on energy intake, body composition and metabolic response to ingested nutrients, eating rate has been identified as a modifiable risk factor for obesity and a potential target for behavioral intervention. Advising individuals with obesity to slow their eating could be beneficial for managing caloric intake and since 2009 the American Obesity Society has recommended to "slow eating speed to better regulate energy intake" (Mechanick et al. 2009). Several approaches have been applied to reduce eating rate using external cues, such as providing feedback to reduce the eating rate via electronic devices or vibrio-tactile sensation (Ford et al. 2010; Galhardo et al. 2012; Hamilton-Shield et al. 2014). These approaches have yielded some success in energy intake regulation in the short-term, demonstrating an effect on eating speed, energy intake and in some cases body weight. In one example, adolescents who were instructed to extend their inter-bite interval using an egg-timer have successfully reduced their eating rate and energy intake (Salazar Vazquez et al. 2016). However, of the initial cohort of 54 adolescents only 14 (25%) adhered to the use of the egg-timer to slow bite rate and completed the study after a year; suggesting there may be significant challenges with adherence with such an intervention. What is less clear is the extent to which an individual's eating behaviors can be "retained" to produce longer term and sustainable changes to eating rate. An early example of an eating rate intervention required women within a weight control program to lower their eating rates by receiving advice to pause between bites, and to cut foods into smaller pieces. This approach yielded some initial success but the change in eating rate was not maintained over time (Spiegel et al. 1991). In a recent 8-week family-based behavioral therapy intervention ("RePace"), children who reduced their eating rate through mealtime instruction and guidance from their parents showed a reduction in eating pace, energy intake and BMI (Faith et al. 2019). However long-term motivation for continuous feedback on eating behavior remains untested, and may be required to maintain changes to eating behaviors after the initial intervention period.

Individuals adapt their eating rates based on the food form and texture of a food that is being consumed (Wee et al. 2018). For example, eating rate varies when consuming a "hard slow" food *vs*. a "soft fast" food as a result of texture and consistency served. Changing the form of a food or modifying its texture can serve as a more natural and sustainable strategy to lower eating rate in the long term. Previous research has shown that consumption of semisolid, solid, and liquid foods can impact satiation and satiety response to ingested nutrients (Mattes 2005), and harder food form can reduce overall food intake (Mourao et al. 2007). Apple slices have been shown to suppress appetite for longer than apple puree, which in turn had a stronger impact than the same calories consumed as an apple juice (Flood-Obbagy and Rolls 2009). Across a series of *ad libitum* feeding studies, the efficacy of a food texture intervention to slow down the eating rate and reduce the overall energy intake has been shown (Bolhuis et al. 2014a; Forde et al. 2013b; McCrickerd et al. 2017). Texture difference between pureed and whole versions of the same savory meals have been shown to effectively reduce eating rate by an average of

20%, which resulted in a reduction of 12% in *ad libitum* energy intake (Forde 2018a). Questions remain about the long-term efficacy of this approach and whether it is sufficient to reduce the eating rate of individual foods or necessary to modify the texture of every food at every meal to produce the same effect.

Experimental evidence provides support that eating rate is a meaningful target for obesity intervention beyond conventional dieting and calorie reduction approaches. Challenges still remain in our understanding of the best approach to changing eating rate in the longer term and beyond a controlled experimental setting. External cues and prompts have been shown to produce clinically meaningful results, although they may present challenges for longer term adherence, and it remains unclear whether these changes are simply guiding rather than re-training the eating behavior. Texture-led changes to eating rate therefore offer an exciting opportunity to adapt an individual's response to the structural properties of the food being consumed in a way that maintains the associated eating experience and satiety from food intake. Further opportunities exist to combine texture-led changes to eating rate with the development of energy reduced foods that maintain their hedonic appeal and keep pleasure central to the eating experience. Using this approach, it may be possible to apply food-based approaches to change eating behaviors and moderate the rate of energy intake. These interventions are also likely to influence the metabolic response to the food consumed.

Conclusion

This current chapter provides a consolidated overview of current evidence regarding the importance of eating rate in regulating energy intake and metabolism, while offering new opportunities for the reduction of risk associated with obesity and non-communicable diseases. Eating rate is a product of both an individual's drive to eat and the food environment they choose to consume. This eating behavior is a modifiable risk factor for food based chronic conditions that is malleable, and has been shown to produce sustained changes in energy intake and body composition over time. The joint-approach of food texture and reductions in energy density offers an effective yet largely unexplored opportunity to influence energy intake in a manner that can sustain the food acceptance and keep eating enjoyment central to the intervention. Wholesale changes to the energy intake rate of the food environment are likely to have a population-wide impact from early childhood through to sustaining nutrient intakes in later life. This offers a food first approach to combating obesity and other food based chronic conditions, and future research should focus on improving our understanding of the long-term implications of energy intake reductions on human health and well-being.

References

Agras, W. S., Kraemer, H. C., Berkowitz, R. I., Korner, A. F., & Hammer, L. D. (1987). Does a vigorous feeding style influence early development of adiposity? *The Journal of Pediatrics, 110*(5), 799–804. https://doi.org/10.1016/S0022-3476(87)80029-X.

Agras, W. S., Kraemer, H. C., Berkowitz, R. I., & Hammer, L. D. (1990). Influence of early feeding style on adiposity at 6 years of age. *The Journal of Pediatrics, 116*(5), 805–809. https://doi.org/10.1016/S0022-3476(05)82677-0.

Allen, F., & McMillan, A. (2002). Food selection and perceptions of chewing ability following provision of implant and conventional prostheses in complete denture wearers. *Clinical Oral Implants Research, 13*(3), 320–326. https://doi.org/10.1034/j.1600-0501.2002.130313.x.

Almiron-Roig, E., Tsiountsioura, M., Lewis, H. B., Wu, J., Solis-Trapala, I., & Jebb, S. A. (2015). Large portion sizes increase bite size and eating rate in overweight women. *Physiology & Behavior, 139*, 297–302. https://doi.org/10.1016/j.physbeh.2014.11.041.

Andrade, A. M., Greene, G. W., & Melanson, K. J. (2008). Eating slowly led to decreases in energy intake within meals in healthy women. *Journal of the American Dietetic Association, 108*(7), 1186–1191. https://doi.org/10.1016/j.jada.2008.04.026.

Batterham, R. L., Cowley, M. A., Small, C. J., Herzog, H., Cohen, M. A., Dakin, C. L., . . . Bloom, S. R. (2002). Gut hormone PYY (3-36) physiologically inhibits food intake. *Nature, 418*(6898), 650–654. https://doi.org/10.1038/nature00887.

Bellack, A. S. (1975). Behavior therapy for weight reduction. *Addictive Behaviors, 1*(1), 73–82. https://doi.org/10.1016/S0306-4603(75)80020-7.

Bellisle, F., & Le Magnen, J. (1980). The analysis of human feeding patterns: The edogram. *Appetite, 1*(2), 141–150. https://doi.org/10.1016/S0195-6663(80)80018-3.

Benelam, B. (2009). Satiation, satiety and their effects on eating behaviour. *Nutrition Bulletin, 34*(2), 126–173. https://doi.org/10.1111/j.1467-3010.2009.01753.x.

Berkowitz, R. I., Moore, R. H., Faith, M. S., Stallings, V. A., Kral, T. V. E., & Stunkard, A. J. (2010). Identification of an obese eating style in 4-year-old children born at high and low risk for obesity. *Obesity (Silver Spring, Md.), 18*(3), 505–512. https://doi.org/10.1038/oby.2009.299.

Bolhuis, D. P., Forde, C. G., Cheng, Y., Xu, H., Martin, N., & de Graaf, C. (2014a). Slow food: Sustained impact of harder foods on the reduction in energy intake over the course of the day. *PLoS One, 9*(4), e93370. https://doi.org/10.1371/journal.pone.0093370.

Bolhuis, D. P., Lakemond, C. M. M., de Wijk, R. A., Luning, P. A., & de Graaf, C. (2014b). Both a higher number of sips and a longer oral transit time reduce ad libitum intake. *Food Quality and Preference, 32*, 234–240. https://doi.org/10.1016/j.foodqual.2013.10.001.

Boretti, G., Bickel, M., & Geering, A. H. (1995). A review of masticatory ability and efficiency. *The Journal of Prosthetic Dentistry, 74*(4), 400–403.

Burger, K. S., Fisher, J. O., & Johnson, S. L. (2011). Mechanisms behind the portion size effect: Visibility and bite size. *Obesity (Silver Spring, Md.), 19*(3), 546–551. https://doi.org/10.1038/oby.2010.233.

Campbell, C. L., Wagoner, T. B., & Foegeding, E. A. (2017). Designing foods for satiety: The roles of food structure and oral processing in satiation and satiety. *Food Structure, 13*, 1–12. https://doi.org/10.1016/j.foostr.2016.08.002.

Clark, H. M., & Solomon, N. P. (2012). Age and sex differences in orofacial strength. *Dysphagia, 27*(1), 2–9. https://doi.org/10.1007/s00455-011-9328-2.

Coulthard, H., Harris, G., & Emmett, P. (2009). Delayed introduction of lumpy foods to children during the complementary feeding period affects child's food acceptance and feeding at 7 years of age. *Maternal & Child Nutrition, 5*(1), 75–85. https://doi.org/10.1111/j.1740-8709.2008.00153.x.

de Castro, J. M. (1994). Family and friends produce greater social facilitation of food intake than other companions. *Physiology & Behavior, 56*(3), 445–445. https://doi.org/10.1016/0031-9384(94)90286-0.

de Graaf, C. (2012). Texture and satiation: The role of oro-sensory exposure time. *Physiology & Behavior, 107*(4), 496–501. https://doi.org/10.1016/j.physbeh.2012.05.008.

de Wijk, R. A., Polet, I. A., Boek, W., Coenraad, S., & Bult, J. H. F. (2012). Food aroma affects bite size. *Flavour, 1*(1), 3. https://doi.org/10.1186/2044-7248-1-3.

Demonteil, L., Tournier, C., Marduel, A., Dusoulier, M., Weenen, H., & Nicklaus, S. (2019). Longitudinal study on acceptance of food textures between 6 and 18 months. *Food Quality and Preference, 71*, 54–65. https://doi.org/10.1016/j.foodqual.2018.05.010.

Devezeaux de Lavergne, M., Derks, J. A. M., Ketel, E. C., de Wijk, R. A., & Stieger, M. (2015). Eating behaviour explains differences between individuals in dynamic texture perception of sausages. *Food Quality and Preference, 41*, 189–200. https://doi.org/10.1016/j.foodqual.2014.12.006.

Drucker, R. R., Hammer, L. D., Agras, W. S., & Bryson, S. (1999). Can mothers influence their child's eating behavior? *Journal of Developmental and Behavioral Pediatrics, 20*(2), 88–92.

Faith, M. S., Scanlon, K. S., Birch, L. L., Francis, L. A., & Sherry, B. (2004). Parent-child feeding strategies and their relationships to child eating and weight status. *Obesity Research, 12*(11), 1711–1722. https://doi.org/10.1038/oby.2004.212.

Faith, M. S., Diewald, L. K., Crabbe, S., Burgess, B., & Berkowitz, R. I. (2019). Reduced eating pace (RePace) behavioral intervention for children prone to or with obesity: Does the turtle win the race? *Obesity, 27*(1), 121–129. https://doi.org/10.1002/oby.22329.

Ferriday, D., Bosworth, M. L., Godinot, N., Martin, N., Forde, C. G., Van Den Heuvel, E., . . . Brunstrom, J. M. (2016). Variation in the oral processing of everyday meals is associated with fullness and meal size; A potential nudge to reduce energy intake? *Nutrients, 8*(5), 315.

Ferster, C. B., Nurnberger, J. I., & Levitt, E. B. (1962). The control of eating. *Journal of Mathematics 1*, 87–109. https://doi.org/10.1002/oby.1996.4.4.401.

Flood-Obbagy, J. E., & Rolls, B. J. (2009). The effect of fruit in different forms on energy intake and satiety at a meal. *Appetite, 52*(2), 416–422. https://doi.org/10.1016/j.appet.2008.12.001.

Fogel, A., Goh, A. T., Fries, L. R., Sadananthan, S. A., Velan, S. S., Michael, N., . . . Forde, C. G. (2017a). A description of an 'obesogenic' eating style that promotes higher energy intake and is associated with greater adiposity in 4.5 year-old children: Results from the GUSTO cohort. *Physiology & Behavior, 176*, 107–116. https://doi.org/10.1016/j.physbeh.2017.02.013.

Fogel, A., Goh, A. T., Fries, L. R., Sadananthan, S. A., Velan, S. S., Michael, N., . . . Forde, C. G. (2017b). Faster eating rates are associated with higher energy intakes during an ad libitum meal, higher BMI and greater adiposity among 4.5-year-old children: Results from the Growing Up in Singapore Towards Healthy Outcomes (GUSTO) cohort. *The British Journal of Nutrition, 117*(7), 1042–1051. https://doi.org/10.1017/s0007114517000848.

Fogel, A., Fries, L. R., McCrickerd, K., Goh, A. T., Chan, M. J., Toh, J. Y., . . . Forde, C. G. (2018a). Prospective associations between parental feeding practices and children's oral processing behaviours. *Maternal & Child Nutrition*, *15*, e12635. https://doi.org/10.1111/mcn.12635.

Fogel, A., Fries, L. R., McCrickerd, K., Goh, A. T., Quah, P. L., Chan, M. J., . . . Forde, C. G. (2018b). Oral processing behaviours that promote children's energy intake are associated with parent-reported appetitive traits: Results from the GUSTO cohort. *Appetite, 126*, 8–15. https://doi.org/10.1016/j.appet.2018.03.011.

Fogel, A., McCrickerd, K., Goh, A. T., Fries, L. R., Chong, Y.-S., Tan, K. H., . . . Forde, C. G. (2019). Associations between inhibitory control, eating behaviours and adiposity in 6-year-old children. *International Journal of Obesity*, *43*, 1344. https://doi.org/10.1038/s41366-019-0343-y.

Ford, A. L., Bergh, C., Södersten, P., Sabin, M. A., Hollinghurst, S., Hunt, L. P., & Shield, J. P. H. (2010). Treatment of childhood obesity by retraining eating behaviour: Randomised controlled trial. *British Medical Journal, 340*, b5388. https://doi.org/10.1136/bmj.b5388.

Forde, C. G. (2016). Flavor Perception and Satiation. In *Flavor: from food to behaviors, wellbeing and health* (pp. 251–276). Woodhead Publishing, United Kingdom. https://doi.org/10.1016/B978-0-08-100295-7.00012-8.

Forde, C. G. (2018a). From perception to ingestion; The role of sensory properties in energy selection, eating behaviour and food intake. *Food Quality and Preference*, *66*. https://doi.org/10.1016/j.foodqual.2018.01.010.

Forde, C. G. (2018b). Measuring Satiation and Satiety. In *Methods in Consumer Research* (Vol. 2, pp. 151–182). Woodhead Publishing, United Kingdom. https://doi.org/10.1016/B978-0-08-101743-2.00007-8.

Forde, C. G., van Kuijk, N., Thaler, T., de Graaf, C., & Martin, N. (2013a). Oral processing characteristics of solid savoury meal components, and relationship with food composition,

sensory attributes and expected satiation. *Appetite, 60*, 208–219. https://doi.org/10.1016/j.appet.2012.09.015.
Forde, C. G., van Kuijk, N., Thaler, T., de Graaf, C., & Martin, N. (2013b). Texture and savoury taste influences on food intake in a realistic hot lunch time meal. *Appetite, 60*, 180–186. https://doi.org/10.1016/j.appet.2012.10.002.
Forde, C. G., Leong, C., Chia-Ming, E., & McCrickerd, K. (2017). Fast or slow-foods? Describing natural variations in oral processing characteristics across a wide range of Asian foods. *Food & Function, 8*(2), 595–606. https://doi.org/10.1039/c6fo01286h.
Forde, C. G., Fogel, A., & McCrickerd, K. (2019). Children's Eating Behaviours and Energy Intake: Overlapping influences and opportunities for intervention. In *Nestle Nutrition Institute Workshop Series* (Vol. 91, pp. 55–67). Karger Press, Basel. https://doi.org/10.1159/000493695.
Fries, L. R., Chan, M. J., Quah, P. L., Toh, J. Y., Fogel, A., Goh, A. T., . . . Chong, M. F. F. (2019). Maternal feeding practices and children's food intake during an ad libitum buffet meal: Results from the GUSTO cohort. *Appetite, 142*, 104371. https://doi.org/10.1016/j.appet.2019.104371.
Galhardo, J., Hunt, L. P., Lightman, S. L., Sabin, M. A., Bergh, C., Sodersten, P., & Shield, J. P. (2012). Normalizing eating behavior reduces body weight and improves gastrointestinal hormonal secretion in obese adolescents. *The Journal of Clinical Endocrinology and Metabolism, 97*(2), E193–E201. https://doi.org/10.1210/jc.2011-1999.
Gaul, D. G., Craighead, E., & Mahoney, M. J. (1975). Relationship between eating rates and obesity. *Journal of Consulting and Clinical Psychology, 43*(2), 123–125. https://doi.org/10.1037/h0076522.
Gerace, T. A., & George, V. A. (1996). Predictors of weight increases over 7 years in fire fighters and paramedics. *Preventive Medicine, 25*(5), 593–600. https://doi.org/10.1006/pmed.1996.0094.
Gisel, E. G. (1988). Chewing cycles in 2- to 8-year-old normal children: A developmental profile. *The American Journal of Occupational Therapy, 42*(1), 40–46. https://doi.org/10.5014/ajot.42.1.40.
Guy-Grand, B., Lehnert, V., Doassans, M., & Bellisle, F. (1994). Type of test-meal affects palatability and eating style in humans. *Appetite, 22*(2), 125–134. https://doi.org/10.1006/appe.1994.1012.
Haber, G. B., Heaton, K. W., Murphy, D., & Burroughs, L. F. (1977). Depletion and disruption of dietary fibre. Effects on satiety, plasma-glucose, and serum-insulin. *Lancet, 2*(8040), 679–682. https://doi.org/10.1016/s0140-6736(77)90494-9.
Hall, K. D., & Guo, J. (2017). Obesity energetics: Body weight regulation and the effects of diet composition. *Gastroenterology, 152*(7), 1718–1727.e1713. https://doi.org/10.1053/j.gastro.2017.01.052.
Hall, K. D., Ayuketah, A., Brychta, R., Cai, H., Cassimatis, T., Chen, K. Y., . . . Zhou, M. (2019). Ultra-processed diets cause excess calorie intake and weight gain: An inpatient randomized controlled trial of ad libitum food intake. *Cell Metabolism*, *30*, 67. https://doi.org/10.1016/j.cmet.2019.05.008.
Hamada, Y., Kashima, H., & Hayashi, N. (2014). The number of chews and meal duration affect diet-induced thermogenesis and splanchnic circulation. *Obesity (Silver Spring, Md.), 22*(5), E62–E69. https://doi.org/10.1002/oby.20715.
Hamada, Y., Miyaji, A., & Hayashi, N. (2016). Effect of postprandial gum chewing on diet-induced thermogenesis. *Obesity (Silver Spring, Md.), 24*(4), 878–885. https://doi.org/10.1002/oby.21421.
Hamilton-Shield, J., Goodred, J., Powell, L., Thorn, J., Banks, J., Hollinghurst, S., . . . Sharp, D. (2014). Changing eating behaviours to treat childhood obesity in the community using Mandolean: The Community Mandolean randomised controlled trial (ComMando)–a pilot study. *Health Technology Assessment (Winchester, England), 18*(47), i.
Hatch, J. P., Shinkai, R. S. A., Sakai, S., Rugh, J. D., & Paunovich, E. D. (2001). Determinants of masticatory performance in dentate adults. *Archives of Oral Biology, 46*(7), 641–648.

Henry, C. J., Ponnalagu, S., Bi, X., & Forde, C. (2018). Does basal metabolic rate drive eating rate? *Physiology & Behavior, 189*, 74–77. https://doi.org/10.1016/j.physbeh.2018.03.013.

Herman, C. P., Roth, D. A., & Polivy, J. (2003). Effects of the presence of others on food intake: A normative interpretation. *Psychological Bulletin, 129*(6), 873–886. https://doi.org/10.1037/0033-2909.129.6.873.

Hermans, R. C., Lichtwarck-Aschoff, A., Bevelander, K. E., Herman, C. P., Larsen, J. K., & Engels, R. C. (2012). Mimicry of food intake: The dynamic interplay between eating companions. *PLoS One, 7*(2), e31027. https://doi.org/10.1371/journal.pone.0031027.

Hermans, R. C. J., Hermsen, S., Robinson, E., Higgs, S., Mars, M., & Frost, J. H. (2017). The effect of real-time vibrotactile feedback delivered through an augmented fork on eating rate, satiation, and food intake. *Appetite, 113*, 7–13. https://doi.org/10.1016/j.appet.2017.02.014.

Hill, S. W., & McCutcheon, N. B. (1984). Contributions of obesity, gender, hunger, food preference, and body size to bite size, bite speed, and rate of eating. *Appetite, 5*(2), 73–83. https://doi.org/10.1016/S0195-6663(84)80026-4.

Hogenkamp, P. S., Stafleu, A., Mars, M., Brunstrom, J. M., & de Graaf, C. (2011). Texture, not flavor, determines expected satiation of dairy products. *Appetite, 57*(3), 635–641. https://doi.org/10.1016/j.appet.2011.08.008.

Hruby, A., Manson, J. E., Qi, L., Malik, V. S., Rimm, E. B., Sun, Q., . . . Hu, F. B. (2016). Determinants and consequences of obesity. *American Journal of Public Health, 106*(9), 1656–1662. https://doi.org/10.2105/ajph.2016.303326.

Hutchings, J. B., & Lillford, P. J. (1988). The perception of food texture – the philosophy of the breakdown path. *Journal of Texture Studies, 19*(2), 103–115. https://doi.org/10.1111/j.1745-4603.1988.tb00928.x.

Ioakimidis, I., Zandian, M., Eriksson-Marklund, L., Bergh, C., Grigoriadis, A., & Sodersten, P. (2011). Description of chewing and food intake over the course of a meal. *Physiology & Behavior, 104*(5), 761–769. https://doi.org/10.1016/j.physbeh.2011.07.021.

Jonge, L. D., Agoues, I., & Garrel, D. R. (1991). Decreased thermogenic response to food with intragastric vs. oral feeding. *American Journal of Physiology-Endocrinology and Metabolism, 260*(2), E238–E242. https://doi.org/10.1152/ajpendo.1991.260.2.E238.

Juvonen, K. R., Purhonen, A. K., Salmenkallio-Marttila, M., Lahteenmaki, L., Laaksonen, D. E., Herzig, K. H., . . . Karhunen, L. J. (2009). Viscosity of oat bran-enriched beverages influences gastrointestinal hormonal responses in healthy humans. *The Journal of Nutrition, 139*(3), 461–466. https://doi.org/10.3945/jn.108.099945.

Karl, J. P., Young, A. J., & Montain, S. J. (2011). Eating rate during a fixed-portion meal does not affect postprandial appetite and gut peptides or energy intake during a subsequent meal. *Physiology & Behavior, 102*(5), 524–531. https://doi.org/10.1016/j.physbeh.2011.01.007.

Karl, J. P., Young, A. J., Rood, J. C., & Montain, S. J. (2013). Independent and combined effects of eating rate and energy density on energy intake, appetite, and gut hormones. *Obesity (Silver Spring, Md.), 21*(3), E244–E252. https://doi.org/10.1002/oby.20075.

Ketel, E. C., Aguayo-Mendoza, M. G., de Wijk, R. A., de Graaf, C., Piqueras-Fiszman, B., & Stieger, M. (2019). Age, gender, ethnicity and eating capability influence oral processing behaviour of liquid, semi-solid and solid foods differently. *Food Research International, 119*, 143–151. https://doi.org/10.1016/j.foodres.2019.01.048.

Kokkinos, A., le Roux, C. W., Alexiadou, K., Tentolouris, N., Vincent, R. P., Kyriaki, D., . . . Katsilambros, N. (2010). Eating slowly increases the postprandial response of the anorexigenic gut hormones, peptide YY and glucagon-like peptide-1. *The Journal of Clinical Endocrinology & Metabolism, 95*(1), 333–337. https://doi.org/10.1210/jc.2009-1018.

Laboure, H., Van Wymelbeke, V., Fantino, M., & Nicolaidis, S. (2002). Behavioral, plasma, and calorimetric changes related to food texture modification in men. *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology, 282*(5), R1501–R1511. https://doi.org/10.1152/ajpregu.00287.2001.

Lean, M. E., & Malkova, D. (2016). Altered gut and adipose tissue hormones in overweight and obese individuals: Cause or consequence? *International Journal of Obesity (2005), 40*(4), 622–632. https://doi.org/10.1038/ijo.2015.220.

Lee, K. S., Kim, D. H., Jang, J. S., Nam, G. E., Shin, Y. N., Bok, A. R., . . . Cho, K. H. (2013). Eating rate is associated with cardiometabolic risk factors in Korean adults. *Nutrition, Metabolism and Cardiovascular Diseases, 23*(7), 635–641. https://doi.org/10.1016/j.numecd.2012.02.003.

Lee, S., Ko, B.-J., Gong, Y., Han, K., Lee, A., Han, B.-D., . . . Mantzoros, C. S. (2016). Self-reported eating speed in relation to non-alcoholic fatty liver disease in adults. *European Journal of Nutrition, 55*(1), 327–333. https://doi.org/10.1007/s00394-015-0851-z.

Levine, J. A. (2004). Non-exercise activity thermogenesis (NEAT). *Nutrition Reviews, 62*(7 Pt 2), S82–S97. https://doi.org/10.1111/j.1753-4887.2004.tb00094.x.

Li, J., Zhang, N., Hu, L., Li, Z., Li, R., Li, C., & Wang, S. (2011). Improvement in chewing activity reduces energy intake in one meal and modulates plasma gut hormone concentrations in obese and lean young Chinese men. *The American Journal of Clinical Nutrition, 94*(3), 709–716. https://doi.org/10.3945/ajcn.111.015164.

Llewellyn, C. H., van Jaarsveld, C. H., Boniface, D., Carnell, S., & Wardle, J. (2008). Eating rate is a heritable phenotype related to weight in children. *The American Journal of Clinical Nutrition, 88*(6), 1560–1566. https://doi.org/10.3945/ajcn.2008.26175.

Madsen, J. L., Sondergaard, S. B., & Moller, S. (2006). Meal-induced changes in splanchnic blood flow and oxygen uptake in middle-aged healthy humans. *Scandinavian Journal of Gastroenterology, 41*(1), 87–92. https://doi.org/10.1080/00365520510023882.

Marchiori, D., Papies, E. K., & Klein, O. (2014). The portion size effect on food intake. An anchoring and adjustment process? *Appetite, 81*, 108–115. https://doi.org/10.1016/j.appet.2014.06.018.

Marciani, L., Gowland, P. A., Spiller, R. C., Manoj, P., Moore, R. J., Young, P., & Fillery-Travis, A. J. (2001). Effect of meal viscosity and nutrients on satiety, intragastric dilution, and emptying assessed by MRI. *American Journal of Physiology. Gastrointestinal and Liver Physiology, 280*(6), G1227–G1233. https://doi.org/10.1152/ajpgi.2001.280.6.G1227.

Martin, C. K., Anton, S. D., Walden, H., Arnett, C., Greenway, F. L., & Williamson, D. A. (2007). Slower eating rate reduces the food intake of men, but not women: Implications for behavioral weight control. *Behaviour Research and Therapy, 45*(10), 2349–2359. https://doi.org/10.1016/j.brat.2007.03.016.

Maruyama, K., Sato, S., Ohira, T., Maeda, K., Noda, H., Kubota, Y., . . . Iso, H. (2008). The joint impact on being overweight of self reported behaviours of eating quickly and eating until full: Cross sectional survey. *British Medical Journal, 337*, a2002. https://doi.org/10.1136/bmj.a2002.

Mattes, R. (2005). Soup and satiety. *Physiology & Behavior, 83*(5), 739–747. https://doi.org/10.1016/j.physbeh.2004.09.021.

McCrickerd, K., & Forde, C. G. (2016). Sensory influences on food intake control: Moving beyond palatability. *Obesity Reviews, 17*(1), 18–29. https://doi.org/10.1111/obr.12340.

McCrickerd, K., & Forde, C. G. (2017). Consistency of eating rate, oral processing behaviours and energy intake across meals. *Nutrients, 9*(8). https://doi.org/10.3390/nu9080891.

McCrickerd, K., Chambers, L., & Yeomans, M. R. (2014). Does modifying the thick texture and creamy flavour of a drink change portion size selection and intake? *Appetite, 73*, 114–120. https://doi.org/10.1016/j.appet.2013.10.020.

McCrickerd, K., Lim, C. M., Leong, C., Chia, E. M., & Forde, C. G. (2017). Texture-based differences in eating rate reduce the impact of increased energy density and large portions on meal size in adults. *The Journal of Nutrition, 147*(6), 1208–1217. https://doi.org/10.3945/jn.116.244251.

Mechanick, J. I., Kushner, R. F., Sugerman, H. J., Gonzalez-Campoy, J. M., Collazo-Clavell, M. L., Spitz, A. F., . . . Sarwer, D. B. (2009). American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery medical guidelines for clinical practice for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient. *Obesity, 17*(S1), S3–S72.

Mioche, L., Bourdiol, P., & Peyron, M. A. (2004). Influence of age on mastication: Effects on eating behaviour. *Nutrition Research Reviews, 17*(1), 43–54. https://doi.org/10.1079/nrr200375.

Mochizuki, K., Misaki, Y., Miyauchi, R., Takabe, S., Shimada, M., Kuriki, K., . . . Goda, T. (2012). A higher rate of eating is associated with higher circulating interluekin-1β concentrations in Japanese men not being treated for metabolic diseases. *Nutrition, 28*(10), 978–983. https://doi.org/10.1016/j.nut.2011.12.001.

Mourao, D. M., Bressan, J., Campbell, W. W., & Mattes, R. D. (2007). Effects of food form on appetite and energy intake in lean and obese young adults. *International Journal of Obesity, 31*, 1688. https://doi.org/10.1038/sj.ijo.0803667.

Nagahama, S., Kurotani, K., Pham, N. M., Nanri, A., Kuwahara, K., Dan, M., . . . Mizoue, T. (2014). Self-reported eating rate and metabolic syndrome in Japanese people: Cross-sectional study. *BMJ Open, 4*(9), e005241. https://doi.org/10.1136/bmjopen-2014-005241.

Okubo, H., Miyake, Y., Sasaki, S., Tanaka, K., & Hirota, Y. (2017). Rate of eating in early life is positively associated with current and later body mass index among young Japanese children: The Osaka Maternal and Child Health Study. *Nutrition Research, 37*, 20–28. https://doi.org/10.1016/j.nutres.2016.11.011.

Otsuka, R., Tamakoshi, K., Yatsuya, H., Wada, K., Matsushita, K., OuYang, P., . . . Toyoshima, H. (2008). Eating fast leads to insulin resistance: Findings in middle-aged Japanese men and women. *Preventive Medicine, 46*(2), 154–159. https://doi.org/10.1016/j.ypmed.2007.07.031.

Palinkas, M., Nassar, M. S., Cecilio, F. A., Siessere, S., Semprini, M., Machado-de-Sousa, J. P., . . . Regalo, S. C. (2010). Age and gender influence on maximal bite force and masticatory muscles thickness. *Archives of Oral Biology, 55*(10), 797–802. https://doi.org/10.1016/j.archoralbio.2010.06.016.

Park, S., & Shin, W. S. (2015). Differences in eating behaviors and masticatory performances by gender and obesity status. *Physiology & Behavior, 138*, 69–74. https://doi.org/10.1016/j.physbeh.2014.10.001.

Percival, R. S., Challacombe, S. J., & Marsh, P. D. (1994). Flow rates of resting whole and stimulated parotid saliva in relation to age and gender. *Journal of Dental Research, 73*(8), 1416–1420. https://doi.org/10.1177/00220345940730080401.

Petty, A. J., Melanson, K. J., & Greene, G. W. (2013). Self-reported eating rate aligns with laboratory measured eating rate but not with free-living meals. *Appetite, 63*, 36–41. https://doi.org/10.1016/j.appet.2012.12.014.

Pritchard, S. J., Davidson, I., Jones, J., & Bannerman, E. (2014). A randomised trial of the impact of energy density and texture of a meal on food and energy intake, satiation, satiety, appetite and palatability responses in healthy adults. *Clinical Nutrition, 33*(5), 768–775. https://doi.org/10.1016/j.clnu.2013.10.014.

Quah, P. L., Ng, J. C., Fries, L. R., Chan, M. J., Aris, I. M., Lee, Y. S., . . . Chong, M. F. F. (2019). Longitudinal analysis between maternal feeding practices and body mass index (BMI): A study in Asian Singaporean preschoolers. *Frontiers in Nutrition, 6*(32). https://doi.org/10.3389/fnut.2019.00032.

Ranawana, V., Henry, C. J., & Pratt, M. (2010a). Degree of habitual mastication seems to contribute to interindividual variations in the glycemic response to rice but not to spaghetti. *Nutrition Research, 30*(6), 382–391. https://doi.org/10.1016/j.nutres.2010.06.002.

Ranawana, V., Monro, J. A., Mishra, S., & Henry, C. J. (2010b). Degree of particle size breakdown during mastication may be a possible cause of interindividual glycemic variability. *Nutrition Research, 30*(4), 246–254. https://doi.org/10.1016/j.nutres.2010.02.004.

Ranawana, V., Leow, M. K., & Henry, C. J. (2014). Mastication effects on the glycaemic index: Impact on variability and practical implications. *European Journal of Clinical Nutrition, 68*(1), 137–139. https://doi.org/10.1038/ejcn.2013.231.

Read, N. W., Welch, I. M., Austen, C. J., Barnish, C., Bartlett, C. E., Baxter, A. J., . . . et al. (1986). Swallowing food without chewing; a simple way to reduce postprandial glycaemia. *The British Journal of Nutrition, 55*(1), 43–47.

Robinson, E., Almiron-Roig, E., Rutters, F., de Graaf, C., Forde, C. G., Tudur Smith, C., . . . Jebb, S. A. (2014). A systematic review and meta-analysis examining the effect of eating rate on energy intake and hunger. *The American Journal of Clinical Nutrition, 100*(1), 123–151. https://doi.org/10.3945/ajcn.113.081745.

Roe, L. S., Kling, S. M. R., & Rolls, B. J. (2016). What is eaten when all of the foods at a meal are served in large portions? *Appetite, 99*, 1–9. https://doi.org/10.1016/j.appet.2016.01.001.

Sakurai, M., Nakamura, K., Miura, K., Takamura, T., Yoshita, K., Nagasawa, S.-Y., . . . Nakagawa, H. (2012). Self-reported speed of eating and 7-year risk of type 2 diabetes mellitus in middle-aged Japanese men. *Metabolism, 61*(11), 1566–1571. https://doi.org/10.1016/j.metabol.2012.04.005.

Salazar Vazquez, B. Y., Salazar Vazquez, M. A., Lopez Gutierrez, G., Acosta Rosales, K., Cabrales, P., Vadillo-Ortega, F., . . . Schmid-Schonbein, G. W. (2016). Control of overweight and obesity in childhood through education in meal time habits. The 'good manners for a healthy future' programme. *Pediatric Obesity, 11*(6), 484–490. https://doi.org/10.1111/ijpo.12091.

Sasaki, S., Katagiri, A., Tsuji, T., Shimoda, T., & Amano, K. (2003). Self-reported rate of eating correlates with body mass index in 18-y-old Japanese women. *International Journal of Obesity, 27*(11), 1405–1410. https://doi.org/10.1038/sj.ijo.0802425.

Schwahn, C., Polzer, I., Haring, R., Dörr, M., Wallaschofski, H., Kocher, T., . . . Völzke, H. (2013). Missing, unreplaced teeth and risk of all-cause and cardiovascular mortality. *International Journal of Cardiology, 167*(4), 1430–1437.

Scisco, J. L., Muth, E. R., Dong, Y., & Hoover, A. W. (2011). Slowing bite-rate reduces energy intake: An application of the bite counter device. *Journal of the American Dietetic Association, 111*(8), 1231–1235. https://doi.org/10.1016/j.jada.2011.05.005.

Spiegel, T. A. (2000). Rate of intake, bites, and chews – The interpretation of lean–obese differences. *Neuroscience & Biobehavioral Reviews, 24*(2), 229–237. https://doi.org/10.1016/S0149-7634(99)00076-7.

Spiegel, T. A., & Jordan, H. A. (1978). Effects of simultaneous oral–intragastric ingestion on meal patterns and satiety in humans. *Journal of Comparative and Physiological Psychology, 92*(1), 133–141. https://doi.org/10.1037/h0077437.

Spiegel, T. A., Wadden, T. A., & Foster, G. D. (1991). Objective measurement of eating rate during behavioral treatment of obesity. *Behavior Therapy, 22*(1), 61–67. https://doi.org/10.1016/S0005-7894(05)80244-8.

Spiegel, T. A., Kaplan, J. M., Tomassini, A., & Stellar, E. (1993). Bite size, ingestion rate, and meal size in lean and obese women. *Appetite, 21*(2), 131–145. https://doi.org/10.1016/0195-6663(93)90005-5.

Stubbs, R. J., Ritz, P., Coward, W. A., & Prentice, A. M. (1995). Covert manipulation of the ratio of dietary fat to carbohydrate and energy density: Effect on food intake and energy balance in free-living men eating ad libitum. *The American Journal of Clinical Nutrition, 62*(2), 330–337. https://doi.org/10.1093/ajcn/62.2.330.

Sun, L., Ranawana, D. V., Tan, W. J. K., Quek, Y. C. R., & Henry, C. J. (2015). The impact of eating methods on eating rate and glycemic response in healthy adults. *Physiology & Behavior, 139*, 505–510. https://doi.org/10.1016/j.physbeh.2014.12.014.

Tanihara, S., Imatoh, T., Miyazaki, M., Babazono, A., Momose, Y., Baba, M., . . . Une, H. (2011). Retrospective longitudinal study on the relationship between 8-year weight change and current eating speed. *Appetite, 57*(1), 179–183. https://doi.org/10.1016/j.appet.2011.04.017.

van den Boer, J. H. W., & Mars, M. (2015). Modeling of eating style and its effect on intake. *Appetite, 86*, 25–30. https://doi.org/10.1016/j.appet.2014.08.032.

van den Boer, Kranendonk, J., van de Wiel, A., Feskens, E. J., Geelen, A., & Mars, M. (2017a). Self-reported eating rate is associated with weight status in a Dutch population: A validation study and a cross-sectional study. *The International Journal of Behavioral Nutrition and Physical Activity, 14*(1), 121–121. https://doi.org/10.1186/s12966-017-0580-1.

van den Boer, J., Werts, M., Siebelink, E., de Graaf, C., & Mars, M. (2017b). The availability of slow and fast calories in the Dutch diet: The current situation and opportunities for interventions. *Foods (Basel, Switzerland), 6*(10), 87. https://doi.org/10.3390/foods6100087.

Van der Bilt, A. (2011). Assessment of mastication with implications for oral rehabilitation: A review. *Journal of Oral Rehabilitation, 38*(10), 754–780. https://doi.org/10.1111/j.1365-2842.2010.02197.x.

Viggiano, D., Fasano, D., Monaco, G., & Strohmenger, L. (2004). Breast feeding, bottle feeding, and non-nutritive sucking; effects on occlusion in deciduous dentition. *Archives of Disease in Childhood, 89*(12), 1121–1123. https://doi.org/10.1136/adc.2003.029728.

Viskaal-van Dongen, M., Kok, F. J., & de Graaf, C. (2011). Eating rate of commonly consumed foods promotes food and energy intake. *Appetite, 56*(1), 25–31. https://doi.org/10.1016/j.appet.2010.11.141.

Wang, X. T., & Ge, L. H. (2015). Influence of feeding patterns on the development of teeth, dentition and jaw in children. *Beijing Da Xue Xue Bao Yi Xue Ban, 47*(1), 191–195.

Wee, M. S. M., Goh, A. T., Stieger, M., & Forde, C. G. (2018). Correlation of instrumental texture properties from textural profile analysis (TPA) with eating behaviours and macronutrient composition for a wide range of solid foods. *Food & Function, 9*(10), 5301–5312. https://doi.org/10.1039/c8fo00791h.

Wijlens, A. G., Erkner, A., Alexander, E., Mars, M., Smeets, P. A., & de Graaf, C. (2012). Effects of oral and gastric stimulation on appetite and energy intake. *Obesity (Silver Spring, Md.), 20*(11), 2226–2232. https://doi.org/10.1038/oby.2012.131.

Wren, A. M., Seal, L. J., Cohen, M. A., Brynes, A. E., Frost, G. S., Murphy, K. G., . . . Bloom, S. R. (2001). Ghrelin enhances appetite and increases food intake in humans. *The Journal of Clinical Endocrinology and Metabolism, 86*(12), 5992. https://doi.org/10.1210/jcem.86.12.8111.

Xue, S. A., & Hao, J. G. (2006). Normative standards for vocal tract dimensions by race as measured by acoustic pharyngometry. *Journal of Voice, 20*(3), 391–400. https://doi.org/10.1016/j.jvoice.2005.05.001.

Yeomans, M. R. (1996). Palatability and the micro-structure of feeding in humans: The appetizer effect. *Appetite, 27*(2), 119–133. https://doi.org/10.1006/appe.1996.0040.

Zandian, M., Ioakimidis, I., Bergh, C., Brodin, U., & Södersten, P. (2009). Decelerated and linear eaters: Effect of eating rate on food intake and satiety. *Physiology & Behavior, 96*(2), 270–275. https://doi.org/10.1016/j.physbeh.2008.10.011.

Zhu, Y., Hsu, W. H., & Hollis, J. H. (2013a). The impact of food viscosity on eating rate, subjective appetite, glycemic response and gastric emptying rate. *PLoS One, 8*(6), e67482. https://doi.org/10.1371/journal.pone.0067482.

Zhu, Y., Hsu, W. H., & Hollis, J. H. (2013b). Increasing the number of masticatory cycles is associated with reduced appetite and altered postprandial plasma concentrations of gut hormones, insulin and glucose. *The British Journal of Nutrition, 110*(2), 384–390. https://doi.org/10.1017/s0007114512005053.

Zhu, B., Haruyama, Y., Muto, T., & Yamazaki, T. (2015). Association between eating speed and metabolic syndrome in a three-year population-based cohort study. *Journal of Epidemiology, 25*(4), 332–336. https://doi.org/10.2188/jea.JE20140131.

Zijlstra, N., Mars, M., de Wijk, R. A., Westerterp-Plantenga, M. S., & de Graaf, C. (2008). The effect of viscosity on ad libitum food intake. *International Journal of Obesity (2005), 32*(4), 676–683. https://doi.org/10.1038/sj.ijo.0803776.

Zijlstra, N., de Wijk, R. A., Mars, M., Stafleu, A., & de Graaf, C. (2009). Effect of bite size and oral processing time of a semisolid food on satiation. *The American Journal of Clinical Nutrition, 90*(2), 269–275. https://doi.org/10.3945/ajcn.2009.27694.

Zijlstra, N., Mars, M., Stafleu, A., & de Graaf, C. (2010). The effect of texture differences on satiation in 3 pairs of solid foods. *Appetite, 55*(3), 490–497. https://doi.org/10.1016/j.appet.2010.08.014.