Slower Eating Speed Lowers Energy Intake in Normal-Weight but not Overweight/Obese Subjects

Meena Shah, PhD; Jennifer Copeland, MS; Lyn Dart, PhD; Beverly Adams-Huet, MS; Ashlei James, MS; Debbie Rhea, EdD

BACKGROUND
The effect of eating speed on energy intake by weight status is unclear.

OBJECTIVE
To examine whether the effect of eating speed on energy intake is the same in normal-weight and overweight/obese subjects.

DESIGN
The effect of slow and fast eating speed on meal energy intake was assessed in a randomized crossover design.

PARTICIPANTS/SETTING
Thirty-five normal-weight (aged 33.3 ± 12.5 years; 14 women and 21 men) subjects and 35 overweight/obese (44.1 ± 13.0 years; 22 women and 13 men) subjects were studied on 2 days during lunch in a metabolic kitchen.

INTERVENTION
The subjects consumed the same meal, ad libitum, but at different speeds during the two eating conditions. The weight and energy content of the food consumed was assessed. Perceived hunger and fullness were assessed at specific times using visual analog scales.

STATISTICAL ANALYSES
Effect of eating speed on ad libitum energy intake, eating rate (energy intake/meal duration), energy density (energy intake per gram of food and water consumed), and satiety were assessed by mixed-model repeated measures analysis.

RESULTS
Meal energy intake was significantly lower in the normal-weight (804.5 ± 438.9 vs 892.6 ± 330.2 kcal; \(P < 0.04\)) but not the overweight/obese (667.3 ± 304.1 vs 724.8 ± 355.5 kcal; \(P = 0.18\)) subjects during the slow vs the fast eating condition. Both groups had lower meal energy density (P = 0.005 and P = 0.001, respectively) and eating rate (P < 0.0001 in both groups) during the slow vs the fast eating condition. Both groups reported less hunger (P = 0.01 and P = 0.03, respectively) and the normal-weight subjects reported more fullness (P = 0.02) at 60 minutes after the meal began during the slow compared with the fast eating condition. There was no eating speed by weight status interaction for any of the variables.

CONCLUSIONS
Eating slowly significantly lowered meal energy intake in the normal-weight but not in the overweight/obese group. It lowered eating rate and energy density in both groups. Eating slowly led to lower hunger ratings in both groups and increased fullness ratings in the normal-weight group at 60 minutes from when the meal began.

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FINDINGS
Findings from a number of epidemiologic studies show that eating speed is positively related to body weight. However, most of the studies were conducted in subjects with normal or mostly normal weight (BMI 18.5 to 24.9) and from largely Asian populations. These limitations make it difficult to generalize the findings to the US population. In addition, the information on eating rate was self-reported. Melanson and colleagues found that self-reported eating rate may not be correlated with measured free-living eating rate. Methodologic issues with assessment of eating rate render the epidemiologic results more difficult to evaluate.

A number of investigators have conducted intervention studies on the effect of food intake of eating speed, modified by changing the bite size, bite rate, number of chews per bite, and/or eating duration, or by giving foods with different textures, and the results are controversial. Several studies...
have found a decrease in energy or food intake with a reduction in eating rate.\textsuperscript{14-17} Some studies observed lower food intake in response to slower eating in men but not women\textsuperscript{18} or in linear (typically eating at a constant rate) but not decelerated eaters.\textsuperscript{19} Three studies found no relationship between eating rate and energy intake\textsuperscript{20-22} and one study\textsuperscript{23} observed a higher energy intake with more pauses within meals. In addition, Forde and colleagues\textsuperscript{24} reported a lower eating rate and ad libitum intake when subjects were given a solid-savory meal vs a mashed-savory meal, and Zijlstra and colleagues\textsuperscript{25} reported higher ad libitum intake in the highest quartile vs the lowest quartile of eating rate. Moreover, only three of these studies\textsuperscript{15,20,21} have examined how eating speed influences energy intake in obese/overweight vs normal-weight subjects. One of these three studies\textsuperscript{15} found a reduction in energy intake with increased chewing activity per bite in both the normal-weight and overweight/obese groups, whereas the other two studies\textsuperscript{20,21} found no significant effect of ingestion rate on energy intake in either the normal-weight or overweight/obese groups. The controversial results by weight status may be due to the fact that the three studies\textsuperscript{15,20,21} had a limited number of subjects (six to 14 obese subjects) and did not mention controlling for potential confounding factors such as energy intake and/or physical activity before the study. In addition, two\textsuperscript{15,21} of the three studies did not randomly assign the meals. Lastly, Laessle and colleagues\textsuperscript{26} reported higher eating rate, bite size, and ad libitum energy intake in overweight compared with normal-weight subjects. Laessle and colleagues\textsuperscript{26} did not assess the effect of different eating speeds on energy intake.

The above issues, as well as the fact that some professional organizations\textsuperscript{27} and weight loss programs advise obese individuals to reduce eating speed to control energy intake, stress the importance of further examining the relationship between eating speed and energy intake in a well-designed study with a larger group of normal-weight and overweight/obese subjects. We investigated whether eating a meal slowly would lead to lower meal energy intake and less hunger and desire to eat and higher levels of fullness after the meal compared with eating the same meal more quickly in normal-weight and overweight/obese subjects. Subjects were given general instructions on how to change their eating speed. The two eating conditions were implemented in each subject in a randomized crossover design, and physical activity and energy intake before the study were controlled.

**MATERIALS AND METHODS**

**Subjects and Recruitment**

Normal-weight (n=35) and overweight/obese (n=35) men and women between the ages of 19 and 65 years were recruited for the study (Table 1). To be classified as overweight, a subject had to meet two of the following three criteria: waist circumference >88 cm for women or >102 cm for men, BMI ≥25.0 for both men and women, and percent body fat >25% for men and >32% for women.\textsuperscript{28} Exclusion criteria included being severely obese (BMI ≥40), dieting, taking medications that affect appetite, participating in >150 minutes per week of vigorous physical activity, smoking, or drinking heavily (men: >14 alcoholic drinks per week; women: >7 alcoholic drinks per week). Other exclusion criteria were self-reported disordered eating, depression, type 1 or 2 diabetes, adrenal disease, or untreated thyroid disease. Severely obese subjects were excluded because binge eating is related to the degree of obesity\textsuperscript{29} and the presence of a binge eating disorder may affect the results.

The subjects were recruited from Texas Christian University (TCU) and the surrounding community. The study was conducted in a metabolic kitchen at TCU. Before data collection, each subject signed a consent document approved by the TCU Institutional Review Board. The TCU Institutional Review Board has a Federalwide Assurance with the US Office of Human Research Protection and has committed to comply with the requirements of the US Department of Health and Human Services Protection of Human Subjects regulations.

**Experiment Design**

The effect of eating condition (slow or fast eating speed) on meal energy intake was assessed in normal-weight and overweight/obese subjects using a randomized crossover design. Following screening, each subject reported to the metabolic kitchen on 2 study days for lunch. The 2 study days were separated by a washout period of at least 4 days (13.8±12.6 days). On the first study day, subjects were randomly assigned to consume a meal at a fast or slow eating speed. On the subsequent study day, subjects consumed the same meal but at the alternative eating speed.

**Test Meal**

The test meal during each study day was a mixed meal of vegetable pasta. The mixed meal was made with ditalini pasta, tomatoes, olive oil, green onions, garlic, parsley, basil, sugar, salt, pepper, and Parmesan cheese. Women were served 900 g and men were served 1,200 g mixed meal corresponding to 1,300 kcal and 1,734 kcal, respectively, during each study day. The meal contained 50.5% energy from carbohydrate, 38.6% energy from fat, 12.2% energy from protein, and 330 mg sodium per 100 g. The subjects were also given 355 mL (12 fl oz) water with each meal and allowed more water, ad libitum, if they wished.

**Study Protocol**

Each subject consumed the meal at the same time on the 2 study days. For menstruating women, each study day was scheduled in the follicular phase of the menstrual cycle. Subjects were instructed to keep their food/drink intake and physical activity levels the same on the day before the study days and the morning of the study days. During the study days, subjects were instructed to consume the same breakfast at least 4 hours before lunch and not to consume any food or drink other than water between breakfast and lunch and any water an hour before lunch. To verify that the above conditions were met, subjects were asked to keep a food record the day before the study days and the morning of the study days as well as recall their physical activity levels during that time.

During the fast eating condition the subjects were asked to consume their meal as quickly as possible without feeling uncomfortable. To speed their eating they were instructed to eat as if they had a time constraint, take large bites, chew quickly, and refrain from pausing and putting the spoon down between bites. During the slow eating condition, they...
were instructed to eat as though they had no time constraint, take small bites, chew each bite thoroughly, and pause and put the spoon down between bites. Subjects were not given specific instructions during the two eating conditions such as the precise size of each bite, the bite rate, or the number of chews per bite to keep the eating experience as natural as possible. During both eating conditions, subjects were asked to eat as much food as they wished until comfortably satisfied.

To minimize the effect of the environment on food intake, subjects were served the pasta in the same size white bowls and were given the same spoon during each eating condition. They were also seated in their own area away from the other subjects and not facing anyone.

Table 1. Demographic and behavioral characteristics of participants in a study to compare the effect of eating speed on energy intake in normal-weight and overweight/obese subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal weight (n = 35)</th>
<th>Overweight/obese (n = 35)</th>
<th>P valuea</th>
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<tr>
<td>Body mass index</td>
<td>23.9±2.6</td>
<td>31.3±4.6</td>
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<td>Body fat (%)</td>
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<td>Male</td>
<td>16.5±4.5</td>
<td>24.4±3.5</td>
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<td>Female</td>
<td>23.5±5.4</td>
<td>34.5±5.9</td>
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<td>Waist circumference (cm)</td>
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<tr>
<td>Male</td>
<td>88.1±6.8</td>
<td>109.1±7.1</td>
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<td>Female</td>
<td>79.2±5.5</td>
<td>100.1±14.8</td>
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<td>Age (y)</td>
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<td>44.1±13.0</td>
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<td>Sex (%)</td>
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<tr>
<td>Non-Hispanic</td>
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<td>Self-reported eating rate (%)</td>
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<td>0</td>
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<td>Relatively slow</td>
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<tr>
<td>Medium</td>
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<td>Fast</td>
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<td>Very fast</td>
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<td>3</td>
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<td>Eating attitudesb</td>
<td>4.3±3.1</td>
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<td>Depressionc</td>
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<td>30.2±5.8</td>
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<td>Three Factor Eating Questionnaired</td>
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<td>Disinhibition score</td>
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<td>Hunger score</td>
<td>5.9±3.1</td>
<td>6.2±2.5</td>
<td>0.70</td>
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</table>

*aThe differences in subject characteristics by weight status were analyzed by independent t test (2-tailed) for continuous variables and by χ² test for categorical variables.

bDisordered eating was assessed using the eating attitudes test by Garner and colleagues32,33, and a score >20 on the test may indicate disordered eating.

cDepression was assessed by the self-rating depression scale by Zung.31 A higher score indicates a greater level of depression and the maximum possible score is 80. Most individuals with depression score between 50 and 69.

dDietary restraint, disinhibition, and hunger were assessed using the Three-Factor Eating questionnaire by Stunkard and Messick.30
Subjects were also not allowed to communicate with each other while eating.

Subjects were inconspicuously observed by the investigators and encouraged if necessary to ensure that the study conditions were being followed. The time spent eating was assessed using a stopwatch and the amount of food and water consumed was measured to the nearest 0.5 g using a digital scale (FD Series, OHAUS Corporation).

Many participants said they enjoyed the meals and a few requested the recipe for the meal. One participant, however, would have preferred a spicier meal. Three participants expressed feeling slightly uncomfortable after the fast meal condition despite being instructed to eat until they were comfortably full. The participants did not have questions regarding the two conditions, possibly because they were given detailed instructions by the investigators. In addition, many participants were aware of the two meal conditions from previous participants before the study was explained to them by the study investigators. One participant asked whether reading or telephone use was allowed during the slow eating condition and was instructed to focus only on the eating. The eating condition may have influenced eating behavior beyond changing the speed of eating. Eating condition affected water intake (see the Results section).

Measures

Energy Intake, Rate of Energy Intake, and Energy Density during the Eating Conditions. Ad libitum energy intake during the slow and fast eating conditions was calculated from the weight (in grams) of the mixed meal consumed during the respective eating conditions and the energy content of the meal per 100 g. The rate of energy intake was assessed by dividing the energy intake in kilocalories during the two eating conditions by the respective eating duration in minutes. Energy density was calculated by dividing energy intake during the two eating conditions by the respective total grams of food and water consumed.

Health Questionnaires. All subjects completed a demographic, lifestyle, and health questionnaire that included questions on age, sex, ethnicity, race, and self-reported eating rate. The question on the self-eating rate question was adopted from the study by Sasaki and colleagues. Subjects also completed three questionnaires, including the three-factor eating questionnaire by Stunkard and Messick to measure dietary restraint, hunger, and disinhibition; the self-rating depression scale by Zung; and the eating attitudes test to assess disordered eating by Garner and colleagues.

A higher score on the self-rating depression scale indicates a higher level of depression with a maximum possible score of 80. Most individuals with depression score between 50 and 69 on the self-rating depression scale. A score >20 on the eating attitudes test may indicate disordered eating.

Anthropometric Measurements. Height was measured to the nearest millimeter without shoes using a Seca wall mounted stadiometer (model 222). Body weight was measured in light clothing and without shoes to the nearest 0.1 kg using Befour scales (model FS-0961). Measured height and weight were used to calculate BMI. Waist and hip circumferences were measured in duplicate to the nearest 0.25 cm using Sammons Preston Gulick cloth tape measure with spring loading (model 5193). Skinfold thickness was measured in duplicate at the abdominal, triceps, chest, midaxillary, subscapular, suprailliac, and thigh sites to the nearest 1 mm using the Lafayette Skinfold II Calipers (model 01128). Body density was calculated from the sum of seven skinfold measurements and percent body fat was calculated from body density.

Assessment of Food Intake and Physical Activity Prior to the Meals. Subjects were instructed to record all the food and drink consumed on the day before the study days and the morning of the study days. The food records were analyzed for nutrient content using the Food Processor SQL software program (ESHA Research Inc). Physical activity level was also assessed during the same time period using a modified version of the validated 7-day Physical Activity Recall.

Assessment of Hunger, Fullness, Desire to Eat, Thirst, and Palatability. During both eating conditions, perceived hunger, fullness, desire to eat, and thirst were assessed using a validated 100 mm visual analog scale (VAS). The measurements were taken immediately before the meal was served and periodically after the meal began in both eating conditions. The measurements from when the meal began were taken at 5, 10, 15, 20, 25, 30, 45, and 60 minutes. The palatability of the meal was also assessed, using VAS, at 1 minute after the meal began and at meal completion. Each scale was labeled with opposite evaluative labels (“Not at all” and “Extremely”) at either end of the scale.

Statistical Analyses and Power Calculation

A mixed-model repeated measures analysis was used to examine the effect of eating condition (slow and fast), weight status (normal-weight and overweight/obese), and eating condition by weight status interaction on meal duration, weight of food consumed, energy intake, water intake, combined weight of food and water consumed, energy density, rate of energy intake, and palatability rating of the meal (average of the rating at 1 minute and at meal completion). The differences in these variables by eating condition and weight status were assessed by least squares means. The above analyses were also performed with age and sex adjustment. In addition, the above analyses were performed by age tertile.

A mixed-model repeated measures analysis was also used to assess the effect of the eating condition, weight status, and meal stage (before the meal and 5, 10, 15, 20, 25, 30, 45, and 60 minutes after the meal began) and the interaction between these factors on hunger, fullness, desire to eat, and thirst. The differences in these variables by eating condition, and weight status were analyzed by least squares means. The data were analyzed using SAS software, version 9.2 (2008, SAS Institute Inc).

The sample size of 35 normal-weight and 35 overweight/obese subjects had 95% power to detect an expected difference of 70 kcal between the slow and fast eating condition.
within each group while assuming $\alpha<.05$ and a standard deviation of the difference for repeated measures analysis of 110 kcal.$^{34,38}$

**RESULTS**

**Subject Characteristics**

Table 1 shows the subject characteristics. BMI, percent body fat, waist circumference, and age were significantly higher in the overweight/obese compared with the normal-weight subjects. There were more men in the normal-weight group than in the overweight/obese group but this difference was not statistically significant. In both groups, about 90% of the subjects were of non-Hispanic origin and nearly 30% were minorities. There was no difference in ethnicity and race by weight status. Most subjects in both groups reported their eating speed to be either “medium” or “fast” and there was no difference by weight status. The scores for eating attitudes and depression did not indicate disordered eating or depression and were not different by weight status. Dietary restraint, disinhibition, and hunger levels were also similar by weight status.

**Energy Intake and Physical Activity Levels Before the Study Days**

Energy intake and physical activity levels on the day before the study days and in the morning of the study days were not different by eating condition. The data are not shown here.

**Palatability of the Meal**

The average palatability rating (there was no difference between the rating at 1 minute and at meal completion) was high and not different between the slow and fast eating conditions in the normal-weight subjects ($80.8\pm14.0$ mm vs $80.6\pm13.9$ mm, respectively; $P=0.92$) or overweight/obese subjects ($83.1\pm14.6$ mm vs $82.8\pm14.6$ mm, respectively; $P=0.86$). There was no eating condition by weight status interaction effect on the mean palatability rating of the meal ($P=0.96$).

**Meal Duration, Food, Energy, and Water Intake, Energy Density, and Rate of Energy Intake**

Data on meal duration, food, energy, and water intake, energy density, and rate of energy intake are presented in Table 2. There was no eating condition by weight status interaction effect for any of the above variables. Food and energy intake were lower during the slow compared with the fast eating condition in both the groups, but the differences were only statistically significant in the normal-weight subjects ($P=0.04$) and not the overweight/obese subjects ($P=0.18$). Both groups had significantly lower energy density ($P=0.005$ and $P=0.001$, respectively) and rate of energy intake ($P=0.0001$ in both groups), and higher meal duration ($P=0.0001$ in both groups) and water intake ($P=0.02$ and $P=0.003$, respectively), during the slow compared with the fast eating condition. The combined weight of the food and water consumed was not different by eating condition in either the normal weight ($P=0.85$) or overweight/obese ($P=0.21$) group. None of the above trends by eating speed in the different outcome variables changed after adjustment for age. The trends were also the same after adjustment for sex. Only the unadjusted data have been shown.

In addition, the trends in the above outcome variables were the same by age tertile (19 to 29 years, 30 to 48 years, and 49 to 65 years). Mean eating duration was significantly higher ($P<0.0001$) during the slow compared with the fast eating condition across the different age groups (effect size: 12.6, 13.1, and 12.5 minutes, respectively). Food and energy intake were lower during the slow vs the fast eating condition in the three age groups (food intake: 58.9, 55.9, and 36.2 g, respectively; energy intake: 84.9, 80.5, and 52.1 kcal, respectively), but the differences were significant ($P=0.02$)

| Table 2. The effect of eating speed on meal duration; food, energy, and water intake; energy density; and rate of energy intake in normal-weight and overweight/obese subjects |
|-----------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                   | Normal Weight (n = 35) | Overweight/Obese (n = 35) |
|                                   | Slow             | Fast             | Slow             | Fast             | $P$ value*      |
| Meal duration (min)               | 21.9±7.0         | 9.4±4.1***      | 21.9±10.1        | 9.0±4.5***      | 0.80            |
| Weight of food consumed (g)       | 556.9±303.8      | 617.9±228.6*    | 461.9±210.5      | 501.7±246.1     | 0.62            |
| Energy intake (kcal)              | 804.5±438.9      | 892.6±330.2*    | 667.3±304.1      | 724.8±355.5     | 0.62            |
| Weight of water intake (g)        | 324.0±199.5      | 255.8±121.7*    | 358.1±188.4      | 270.1±128.0**   | 0.63            |
| Weight of food and water intake (g)| 880.9±403.4      | 873.7±302.2     | 820.0±319.8      | 771.8±294.8     | 0.45            |
| Energy density (kcal/g of food and water) | 0.91±0.21        | 1.02±0.16**    | 0.81±0.21        | 0.93±0.25**     | 0.72            |
| Rate of energy intake (kcal/min)  | 38.7±22.1        | 102.2±39.4***   | 34.0±17.7        | 91.8±49.3***    | 0.55            |

*A mixed-design repeated measures analysis was used to examine the effect of eating condition by weight status interaction effect on meal duration; food, energy, and water intake; energy density; and rate of energy intake.

**P<0.05 for the difference in the outcome variables between the slow and fast eating condition within the normal-weight and overweight groups, assessed by least squares means.

***P<0.01 between the slow and fast eating condition within the normal-weight and overweight/obese groups.

****P<0.0001 for the difference in the outcome variables between the slow and fast eating condition within the normal-weight and overweight/obese groups, assessed by least squares means.
only in the middle tertile for age. Water intake was higher in the slow compared with the fast eating condition across the three age groups (102.4, 72.0, and 60.2 g, respectively), but the difference was significant only in the first ($P=0.02$) and second ($P=0.04$) age tertiles. The total amount of food and water consumed was not different ($P>0.41$) between the slow and fast eating conditions across the three age groups. Both energy density ($P<0.05$) and rate of energy intake ($P<0.0001$) were significantly lower in the slow compared with the fast eating condition in the three age groups (energy density: 0.13, 0.09, and 0.12 kcal/g food and water consumed, respectively; rate of energy intake: 72.9, 64.9, and 43.9 kcal/min, respectively). Some of the subgroup differences above by eating condition did not reach statistical significance possibly because the analyses by age tertile were not adequately powered.

**Hunger, Fullness, Desire to Eat, and Thirst**

Data on hunger, fullness, desire to eat, and thirst are presented in the Figure. There was no eating condition by weight status interaction effect for hunger ($P=0.13$), fullness ($P=0.11$), desire to eat ($P=0.13$), and thirst ($P=0.77$). In both the normal-weight and overweight/obese groups, there was a significant eating condition by time effect ($P=0.001$ or less) for hunger, fullness, and desire to eat, and thirst; that is, the VAS measures were influenced by the interaction between eating condition and time.

The normal-weight group reported significantly higher ratings of hunger at 5 ($P<0.0001$), 10 ($P<0.0001$), and 15 ($P<0.0001$) minutes but lower ratings at 60 minutes ($P=0.01$) after the start of the meal in the slow compared with the fast eating condition. The overweight/obese group reported significantly higher ratings of hunger at 5 ($P<0.0001$), 10 ($P<0.0001$), 15 ($P<0.0001$), 20 ($P=0.003$), and 60 ($P=0.03$) minutes in the NW group and at 5 ($P<0.0001$), 10 ($P<0.0001$), 15 ($P<0.0001$), 20 ($P=0.003$), and 25 ($P=0.04$) minutes in the OW/O group. Thirst ratings (D) by eating condition were different at 5 ($P<0.0001$), 45 ($P=0.03$), and 60 ($P=0.04$) minutes in the NW group at 10 minutes ($P=0.008$) in the OW/O group.

**Figure**. Changes in postprandial hunger (A), fullness (B), desire to eat (C), and thirst (D) ratings during the slow and fast eating conditions in 35 normal-weight (NW) and 35 overweight/obese (OW/O) subjects. The values are means and standard deviations. There was no eating condition by weight status interaction effect for any of the appetite or thirst ratings as evaluated by a mixed-model repeated measures analysis. In both the NW and OW/O groups, there was a significant eating condition by time effect ($P=0.001$ or less) for hunger, fullness, desire to eat, and thirst. Hunger ratings (A) by eating condition were significantly different at 5 ($P<0.0001$), 10 ($P<0.0001$), 15 ($P<0.0001$), and 60 ($P=0.01$) minutes in the NW group and at 5 ($P<0.0001$), 10 ($P=0.001$), 15 ($P=0.001$), 20 ($P=0.003$), and 60 ($P=0.03$) minutes in the OW/O group as assessed by least squares means. Fullness ratings (B) by eating condition were different at 5 ($P<0.0001$), 10 ($P<0.0001$), 15 ($P<0.0001$), 30 ($P=0.04$), 45 ($P=0.01$), and 60 ($P=0.02$) minutes in the NW group and at 5 ($P<0.0001$), 10 ($P<0.0001$), 15 ($P<0.0001$), 20 ($P=0.003$) minutes in the OW/O group. Desire to eat ratings (C) by eating condition were different at 5 ($P<0.0001$), 10 ($P<0.0001$), 15 ($P<0.0001$), and 20 ($P=0.003$) minutes in the OW/O group. Thirst ratings (D) by eating condition were different at 10 ($P=0.02$), 45 ($P=0.03$), and 60 ($P=0.04$) minutes in the NW group at 10 minutes ($P=0.008$) in the OW/O group.
Energy intake during the slow compared with the fast eating condition. Speigel and colleagues found no difference in energy intake between the slow and fast eating conditions, irrespective of taste and the condition in which the data were examined by weight status. Water intake was higher during the slow eating condition probably because the subjects were asked to slow their speed of eating during that phase. The total weight of food and water consumed was not different between the two eating conditions in either the normal weight or overweight/obese group. Bell and colleagues have shown that subjects consume the same weight of food irrespective of the energy density of the meal. Among the studies that did not examine the results by weight status, two studies controlled water intake across the different eating conditions, and Andrade and colleagues reported a higher water intake (120 g) during the slow compared with the fast condition.

Energy density was lower in the slow compared with the fast eating condition by 0.11 kcal/g in the normal-weight and 0.12 kcal/g in the overweight/obese group. These changes can be attributed to the greater amount of water and lesser amount of food and energy consumed in the slow eating condition in both groups. Andrade and colleagues found a decrease in energy density of 0.2 kcal/g during the slow compared with the fast condition. Andrade and colleagues observed a higher difference than that observed in our study, possibly because the difference in water intake by eating conditions was higher in their study than in our study. Energy density may be related to energy intake. Bell and colleagues have reported that ad libitum intake in normal-weight subjects was higher when given high-energy dense foods compared with lower-energy dense foods of similar palatability. In another study, Bell and Rolls have shown that lowering energy density during a meal lowers ad libitum energy intake in both normal weight and obese subjects.

In both the groups, ratings of hunger were lower at 60 minutes from the beginning of the meal during the slow eating condition compared with the fast eating condition. The normal-weight subjects also reported feeling more full at 60 minutes during

**DISCUSSION**

Compared with the fast eating condition, the slow eating condition led to a reduction in energy intake by 10% (88 kcal) in the normal-weight and 8% (58 kcal) in the overweight/obese subjects. The difference in the overweight/obese group was smaller and not statistically significant. Among the studies that examined results by weight status, Li and colleagues reported lower energy intake (11.9%) during the slow eating condition compared with the fast eating condition in both the normal-weight and obese groups, whereas Kaplan and Spiegel and colleagues found no difference in energy intake (amounts not given) by eating rate in either group. Among the studies that did not compare the results by weight status, Andrade and colleagues reported a reduction of 67 kcal in energy intake during the slow compared with the fast eating condition and Scisco and colleagues observed a reduction of 71 kcal when participants were asked to slow their bite rate by 50%. Martin and colleagues, who asked subjects to reduce their eating rate by 50%, observed a reduction of 102 kcal in men but only 3 kcal in women during the slow compared with the fast eating condition. Zijlstra and colleagues reported significantly lower food intake (52%) in subjects in the lowest quartile of eating rate compared with subjects in the highest quartile of eating rate. Smit and colleagues examined the effect of different chewing counts (35 and 10 chews per mouthful) on ad libitum energy intake and found that the higher chewing count increased the duration of eating but reduced energy intake by 12.6% compared with the lower chewing count. In addition, Forde and colleagues examined the effect of texture (mashed vs whole) and taste (savory vs standard) on ad libitum food intake at a meal and reported that eating rate was lower in the whole compared with the mashed meal condition irrespective of taste and the whole condition led to less food intake (91 g) than the mashed condition only during the savory meal.

Slowing the speed of eating in our study led to a significant reduction in energy intake in the normal-weight but not the overweight/obese group, probably because the latter group consumed less food during both the eating conditions compared with the normal-weight subjects. It is possible that the overweight/obese subjects were more self-conscious and, thus, ate less during the study. In a study of social influences on meal size, overweight adults purchased less food, whereas normal-weight adults purchased more food for lunch when accompanied by others compared with when alone. Salvy and colleagues reported similar findings in children. Overweight children consumed less energy, whereas normal-weight children consumed more energy when they were with their peers compared with when they were alone.

The rate of energy intake in our study was lowered by the same amount (62% to 63%) during the slow compared with the fast eating condition in both groups, implying that reducing the speed of eating has the same effect on energy consumed per minute irrespective of weight status. Andrade and colleagues reported a reduction of 75% in the rate of energy intake during the slow compared with the fast eating condition. Smit and colleagues reported a 53% reduction in ingestion rate during the prolonged chewing condition compared with the less prolonged chewing condition.

Water consumption was higher during the slow compared with the fast eating condition by 27% (68 g) in the normal weight and 33% (88 g) in the overweight/obese group. Water intake was higher during the slow eating condition probably because the subjects were asked to slow their speed of eating during that phase. The total weight of food and water consumed was not different between the two eating conditions in either the normal weight or overweight/obese group. Bell and colleagues have shown that subjects consume the same weight of food irrespective of the energy density of the meal. Among the studies that did not examine the results by weight status, two studies controlled water intake across the different eating conditions, and Andrade and colleagues reported a higher water intake (120 g) during the slow compared with the fast condition.
the slow condition. These results indicate that greater satiety could be expected from a meal that is consumed more slowly across both groups. Andrade and colleagues\textsuperscript{14} reported that upon meal completion, despite lower energy intake, satiety ratings were significantly higher under the slow eating condition compared with the fast eating condition. Zanadian and colleagues\textsuperscript{10} also reported a higher level of satiety when eating rate was decreased but only in subjects who typically ate at a constant rate. Other investigators, including researchers who evaluated the data by weight status,\textsuperscript{15} found no difference in fullness or satiety ratings by eating or chewing rate\textsuperscript{15-18} or observed lower levels of satiety with pauses within a meal compared with no pauses within the same meal.\textsuperscript{23} If the increased satiety observed in our study during the slow eating condition could be maintained beyond 60 minutes and prevent a compensatory increase in energy intake at the subsequent meal is unknown and remains to be evaluated.

The lower energy intake during the slow eating condition in our study may be due to the greater consumption of water during the slow meal. This may have caused more stomach distention during the slow meal. Statistically adjusting for water intake did not change the effect of eating speed on energy intake in either group, suggesting that other mechanisms may be more important. The slow eating condition may also have allowed subjects to eat more mindfully and better sense their feelings of hunger suppression and satiety.\textsuperscript{41} Another mechanism may be that foods that are eaten slowly remain in the oral cavity for a longer period of time and lead to increased orosensory exposure that may be related to lower food intake.\textsuperscript{4,5} A high eating rate, on the other hand, impairs the congruent relationship between the sensory signals and the metabolic processes that determine how much we eat.\textsuperscript{4,5} Wijlens and colleagues\textsuperscript{44} examined the effect of oral (1 or 8 minutes modified sham feeding) and gastric (100 or 800 mL intragastrically infused liquid) stimulation on ad libitum energy intake and found that the longer (8 minutes) but not the shorter (1 minute) oral exposure with either the 100 or 800 mL gastric stimulation led to a significant decrease in energy intake compared with the control condition without any oral or gastric stimulation.

Eating speed may be associated with different responses in the anorexigenic (peptide YY, glucagon-like peptide-1, and cholecystokinin) and orexigenic (ghrelin) gut hormones. Kokkinos and colleagues\textsuperscript{45} reported higher peptide YY and glucagon-like peptide-1 response following consumption of a test meal in 30 minutes vs 5 minutes. Li and colleagues\textsuperscript{15} reported lower ghrelin and higher glucagon-like peptide-1 and cholecystokinin concentrations, and Zhu and colleagues\textsuperscript{46} reported a higher concentration of cholecystokinin following consumption of a meal with more vs less chews per bite. In all the above studies, the hormone differences by eating speed, however, occurred at 30, 60, or 90 minutes after the meal began and could not have played a role in the amount of food consumed during that meal. Zhu and colleagues\textsuperscript{46} also examined future food consumption and found that the changes in the gut hormones did not affect food intake at the subsequent meal.

A limitation of this study is that the meals were consumed in a metabolic kitchen rather than in a natural setting. To make the metabolic laboratory more appealing, we laid each table with attractive place settings and flowers and played classical music. Nevertheless, even an aesthetic laboratory setting cannot substitute for a natural setting. In addition, the slow and fast eating conditions were engineered; that is, subjects were instructed on how to slow or speed their eating rate. A more natural approach would be to manipulate the eating speed by choosing foods based on their oral processing characteristics. Forde and colleagues\textsuperscript{47} and Viskaal-Van Dongen and colleagues\textsuperscript{48} have determined the eating rate of a variety of foods and have found that it varies widely across foods. Based on this, Forde and colleagues\textsuperscript{24} designed meals with different eating rates and demonstrated a decrease in both eating rate and energy intake. Another issue with conducting this research in a laboratory setting is that eating rates in a non-natural setting may not be the same as eating rates in a free-living situation. Melanson and colleagues\textsuperscript{13} have reported that ad libitum lunches in a laboratory setting tend to be consumed at a faster rate than home breakfasts or free-living dinners.

Our study also did not assess prospective food intake, so it is not known whether eating less food or feeling less hungry at 60 minutes during the slow eating condition would affect food consumption later on. The study also did not include an eating condition with the usual eating rate, so it is not possible to assess how changing a subject’s usual eating rate would change energy intake. Another limitation is that bite size and chew rate were not assessed and the subjects were not screened for having normal dentition and eating and chewing abilities. All of these factors could potentially affect the findings. The crossover design may mitigate the effect of these potential confounders on energy intake. Our study also cannot distinguish the roles of taking smaller bites, chewing more thoroughly, and pausing between bites on energy intake because the subjects were asked to engage in all three activities simultaneously to reduce their eating speed. Forde and colleagues\textsuperscript{47} studied the relationship between oral processing characteristics of solid savory meal components and expected satiation and found that foods that were consumed in smaller bites were chewed more and for longer and expected to result in higher satiation. The overweight/obese group in our study was older than the normal-weight group.

Adjusting the data for age did not change the results. In addition, similar trends in energy intake by eating condition were observed in the different age groups.

Strengths of this study include the fact that it was a randomized, crossover study. Our study also compared the same number of normal-weight and overweight/obese subjects. In addition, our subjects included approximately the same number of men and women and nearly 30% minorities, making the results more generalizable than most of the previous studies. We also minimized the effect of eating with others on energy intake\textsuperscript{49,50} by seating each subject in a private area. In addition, physical activity levels and energy intake before the study were controlled, minimizing any confounding effect of the prior energy intake and expenditure.

Whether the results from this study, conducted in a laboratory setting, can be reproduced in a more natural setting remains to be tested. Some research has already been conducted on how to reduce the speed of eating and food intake in a more natural way using different foods with different textures, as mentioned above.\textsuperscript{24,47,48} It is also important to examine whether slowing eating speed over the long term will lead to weight loss. Ford and colleagues\textsuperscript{51} used a
computerized device, Mandometer (AB Mando), to provide real-time feedback to obese adolescents to slow down the speed of eating during meals. They reported that using the Mandometer as well as lifestyle counseling led to a lower BMI at 12 months compared with just lifestyle counseling. Using a Mandometer, however, creates an unnatural environment and it is not clear whether the device use will be maintained. Further studies are needed to examine if reducing the speed of eating more naturally leads to weight loss in the long term.

CONCLUSIONS
Consuming a meal at a slower vs faster speed resulted in a significant reduction in food and energy intake in normal-weight but not in overweight/obese subjects. Energy density and rate of energy intake were significantly lower and water intake was significantly higher in the slow compared with fast eating condition in both groups. At 60 minutes after the start of the meal, normal-weight subjects reported higher ratings of fullness and less hunger and overweight/obese subjects reported less hunger in the slow compared with the fast eating condition. There was no eating speed by weight status interaction for any of the variables. Further research is needed to examine the influence of eating slowly on energy intake by weight status in a more natural setting.

References


AUTHOR INFORMATION

M. Shah and D. Rhea are professors, Department of Kinesiology, and L. Dart is an associate professor, Department of Nutritional Sciences, all at Texas Christian University, Fort Worth. J. Copeland is a nursing student, Texas A&M University, College Station; at the time of the study, she was a graduate student, Department of Kinesiology, Texas Christian University, Fort Worth. B. Adams-Huet is an assistant professor, Department of Clinical Sciences, University of Texas Southwestern Medical Center at Dallas. A. James is an exercise physiologist, Cardiology and Interventional Vascular Associates, Dallas, TX; at the time of the study, she was a graduate student, Department of Kinesiology, Texas Christian University, Fort Worth.

Address correspondence to: Meena Shah, PhD, Department of Kinesiology, Texas Christian University, TCU Box 297730, Fort Worth, TX 76129. E-mail: m.shah@tcu.edu

STATEMENT OF POTENTIAL CONFLICT OF INTEREST

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