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A comparison of chewing rate between overweight and normal BMI individuals

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HIGHLIGHTS

- We use surface EMG for the assessment of chewing features both in laboratory and real-life settings.
- Individual chewing rates are remarkably consistent over time, regardless of food type eaten.
- The chewing features of overweight and normal BMI participants are very similar.

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ABSTRACT

Objective: Previous attempts to identify an 'obese eating style' have led to conflicting findings. This observational study compared the chewing features of overweight or obese young adults with those of normal range BMI. We hypothesised that chewing features are individual-specific and differ between participants of a normal BMI and high BMI.

Methods: Fourteen overweight to obese participants (BMI ≥ 25.0) were pairwise matched with 14 normal range BMI participants (18.5 < BMI < 25.0). Masticatory muscle activity was recorded using portable recorders during consumption of two rice meals in a laboratory setting and one pizza meal in the natural environment. A previously validated algorithm was used to assess time-frequency features of chewing episodes, including rate, duration, and power. Masticatory performance was assessed by a sieve test and was expressed as the percentage of particles ≤2 mm after a standardised chewing test.

Results: Regardless of the meal, chewing rate was remarkably consistent among participants (ICC = 0.89; 95% CI = 0.79–0.94). Chewing rate did not differ between high and normal BMI participants ($p > 0.05$), whereas chewing power was significantly higher in high BMI participants ($p < 0.05$). No other differences in chewing characteristics were found between BMI groups. Participants chewed at similar rate in the natural environment (pizza) and in the laboratory (rice) setting ($p > 0.05$). Masticatory performance did not differ significantly ($p > 0.05$) between the high (55.9%) and normal (52.4%) BMI groups.

Conclusions: Within the limitations of the present study, chewing characteristics appear to be individual-specific with wide variability. Overweight participants chew at a similar rate to control participants, albeit slightly stronger. Our preliminary findings need to be replicated in larger samples.

1. Introduction

Chewing features such as chewing time, mandibular movements, and intensity of masticatory muscle contractions vary largely between individuals [1,2]. However, some of these features appear to be consistent within an individual, making it plausible that an individual eating style could be defined. For example, chewing rate, defined as the frequency of chewing cycles per unit of time, seems to be remarkably stable within individuals, even across different days and foods [3,4].

Abbreviations: BMI, body mass index; ICCs, intraclass correlation coefficients; CI, confidence intervals.

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Interestingly, obesity has been associated with a specific 'eating style', which in turn promotes overeating [5]. Indeed, several studies provided evidence that overweight or obese participants chew differently from normal weight participants in terms of: fewer chews per gram food or per bite [6–9], higher ingestion rate [5–9], and a larger bite size [5]. Cross-sectional studies that used self-reported measures of eating rate have also shown a positive association between rate of eating and body mass index (BMI), after adjusting for potential confounders [10–13]. Conversely, obese-specific chewing features were not supported by other research [3,14–17], when assessing features such as chewing rate [3,17–19], ingestion rate [3,19,20], number of chews [17], chews per bite [3], and total bites [18,20,21].

The inconsistent results may arise from reliance on self-reports, visual observations, and conduct under laboratory conditions — making it unlikely that the research settings are truly representative of natural chewing behaviours. For example, the amount of food consumed varies if participants know that their eating is being watched [15], and many studies have failed to leave participants unaware of or unaffected by scrutiny. Whether or not previous studies assessed the natural or laboratory environment, none presented data from both settings.

The aim of this study was to investigate and compare the chewing features of overweight young adults with those of normal range BMI in both laboratory and natural environments, and to evaluate whether particular chewing features are related to being overweight. The hypotheses were that chewing features are individual-specific and that they differ among overweight and normal BMI adults in the laboratory and natural environments.

2. Materials and methods

2.1. Participants

The required sample size was estimated using previous data showing variability of chewing rate (main outcome variable) in a cohort of healthy participants [4]. We aimed to detect a medium-to-large effect size ($d \geq 0.5$) using a repeated measurement study design. The correlation among repeated measurements was estimated at 0.88 using previous data [4]. To detect this effect size, and setting α-error to 0.05 and β-error to 0.80 (one-tailed test), we estimated that 15 participants per group were needed.

Healthy adult paid volunteers were recruited as a convenience sample from Dunedin, New Zealand and assessed for eligibility using an online questionnaire (Survey Monkey, Palo Alto, CA, USA), which was completed by 325 persons. Inclusion criteria were: having an age between 18 and 45 years; and currently living locally in Dunedin. Exclusion criteria included self-reported: pain or restricted function of the mouth, face, or jaws; current pregnancy or breast-feeding; taking medications or supplements that influence fat and carbohydrate metabolism; diagnosed diabetes; eating or digestive disorders; facial hair preventing attachment of the chewing recorders; more than two missing teeth (excluding 3rd molars); and active orthodontic treatment.

Eligible persons who responded to follow up emails ($n = 77$) were selected based on their BMI, which was calculated from self-reported height and weight by dividing weight (kg) by height-squared (m^2). Participants with a BMI $\geq$ 25.0 kg/m^2 (overweight or obese [22]) were categorized 'overweight' and those with a BMI of 18.5–24.9 kg/m^2 (normal [22]) were identified as a 'control'. Based on these criteria, 42 individuals were invited to further screening, where height and weight was accurately measured by one investigator to the nearest 0.001 m or 0.1 kg using a stadiometer or Segmental Body Composition Analyzer (BC-418, Tanita, Tokyo, Japan) respectively. Five of these individuals later withdrew their interest in participation because of other commitments.

A BMI $\geq$ 25.0 kg/m^2 was found in 14 participants (5 male and 9 female); of these, 8 participants had a BMI $\geq$ 30 (obese). Overweight and obese participants were pairwise matched by sex, age and ethnicity [23] with participants of a normal BMI. Nine control participants could not be matched with overweight participants and were not invited to proceed further with the study.

This study was approved by the University of Otago Human Ethics Committee (12/333) and the Auckland University of Technology Ethics Committee (13/05). Participants signed informed consent and received NZ$100 reimbursement for their contribution to the research. Participants were simultaneously involved in a separate project exploring the glycaemic response to rice meals, which is not reported on here (Lu et al., manuscript in preparation).

2.2. Electromyographic equipment

Masticatory muscle activity for the duration of a meal was recorded using portable electromyographic (EMG) recorders (BSR release 2, Zurich, Switzerland) and surface pre-gelled self adhesive electrodes (model 9013S0212, Alpine Biomed ApS, Skovlunde, Denmark; 20 × 15 mm). Input signals were band-pass filtered (70–500 Hz), digitized (10-bit resolution, sampling rate 2 kHz), amplified (×8692) and stored as waveform audio file format (WAV) in a MMC memory card (512 MB) within the unit.

At each recording session, surface EMG electrodes were positioned by the same examiner unilaterally on the participant's self-reported dominant chewing side, or right hand side if no preference was reported. The skin underlying the electrodes was scrubbed vigorously with an alcohol wipe (product 5530, Briemar Nominees Pty. Ltd., Victoria, Australia) and when needed, dry-shaved using disposable razors (Exacta 2, Schick, CT, USA). The first electrode was positioned in the centre of the masseter at its most prominent point during contraction, and the second electrode superior and parallel to the main muscle fibres at a centre-to-centre distance of 20 mm with the first electrode. A third reference electrode was placed on the skin overlying the mastoid process. Electrodes were secured firmly with adhesive medical tape (3M Micropore Surgical Tape, Nexcare, MN, USA; 19 mm × 7.31 m). Two recorded standardised simulated chewing tasks preceded all meals to provide a baseline measurement for analysis. Tasks were completed with guidance and verbal encouragement from the experimenter; the participant held one end of a soft plastic cylinder (Aligner Chewies AC-25GMPP, Dentsply Raintree Essix Glenroe, FL, USA; 35 mm × 11 mm) while positioning the other end between their molars of the same side as the electrodes. First, participants clenched down on the cylinder as hard as possible for a period of 3 s, repeated 3 times, with a 5 s rest pause between each effort. Second, they repeatedly chewed the cylinder as hard as possible at an even, regular pace guided by the experimenter for 30 s. Following this, recording of the test meals could begin. When recording in the natural environment, participants were asked not to remove or touch the electrodes or unit during the day, and to avoid showering, swimming, sports, sleep, and operating their mobile phone near the unit.

2.3. Masticatory performance

Masticatory performance was assessed using a sieving test. Participants were asked to chew a standard spoonful (10 g) of rice as normal, but expectorate the bolus of chewed rice into a container at the point they would normally swallow it. They then rinsed their mouth with a sip of water and expectorated this into the same container. The samples were washed over stainless steel sieves with a mesh aperture of 2.0 mm, then collected and dried in a convection oven at 70 °C for 24 h or until constant weight was achieved. The samples dry weight (to nearest 0.01 g) and the moisture content from a non-expectorated duplicate sample were used to calculate the proportion of rice particles that passed through the sieves (i.e. ≤2 mm).