Original article

Evaluation of masticatory parameters in overweight and obese children

Darlle Santos Araujo*, Maria Carolina Salomé Marquezin*, Taís de Souza Barbosa*, Maria Beatriz Duarte Gavião* and Paula Midori Castelo**

*Department of Pediatric Dentistry, Piracicaba Dental School, University of Campinas (UNICAMP), Brazil and **Department of Biological Sciences, Federal University of São Paulo (UNIFESP), Diadema, Brazil

Correspondence to: Paula Midori Castelo, Departamento de Ciências Biológicas, Universidade Federal de São Paulo (UNIFESP), R. São Nicolau, 210 – 1. Andar, Diadema – SP, Brasil 09913-030. E-mail: pcastelo@yahoo.com

Summary

Objectives: Mastication is an essential function that prepares the food for swallowing and digestion and may be related to nutritional status. Thus, the aims of this study were to evaluate the masticatory parameters in overweight and obese children and the relation between bite force and anthropometric evaluation, food consistency, breast/bottle-feeding, and occlusion.

Materials and methods: The sample consisted of 204 children of both genders, age range 8–10 years, divided into normal weight, overweight, and obese. Unilateral bite force was measured using a digital gnatodynamometer with 10 mm force fork. Anthropometric and nutritional evaluation involved the measurements of body mass index and skeletal muscle mass using bioelectric impedance analysis. Occlusion was evaluated as regards orthodontic treatment need and food consistency was analysed using a structured questionnaire. In addition, the time of breast- and bottle-feeding was investigated. The results were submitted to chi-square and correlation tests, analysis of variance, and multiple linear regression to determine the relation between bite force and the independent variables under study (α = 0.05).

Results: Statistical analysis showed that the time of breast- and bottle-feeding and food consistency did not differ among groups. The regression model showed that body mass index, orthodontic treatment need, and body skeletal muscle mass contributed significantly to the variation in bite force.

Conclusions: Breast- and bottle-feeding behaviour and food consistency did not differ in normal-weight, overweight, and obese children. However, bite force was dependent on body skeletal muscle mass, body mass index, and orthodontic treatment need.

Introduction

Chewing is an important function of the stomatognathic system; it consists in biting, grinding, and breaking foods into smaller particles, and preparing them with saliva for swallowing and digestion (1). An efficient mastication is acquired with the action of teeth and proper mandibular movements, co-ordinated by the neuromuscular system (2). In addition to mechanical functions, chewing is also related to the pleasure provided by the food flavours. Proper chewing favours the first stages of digestion by stimulating saliva production and activation of cephalic control, which starts food assimilation (3).

Recent studies have suggested that chewing slowly or increasing the number of chewing cycles during the meal is associated with a lower body mass index (BMI), probably because it interferes in appetite control (4). The relationship between physical constitution and masticatory function in the elderly people has been studied, since loss of body skeletal muscle mass resulting from ageing may have an
influence on the masticatory ability of these individuals (5, 6), thus influencing their nutritional status. However, in children this subject has received little attention.

Chewing difficulties lead to alterations in food preference, being foods with soft (versus hard) and with smooth (versus rough) properties the most preferred; they are easier to chew, but high in calories. In this way, the unbalanced intake of foods may also increase the risk of diseases related to nutritional deficiencies (7) and tooth decay (8). Foods with harder and more fibrous consistency have a positive influence on the development of stomatognathic structures, such as masticatory muscles, periodontal supporting tissues, and the maintenance of bone integrity. Foods with soft consistency may have an atrophic effect on the bones and muscles, contributing to the appearance of malocclusion and loss of muscle force (9, 10).

The strength of the jaw muscles determines the amount of available force to cut or crush the food. Masticatory muscle strength can be evaluated by measuring the maximum bite force (1), which varies within the region of the oral cavity and is greater in the region of the first permanent molars (11). Previous studies have shown that bite force is associated with the stomatognathic system integrity, as well as with the morphology and efficiency of the muscles, bones, joints, and dentition, (12–14) and may be used as a parameter of masticatory function.

Previous studies have emphasized the positive influence of good masticatory ability on oral health, food's digestion, and nutritional status. The hypothesis to be tested was whether masticatory parameters would be different among children with different nutritional status and would be related with body composition. In this way, the aims of this study were to evaluate masticatory parameters in overweight and obese children and the relationship between bite force and anthropometric evaluation, food consistency, breast-feeding, and occlusion.

### Materials and methods

#### Sample

A convenience sample was selected and consisted of 204 prepubertal subjects from 8 to 10 years of age, from public schools of Piracicaba (SP, Brazil). Each subject and his parent/guardian gave voluntary consent to participate in this research by signing an informed assent form and a parental/guardian consent form, respectively, after having their questions and concerns addressed, in accordance with the Research Ethics Committee of the Piracicaba Dental School Dental School criteria (protocol No.017/12).

The sample size calculation was based on previous results from our laboratory, in which bite force was evaluated in subjects of the same age group, using the same methodology (unpublished work). Considering a correlation coefficient between bite force and BMI equal to 0.19, power = 0.80, and α level 0.05, it was found that 215 subjects would satisfy the criteria adopted.

A questionnaire was sent to the children's parents/guardians in order to gather information concerning socioeconomic indicators, medical and nutritional history (time of breast- and bottle-feeding, birth weight, delivery type, childhood diseases), comorbidities (hypertension, diabetes mellitus, dyslipidemia), treatments and use of health services, and history/presence of non-nutritional sucking habits (fingers, pacifier, and/or lips). This information was useful to check the homogeneity of the sample and exclusion criteria. The exclusion criteria adopted were: presence of systemic disorder, such as neurological disorders, cerebral palsy, diabetes, hypertension, and others; use of medicines which interfere in the central nervous system (anxiolytics, antidepressants, anticonvulsants), girls who had gone through the first menstrual cycle, and subject’s refusal to participate in the research.

#### Clinical oral examinations

The oral examination was performed at the school, using a clinical mirror with LED light, exploratory probe, mouth retractors, after performing biofilm control. Caries experience was evaluated by determining the number of decayed, missing, and filled primary and permanent teeth (DMFT and dmft, respectively).

The individuals were classified according to their stage of dentition as follows: early mixed, intermediate mixed, final mixed, and permanent dentition. Occlusal evaluation was performed using the Index of Orthodontic Treatment Need (IOTN)-Dental Health Component (DHC), which is based on the contribution of various occlusal characteristics to the orthodontic treatment need. The DHC measurements were obtained with the use of a periodontal probe, and individuals were classified on a scale of 5 degrees in ascending order of orthodontic treatment need: 1. no need for treatment, 2. little need, 3. moderate need/ borderline, 4. great need, and 5. very great need (15).

#### Evaluation of food consistency

Food consistency was evaluated using a questionnaire developed previously for children, in which the parents/guardians answered to eight questions with dichotomous responses (yes/no) with reference to the child's eating habits (for example, “Does your child eat beef steak?”) (16). In this study, the total score was used to grade the foods from soft to hard consistency.

#### Evaluation of maximum unilateral bite force

The maximum unilateral bite force was measured by means of a digital gnatodynamometer (model DDK, Kratos Equipamentos Industriais Ltda., Cotia, SP, Brazil), with a 10 mm force fork connected to a digital appliance, which provided the maximum bite force values in Newtons (N). During the evaluation, the subject remained seated, with the head in a relaxed position. The fork was placed between the maxillary and mandibular arches, in the permanent first molars region. The child was instructed and trained before to bite it with maximum force, and two measurements were made for each side of the dental arches (left and right). The maximum value of the two measurements on each side was considered as final value, with an approximation of 0.1N.

#### Physical examination

Anthropometric and nutritional evaluations involved the measurements of height, weight, and body skeletal muscle mass, by means of a digital stadiometer scale and bioelectric impedance analysis. Body mass index (BMI = kg/m²) was determined in order to classify the selected sample into three groups, according to the reference data BMI-for-age and gender (5–19 years) into: normal weight, overweight, and obese (17).

To quantify the body skeletal muscle mass, bioelectric impedance analysis was used (InBody 230, Biospace Co. Ltd., Gangnan-gu, Seul, South Korea). The measurement system is tetra-polar with eight tactile electrodes: two sets of electrodes in metal plates for each foot on which the subject was placed; at the top part of the scale column, there are two devices for the hands, which were held by the subject at the time of analysis. The children were in a standing position, with the arms and legs extended, in accordance with the manufacturer’s instructions. Analyses were performed in the morning, without the
subject having done exercise or eaten before this (at least 2 hours after the last meal).

Statistical analysis

The data collected were statistically analysed using the BioEstat 5.3 (Mamirauá, Belém, PA, Brazil) and SigmaPlot 11.0 (Systat Software Inc., San Jose, California, USA) statistical software packages. The Kolmogorov–Smirnov test was used to examine distribution of the variables; for those that presented deviation from normal distribution, non-parametric tests or logarithmic transformation were used. A P-value <0.05 was adopted.

A pilot study was conducted before beginning the data collection to verify the reproducibility of the measurements made, and later calculation of agreement (kappa test) and intraclass correlation coefficient (ICC). In addition, the questionnaire used for food consistency evaluation was tested to check the clarity of the questions. The questionnaire was applied to a group of 10 parents/guardians who were not included in the final sample, and the alternative “I didn’t understand” was added to each question for identifying the questions that were not understood by them.

The descriptive statistics consisted of means, standard deviation, median, interquartile range, and percentages. The proportion of individuals in different stages of dentition (early mixed, intermediate mixed, late mixed, and permanent) and the distribution of genders in each group (normal weight, overweight, and obese) was tested for differences by means of the chi-square test. The differences in mean age, time of breast- and bottle-feeding, scores of food consistency, and skeletal muscle mass among groups were analysed using analysis of variance (ANOVA) or Kruskal–Wallis test, where appropriate.

The correlation between bite force and the studied variables was analysed by means of Pearson or Spearman correlation tests. This test was applied before the multiple regression analysis was performed, because if there were two or more variables with very strong correlation (r equal to or higher than 0.95), they would interfere in the multiple regression model.

Thus, to evaluate which of the variables under study contributed to the variation in bite force magnitude, a multiple linear regression model with backward stepwise elimination was used. The stepwise procedure was employed to choose the model with the highest adjusted R² and the variance inflation factor (VIF) at or near 1.0. The following independent variables were added to the initial model: age, gender, stage of dentition, BMI, time of breast/bottle-feeding, presence of sucking habit, food consistency, IOTN score, dmf-t and DMFT, and skeletal muscle mass. The variables gender, IOTN scores, dmf-t, and DMFT were forced to remain in the final model with the aim of controlling these confounding variables. The independent variables were thus eliminated step-by-step until those that attained a P-value <0.05 remained in the final model.

Results

Table 1 shows the measures of reproducibility obtained in the pilot study and their interpretation. The food consistency questionnaire was applied to the parents/guardians in the pilot study and it has demonstrated no significant difficulty in understanding the questions (the number of responses “I did not understand/not applicable” was less than 15%, which was deemed acceptable).

The demographic data of the three groups are shown in Table 2. Statistical analysis showed that the three groups were not significantly different in regard to gender (P = 0.285), age (P = 0.279), and stage of dentition (P = 0.643). The total time of breast-feeding (P = 0.402) and exclusive breast-feeding (P = 0.792), as well as time of bottle-feeding (P = 0.635) did not differ significantly among groups. Also, no significant difference was observed in food consistency scores (P = 0.643).

Table 3 shows the correlation coefficients obtained between bite force and the clinical and physical variables. According to the correlation coefficients found, it was observed that there was significant positive correlation between bite force and age and skeletal muscle mass. As these variables could concomitantly be correlated with the other variables under study, a multiple linear regression analysis was performed.

Table 4 shows the results obtained using the multiple linear regression model. It was observed that the independent variables BMI, orthodontic treatment need, and body skeletal muscle mass significantly contributed to the variance in bite force magnitude. Higher BMI and orthodontic treatment need were related to lower bite force, whereas greater body skeletal muscle mass was related to greater bite force. The ANOVA validated the model (F = 3.452 and P-value = 0.004). In addition, this model explains 17.2% of the variance in bite force, with the remaining being explained by variables that were not included in the study.

Considering the sample size calculation, 215 subjects would satisfy the criteria adopted for the present study; although, due to the loss of some of the volunteers, the final sample consisted of 204 subjects. The power of the regression model was above the satisfactory level (99%), which demonstrates that the sample included was sufficient.

Discussion

Chewing may provide beneficial effects on satiety and appetite controls (4, 18). However, over the last years, changes have occurred in the eating habits, in which the home meal rich in fibres has been replaced by processed food, poor in fibres, and complex carbohydrates, but rich in simple carbohydrates and lipids, with soft and highly palatable consistency (19). Although the use of a specific questionnaire did not find significant differences in food consistency among children with different nutritional status, it is clear that there is a need for further studies to assess the relation between food’s characteristics, consistency, palatability, and nutritional status.

The development of the stomatognathic system begins at birth, with the maturation of sucking, breathing, and swallowing. Breast-feeding promotes greater stimulus to the orofacial muscles in comparison with bottle-feeding (20). It may also be related to lower rates of overweight/obesity, since the use of formulas in the first years has been shown to be associated with greater weight gain and increased skin folds (21). The findings of the present study showed no significant difference in the time of breast- and bottle-feeding in normal-weight, overweight, and obese individuals. However, one
Table 2. Demographic data and physical and clinical variables of the studied sample, divided in accordance with body mass index for age and gender. BMI, body mass index; SD, standard deviation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal weight</th>
<th>Overweight</th>
<th>Obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (months)</td>
<td>Median</td>
<td>Mean (SD)</td>
<td>Median</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>111.7 (12.7)</td>
<td>16.3 (1.4)</td>
<td>12.9 (1.2)</td>
</tr>
<tr>
<td>Male</td>
<td>111.7 (12.7)</td>
<td>16.3 (1.4)</td>
<td>12.9 (1.2)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>11.7 (0.4)</td>
<td>1.7 (0.2)</td>
<td>2.4 (0.2)</td>
</tr>
<tr>
<td>Breast-feeding (months)</td>
<td>8.0 (1.0)</td>
<td>5.0 (0.5)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Exclusive breast-feeding (months)</td>
<td>4.0 (0.4)</td>
<td>3.5 (0.4)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Presence of sucking habit (%)</td>
<td>9.9 (2.4)</td>
<td>9.9 (2.4)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Skeletal muscle mass (kg)</td>
<td>190 (4.7)</td>
<td>243 (2.4)</td>
<td>277.4 (15.8)</td>
</tr>
</tbody>
</table>

Table 3. Correlation coefficients obtained between bite force and physical and clinical studied variables. BMI, body mass index; r, correlation coefficient.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Bite force</th>
<th>Age</th>
<th>BMI</th>
<th>Breast-feeding time</th>
<th>Food consistency</th>
<th>Skeletal muscle mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>0.16</td>
<td>0.11</td>
<td>0.09</td>
<td>-0.03</td>
<td>0.768</td>
<td>0.23</td>
</tr>
<tr>
<td>P-value</td>
<td>0.024</td>
<td>0.132</td>
<td>0.310</td>
<td>0.024</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Table 4. Final multiple linear regression model with backward stepwise elimination used to verify the relation between bite force and the independent studied variables. Ln, logarithmic transformation; BMI, body mass index; IOTN, Index of Orthodontic Treatment Need; DMFT, decayed, missing, filled permanent teeth; dmf-t, decayed exfoliated and filled primary teeth.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>P-value (P-value)</th>
<th>R²</th>
<th>Power 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bite force</td>
<td>-3.452</td>
<td>0.002</td>
<td></td>
<td>0.846</td>
</tr>
<tr>
<td>Gender</td>
<td>-1.257</td>
<td>0.005</td>
<td></td>
<td>0.367</td>
</tr>
<tr>
<td>Ln (BMI)</td>
<td>-31.266</td>
<td>0.004</td>
<td></td>
<td>0.994</td>
</tr>
<tr>
<td>IOTN score</td>
<td>-3.379</td>
<td>0.005</td>
<td></td>
<td>0.095</td>
</tr>
<tr>
<td>DMFT</td>
<td>-8.779</td>
<td>0.001</td>
<td></td>
<td>0.23</td>
</tr>
<tr>
<td>Ln (skeletal muscle mass)</td>
<td>-3.219</td>
<td>0.005</td>
<td></td>
<td>0.011</td>
</tr>
</tbody>
</table>

should consider the multifactorial nature of obesity, in which several variables may influence this condition and may be relevant to the subject’s nutrition, such as hereditary, family environment, sedentarism, among others (19). A published meta-analysis showed that breast-feeding was associated with a lower BMI when compared to artificial feeding (22), although this difference was small and vulnerable to confounding factors.

In this study, a trend towards bite force being dependent on BMI was observed, while past studies have failed to establish a relationship between BMI and bite force, in both adults and young individuals (21, 23). Taking into consideration a possible alteration in the obese individuals’ diet, it may be suggested that the increase in processed foods ingestion, with soft consistency and rich in carbohydrate and fat, would promote reduced stimulation of the masticatory muscles than those rich in fibres, such as grains and fruits (24). In a previous study (13), BMI contributed 1.3% to the variation in maximum bite force in adolescents and young adults. In the elderly, this relationship appears to be clearer as past studies observed an association between gastrointestinal and masticatory function alterations, loss of teeth and appetite, and a compromised nutritional status (6, 25) However, the relationship between BMI and masticatory force and performance may not be linear in all ages, therefore the difficulty in obtaining evidence that supports the importance of masticatory function for the adequate digestion and absorption of nutrients (25).

Variations in the normal position of teeth are able to change facial appearance and occlusal function and, possibly, make chewing difficult (26). The IOTN is not cumulative and takes into account the most severe occlusal feature, which reflects the functional, dental health, and/or aesthetic impairment. In this way, the present study observed that the severity of malocclusion related with lower bite force magnitude, corroborating previous studies conducted in children (27, 28). Occlusal alterations may lead to changes in
mandibular posture to an unfavourable position, which affects muscle biomechanics and force production.

Bioelectric impedance analysis has been shown to be valid and reliable in the evaluation of body composition, even in children. It is a fast and non-invasive exam, appropriate for epidemiological studies. As far as we know, this is the first study that described the role of body skeletal muscle mass in the variation of bite force in children using bioelectric impedance analysis. This result supports the hypothesis that bite force is dependent on the muscular integrity of the body, and previous studies have shown that masticatory ability is related to body muscle force and physical performance in the elderly population (5, 29).

The model used explained only 17.2% of the variance in bite force, with the remaining being explained by variables that were not included in this study, such as craniofacial morphology, occlusal contacts, and other. The study design—cross-sectional—also limits generalization of the results, but the results found showed important trends to be evaluated in future longitudinal studies.

In the studied sample, the time of breast- and bottle-feeding and the characteristics of food did not differ among normal-weight, overweight, and obese children. It was also observed that bite force was dependent on body skeletal muscle mass, BMI, and orthodontic treatment need.

Funding

References