Reference value of masticatory performance by measuring the amount of glucose extraction from chewing gummy jelly

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Abstract

Purpose: The purpose of this study was to determine a reference value for masticatory performance (MP) by measuring the amount of glucose extracted (AGE) from chewing gummy jelly.

Methods: A total of 237 young adults (young group, 20-39 years), 147 middle-aged adults (middle-aged group, 40-59 years), and 177 older adults (old group, 60-87 years) participated in this study. All participants had natural dentition, excluding the third molars. AGE was measured when the participant chewed gummy jelly and used as a parameter of MP. AGE was compared among the three groups. Next, AGE in each group was compared between the habitual chewing side and non-habitual chewing side, and between males and females. The correlation between age and AGE was also investigated.

Results: AGE in the young, middle, and old groups were similar, and no significant differences were observed. AGE was significantly higher in the habitual chewing side compared to the non-habitual chewing side, and in males than that in females. No significant correlations were found between age and AGE. AGE in the habitual chewing side of all ages was 221.9 ± 34.4 mg/dL for males and 206.0 ± 28.7 mg/dL for females. The mean-2SD (standard deviation) value representing the reference value of healthy adults was 153.1 mg/dL for males and 148.6 mg/dL for females, which was close to 150 mg/dL.

Conclusion: It was concluded that the reference value of masticatory performance as measured by the amount of glucose extraction after chewing gummy jelly was 150 mg/dL.

Keywords: Reference value, Amount of glucose extraction, Masticatory performance, Healthy dentate adults, Gummy jelly

1. Introduction

Masticatory performance (MP) is an important objective parameter for evaluating masticatory function. The sieve method has long been used to measure MP; however, this method has significant limitations, in that the operation is complicated, and the analysis is lengthy. Therefore, many methods using impression material[1], color-changing gum[2,3], paraffin wax[4], fuchsin beads[5], and gummy jelly[2,3,6–21] have been reported. Of these, measuring the amount of glucose extraction (AGE) from chewing gummy jelly was the most advantageous. This method is characterized by using gummy jelly as a test food that can be standardized (e.g., physical properties and shape), hygiene management is easy, and the procedures and analysis are simple. It has been reported that there was a positive correlation between MP as measured by AGE and MP as measured by the sieve method[22].

Assessment of MP by measuring AGE from chewing gummy jelly is performed in healthy dentate adults[6,7,12,16,21], elderly adults[13,14,17,21], removable partial denture patients[2,3,10], removable complete denture patients[9,15,19], implant denture patients[10,11], mandibullectomy patients[20], and other groups. In addition, it has also been reported that AGE tends to decrease due to tooth loss[8,14], and increases after treatment[2,11,15] and with growth[18]. However, the reference value of healthy adults, which is important for the evaluation of MP, has not yet been fully clarified.

It is clear that MP by measuring AGE decreases when teeth are lost[8,14], and improves with dental treatment[2,11,15]. At present, only the values[6,12] of a small number of healthy adults are referred to when evaluating the data[8,16] obtained in MP studies. This may be due to the lack of studies that specify a reference value for AGE in healthy adults. Since MP is strongly influenced by occlusal support[23], and differs between the genders[6,7], it is considered that the reference value should be set while paying attention to occlusal support and gender differences. However, no studies have yet investigated the reference value of healthy adults while paying attention to occlusal support and gender differences.

Therefore, in this study, the AGE of adults with completely natural dentition was investigated to clarify the reference value of MP by measuring the AGE from chewing gummy jelly. Clarifying the reference value of AGE in healthy adults with natural dentition is clinically significant, because it can be used to evaluate the degree of masticatory performance and the therapeutic effect, or to detect people with reduced masticatory performance.
2. Materials and methods

2.1. Ethics statement

This study was approved by the Ethics Committee of the Nippon Dental University School of Life and Dentistry (NDU-T2012-29). Informed consent was obtained from the participants after explaining the purpose of the study and before the study commenced.

2.2. Participants

A total of 237 young adults (young group: 121 males and 116 females; 20–39 years, median age 29 years), 147 middle-aged adults (middle group: 65 males and 82 females; 40–59 years, median age 48 years), and 177 older adults (old group: 73 males and 104 females; 60–87 years, median age 74 years) participated in this study. The sample size was calculated using the software program G*Power 3.1.9.2 (Heinrich-Heine-Universität Düsseldorf). When the sample size was calculated by setting α = 0.05, β = 0.8, and effect size = 0.5, 64 participants were needed. The participants consisted of people who participated in the Kita-ku Enjoy Dietary Education Together Fair held in Kita-ku, Tokyo from 2016 to 2020 and staff and students of the Nippon Dental University. They meet the following criteria, have a healthy and complete natural dentition, and can be considered representative of healthy individuals in this study. The inclusion criteria were: 1) natural dentition excluding third molars, 2) no complaints about the occlusion, 3) good general health or adequately controlled systemic diseases, and 4) satisfactory cognitive functions. The exclusion criteria were as follows: 1) clinical abnormalities in the masticatory system, 2) complaints regarding the occlusion, and 3) signs or symptoms of temporomandibular disorder (TMD) and/or orofacial pain.

2.3. Test food

The test food was a cylindrical-shaped gummy jelly with a diameter of 14 mm, height of 10 mm, and weight of 2.3 g (Fig. 1-1). Gummy jelly comprised 41% of reduced sugar syrup, 22% maltitol, 20% sorbitol, 5% glucose, and 8% gelatin. Gummy jellies may be stored at normal temperature but ideally, the gummy jellies should be stored in a refrigerator. If refrigerated, the gummy jelly should be warmed to room temperature before recording data.

2.4. Recording method

Before the experiment, the habitual chewing side was diagnosed by having the participants chew the test food freely and selecting the side that felt easier to chew on.

Participants were asked to chew the test food on one side for 20 seconds and then spit it out into a cup with a filter. The glucose concentration of the filtrate containing glucose eluted from gummy jelly was measured using a glucose-measuring device (GS-2, GC, Tokyo, Japan). The measured value was taken as AGE. The recording was performed first on the right side and then on the left side, with a rest interval of 1 min.

2.5. Statistical analysis

All data were analyzed using SPSS for Windows (version 15.0; SPSS, Chicago, IL, USA). Normality was confirmed using the Shapiro-Wilk test. Differences in AGE from the young, middle, and old groups were evaluated using ANOVA. A paired t-test was used to compare habitual and non-habitual chewing sides. An independent t-test was used to compare males and females. Pearson’s correlation coefficient was used to investigate the correlation between age and AGE. Subsequently, stepwise multiple linear regression analysis was performed using MP as a dependent variable and age, gender, and chewing side as independent variables. A post-hoc power analysis was performed to confirm the validity of the sample size. Statistical significance was set at p< 0.05.

3. Results

AGE in the young, middle, and old groups were similar, and no significant differences were observed among the three groups. When comparing the habitual chewing side and non-habitual chewing side, AGE on the habitual chewing side was significantly greater than that on the non-habitual chewing side (Table 1). When comparing males and females, AGE in males was significantly greater than that in females (Table 2). The mean – 2SD (SD, standard deviation) value representing the reference value of all adults when chewing on the habitual chewing side were 153.1 mg/dL for males and 148.6 mg/dL for females, respectively. Furthermore, no significant correlation was found between age and AGE in any of the groups (Table 3). Stepwise multiple linear regression analysis showed that only gender was significantly associated with MP in each group (young, p<0.001; middle, p=0.004; old, p=0.005; all, p<0.001). Power analysis revealed the power to be 0.817 or more, excluding between males and females on
the non-habitual chewing side, confirming the validity of the sample size (Tables 1 and 2).

4. Discussion

The reference value used in clinical tests is based on the test data of healthy people, excluding 2.5% of participants at both the upper and lower limits, and the mean ± 2SD is the reference interval, including 95% of healthy people. In some cases, only one reference limit is of medical importance [24]. In the case of MP, the mean + 2SD or more could be regarded as healthy; thus, in this study, the mean − 2SD was set as the reference value. Therefore, 97.5% of healthy people were included in the study. By comparing the value obtained by the test with the reference value, it will be possible to objectively evaluate the degree of impaired MP and the treatment effect.

MP is affected by the number of molars and the occlusal state, in particular, the available occlusal support [23]. MP is significantly reduced even if one tooth is missing [14]. Therefore, in this study, participants with a completely natural dentition other than the third molar were selected to eliminate the effect of occlusal support.

Humans generally have a habitual chewing side. Functional differences in masticatory movements between the habitual chewing side and non-habitual chewing side have been observed [7,25] and studies adopting the habitual chewing side have been performed [12,26,27]. For this reason, studies have been conducted in which mastication on the habitual chewing side is used in the evaluation of MP [6,9,12,14,15,21,28–30]. However, some reports have concluded that there are no functional differences between the chewing sides [31]. It is necessary to be careful when selecting the habitual chewing side. It has been pointed out that there are doubts regarding the validity of simply asking the participant which side is easier to chew on [31,32]. An electromyographic method [32] or a method of examining the first chewing side after the start of mastication [33] is used as more objective method selection the habitual chewing side. The authors were empirically aware that when simply asking the participants about the habitual chewing side, the subjects often answered the dominant hand side if they were not clearly aware of their habitual chewing side. In this study, before the experiment, the participants were interviewed after chewing a gummy jelly freely to determine the habitual chewing side.

MP decreases when a tooth is lost. On the other hand, MP is improved by dental prosthetic treatment [2,11,15]. To evaluate treatment, it is necessary to compare the reference value obtained from healthy adults. Liu et al. [20] evaluated the masticatory function after wearing a denture with an occlusal ramp and compared the measurement with data from 30 healthy males [12], and reported that the patients recovered to the healthy range. It has also been reported

| Table 1. Comparison of the mean and standard deviation of the amount of glucose extraction from the habitual chewing side and non-habitual chewing side according to the participants’ gender |
|----------------------------------|------------------|------------------|------------------|------------------|
|                                 | Young (mg/dL)    | Middle (mg/dL)   | Old (mg/dL)      | F-ratio          |
| Mean ± SD                        | Mean ± SD        | Mean ± SD        | Mean ± SD        | P-value          |
| Male                             | Habitual         | Non-Habitual     | Habitual         | Non-Habitual     | Habitual         | Non-Habitual     | Habitual         | Non-Habitual     |
|                                 | 223.4±34.8       | 200.8±27.8       | 206.3±29.0       | 0.100            |
|                                 | 220.3±35.7       | 194.5±32.1       | 206.4±28.8       | 0.006            |
|                                 | 220.3±32.8       | 195.4±29.6       | 206.5±28.7       | 0.034            |
| P-value                          | <0.001           | <0.001           | <0.001           | <0.001           |
| Post hoc power                   | 0.999            | 0.999            | 0.999            | 0.999            |
| Female                           | Habitual         | Non-Habitual     | Habitual         | Non-Habitual     | Habitual         | Non-Habitual     | Habitual         | Non-Habitual     |
|                                 | 206.3±29.0       | 189.1±28.5       | 206.4±28.7       | 0.048            |
|                                 | 205.0±28.8       | 182.5±27.2       | 206.5±28.7       | 0.134            |
|                                 | 206.4±28.7       | 185.7±26.5       | 206.5±28.7       | 0.034            |
| P-value                          | <0.001           | <0.001           | <0.001           | <0.001           |
| Post hoc power                   | 0.999            | 0.999            | 0.999            | 0.999            |

| Table 2. Comparison of the amount of glucose extraction between males and females. |
|----------------------------------|-------------------|-------------------|-------------------|-------------------|
|                                 | Young (mg/dL)     | Middle (mg/dL)    | Old (mg/dL)       | All (mg/dL)       |
| Mean ± SD                        | Mean ± SD         | Mean ± SD         | Mean ± SD         | Mean ± SD         |
| Male                             | Habitual          | Non-Habitual      | Habitual          | Non-Habitual      | Habitual          | Non-Habitual      | Habitual          | Non-Habitual      |
|                                 | 223.4±34.8        | 200.8±27.8        | 206.3±29.0        | 221.9±34.4        |
|                                 | 220.7±35.7        | 194.5±32.1        | 206.4±28.7        | 200.8±32.8        |
| P-value                          | <0.001            | <0.001            | <0.001            | <0.001            |
| Post hoc power                   | 0.999             | 0.999             | 0.999             | 1.000             |

| Table 3. Correlation coefficients for the relationship between age and amount of glucose extraction in the young, middle, old groups and overall. |
|----------------------------------|-------------------|-------------------|-------------------|-------------------|
|                                 | Young (mg/dL)     | Middle (mg/dL)    | Old (mg/dL)       | All (mg/dL)       |
| Mean ± SD                        | Mean ± SD         | Mean ± SD         | Mean ± SD         | Mean ± SD         |
| Male                             | Habitual          | Non-Habitual      | Habitual          | Non-Habitual      | Habitual          | Non-Habitual      | Habitual          | Non-Habitual      |
|                                 | -0.071            | -0.070            | -0.113            | -0.091            | -0.111            | -0.048            | -0.056            | -0.098            |
| P-value                          | 0.441             | 0.445             | 0.371             | 0.469             | 0.924             | 0.688             | 0.368             | 0.115             |
| Female                           | Correlation coefficient | 0.018           | -0.030            | 0.175             | 0.121             | -0.104            | -0.127            | 0.005             | -0.056            |
|                                 | 0.846             | 0.751             | 0.117             | 0.279             | 0.291             | 0.197             | 0.934             | 0.329             |


that AGE[8,16] in healthy adults was almost the same as the data[6] of 30 healthy males and females. These reports indicate that a reference value must be calculated from a large number of healthy adults.

In this study, AGE in the young, middle, and old groups was significantly higher on the habitual chewing side than on the non-habitual chewing side. These results indicate that there is a functional difference between the habitual and non-habitual chewing sides when measuring AGE from chewing a gummy jelly. Hence, the reference value should use the data obtained from the habitual chewing side. AGE in the young, middle, and old groups was similar, and no significant difference was observed among the three groups. Furthermore, no constant trend was observed between age and AGE in each group. These results indicate that MP as measured by AGE from chewing gummy jelly was not affected by age. Ikebe et al.[34] investigated the masticatory function of older adults aged 60-84 years and reported that age was not related to masticatory performance, suggesting that masticatory performance need not decline with age if natural dentition is maintained. The results of this study can be said to prove their ideas. Sano et al.[21] compared MP of adults with completely natural dentitions and found that the occlusal force is affected by aging, but MP was not affected by aging. They considered the reason as follows. Even if there is a decrease in muscle strength with aging[35,36], older adults can fully exert adequate muscle strength required for mastication because mastication is not performed using the maximal force[37,38]. As a result, there is no significant decrease in MP. From the results of this study, it can be said that MP is maintained if the dentition is completely natural.

Regarding the gender difference in MP, males in the young, middle, and old groups had significantly higher AGE than females. These results concurred with previous studies that have shown gender differences in MP[6].

From these facts, it can be said that the reference value of AGE should be set separately for males and females of all ages by using the value obtained from the habitual chewing side. AGE from the habitual chewing side in all age groups was 221.9 ± 34.4 mg/dL for males and 206.0 ± 28.7 mg/dL for females. The mean-2SD value, which indicates the reference value of healthy adults, was relatively close to 153.1 mg/dL for males and 148.6 mg/dL for females. This is thought to be due to the fact that the mean value of females is significantly lower than that of males, but females have a smaller standard deviation. From the above, it seems that approximately 150 mg/dL can be considered as a reference value common to both males and females.

In this study, to eliminate the influence of occlusal support, healthy adults with completely natural dentition, excluding the third molars, were selected. However, the young and middle groups included university staff and students in addition to the participants in the dietary education fair, which consisted of the general population. University staff and students have more knowledge of masticatory function than the participants in the dietary education fair, so the value of the masticatory performance test may be slightly higher. In addition, since the inclusion criteria included those with natural dentition, the maximum age of participants in the old group was 87 years. The possibility of aging effects if participants in their 90s were included cannot be ruled out.

5. Conclusion

The amount of glucose extraction from 561 adults (20-87 years old) with complete natural dentition was investigated to determine a reference masticatory performance value. Based on the measurements and analysis, it was concluded that the reference value of masticatory performance measured as the amount of glucose extraction from chewing gummy jelly was 150 mg/dL.

Conflicts of interest

The authors declare that they have no conflict of interest.

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