

*Original Article***Evaluation of food texture by a questionnaire utilizing oropharyngeal sensation**

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ABSTRACT

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Purpose: With the objective to develop a standardized sensory test for food texture, which allows simple diet evaluation using oropharyngeal sensation in clinical and domiciliary settings, we added items to an existing questionnaire and evaluated the reliability and criterion-related validity of the new instrument.

Methods: Twenty healthy adult volunteers were instructed to chew and swallow test foods adjusted to three grades of food property using the enzyme homogeneous permeation or freeze-dry method, and then respond to a questionnaire containing nine items.

Results: The highest κ , which is the statistic value for reliability, was 0.523 for question 1 and the lowest κ was 0.281 for question 2. For criterion-related validity, a significant relationship was observed between multiple questionnaire items and “hardness stress” ($p < 0.05$), whereas almost no significant correlation was observed between the questionnaire items and “adhesiveness” or “cohesiveness” ($p \geq 0.05$).

Conclusion: Criterion-related validity was confirmed for several questionnaire items in relation to “hardness stress”. Future studies are required to explore questionnaire items related to “adhesiveness” and “cohesiveness” and to improve the reliability of the instrument.

Key words: dysphagia, food texture, questionnaire, oropharyngeal sensation

Introduction

Japan is experiencing a decline in total population, accompanied by a dwindling birthrate and an aging population. In 2010, the population exceeding 65 years of age was 29,250,000 (23% of the total population), an increase of 3,570,000 (14%) from 2005 [1]. The elderly population is projected to reach 30.5% in 2025. Furthermore, persons assessed as requiring nursing care (requiring support) numbered 4,850,000 at the end of 2009, which is equivalent to 16% of those aged over 65 [2]. In elderly persons requiring nursing care, the development of dysphagia is widely recognized, as a result of cerebrovascular disease or aging-related functional impairment. Dysphagia is not only an important risk factor of under-nutrition, but may also cause serious consequences such as suffocation and infections including aspiration pneumonitis. Therefore, dysphagia management is a pressing issue for medical, nursing and care providers, both in the domicile and in institutions with elderly and long-term institutionalized patients. Currently, pneumonitis is the fourth cause of death among Japanese; approximately 30% of the deaths were due to aspiration pneumonitis [3].

Food with modified physical properties plays an important role in the management of persons with

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dysphagia [4–6]. Germain et al. [7] reported that a diet with modified texture contributed to increased food intake and consequently weight gain in elderly dysphagic persons. During the treatment process of dysphagic patients, adjustment of food property is also very important [8, 9]. The commonly used indicators for food property are “elasticity” and “viscosity”, which are mechanical attributes derived from “deformation” and “fluidity”. In addition, many foods and the actual diet exhibit “viscoelasticity”, a combination of both elasticity and viscosity. Therefore, evaluating food property by physical measurements alone is difficult [6]. Furthermore, in the food preparation setting, performing physical measurements on all the food items is troublesome and impractical. Therefore, in the medical, nursing and care settings that include also the food preparation process, evaluation of food texture using the human oropharyngeal sensation is a practical approach. Based on the same concept, Wendin et al. [6] proposed to categorize foods not only by rheological measurements but also by oral sensory rating. In their classification, terms are defined for each food category according to oral sensory descriptions, so that medical and health care personnel can communicate more easily to the patients and families regarding the food that can be taken during the process of treatment for dysphagia. However, when medical, nursing or care providers perform oropharyngeal sensory evaluation of foods in the clinical or domiciliary setting using their method, there is a shortcoming that food items that are not included in their categorization cannot be evaluated.

On the other hand, Igarashi et al. [10] evaluated foods using a questionnaire. Mizukami et al. [11] also used a questionnaire to evaluate the physical property of jelly for dysphagic patients. Therefore, the questionnaire method provides a simple mean to evaluate foods with different textures in the medical or domiciliary setting. However, even for the same food item, differences in the perceived texture can be expected depending on the person eating the food. Although Igarashi et al. [10] discussed the relationship between the questionnaire items and the food texture,

the questionnaire used in their study was not a standardized scale. To perform a valid sensory test, standardization of the questionnaire, including analyses of the reliability and validity of the questionnaire, is essential.

With the purpose to develop a standardized sensory test method for the evaluation of food texture, we constructed a questionnaire based on that of Igarashi et al. [10] but with additional items that we designed independently, and examined its reliability as well as the criterion-related validity using adjusted test foods.

Methods

Subjects

Twenty health adult volunteers (9 men and 11 women, mean age 32.9 ± 9.8 years) with no functional or organic disease related to mastication and swallowing, and had no problem regarding the ability of judging oral and pharyngeal sensation participated in the study. Protection of the subjects' rights and management of personal information were in compliance with the ethical guidelines of National Center for Geriatrics and Gerontology (Ethical Committee Approval Number: 528). Informed consent was obtained from all subjects before participation in the study.

Test foods

Chicken meat samples with three grades of food property processed at EN Otsuka Pharmaceutical Co. Ltd. using the enzyme homogeneous permeation or freeze-dry method were used. The methods for preparing the test foods are shown in Table 1.

Oropharyngeal sensory test

A questionnaire containing 9 items was constructed, which was based on the questionnaire of Igarashi et al. [10], plus some items deemed essential for evaluating texture (Table 2). Each subject was instructed to freely chew and swallow each of the three test foods, and evaluated the food texture using the questionnaire that we constructed. The three test foods were taken and

Table 1. Methods of preparation of test foods.

Food (soft)	Chicken breast meat (raw) was subjected to enzyme infusion treatment, and the softened chicken breast meat was frozen rapidly and then freeze-dried. The freeze-dried softened chicken breast meat was reconstituted with over 4 times the dry weight of water, and incubated at 20°C.
Food (usual)	The reconstituted chicken breast meat was placed in a container and sealed. A venting hole was made and the content was heated in a microwave oven* at defrost mode for 3 min, and then incubated at 20°C.
Food (hard)	Chicken breast meat (raw) was steamed until the core temperature reached 90°C, frozen rapidly, and freeze-dried. The freeze-dried chicken breast meat was reconstituted in over 4 times the dry weight of water for over 30 min, and incubated at 20°C.

*A microwave oven CMO-650S (Crystal Electric Co. Ltd.) was used at defrost mode (equivalent to 190 W).

Table 2. The questionnaire consisting of 9 items.

Question 1	How hard was it to break the food down in the mouth ?
Question 2	How pleasant was the food in the mouth ?
Question 3	How tasty was the food ?
Question 4	How thin was the food in the mouth ?
Question 5	How easy was it to swallow the food ?
Question 6	How was the pharyngeal clearance ?
Question 7	How much did you chew ?
Question 8	How easy did the food gather in the mouth ?
Question 9	How sticky did it feel in the mouth ?

*Questions 1 to 6 are adopted from the questionnaire items from Igarashi et al. [10], and questions 7 to 9 are newly added items.

Table 3. Evaluation of reliability of the questionnaire.

	κ	z	p
Question 1	0.523	7.53	<0.01
Question 2	0.281	3.82	<0.01
Question 3	0.494	6.74	<0.01
Question 4	0.383	5.20	<0.01
Question 5	0.482	6.36	<0.01
Question 6	0.370	5.08	<0.01
Question 7	0.456	6.75	<0.01
Question 8	0.471	5.74	<0.01
Question 9	0.512	6.58	<0.01

evaluated in random order, and the subject was single-blinded to the food property. Each question was scored on a scale of 5: very much = +2.0, moderately = +1.0, somewhat = 0.0, not really = -1.0, and not at all = -2.0.

Furthermore, to analyze the intra-rater reliability of each questionnaire item, each subject performed the evaluation twice, at an interval of at least one week.

Measurements of food property

Using a Creep Meter RE33005 (Yamaden Co., Japan), the mechanical properties of the three test foods were measured. According to the approval standards for “foods for dysphagia” provided by the Consumer Affairs Agency [12], a dish measuring 40 mm in diameter and 20 mm in height was filled with the test material, and compressed twice with a resin plunger measuring 20 mm in diameter and 8 mm in height, at a compression speed of 10 mm/sec and clearance of 5 mm. From the texture curve, hardness stress, adhesiveness and cohesiveness were obtained. The temperature of test material at the time of measurement was $20 \pm 2^\circ\text{C}$.

Evaluations of reliability and validity

To assess the intra-rater reliability of each questionnaire item, κ (kappa) was calculated. Kappa is a statistical value indicating reproducibility: $\kappa > 0.75$ denotes excellent reproducibility; $0.4 \leq \kappa \leq 0.75$ denotes good reproducibility; and $0 \leq \kappa \leq 0.4$ denotes marginal reproducibility. From each κ value, the z and p values were calculated to confirm the superiority of κ .

Furthermore, to assess the validity of each questionnaire item, the relationship between the mean score for the first and second sensory tests and the food properties (hardness, adhesiveness and cohesiveness) was analyzed using Spearman correlation coefficient.

Results

Assessment of the intra-rater reliability of each questionnaire item

The κ value of each questionnaire item is shown in Table 3. The highest κ was 0.523 for question 1 and the lowest κ was 0.281 for question 2. The κ values for questions 1, 3, 5, 7, 8 and 9 were within the range of

Table 4. Mechanical properties of the test foods.

	Food (soft)	Food (usual)	Food (hard)
Hardness stress [10^4 N/m ²]	3.7±1.6	11.0±25.1	31.8±38.8
Adhesiveness [J/m ³]	440±250	580±150	480±440
Cohesiveness	0.57±0.03	0.43±0.06	0.57±0.00

Table 5. Correlation between questionnaire items and food properties.

	Hardness stress	Adhesiveness	Cohesiveness
Question 1	0.788**	0.388**	0.006
Question 2	-0.231*	-0.089	-0.031
Question 3	-0.010	-0.011	0.006
Question 4	-0.462**	-0.146	-0.098
Question 5	-0.498**	-0.173	-0.088
Question 6	0.472**	0.181*	0.063
Question 7	0.734**	0.332**	0.041
Question 8	-0.224*	-0.056	-0.065
Question 9	0.197*	0.067	0.037

** $p \leq 0.01$; * $p \leq 0.05$

$0.4 \leq \kappa \leq 0.75$, while those for questions 2, 4 and 6 were within the range of $0 \leq \kappa \leq 0.4$. For all the items, p was less than 0.01 indicating that the κ values obtained were significant.

Mechanical properties of test foods

The food property measurements (hardness, adhesiveness and cohesiveness) of the three test foods are shown in Table 4. "Hardness stress" increased from Food (soft) to Food (hard). On the other hand, "adhesiveness" and "cohesiveness" showed no fixed tendency among the three test foods.

Validity of each questionnaire item for texture evaluation

The Spearman correlation coefficients between each of the questionnaire items and the food property measurements are shown in Table 5. At a significance level of $p < 0.01$, questions 1 and 7 correlated with "hardness stress" and "adhesiveness", and questions 4, 5 and 6 correlated with "hardness stress". In addition, at a significance level of $p < 0.05$, questions 2, 8 and 9 correlated with "hardness stress", and question 6 correlated with "adhesiveness".

Discussion

Previously Igarashi et al. [10] and Mizukami et al. [11] evaluated the texture of foods using a

questionnaire. However, both reports did not examine reliability and validity, and a standardized questionnaire for the evaluation of food property is not yet available. Therefore, with the objective to construct a standardized sensory test for food texture, the present study examined the reliability and validity of a questionnaire that we constructed. The questionnaire consisted of 9 items, which was based on the questionnaire of Igarashi et al. [10] plus some items deemed essential for accurate evaluation of texture (Table 2). Questions 1–6 were based on the questionnaire of Igarashi et al. [10]. Question 1 relates to the hardness of food, and questions 2, 5 and 6 are rheology-related items. Question 3 evaluates the taste of food, and question 4 attempts to evaluate how easy food is processed in the oral cavity. Questions 7–9 are the newly added items. Question 7 evaluates hardness, question 8 evaluates cohesiveness, and question 9 evaluates adhesiveness.

We assessed the intra-rater reliability of the questions by repeating the sensory test and calculating κ from the scores obtained from the first and second tests. While κ for questions 1, 3, 5, 7, 8 and 9 were within the range of $0.4 \leq \kappa \leq 0.75$, those for questions 2, 4 and 6 were within the range of $0 \leq \kappa \leq 0.4$. Some possible reasons for the lower κ for questions 2, 4 and 6 are as follows. The expression "pleasant" used in question 2 is not specific, resulting in individual differences. In question 4, the criterion for "thin" is

not specified, which may have led to divided judgment in response. In 6, the expression “pharyngeal clearance” may be difficult to evaluate for the healthy subjects in the present study. Therefore, it is necessary to delete or improve the contents of questions 2, 4 and 6. The present evaluation showed that the other items have marginal reliability. With respect to intra-rater reliability, the questionnaire is usable after excluding questions 2, 4 and 6.

Regarding the relationship between each questionnaire item and texture, we evaluated the criterion-related validity using Spearman correlation coefficient. “Hardness stress” correlates with all the questionnaire items excluding question 3, and the correlation with questions 1 and 7 is especially strong (0.788 and 0.734, respectively). Question 1 is an evaluation item for hardness, and a strong correlation with “hardness stress” is a natural outcome. Question 7 evaluates the degree of mastication. Since mastication plays a role to adjust the food to a texture that can be swallowed [13], this result may reflect that harder food requires extra mastication. The other questions had a weak correlation with “hardness stress”. However, the correlation coefficients of questions 4–6 were higher than those of questions 2, 8 and 9. The fact that questions 2, 8 and 9 are not related to hardness while questions 4–6 are related to mastication may have influenced the results. Question 3 is an item that evaluates the taste, and for this reason this item shows no significant correlation with any of the texture parameters. Since our questionnaire was designed for the purpose of evaluation food texture, whether question 3 that evaluates taste should be included is debatable. However, it cannot be denied that taste is an important element when medical, nursing or care providers conduct oropharyngeal sensory evaluation of the actual diet in the clinical or domiciliary setting. “Adhesiveness” correlated with questions 1, 6 and 7, but the correlation was not strong. Also “cohesiveness” did not correlate with any questionnaire item. Summarizing the relationship between the questionnaire items and food texture, while “hardness stress” showed a significant correlation with many items, “adhesiveness” and “cohesiveness” showed no significant correlation with any of the items or only a weak correlation with a few items. A possible reason may be that “adhesiveness” and “cohesiveness” of the three test foods have no linear relationship with “hardness stress”, or that the three test foods did not show similar degrees of “adhesiveness” and “cohesiveness”. These factors may account for the lack of high correlation between the questionnaire items and “adhesiveness” or “cohesiveness”. In other words, for the foods tested in the present study, “adhesiveness” and “cohesiveness” were difficult to rate even by healthy people.

The test foods used were chicken meat samples with three grades of food property processed at EN Otsuka

Pharmaceutical Co. Ltd. using the enzyme homogeneous permeation or freeze-dry method. The enzyme homogenous permeation method is a technology for softening food materials without destroying the form of the food, by permeating the food with specific tissue-degrading enzymes that break down the components that form the framework of food materials. For animal food material, the myofibrillar protein is effectively degraded to smaller molecules, thus increasing the disintegratability and solubility of the food material [14]. The textural properties of the three test foods, as shown in Table 4, were as follows: “hardness stress” was $3.7 \pm 1.6 (\times 10^4 \text{ N/m}^2)$ for Food (soft), $11.0 \pm 25.1 (\times 10^4 \text{ N/m}^2)$ for Food (usual), and $31.8 \pm 38.8 (\times 10^4 \text{ N/m}^2)$ for Food (hard), showing an increase in stress from Food (soft) to Food (hard). In contrast, no linear relationship with the three test foods was found for “adhesiveness” and “cohesiveness”. This finding suggests that although the enzyme homogeneous permeation method can adjust hardness, it is difficult to control “adhesiveness” and “cohesiveness”.

In order to completely verify the criterion-related validity of the evaluation scale for sensory testing constructed in the present study, further investigations are necessary using foods linearly adjusted with respect to the elements of “adhesiveness” and “cohesiveness”.

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