jdhs
Journal of Dental Hygiene Science

J Dent Hyg Sci Vol. 23, No. 4, 2023, pp.320-329
https://doi.org/10.17135/jdhs.2023.23.4.320

RESEARCH ARTICLE

Comparison of the Tongue-Palate Pressure Patterns According to the Tongue Pressure in Community-Dwelling Older Adults

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Background: Oral frailty has garnered considerable interest following its identification as a risk factor for physical frailty. The Korean oral frailty diagnosis criteria have emphasized the need for extensive research on oral frailty diagnostic items and interventions. Our study performed an in-depth analysis of the tongue-palate pressure patterns in healthy community-dwelling older adults.

Methods: Of the 217 older adults aged ≥60 years who visited a senior center in Wonju, 205 participants who completed tongue pressure measurement were included in the final analysis. Pressure changes over time were recorded by instructing the participants to press their tongue against the hard palate with for 7 seconds per cycle. The participants were divided into the normal and abnormal tongue pressure (NTP and ATP, respectively) groups based on whether they achieved the target tongue pressure at least once; tongue pressure patterns were compared between the groups. Furthermore, the average time taken to achieve the standard tongue pressure value was calculated for the participants in the NTP group and used to evaluate the decrease in tongue pressure in the ATP group.

Results: Among the 205 participants, 40.5% had ATP. The tongue pressure graph revealed a gentle and consistent incline that was maintained even after achieving standard tongue pressure in the NTP group. The graph was more extreme in the ATP group, and the changes in the pressure type varied across individuals; the tongue pressure was only 48.4%, 40.7%, 31.9%, and 22.6% of the NTP in the participants in their 60s, 70s, 80s, and ≥90s, respectively ($p<0.05$).

Conclusion: Tongue pressure weakness was observed in 40.5% of the healthy community-dwelling older adults. Furthermore, ATP graphs were observed in the patients with tongue pressure weakness. Thus, activities improving the oral function in community-dwelling older adults and systematic oral rehabilitation programs should be devised to promote normal swallowing.

Key Words: Aging, Older adult, Oral frailty, Tongue pressure

Introduction

1. Background

South Korea is reportedly the most rapidly aging country worldwide. Statistics Korea revealed individuals aged ≥65 years to constitute 17.5% of the total population by 2022. South Korea is projected to become a super-aged society by 2025, with 20.6% of its population comprising individuals aged ≥65 years[1)]. In contrast to other advanced countries, such as Austria (53 years), the United Kingdom (50 years), the United States (15 years), and Japan (10 years), the shift from an aging society to a super-aged society has occurred over an exceptionally brief period of seven years in South Korea, which is anticipated to result

Received: November 14, 2023, **Revised:** December 3, 2023, **Accepted:** December 7, 2023 eISSN 2233-7679

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in an array of problems[1]. This rapid aging trajectory has resulted in a range of challenges concerning the health and quality of life of older adults, thereby contributing to an increasing interest in the concept of frailty.

Aging refers to the natural decline in bodily functions that occurs with age. Frailty represents a state of overall physical deterioration in which the physiological functions necessary for maintaining homeostasis decline, resulting in increased susceptibility to external factors. Frailty can result in the development of various diseases, disabilities, dependence, falls, and mortality[2]. Oral frailty may be overlooked during the progression of physical frailty; however, several studies have identified oral frailty as a risk factor for physical frailty. Tanaka analyzed the association between oral frailty and physical frailty (physical disability and mortality rate) and revealed that individuals with both oral frailty and physical frailty had a high hazard ratio (5.09) and substantially higher odds ratio[3].

As the demographics of society continue to evolve, it is necessary to shift the focus from the prevention of oral diseases to the restoration of oral function and prevention of its deterioration. Oral hypofunction is included in the National Health Insurance system in Japan, which is the first country to experience an aging population. This has facilitated the early diagnosis and management of the progression of oral functional impairments in older adults[4,5].

The criteria for diagnosing oral frailty include number of teeth, occlusal force, chewing ability, dry mouth, diadochokinesis, tongue pressure, and swallowing ability. Dysphagia is associated with tongue pressure and swallowing ability. Swallowing food is a fundamental necessity for sustaining life and a crucial element for enhancing the quality of life of older adults. However, a decline in the tongue pressure is observed in older adults owing to decreased muscle function sarcopenia attributed to aging, resulting in impaired swallowing and consequent dysphagia[6]. Dysphagia is a major cause of aspiration pneumonia[7,8], which is a leading cause of death among older adults. Dysphagia has been reported in 15～22% of community-dwelling older adults in the United States[9]. The Korean Dysphagia Society reported that 30～40% of older adults aged ≥65 years in Korea are diagnosed with dysphagia. The tongue plays a significant role in the oral and pharyngeal phases of the swallowing process[10-13]; therefore, tongue atrophy or decreased tongue pressure increases the risk of foreign body aspiration into the airway and malnutrition. Moreover, decreased tongue pressure can impair the quality of life of older adults. Tongue-strengthening exercises (TSE) have been reported to increase tongue thickness and pressure in older adults with dysphagia by 5% and 18%, respectively.

Healthcare professionals used the TPM-02 (JMS Co., Ltd., Tokyo, Japan) and the Iowa Oral Performance Instrument (IOPI Pro Standard; IOPI Medical LLC, Washington D.C., USA) to measure tongue pressure and diagnose tongue muscle weakness. Peko-Panda (JMS Co., Ltd.) and IOPI Trainer (IOPI Medical LLC) are oral rehabilitation training tools that can be used by patients; however, the IOPI Trainer has not yet been approved in Korea.

2. Objectives

Studies have been conducted to measure and record tongue pressure data in the field of dentistry owing to the increasing interest in oral frailty in recent years[12-15]. However, most previous studies have collected data regarding maximum tongue pressure or improvements following oral rehabilitation training. Consequently, data on the tongue pressure maintenance patterns during swallowing in older adults with decreased tongue pressure are lacking. Therefore, this study aimed to perform an in-depth analysis of the tongue-palate pressure patterns in older adults to obtain foundational data for the development of oral rehabilitation programs for older adults.

Materials and Methods

1. Participants

This study was approved by the Institutional Review Board of the Yonsei University (IRB No. 1041849-202212-SB-239-02). Among the 217 older adults residing in Wonju, Gangwon State, who consented to participate in the study, 205 completed tongue pressure measurements and were included in the final analysis.

2. Tongue-palate pressure data collection

Tongue-palate pressure was measured using a TPM-02

digital tongue pressure measurement device (TPM-02; JMS Co., Ltd.). In accordance with the manufacturer's instructions, the participants were instructed to bite lightly on a soft ring with their anterior teeth and push their tongue against the hard palate with maximum force while maintaining maximum tongue pressure for 7 seconds per cycle. The measurements were acquired again after a 30-second rest period for a total of three cycles. Maximum tongue pressure and pressure changes over time (seconds) were recorded and stored in a separate Excel file.

3. Criteria for tongue-palate pressure analysis

Fig. 1 illustrates the algorithm for classifying data from the 205 participants based on the normal tongue pressure (NTP). Three measurements were obtained for each participant. Participants who achieved the target tongue pressure recommended by the manufacturer on at least one of the three tongue-palate pressure graphs were included in the NTP group. The remaining participants were assigned to the abnormal tongue pressure (ATP) group. The target tongue pressure was 30 and 20 kPa for participants aged 60～69 and ≥70 years, respectively. Only the graphs that showed a plateau (consistent tongue strength) after reaching a certain tongue pressure were included in the analysis. Graphs that did not show a plateau were excluded from the graph analysis.

4. In-depth analysis of the tongue-palate pressure patterns

The tongue-palate pressure patterns in the NTP and ATP groups were analyzed as follows: 1) comparison of the tongue-palate pressure graphs between the NTP and ATP groups; 2) determination of the percentage of tongue-palate graphs meeting the manufacturer's criteria; and 3) identification of a decrease in the tongue-palate pressure in the ATP group.

The tongue pressure graph patterns for 7 seconds were compared between the groups. The graph patterns were subsequently analyzed to calculate the percentage of graphs that satisfied the criteria. Graphs from all the graphs were included in the final analysis. Graphs that reached the manufacturer's cutoff value at least once during the three measurements were considered normal in the first classification. However, only graphs that showed good maintenance of tongue pressure after reaching a certain pressure point were included in the in-depth analysis; thus, the percentage of graphs that reached the manufacturer's cutoff value was also assessed. Tongue-palate pressure values across the time points were calculated in the NTP group for comparison with those in the ATP group to analyze the degree of tongue pressure impairment.

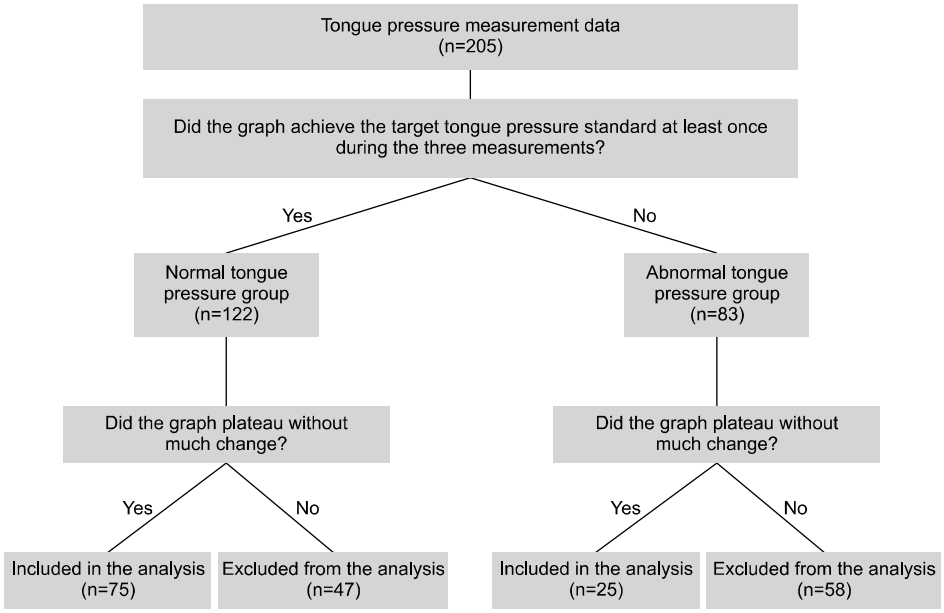

Fig. 1. Decision process for tongue pressure graph analysis.

5. Statistical analysis

The IBM SPSS software (ver. 26.0; IBM Corp., Armonk, NY, USA) was used for the statistical analysis. The differences in the general characteristics and rate of achieving the target criterion for the tongue-palatal pressure graph according to the NTP were analyzed using frequency and descriptive analyses. One-way analysis of variance (ANOVA) and Games-Howell post-hoc tests were used to compare the time taken to achieve the target tongue pressure in the NTP group and changes in the tongue pressure over time in the ATP group.

Table 1. General Characteristics of the Participants according to the Tongue Pressure Group

Variable	Number (%)
Total	205 (100.0)
Sex	
Male	59 (28.8)
Female	146 (71.2)
Age (y)	
60～69	34 (16.6)
70～79	77 (37.6)
80～89	85 (41.5)
≥90	9 (4.4)
Target tongue pressure reached	
Yes	122 (59.5)
No	83 (40.5)
Number of systemic diseases	
0	36 (17.6)
1	53 (25.9)
≥2	116 (56.6)
Body mass index	
Under weight	5 (2.4)
Normal range	56 (27.3)
Overweight	47 (22.9)
Class 1 obesity	81 (39.5)
Class 2 obesity	16 (7.8)

Data analyzed using frequency and descriptive analysis.
Under weight: <18.5 kg/m^2; Normal range: 18.5～22.9 kg/m^2; Overweight: 23.0～24.9 kg/m^2; Class 1 obesity: 25.0～29.9 kg/m^2; Class 2 obesity: ≥30.0 kg/m^2.

Results

1. General characteristics of the participants according to the NTP

The participants were classified into the 60s and ≥70s group according to their age. Each group was subsequently classified into the NTP and ATP groups.

Table 1 presents the general characteristics of the participants. Of the 205 participants in this study, 28.8% were males and 71.2% were females. Among the 205 participants, 41.5%, 37.6%, 16.6%, and 4.4% were aged 80～89 years, 70～79 years, 60～69 years, and ≥90 years, respectively. The rate at which the target pressure was achieved was 59.5%. According to the age group, the rate was 47.6% in the 60s group and 62% in the ≥70s group (data not shown).

Approximately 56.6% of the participants had ≥2 systemic conditions. According to the World Health Organization (WHO) body mass index (BMI) criteria for the Asian population[16], 39.5%, 27.3%, 22.9%, 7.8%, and 2.4% of the participants were classified into class 1 obesity, normal, over-

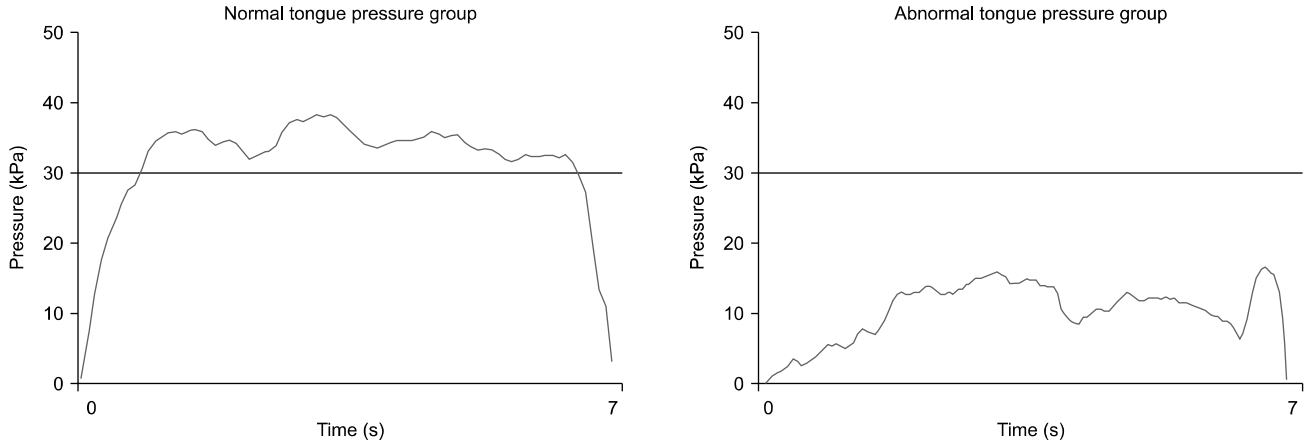

Fig. 2. Differences in the graphical aspects based on age and tongue pressure group (60s group).

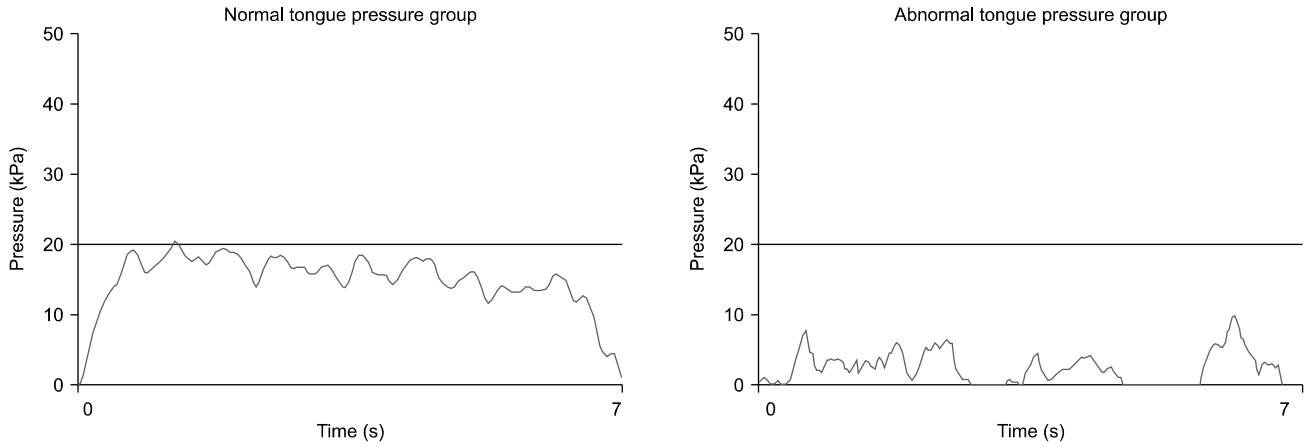

Fig. 3. Differences in the graphical aspects based on the age and tongue pressure group (≥70s group).

Table 2. Rates of the Tongue-Palate Pressure Graphs that Achieved the Target Criterion

Age group	n	Normal tongue pressure		Abnormal tongue pressure	
		Yes	No	Yes	No
60～69	34	15 (93.8)	1 (6.2)	8 (44.4)	10 (55.6)
≥70	171	60 (56.6)	46 (43.4)	17 (26.2)	48 (73.8)
Total	205	75 (61.5)	47 (38.5)	25 (30.1)	58 (69.9)

Values are presented as n (%).
Data analyzed using frequency analysis.

weight, class 2 obesity, and underweight groups, respectively.

2. Comparison of the tongue-palate pressure graphs by age and NTP

The tongue-palate pressure graphs were classified according to the NTP and age (60s vs. ≥70s) (Fig. 2, 3). A gentle curvature was observed in the graphs of the participants in the NTP group after achieving the target tongue pressure, which was consistently maintained. In contrast, the graphs of the participants in the ATP group did not show gentle curvatures and had varying shapes, such as large fluctuations in pressure. Moreover, consistent pressure was not maintained after the target pressure was achieved. The tongue-palate pressure graphs in the 60s and ≥70s NTP groups also varied according to age. Pressure was maintained at a constant level after achieving the target tongue pressure in the 60s NTP group. In contrast, several peaks were observed even after achieving the target tongue pressure in the ≥70s NTP group. The adequacy of tongue pressure change could not be measured in the ATP group because the tongue pressure did not reach the target tongue pressure or showed a gentle curvature. In 29 patients in the 70s ATP group, the tongue pressure dropped to 0 kPa during measurement.

3. Rate of achieving the target criterion among the tongue-palate pressure graphs included in the in-depth analysis

Table 2 presents the rates of the tongue-palate pressure graphs that achieved the target pressures included in the in-depth analyses. The rate of tongue-palate pressure graphs achieving the target pressure was 93.8% and 44.4% in the 60s NTP and 60s ATP groups, respectively. The rate of tongue-palate pressure graphs achieving the target pressure was 56.6% and 26.2% in the 70s NTP and 70s ATP groups, respectively. The rates of the tongue-palate pressure graphs achieving the target pressure were 61.5% and 30.1% in the entire NTP and ATP populations, respectively.

4. Degree of decrease in the tongue-palate pressure in the ATP group

The time to achieve the target tongue pressure in the

NTP group was calculated to assess the degree of decrease in the tongue-palate pressure in the ATP group compared to that in their healthy counterparts in the same age group (Table 3). The time taken to achieve the target tongue pressure was 1.34±0.90 seconds, 1.41±1.60 seconds, 1.47±1.41 seconds, and 1.40±0.80 seconds in the participants aged 60～69 years, 70～79 years, 80～89 years, and ≥90 years, respectively. The mean time taken to achieve the target tongue pressure was 1.42±1.43 seconds in the NTP population. No significant differences were observed among the age groups ($p > 0.05$).

Tongue-palate pressure in the ATP group was calculated based on the time taken to achieve the target tongue pressure in the healthy counterparts of the same age group. The pressure was compared to the NTP, the tongue pressure was only 48.4%, 40.7%, 31.9%, 22.6% of the NTP in the participants aged 60～69 years, 70～79 years, 80～89 years, and ≥90 years groups (Table 4). Significant differences were observed among the age groups (Table 4). The post-hoc test revealed that the tongue-palate pressure was significantly higher in the participants aged 60～69 years than that in participants aged ≥70 years.

Discussion

1. Interpretation

Oral health is an essential component to be considered during the promotion of the general health of older adults, as poor oral health adversely affects the general health status[17,18]. Oral health plays a pivotal role in the nutritional status of older adults; however, the diagnostic criteria and clinical practice guidelines for oral frailty are not well established in Korea. The National Evidence-based Healthcare Collaborating Agency published an expert consensus on the "Korean version of the oral frailty diagnostic criteria and treatment" in 2022. Nevertheless, diverse approaches and interventions are needed to promote oral health among older adults.

2. Key results and comparison with previous studies

Previous studies have demonstrated that TSE performed using the IOPI over a 6-week period resulted in statistically significant improvements. Significant improvements in the videofluoroscopic dysphagia scale (VDS) score, which is based on the videofluoroscopic swallowing study (VFSS), have been reported[19]. An increase of 5% and 18% in the tongue thickness and tongue-palate pressure, respectively have been reported in older adults with dysphagia following TSE[20]. Improved tongue muscle strength, increased saliva secretion, increased thickness of the suprahyoid and tongue muscles, and a decrease in the VDS scores have been reported following tongue rehabilitation training[21-26]. These positive outcomes have been reported in the field of dentistry in recent years, in addition to the field of rehabilitation medicine and occupational therapy.

Given the rapid increase in the older adult population and aging of patients visiting dental clinics, it is important for dental hygienists to have a proper understanding of the tongue-palate pressure patterns and differences between

Table 3. Comparison of the Time Taken to Achieve the Target Tongue Pressure in the Normal Pressure Group

Age group	n	Normal pressure group (s)	p-value	Target tongue pressure (kPa)
60～69	16	1.34 (0.90)	0.100	30
70～79	62	1.41 (1.60)		20
80～89	41	1.47 (1.41)		20
≥90	3	1.40 (0.80)		20
Total	122	1.42 (1.43)		

Values are presented as mean (standard deviation).
Data analyzed using one-way analysis of variance.

Table 4. Comparison of the Pressure Achieved in the Abnormal Pressure Group and the Time Taken to Achieve the Target Tongue Pressure in the Normal Pressure Group

Age group	n	Abnormal pressure group (kPa)	p-value	Standard tongue pressure (kPa)
60～69	18	14.53 (7.58)[a]	<0.001	30
70～79	15	8.14 (4.15)[b]		20
80～89	44	6.38 (5.01)[c]		20
≥90	6	4.52 (2.86)[d]		20
Total	83			

Values are presented as mean (standard deviation).
Data analyzed using one-way analysis of variance and Games-Howell post-hoc ($p < 0.05$).
[a,b,c,d]Different superscript letters indicate significant differences between groups ($p < 0.001$).

individuals with normal and impaired tongue pressure to ensure patient-centered interventions. Therefore, this study aimed to obtain fundamental data that could be utilized in future oral function rehabilitation programs for older adults by performing an in-depth analysis of the tongue-palate pressure patterns.

Older adults aged ≥60 years who visited one of the 17 senior centers in Wonju, Gangwon State were enrolled in this study. The percentage of women was found to be two-fold higher than that of the men in the present study. Most participants were aged 80～89 years (41.5%) and 40.5% of the study population did not achieve the target tongue pressure, highlighting the status of tongue pressure among community-dwelling older adults. Approximately 56.6% of the participants had ≥2 systemic diseases, with metabolic syndrome being the most common condition.

The tongue-palate pressure graph patterns were compared according to the age and NTP. The graphs of the participants in the NTP group showed a gentle curvature with no large fluctuations in the tongue pressure after achieving the target pressure. In contrast, participants in the ATP group showed more irregular graphs with large variations across individuals. The differences in the tongue-palate pressure graph patterns between the NTP and ATP groups were more prominent in the ≥70 years age group. Several peaks were observed even after achieving the target pressure in the 70s NTP group, suggesting that the participants consciously exerted force to achieve the target pressure, as opposed to the tongue maintaining a consistent level of force. This is similar to the findings of a previous study, which reported that endurance declines with aging[27]. The tongue pressure was lower in the ATP group. Moreover, it was difficult to measure tongue pressure, or the participants did not achieve the target tongue pressure even after reaching a certain level of tongue pressure, indicating that they did not reach the minimum pressure required to swallow food. The ≥70 years ATP group had difficulty maintaining a consistent level of pressure, and several participant's tongue pressure dropped to 0 kPa during measurement in this group. This pattern is consistent with the findings of a previous study evaluating the maximal tongue strength and endurance in Korean adults that reported a significant decrease in the tongue strength with increasing age among Korean adults[12].

Participants who achieved the target tongue pressure at least once during the three measurements were assigned to the NTP group (Fig. 1). However, only one of the three graphs from each participant that showed consistent tongue pressure after achieving the target tongue pressure, as recommended by the manufacturer, was included in the final analysis. Thus, the rate of graphs that achieved the target tongue pressure among those selected for the final analysis was assessed in this study. The rates were 93.8%, 44.4%, 56.6%, and 26.2% in the 60s NTP, 60s ATP, ≥70s NTP, and ≥70s ATP groups, respectively (Table 2). Similar results were obtained from the three repeated measurements in the 60s NTP group; however, the three repeated measurements were not consistent in the 70s NTP group. Weakening of strength due to repeated measurements in the older participants may have influenced the results.

The time taken to achieve the target tongue pressure was analyzed in the NTP group (Table 3). The mean time taken to achieve the target tongue pressure in the NTP group was 1.42±1.43 seconds, which is considered to be within the normal swallowing time compared with the mean time of 1～1.5 seconds[28,29] reported in the general adult population. In contrast, in a previous study, the time taken to swallow was longer in the ATP group. Therefore, tongue-palate pressure was computed using the time taken by the NTP group to achieve the target tongue pressure. This type of analysis was selected because the ATP group failed to achieve the target tongue pressure, and indirect measurement of the swallowing time was challenging.

The tongue pressure was only 48.4% (14.53±7.58 kPa) of the recommended tongue pressure of 30 kPa in the 60～69 years group. The tongue pressure was only 40.7% (8.14±4.15 kPa) of the recommended pressure in the 70～79 years group. The tongue pressure was only 31.9% (6.38±5.01 kPa) of the recommended pressure in the 80～89 years group, whereas it was only 22.6% (4.52±2.86 kPa) of the recommended pressure in the ≥90s group. This finding indicates a drastic decline in the percentage of the target pressure reached with advancing age and that older adults face more challenges in achieving the target pressure as they get older, which is consistent with the findings of previous studies[30,31].

3. Suggestion

The findings of the present study shed light on impaired tongue muscle strength, an indicator of oral frailty, in community-dwelling older adults, and the in-depth analysis data could serve as foundational data for developing oral rehabilitation programs. In the oral functional rehabilitation of elderly individuals with decreased tongue pressure, tongue pressure-strengthening training can be programmed by setting the tongue pressure pattern (such as target value of maximum tongue pressure and maintenance time of tongue pressure.) in the ATP group of the same age. In addition, the results of this study suggest that even elderly people living in healthy communities suffer from a decline in tongue pressure. Therefore, institutional support is needed to prevent and manage tongue function at an early stage to prevent decline.

4. Limitations

However, as this study included only older adults residing in Wonju City, the findings cannot be generalized. Therefore, further follow-up studies are warranted. In addition, as the concept of oral frailty and its diagnostic criteria are fairly new in Korea, in-depth and multidisciplinary research should be conducted in the future on this topic.

5. Conclusion

This study compared the tongue-palate pressure patterns in community-dwelling older adults with normal and ATP and obtained baseline research data for developing oral rehabilitation programs in the future. The results of this study can be used to plan systematic oral rehabilitation training to shorten the time required to reach maximum tongue pressure and strengthen the tongue muscle endurance based on the target value of the tongue pressure required during the swallowing process in patients with oral dysphagia. The key findings are as follows:

1. A total of 59.5% of the participants achieved the target tongue pressure.
2. In the NTP group, the tongue pressure graph showed a gentle curve, which was maintained at a consistent level after a certain point. Marked pressure changes were observed in participants aged ≥70 years compared to those aged 60～69 years.
3. In the ATP group, the tongue pressure graph did not show a gentle curvature but revealed large fluctuations in the tongue pressure. Moreover, the tongue pressure was not maintained consistently in 29 cases in the ≥70 years group.
4. The tongue-palate pressure during normal swallowing time declined significantly with advancing age in the ATP group.

The results of the present study indicated that 40.5% of the healthy community-dwelling older adults experienced tongue muscle weakening, highlighting the need to implement oral function-improving activities for inpatients and community-dwelling older adults. Diverse and multidisciplinary research should be further conducted to enhance and facilitate the rehabilitation of tongue muscle strength, which is an indicator of oral frailty in older adults. Moreover, developing systematic oral rehabilitation programs is important to ensure maintenance of adequate tongue pressure for normal swallowing in the older adult population.

Notes

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Ethical approval

Approved by the Institutional Review Board at Yonsei University (IRB No. 1041849-202212-SB-239-02).

Author contributions

Conceptualization: Sun-Young Han and Hye-Jin Park. Data acquisition: Min-Ji Jo, Seong-Chan Park, Soo-Min Kim, Hye-Jin Park, and Yun-Seon Lee. Data analysis: Min-Ji Jo. Funding: Sun-Young Han. Supervision: Tae-Woo Kim, Eui-Yeon Lee, and Sung-Hoon Kim. Writing-original draft: Min-Ji Jo. Writing-review & editing: Min-Ji Jo, Tae-Woo Kim, Ji-Seon Hong, Eui-Yeon Lee, Sung-Hoon Kim, and Sun-Young Han. All authors approved the final manuscript.

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Acknowledgements

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (MOE) in 2023 (2022RIS-005).

Data availability

The Authors may provide raw data upon reasonable request.

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