Hirosaki Med. J. 66 : 55—64, 2015

ORIGINAL ARTICLE

EFFECTS OF POSTURE AND BALANCE EXERCISES AIMED AT ORAL FUNCTION IMPROVEMENT IN THE FRAIL ELDERLY

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Abstract Objectives: To elucidate the relationship between posture and oral function in the elderly and to verify the effects of interventions aimed at improving posture on oral functions, particularly in the frail elderly.
Methods: We evaluated postural conditions and oral and respiratory functions in 11 healthy elderly people living locally and 9 frail elderly persons using day-care services. The frail elderly were assigned to 2 groups. Interventions were performed for a total of 16 weeks in a crossover design; they comprised regular swallowing exercises and fall-prevention exercises aimed at improving posture and balance.
Results: Postural conditions in the elderly were correlated with oral function and respiratory function. Intervention with either the aspiration-prevention exercises or the fall-prevention exercises significantly improved kyphotic posture in the frail elderly. Intervention with the fall-prevention exercises alone improved swallowing function and oral-related quality of life (QOL).
Conclusions: To effectively improve oral function in the frail elderly, exercises helping to improve posture and balance should be added to swallowing exercises.

Hirosaki Med. J. 66 : 55—64, 2015

Key words: posture; preventive care; swallowing function; hypnosis; physical exercise.

Introduction

Aspiration pneumonia is one of the major causes of death in the Japanese elderly[1]. Decreased swallowing function has been suggested to induce aspiration pneumonia[2,3]. Therefore, one important goal in the elderly is to maintain and enhance eating and swallowing functions to prevent aspiration. The oral cavity is the site of eating and swallowing for nutrient intake, as well as respiration and articulation for communication, all of which are critically important functions in our daily lives[4-7].

Programs to improve oral function have been newly incorporated into Japanese care services on the basis of revisions to the nursing-care insurance law in FY 2006. These programs have been implemented all over the country[8]. However, the Survey of Long-term Care Benefit Expenditures conducted by the Ministry of Health, Labour, and Welfare in February 2011[9] revealed that the executing rate of oral function improvement services was 1.4%—a remarkably low level—compared with 90.4% for locomotive function improvement programs. The underlying cause of this discrepancy is that the elderly do not sufficiently understand the need for oral function improvement, unlike the case with motor function improvement, and that service providers have not fully grasped the effects of potential improvements[9]. Posture adjustment is considered important in the rehabilitation of oral function disorders associated with neurological diseases, including stroke[10]. This is because swallowing function is greatly influenced by the alignment between the head and neck and the trunk, as well as by the movement of the head and neck[11-15]. In contrast, in oral

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Received for publication, December 15, 2014
Accepted for publication, January 5, 2015

function improvement programs in preventive care services, most of the patients do not have neurological diseases such as stroke. Therefore, intervention for posture adjustment is rarely considered important. However, aging decreases the strength of the back extensor muscles that are essential for posture maintenance, and spinal deformities such as kyphosis gradually progress[16), 17)]. Consequently, it is likely to be worthwhile to include exercises to improve the posture for not only the head and neck but also the whole body in programs for maintaining and enhancing oral function in the elderly.

Our earlier study in healthy adults confirmed that kyphotic posture influences oral function and respiratory function. This finding suggests that kyphotic posture is likely to be closely related to oral function in the elderly, too. It also suggests that improving the alignment and movement of the head, neck, and trunk can improve oral function.

Our objectives here were to clarify the relationship between kyphotic posture and oral and respiratory functions in the elderly, and to evaluate the effects of interventions aimed at posture improvement on oral function in the frail elderly.

Methods

1. Subjects

A total of 20 subjects were enrolled in the study. There were 11 community-dwelling elderly adults without central nervous system diseases, respiratory diseases, oral-related diseases, or orthopedic disorders [healthy elderly group; mean age, 71.1; standard deviation (SD), 6.6] and 9 frail elderly who were authorized as requiring primary nursing care and were using day-care services (frail elderly group; mean age, 84.3; SD 4.9). Nursing care levels in the frail elderly requiring help were: support level 1, five subjects; support level 2, one subject; long-term care level 1, two subjects; and long-term care level 2, one subject. For the study we obtained an approval from the Ethics Committee of Hirosaki University Graduate School of Medicine (serial number 2011-249). Informed consent was obtained from all subjects before the study started.

2. Study design

The study was implemented in 2 steps: a survey and research (Step 1) to clarify the relationship among posture, respiratory function, and oral function in the elderly, and an intervention study with a crossover design (Step 2) to clarify the effects of swallowing exercises and fall-prevention exercises.

Step 1: Research on posture, respiratory function, and oral function

The posture, respiratory function, and oral function of all the subjects were measured.

1) Posture evaluation

The extents of cervical lordosis and kyphosis were measured and quantitatively evaluated by using the forward head posture index (FHP) [18)] and the kyphosis index[19)], respectively.

To determine the relative position of the thyroid cartilage, we measured the distance from the genion to the upper end of the thyroid cartilage at maximum extension of the head and neck [genio-thyroid distance (GT)] in 5-mm units; we then measured the distance from the upper end of the thyroid cartilage to the upper end of the sternum [thyroid–sternum distance (TS)]. Values calculated by using the formula $GT/(GT+TS)$ were used as an index of the relative position of the larynx[20)].

2) Respiratory function evaluation

Respiratory function was measured in a sitting position by using an electronic spirometer (Chestgraph Jr. HI-101; CHEST M.I., Inc. Tokyo, Japan). We measured the following items: forced vital capacity (FVC), %FVC, forced expiratory volume in 1.0 s (FEV1.0), FEV1.0%, and peak

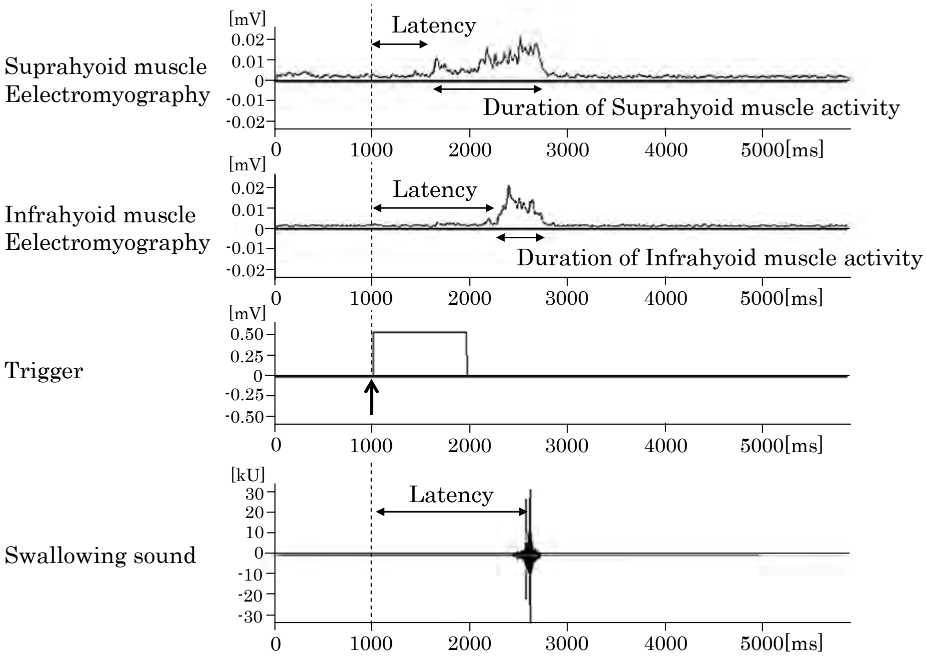

Figure 1 Methods of data processing.

expiratory flow (PEF).

3) Oral function evaluation

Oral function was evaluated by using the repetitive saliva swallowing test[21], which was conducted for 30 s in a stable sitting position. The number of swallows achieved within 30 s and the time needed for 3 continuous swallows were measured.

Coordinated movements of the tongue and lips were measured by instructing the subjects to continuously articulate the syllables “pa/ta/ka” continuously as fast as possible. The number of oral diadochokinesis (OD) movements was measured[22].

A comprehensive quality of life (QOL) assessment related to the patients’ oral function was conducted with the General Oral Health Assessment Index (GOHAI) [23, 24].

4) Evaluation of muscular activity and swallowing sound at the time of swallowing

Swallowing movements were evaluated by using surface electromyography to analyze muscle movements and by recording swallowing sounds (Figure 1).

Muscle activity at the time of swallowing was measured with an EMG Master (Ozawa Medical Instruments Co., Ltd.). A surface EMG was derived at a 1-kHz sampling frequency from the suprahyoid muscles and infrahyoid muscles[25]. Subjects were instructed to quickly swallow saliva once when the tester gave a signal that read “Now” to initiate swallowing (trigger point). The recorded EMG was processed with band-pass filtering (60–350 Hz) and full-wave rectification, followed by low-pass filtering. The EMG data obtained were used to calculate the time from the trigger time point to the muscle movement starting point (i.e. the latency). The starting point of muscle activity was defined as the time point when the value was greater than the sum of the average amplitude of the baseline activity 1 s before the trigger point and the doubled SD value. The static point of muscle activity was defined as the time point at which the value returned to the same level as the sum of the average amplitude of baseline activity and the doubled SD value[26].

The swallowing sound was collected from the

Table 1 Swallowing exercises

No.	Exercise menu
1	Deep breathing with pursed lips
2	Rotation of cervical spine
3	Elevation and depression of shoulder girdle
4	Lateral bending of thoracic and lumbar spine with the hands crossed on the head
5	Puffing out and sucking in cheeks
6	Poking out and pulling in tongue
7	Touching right and left corners of mouth with the tongue
8	Taking a deep breath
9	Oral diadochokinesis ("pa/ta/ka")
10	Deep breathing with pursed lips
11	Salivary gland massage

area surrounding the trachea directly below the cricoid cartilage by using an electret condenser throat microphone (SH-12ik: Nanzu Electric Co. Ltd.) simultaneously with EMG; the sound was recorded at a sampling frequency of 44.1 kHz[27]. Waveform data from the swallowing sound were used to measure the time needed for the swallowing sound to reach its peak from the trigger point as the latency.

The EMG and swallowing sound were measured 3 times, with intermissions, and the dataset in which the swallowing time was fastest from the trigger point was used for the analysis.

Step 2: Assessment of the effects of intervention with swallowing exercises or fall- prevention exercises

1) Intervention methods

Interventions in the form of swallowing exercises or fall-prevention exercises were given to the frail elderly once a week for 16 weeks, and the effects were assessed. The frail elderly were assigned to Group A or Group B. Interventions in each group were implemented in accordance with a crossover comparative study. Group A received fall-prevention exercises for 8 weeks, followed by swallowing exercises for 8 weeks. Group B received swallowing exercises for 8 weeks, followed by fall-prevention exercises for 8 weeks. There was a 4-week interval between the swallowing exercise and fall-prevention exercise courses.

2) Outcome indices for assessing effects

Posture, respiratory function, oral function, and QOL, before and after swallowing exercises and fall-prevention exercise, were used as outcome indices for assessing the intervention effects.

3) Exercises used in the interventions

Salivary gland massage was added to swallowing exercises designed by the Japanese Society of Dysphagia Rehabilitation[28] (Table 1). For the fall-prevention exercises we used the "Tentoumushi Exercises" compiled by Hirosaki University and aimed at improving the flexibility and balance of the trunk muscles and lower limb muscles[29]. There were 18 fall-prevention exercises; we used numbers 1 to 14 and 18 but not 15 to 17 because of the low levels of endurance of the subjects (Table 2).

Two subjects were withdrawn in the middle of the study—1 during the fall-prevention exercise part of the study and 1 during the swallowing exercise part of the study: 1 subject in Group A developed pneumonia and 1 subject in Group B fell at home and suffered an injury.

4. Statistical analyses

Spearman's rank correlation coefficient was used to analyze the relationship among endpoints. The Mann-Whitney U test was used for comparisons between the healthy elderly and frail elderly. The Wilcoxon signed-rank test

Table 2 Outline of the Hirosaki University Tentoumushi exercises (fall-prevention exercises)[29]

Position	No.	Exercise menu	Training aim
Sitting	1	Repeated dorsiflexion of left/right ankle	Strengthening of ankle dorsiflexion
	2	Extension of knee joint and abduction of hip joint	Strengthening of hip abductors. Improvement of sitting balance
	3	Coordination exercise of the upper and lower extremities	Improvement of coordination of upper and lower extremities. Improvement of sitting balance
	4	Writing the Japanese letter te/mu/shi with the foot in the air	Strengthening of knee extensors and hip muscles. Improvement of sitting balance
Standing	5	Trunk rotation	Improvement of trunk flexibility. Improvement of standing balance
	6	Rising up on to the toes in a stepping position	Strengthening of calf muscles. Improvement of standing balance
	7	Touching knee with contralateral hand	Strengthening of abdominal muscles. Improvement standing balance
	8	Stretching the hamstrings and calf muscles	Improvement of flexibility of hamstrings and calf muscles. Improvement of standing balance
	9	Writing the Japanese letter te/mu/shi with the foot in the air beneath the chair (holding on to the chair)	Strengthening of hip muscles. Improvement of standing balance
	10	Hip extension	Strengthening of hip extensors
	11	Quarter-squatting	Strengthening of antigravity muscles of lower extremities
	12	Writing the Japanese letter te/mu/shi with the foot in the air behind the body (holding on to the chair)	Strengthening of hip extensors. Improvement of standing balance
	13	Shifting of lateral weight in shoulder-width stance	Strengthening of hip abductors. Improvement of standing balance
	14	Contralateral extension of upper and lower extremities with trunk extension	Strengthening of trunk and hip extensors. Improvement of standing balance
	15	Stepping	Strengthening of hip flexors, Improvement of standing balance
	16	Toe walking	Strengthening of calf muscles. Improvement of standing balance
	17	Tai chi–type walking	Strengthening of antigravity muscles of lower extremity
	18	Deep breathing	Improved control of breathing

was used for comparisons between before and after the fall-prevention exercises or swallowing exercises. The significance levels in the tests were set as $P < 0.05$.

Results

1. Step 1: Relationships among posture, respiratory function, and oral function in the elderly

Significant differences between the healthy elderly and frail elderly were noted in the index of kyphosis, the position of the thyroid cartilage, and %FVC. A trend toward difference was found in the latency of the suprahyoid muscles. The kyphotic posture was more marked, the position of the thyroid cartilage lower, and the %FVC value lower in the frail elderly than in the healthy elderly (Table 3). Initiation of activity of the suprahyoid muscles at swallowing in the frail elderly tended to be delayed compared with that in the healthy elderly.

Assessment of posture (index of kyphosis, FHP, position of the thyroid cartilage), respiratory function, and oral function in the healthy elderly

Table 3 Comparison of scores in health elderly and frail elderly

	Median (quartile deviation)		P-value[a]	
	Healthy elderly	Frail elderly		
Kyphosis index	8.8 (1.4)	12.3 (1.1)	0.016	*
FHP	48.7 (4.0)	44.7 (6.5)	0.710	
Thyroid cartilage position	0.36 (0.02)	0.42 (0.03)	0.007	**
%FVC	100.0 (5.9)	84.7 (8.5)	0.000	**
FEV1.0%	85.1 (4.7)	89.7 (2.9)	0.230	
PEF (L/s)	5.6 (1.4)	3.6 (0.6)	0.112	
OD	10.7 (1.1)	10.7 (0.5)	0.882	
GOHAI	55.0 (2.8)	53.0 (3.5)	0.656	
No. of swallows in 30 s	3.0 (0.0)	3.0 (0.5)	0.503	
Time taken to swallow 3 times in succession (ms)	10203.0 (2986.5)	9666.5 (2309.0)	0.388	
Latency of suprahyoid muscle activity (ms)	459.0 (219.5)	801.0 (215.0)	0.067	
Duration of suprahyoid muscle activity (ms)	1518.0 (558.5)	1791.0 (509.5)	0.175	
Latency of infrahyoid muscle activity (ms)	711.0 (241.3)	873.0 (209.5)	0.113	
Duration of infrahyoid muscle activity (ms)	1465.0 (710.6)	1727.0 (307.0)	0.720	
Latency of swallowing sound (ms)	1616.0 (195.0)	1529.0 (433.0)	0.710	

FHP, forward head posture; %FVC, % forced vital capacity; FEV1.0%, forced expiratory volume in 1.0 s as percent of FVC; PEF, peak expiratory flow; OD, oral diadochokinesis; GOHAI, General Oral Health Assessment Index
[a] P-value by Mann-Whitney U test
* significant at $P < 0.05$; **significant at $P < 0.01$

revealed no significant correlations between posture and respiratory function. However, a significant correlation was noted between the position of the thyroid cartilage and the number of swallows in 30 s or the time taken for 3 swallows (Table 4).

In contrast, significant correlations were noted between FHP and FEV1.0% and between the position of the thyroid cartilage and FEV1.0% in the frail elderly. In addition, there was a significant correlation between the index of kyphosis and OD and between the index of kyphosis and the duration of infrahyoid muscle activity in the frail elderly (Table 4).

There was therefore a relationship between posture and oral function in both the healthy elderly and the frail elderly.

2. Step 2: Effects of swallowing exercises and fall-prevention exercises in the frail elderly

Swallowing exercises and fall-prevention exercises were implemented in the frail elderly, and the evaluations before and after the exercises were compared. In the assessment of the fall-prevention exercises there were significant improvements between before and after in terms of the index of kyphosis, the latency of suprahyoid muscle activity, and the latency of infrahyoid muscle activity (Table 5). There was a trend toward an improvement in GOHAI. In contrast, in the assessment of the swallowing exercises there was a significant improvement between before and after only in terms of the index of kyphosis (Table 5).

Discussion

1. Relationships among posture, respiratory function, and oral function in the healthy elderly and frail elderly

We demonstrated here that, consistent with the results of studies in healthy adults[30], postural status is related to respiratory function and oral function in the frail elderly. Spinal kyphosis and thus kyphotic posture in the elderly may develop in association with decreased back extensor muscle strength due to aging and disuse[16]. Spinal kyphosis degree

Table 4 Spearman's rank correlation coefficients between scores

	Healthy elderly			Frail elderly		
	Kyphosis index	FHP	Thyroid cartilage position	Kyphosis index	FHP	Thyroid cartilage position
%FVC	−0.191	0.445	0.256	−0.267	0.017	−0.628
FEV1.0%	0.245	−0.291	−0.288	0.450	0.717*	0.678*
PEF (L/s)	0.000	0.291	0.005	−0.067	0.317	0.025
OD	−0.242	0.087	−0.124	−0.832**	−0.580	−0.443
GOHAI	0.060	−0.110	−0.032	0.083	0.033	0.293
No. of swallows in 30 s	0.224	0.373	0.674*	−0.129	0.468	0.080
Time taken to swallow 3 times in succession (ms)	0.183	−0.167	0.678*	−0.486	0.029	−0.058
Latency of suprahyoid muscle activity (ms)	0.082	0.145	−0.100	0.100	0.167	0.109
Duration of suprahyoid muscle activity (ms)	0.182	−0.255	0.160	0.533	0.417	0.410
Latency of infrahyoid muscle activity (ms)	−0.127	0.503	−0.140	−0.033	0.117	−0.293
Duration of infrahyoid muscle activity (ms)	0.418	−0.212	0.334	0.783*	0.150	0.418
Latency of swallowing sound (ms)	0.545	−0.182	0.562	0.267	0.450	0.201

*significant at $P<0.05$; **significant at $P<0.01$

Table 5 Pre-test and Post-test scores in fall-prevention exercises and swallowing exercises

	Fall-prevention exercises			Swallowing exercises		
	Median (quartile deviation)			Median (quartile deviation)		
	Pre-test	Post-test	P-value[a]	Pre-test	Post-test	P-value[a]
Kyphosis index	12.4 (0.6)	11.4 (0.7)	0.043*	11.8 (0.4)	10.6 (1.6)	0.025*
FHP	51.7 (3.6)	52.5 (4.3)	0.735	44.5 (6.7)	50.6 (5.4)	0.123
Thyroid cartilage position	0.40 (0.03)	0.45 (0.03)	0.499	0.45 (0.02)	0.40 (0.03)	0.362
%FVC	79.0 (9.7)	85.4 (6.2)	0.327	84.7 (4.9)	85.7 (8.3)	0.401
FEV1.0%	89.7 (1.9)	88.0 (4.9)	0.674	87.2 (7.3)	88.7 (6.4)	0.674
PEF (L/s)	3.6 (0.2)	3.8 (0.5)	0.575	3.6 (0.6)	3.5 (0.4)	0.327
OD	10.7 (0.3)	11.0 (1.0)	0.596	11.0 (1.0)	10.3 (0.6)	0.892
GOHAI	52.0 (3.5)	58.5 (2.3)	0.058	58.0 (3.0)	51.0 (5.8)	0.753
No. of swallows in 30 s	3.0 (0.1)	3.0 (0.0)	0.157	3.0 (0.3)	3.0 (0.0)	0.317
Time taken to swallow 3 times in succession (ms)	8715.0 (1557.8)	4575.0 (3375.5)	0.612	10486.0 (2451.8)	7293.5 (2795.3)	0.917
Latency of suprahyoid muscle activity (ms)	618.5 (213.9)	329.0 (16.3)	0.028*	510.0 (254.5)	606.0 (162.8)	0.237
Duration of suprahyoid muscle activity (ms)	2235.0 (367.4)	2258.0 (566.0)	1.000	2024.5 (441.1)	2405.0 (392.5)	0.866
Latency of infrahyoid muscle activity (ms)	773.0 (276.0)	354.0 (60.5)	0.018*	541.0 (245.9)	650.0 (174.8)	0.237
Duration of infrahyoid muscle activity (ms)	1994.0 (461.3)	2049.0 (334.0)	0.612	1913.0 (323.1)	2270.0 (526.3)	0.735
Latency of swallowing sound (ms)	1512.5 (542.5)	1580.0 (703.3)	0.735	2034.5 (418.1)	1493.0 (587.0)	0.237

FHP, forward head posture; %FVC, % forced vital capacity; FEV1.0%, forced expiratory volume in 1.0 s as percent of FVC; PEF, peak expiratory flow; OD, oral diadochokinesis; GOHAI, General Oral Health Assessment Index
[a]P-value obtained with Wilcoxon signed-rank test. *significant at $P<0.05$

of the frail elderly was greater than that of the healthy elderly in this study. It may be thought that aging has influenced this, because the frail elderly was older than healthy elderly. Kyphotic postures restrict thoracic motion and promote a decrease in the strength of the abdominal and respiratory muscles. Consequently, restrictive ventilatory impairment occurs and respiratory function is decreased[31]. Thoracolumbar kyphotic deformity secondarily promotes a forward head position, leading to compensatory cervical lordosis, which is considered to lower the hyoid bone and thyroid cartilage[32] and may increase the distance the larynx must move to lift up during swallowing.

As a consequence of these mechanisms,

swallowing movements in the elderly with kyphotic posture deteriorate. This is manifested in the form of prolonged duration of activity of the swallowing-related muscles[33] and swallowing movements. We found a trend toward prolonged latency of the suprahyoid muscles, which are involved in swallowing, in the frail elderly. This trend is likely a risk factor for delayed swallowing time, leading to aspiration.

In conclusion, intervention with a view to improving kyphotic posture in the elderly is critical for improving oral function.

2. Verification of the effects of swallowing exercises and fall-prevention exercises in the frail elderly

The results of the interventions demonstrated the effects of swallowing exercises in improving kyphotic posture. However, there was no change in the measures of swallowing function. In contrast, fall-prevention exercises resulted in significant improvements in the index of kyphosis, latency of the suprahyoid muscles, and latency of the infrahyoid muscles. We surmise that the factors contributing to these effects and the significance of the results are as follows.

The fall-prevention exercises comprised movements aimed at improving muscle strength in the trunk and lower limbs, and postural balance. In contrast, the swallowing exercises comprised movements of the perioral region, the upper limbs, trunk, head and neck. Exercises of the trunk and lower limbs, and balance improvement exercises, were not included in the swallowing exercise menu. Consequently, the frail elderly were able to strengthen the muscles of the trunk and lower limbs and the back extensor muscles through the fall-prevention exercises, and eventually their kyphotic postures improved. In addition, enhancement of balance maintenance and improvement in kyphotic posture likely helped efficiently to change the contraction pattern of the posture-related muscles spatiotemporally.

Many of the muscles involved in swallowing have their origins and insertions in the lower jaw, thyroid cartilage, hyoid bone, sternum, and scapula. Therefore, the activity of trunk muscles, which influence the stability of these muscles at the muscle attachment sites, affects the actions of these swallowing-related muscles[34]. Subsequently, improvement in muscle-contraction efficiency related to postural maintenance likely helped to improve the efficiency of muscle contraction related to swallowing. As mentioned above, improvements in posture and balance through the implementation of fall-prevention exercise can facilitate the activity of swallowing-related muscles and shorten the latency of the suprahyoid and infrahyoid muscles. Therefore, improvement in the swallowing problem of poor timing—which is one of the causes of aspiration—can be expected. Moreover, after the fall-prevention exercises the frail elderly showed improvements in GOHAI. Therefore, these exercises should help not only to prevent aspiration pneumonia but also to enhance oral-related QOL. Effects of physical exercise have been reported to carry on for three month after the completion of exercise[35]. As the interval between the swallowing exercise and fall-prevention exercise courses was a 4-week in this study, it was thought that there were carry-over effects. This is a limitation of the study and it is difficult to state which exercise is more effective.

Conclusions

In this study, an exercise program aimed at improving posture and postural balance was an effective preventive intervention for maintaining and enhancing swallowing function. We found here that improving posture and balance with the aim of improving oral function is important, in addition to a conventional swallowing exercise. In programs to enhance oral function in the frail elderly it is important to incorporate a preventive care program focusing on the improvement of kyphotic posture and postural balance in addition to a program targeting swallowing improvement. Presently, oral function improvement programs for preventive care are provided mainly by dental hygienists. However, coordination with specialists such as physical therapists and occupational therapists, who have a thorough knowledge of posture and postural balance improvement, is desirable if we are to obtain greater benefits.

Acknowledgment

The authors thank the participants for their contribution to this study.

References

1) Ohrui T. Current status of elderly pneumonia and its novel preventive strategies. Japanese Journal of Geriatrics 2014;51:222-4. (in Japanese)

2) Gleeson DC. Oropharyngeal swallowing and aging: a review. J Commun Disord. 1999;32:373-95.

3) Teramoto S, Fukuchi Y, Sasaki H, Sato K, Sekizawa K, Matsuse T. High incidence of aspiration pneumonia in community- and hospital-acquired pneumonia in hospitalized patients: a multicenter, prospective study in Japan. J Am Geriatr. 2008;56: 577-9.

4) Takahashi M, Hashimoto Y. Effect of oral functional exercise in day-care center users (1) – Baseline study on oral function and QOL. The Kitakanto Medical Journal. 2009;59:241-6. (in Japanese)

5) Ono K, Kohzuki M, Shiga K, Nagasaka M, Katori Y, Ebihara S, Ito O, et al. The effect of postoperative swallowing rehabilitation on swallowing function and QOL in patients with head and neck cancer. Head and Neck Cancer 2010;36:111-8. (in Japanese)

6) Sekiguchi H, Obuchi S, Kojima N, Arai T, Hirano H, Kojima M. Effect of an oral function improvement program based on remote intervention. Japanese Journal of Geriatrics. 2010; 47:226-34. (in Japanese)

7) Ohuchi A. Amendment of long-term care system and improvement support of oral function. Niigata Dental Journal 2006;36:67-9. (in Japanese)

8) Health, Labour, and Welfare Ministry of Japan. Manual of Oral Function improvement. http://www.mhlw.go.jp/topics/2009/05/dl/tp0501-1f.pdf (Accessed Nov. 26, 2014).

9) Health, Labour, and Welfare Ministry of Japan. Fact Sheet on a Survey of the Status of Grants for Nursing-care Expenses in 2011. http://www.mhlw.go.jp/toukei/saikin/hw/kaigo/kyufu/11/ (Accessed Nov. 26, 2014).

10) Logemann JA: Treatment of oral and pharyngeal dysphagia. Phys Med Rehabil Clin N Am. 2008; 19:803-16.

11) Ohmae Y, Ogura M, Kitahara S, Karaho T, Inouye T. Effects of head rotation on pharyngeal function during normal swallow. Ann Otol Rhinol Laryngol 1998;107:344-8.

12) Stambolis V, Brady S, Klos D, Wesling M, Fatianov T, Hildner C. The effects of cervical bracing upon swallowing in young, normal, healthy volunteers. Dysphagia 2003;18:39-45.

13) Ohmae Y. Rehabilitation for dysphagia: postural strategies to prevent aspiration. J Jpn Bronchoesophagol Soc 2011;62:485-93.(in Japanese)

14) Ota K, Saitoh E, Kagaya H, Sonoda S, Shibata S. Effect of postural combinations. The reclined seated position combined with head rotation – on the transport of boluses and aspiration. Japanese Journal of Comprehensive Rehabilitation Science 2011;2:36-41. (in Japanese)

15) Inui R, Mori S, Nakajima T, Lee H, Nishimori T, Tabira K. Influence of neck position on the activity of pharyngeal and neck muscles during swallowing –examination by surface electromyography. The Japanese Journal of Dysphagia Rehabilitation 2012;16:269-75. (in Japanese)

16) Sinaki M, Itoi E, Rogers JW, Bergstralh EJ, Wahner HW. Correlation of back extensor strength with

thoracic kyphosis and lumbar lordosis in estrogen-deficient women. Am J Phys Med Rehabil. 1996;75:370-4.

17) Miyakoshi N. Pathogenesis and clinical features of spinal kyphosis in the elderly. Orthopedics & Traumatology 2011;54:119-26. (in Japanese)

18) Quek J, Pua YH, Clark RA, Bryant AL. Effects of thoracic kyphosis and forward head posture on cervical range of motion in older adults. Man Ther 2013;18:65-71.

19) Milne JS, Lauder IJ. Age effects in kyphosis and lordosis in adults. Annals of Human Biology 1974;1:327-37.

20) Yoshida T, Uchiyama Y, Kumagai M. The reliability and clinical application of the new indexes for thyroid cartilage position and muscle strength of the suprahyoid muscle group. The Japanese Journal of Dysphagia Rehabilitation 2003;7:143–50. (in Japanese)

21) Oguchi K, Saitoh E, Mizuno M, Baba M, Okui M, Suzuki M. The repetitive saliva swallowing test (RSST) as a screening test of functional dysphagia (1) normal values of RSST. The Japanese Journal of Rehabilitation Medicine 2000;37:375-82. (in Japanese)

22) Kent RD, Kent JF, Rosenbek JC. Maximum performance tests of speech production. J Speech Hear Disord 1987;52:367-87.

23) Naito M, Suzukamo Y, Nakayama T, Fukuhara S. Preliminary study on the development of an oral health-related QOL Scale: Production of a Japanese version of the General Oral Health Assessment Index (GOHAI). Journal of Dental Health 2004;54:110-4.

24) Naito M, Suzukamo Y, Nakayama T, Hamajima N, Fukuhara S. Linguistic adaptation and validation of the General Oral Health Assessment Index (GOHAI) in an elderly Japanese population. J Public Health Dent 2006;66:273-5.

25) Ono T, Iwata H, Hori K, Tamine K, Kondoh J, Hamanaka S, Maeda Y. Evaluation of tongue-, jaw-, and swallowing-related muscle coordination during voluntarily triggered swallowing. Int J Prosthodont 2009;22:493-8.

26) Crary MA, Baldwin BO. Surface electromyographic characteristics of swallowing in dysphagia secondary to brainstem stroke. Dysphagia 1997;12:180-7.

27) Tanaka N, Nohara K, Okuno K, Kotani Y, Okazaki H, Matsumura M, Sakai T. Development of a swallowing frequency meter using a laryngeal microphone. J Oral Rehabil 2012;39:411-20.

28) Exploratory Committee on Medical Care, the Japanese Society of Dysphasia Rehabilitation. Training procedures: improved edition in 2010. The Japanese Journal of Dysphagia Rehabilitation 2010;14:644-63. (in Japanese)

29) Narita H, Fujita T, Tsushima H. Effects of functional improvement program of the musculoskeletal system for potentially dependent elderly – Hirosaki University "TENTOUMUSHI Exercise." Bulletin of Health Sciences Hirosaki 2009;8:39-45. (in Japanese)

30) Fujiwara K, Sato A, Tsushima H. Relationship among oral function, posture, and respiratory function in healthy adults. Medicine and Biology 2013;157:732-41.

31) Ito Y, Yamada T, Takeda M. Investigation of respiratory function and breathing pattern in elderly people with kyphotic posture. Rigakuryoho Kagaku 2007;22:353-8. (in Japanese)

32) Tallgren A, Solow B. Hyoid bone position, facial morphology and head posture in adults. Eur J Orthod 1987;9:1-8.

33) Iwasaki M, Tomita K, Takeshima R, Iizuka M. Relationship between age related changes in the duration of the electromyographic activity of the suprahyoid muscles during swallowing and swallowing function. The Japanese Journal of Dysphagia Rehabilitation 2014;18:123-30. (in Japanese)

34) Yoshida T. Relationships of swallowing disorder to sitting posture in stroke patients. Journal of the Japanese Physical Therapy Association 2006;33:226-30. (in Japanese)

35) Ihara H, Miwa M, Ishibashi T, Takayanagi K, Kawashima M. Maintenance of Effects after Stopping Toe Exercises. Orthopedics & Traumatology. 1997;46:393-7. (in Japanese)