



# Therapeutic Singing as a Swallowing Intervention in Head and Neck Cancer Patients With Dysphagia

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## Abstract

**Background:** Head and neck cancer patients often suffer from dysphagia after surgery and radiotherapy. A singing-enhanced swallowing protocol was established to improve their swallowing function. This study aimed to evaluate the beneficial effects of therapeutic singing on dysphagia in head and neck cancer (HNC) patients. **Methods:** Patients who participated in this study were allocated to the intervention group (15 patients) and the control group (13 patients). Patients assigned to the intervention group received therapeutic singing 3 times per week for 4 weeks. Each group was divided into 2 subgroups, including the oral cavity cancer group and the pharyngeal cancer group. The patients' vocal functions were evaluated in maximum phonation time, pitch, intensity, jitter, shimmer, harmonics to noise ratio, and laryngeal diadochokinesis (L-DDK). To evaluate swallowing function, videofluoroscopic swallowing study was done, and the results were analyzed by videofluoroscopic dysphagia scale (VDS) and dynamic imaging grade of swallowing toxicity (DIGEST). **Results:** Among the voice parameters, L-DDK of the intervention group significantly increased compared to that of the control group. Swallowing functions of the intervention group were significantly improved in VDS and DIGEST after the intervention. Detailed items of VDS and DIGEST showed improvements especially in the pharyngeal phase score of VDS, such as laryngeal elevation, pharyngeal transit time, and aspiration. In addition, the pharyngeal cancer group showed significant improvements in VDS and DIGEST scores after the intervention. **Conclusions:** Our outcomes highlight the beneficial effects of singing for HNC patients with dysphagia. The notable improvements in the pharyngeal phase suggest that therapeutic singing would be more appropriate for HNC patients who need to improve their intrinsic muscle movements of vocal fold and laryngeal elevation.

## Keywords

head and neck cancer, deglutition disorders, laryngeal elevation, aspiration, singing

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## Introduction

Head and neck cancer (HNC) is classified as an epithelial malignancy that grows in the upper aerodigestive tract, including the oral cavity, pharynx, and larynx.<sup>1</sup> Reportedly, there are more than 1,500,000 HNC patients worldwide, and approximately 900,000 deaths occur each year.<sup>2</sup> Although the causes of HNC remain unclear,<sup>3</sup> long-term survival has increased due to advances in medical technology, early detection, and treatment.<sup>4</sup>

Treatments including surgery, radiation therapy, and chemotherapy may often be performed depending on the characteristics of the tumor. As a consequence of treatments, swallowing difficulties have appeared as common symptoms in HNC patients and caused changes in swallowing mechanisms.<sup>5</sup> In surgical cases of HNC patients, the

surgery often involves removing the healthy tissue and the musculoskeletal region surrounding the tumor and the tumor margin to secure a free margin.<sup>6,7</sup> Oral and neck dissection may be performed simultaneously to remove the carcinoma in the head and neck region, which is characterized by a rapid lymph node metastasis.<sup>8</sup> When these operations are carried out, there is a high risk that the patients' anatomical structures classified as upper respiratory and digestive systems, such as oral, pharynx, and larynx, are inevitably defective and deformed.<sup>9,10</sup> Radiotherapy is associated with pain, nausea, vomiting, mucositis, dry mouth, and muscle fibrosis, making it difficult to adapt to and recover from the disease and the treatment process.<sup>11</sup> In addition, psychological problems, including changes in body image and self-perception, depression, and anxiety, may occur due to the treatments for HNC.<sup>12</sup>



Given the extensive impact of dysphagia on the morbidity of HNC patients, therapies to prevent, reduce, and alleviate swallowing difficulties are urgently needed. Most of them are related to respiratory-swallowing training based on a hierarchy of motor skill acquisition to encourage autonomous and optimal respiratory-swallowing coordination.<sup>13</sup> Although meta-analysis has presented the evidence that swallowing exercises are effective in the management of complications from the HNC treatment,<sup>14</sup> there are still many reports that HNC patients suffer from swallowing difficulties.<sup>15,16</sup>

To delay and reverse some of the devastating effects of cancer treatments, it is essential to ensure continued use of swallowing musculature by adherence to targeted vocal, respiration, and swallowing exercises for HNC patients.<sup>13,17</sup> Based on the coordinative relation between respiration, vocalization, and oropharyngeal swallowing, singing can be an efficient therapeutic approach after cancer treatments. Both speech and singing rely on the tension on vocal cords resulting in modulations of the fundamental vocal frequency.<sup>18</sup> Singing a set of tones induces larynx elevations that contract several muscles, including an upper esophageal sphincter, to protect the airway against aspiration.<sup>19-21</sup> Within this context, singing can play a role in functional movement of swallowing, respiration, and vocalization.

Recently, singing has been introduced as a viable treatment in swallowing rehabilitation.<sup>22-24</sup> Singing can improve oral motor functions related to articulation and breathing control. In other words, singing enhances the mobility and breathing functions of the facial and oral cavity muscles by inducing the coordination of vocalization organs and patterned breathing in the singing process.<sup>25,26</sup> In addition, musical elements, such as rhythm, can support timed and controlled muscle movements with oral motor control, laryngeal elevation, and breathing during singing. Moreover, singing also offers additional benefits, including emotional arousal, reduced stress, and ease of self-administration for cancer survivors.<sup>27</sup>

In this context, singing may be considered a beneficial intervention to improve the swallowing function of HNC patients, who need multi-faceted exercises to stimulate

impaired anatomical structures accompanied by dysphagia.<sup>28</sup> Therefore, this study aimed to evaluate the effectiveness of therapeutic singing in HNC patients with dysphagia after surgery, radiation therapy, and chemotherapy.

## Materials and Methods

### Participants

Patients who met the following inclusion criteria were recruited. The inclusion criteria of this study were patients who (1) were diagnosed with HNC, including tongue cancer, oral cavity cancer, nasopharyngeal cancer, oropharyngeal cancer, or mandibular gland cancer; (2) underwent surgical procedures, such as tracheostomy, glossectomy, mandibulectomy, partial laryngectomy, and/or reconstruction of the palate and pharynx; and (3) underwent several sessions of radiotherapy for their tumors. The exclusion criteria were as follows: (1) under 7 years of age; (2) hearing-impaired and unable to hear music stimuli; and (3) unable to speak due to poor vocalization.

This study was approved by the Institutional Review Board of Yonsei University Health System (Approval No. 4-2012-0483). Twenty-eight patients were asked to participate in this study and written informed consent was obtained from 21 patients before the initiation of intervention (Figure 1). The characteristics of patients are presented in Table 2, including gender, age, onset duration, and tumor types. There were no differences in the characteristics of groups. Most of the subjects were outpatients, except for 1 patient. All patients had the capacity for oral intake and showed no other significant cognitive or communication impairment. Premorbid musical ability was not required for participation in the study. All participants received conventional therapy for dysphagia such as oromotor exercise, sensory stimulation, and compensatory maneuver, while participants in the intervention group additionally underwent therapeutic singing.

Participants were randomly allocated to either intervention or control groups by an independent research coordinator who generated random numbers using simple randomization. When

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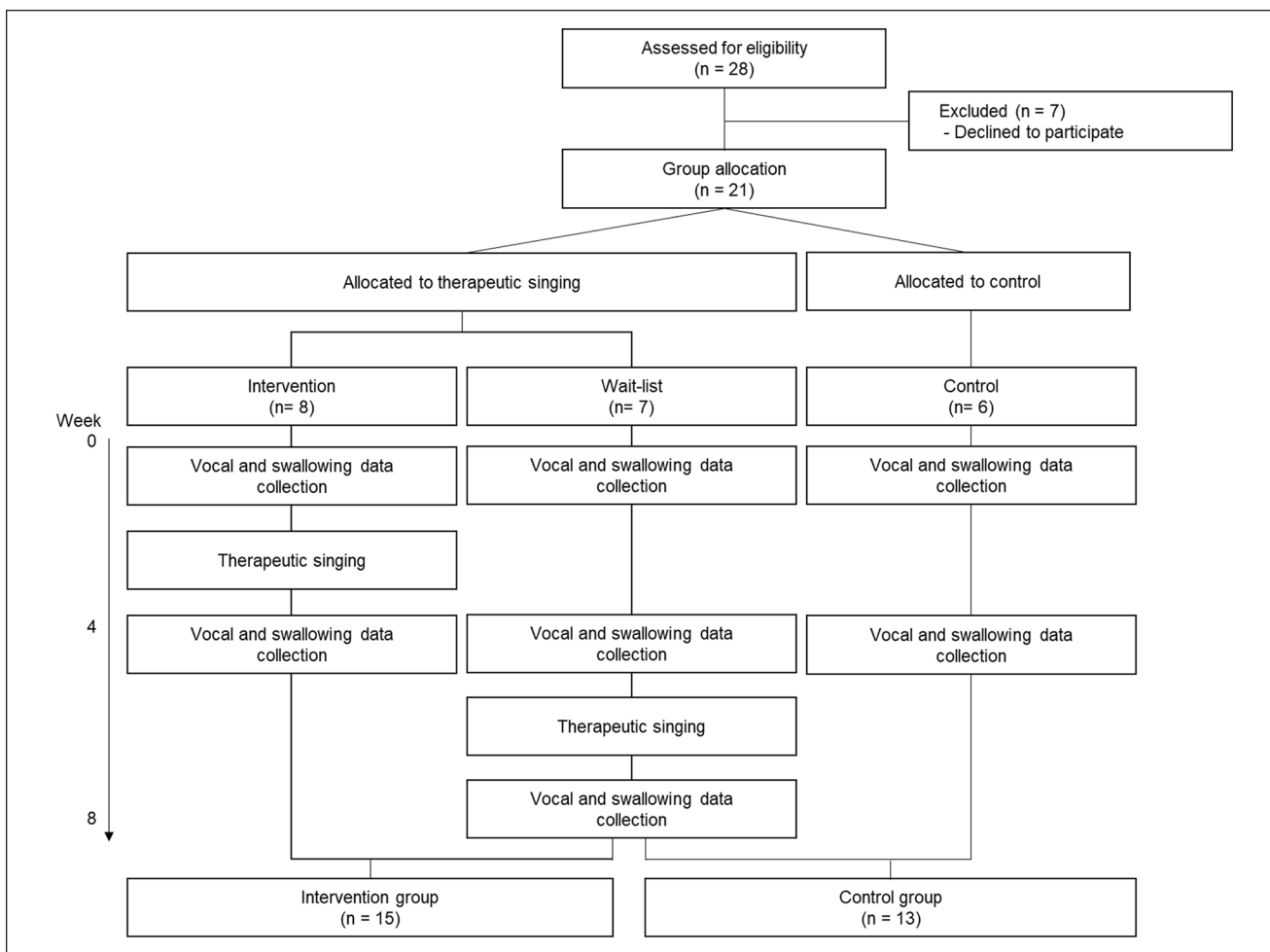
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**Figure 1.** A Diagram Showing the Flow of Participants Through the Study.

each participant was recruited, the independent coordinator informed therapists of the group allocation via random numbers in digital documents. Among participants allocated to the intervention group, a wait-list control design was applied to 7 participants. After the wait-list period, they participated in the intervention with pre- and post-assessments of vocal and swallowing functions. Finally, outcomes from 15 patients in the intervention group and 13 patients in the control group were analyzed in this study (Figure 1). In addition, outcomes were analyzed into 2 subgroups based on the HNC patients' cancer characteristics; oral cavity cancer and pharyngeal cancer.<sup>29</sup> Patients with tongue cancer, oral cavity cancer, and mandibular gland cancer were classified as the oral cavity cancer group. Patients with nasopharyngeal cancer and oropharyngeal cancer were classified as the pharyngeal cancer group.





### Intervention

Each patient received 3 individual sessions per week for 4 weeks (total of 12 sessions). A singing-enhanced swallowing protocol consisted of physical preparation, vocalization

for warm-up, singing exercises for laryngeal elevation, and modified singing of approximately 20 minutes in duration. The interventions using therapeutic singing were designed to develop control and strength in the muscles and mechanisms used for singing. When the patients sang, therapeutic techniques such as feedback, encouragement, prompting, and modeling were also employed to assist the patients in achieving maximum intelligibility, naturalness in speech, and optimizing patient compliance. The study protocol consisted of 4 steps (Table 1).

The first step involved breathing for relaxation of respiratory and oral muscles as physical preparation. During this activity, the music therapist provided instruction to the patient during inhalation and exhalation to gain awareness of diaphragm movements. The patient breathed in and out as cued by live musical accompaniment. The duration and tempo of the music-cued breathing exercises were determined by observing the regular breathing pattern at the beginning of the session. After the breathing exercise, the patients underwent muscle relaxation by stretching their arms, neck, and shoulders. This was achieved through upper

**Table 1.** The Process of Singing-Enhanced Swallowing Protocol.

Steps	Procedures (minute)	Descriptions	
1	Physical preparation (2)	Breathing for relaxation of respiratory and oral muscles and stretching arms, neck, and shoulders to relax the muscles	
2	Vocal warm-up (3)	Humming and pitch glides as preparation for the next step	
3	Singing exercise for laryngeal elevation (10)	Singing two-interval notes from lower to higher pitches in a sequence with /u/ sound (lower pitch) and /i/ sound (higher pitch)	
4	Modified singing (5)	Singing a modified song (by a music therapist) and taking the intervention as a home-task	

body movements: turning the neck right and left, lifting and lowering the shoulders, and stretching by fully extending the arms forward.<sup>30</sup>

The second step was respiratory muscle training, including humming and pitch glides as preparation for step 3. Patients were asked to breathe in and out while following the therapist's accompaniment by a keyboard. They inhaled with an ascending melody and exhaled with a descending melody line. The accompaniment provided cues for the duration of breathing and facilitated flow and competency in breathing. Then, the patients were asked to sing a glissando from their comfortable highest pitch to lowest pitch on the single vowel sound, including /a/, /i/, /o/, and /u/. This activity was designed to stimulate the patient's laryngeal musculature and to prepare for singing exercise for laryngeal elevation.

In the third step, 2 different notes were used in singing for laryngeal elevation. The notes were selected within the range based on the patient's ability to produce vocal sounds while singing. The use of 2 different pitches was more critical than making accurate pitches. The patient vocalized 2 vowel sounds from lower to higher pitches in a sequence. The therapist asked the patient to produce the /u/ sound with a lower pitch and /i/ sound with a higher pitch. When the patient

made the /i/ sound, suggestions were made to be conscious of the lip movement and maintain the lip and mouth shape. Changes in pitches are associated with the direction of vocal folds. Stretched vocal folds produce a higher pitch, and relaxed vocal folds make a lower pitch. Therefore, this activity was designed to facilitate laryngeal elevation as well as the intrinsic muscle movement of the vocal fold.

In the final step, step 4, the patients sang a song that was modified by a music therapist. The patients were asked to sing a song in a comfortable tempo and pitch range about 2 times. In this step, the patients were introduced to structured, sequential vocal patterns that employ gradual dynamics and expanded ranges with intervals to strengthen vocal capacity. Some conversations and verbal feedback regarding the patients' experiences during therapy were also shared. The patients were able to verbally share their feelings related to their voices or the songs.

### Voice Data Collection

Voice data were collected as secondary outcomes of this study. All voice data were collected and measured by music therapists. Sound data were recorded in a quiet room with ambient noise of less than 50 dB. A 10-cm distance was

**Table 2.** Clinical Characteristics of Participants.

Characteristics	Intervention group			Control group		
	Oral cavity cancer (N=11)	Pharyngeal cancer (N=4)	Total (N=15)	Oral cavity cancer (N=8)	Pharyngeal cancer (N=5)	Total (N=13)
Gender (%)						
Male	6 (54.5)	3 (75.0)	9 (60.0)	6 (75.0)	4 (80.0)	10 (76.9)
Female	5 (45.5)	1 (25.0)	6 (40.0)	2 (25.0)	1 (20.0)	3 (23.1)
Age, year	46.82 ± 3.78	62.00 ± 7.04	50.87 ± 3.68	56.60 ± 5.23	60.80 ± 4.35	59.15 ± 4.22
Onset duration, month	24.82 ± 10.24	29.25 ± 15.21	26.00 ± 8.27	23.40 ± 11.59	29.60 ± 14.19	25.31 ± 12.41
T classification (%)						
1	1 (9.1)	2 (50.0)	3 (20.0)	3 (37.5)	2 (40.0)	5 (38.4)
2	0 (0)	0 (0)	0 (0)	1 (12.5)	2 (40.0)	3 (23.1)
3	1 (9.1)	1 (25.0)	2 (13.4)	1 (12.5)	1 (20.0)	2 (15.4)
4a	8 (72.7)	1 (25.0)	9 (60.0)	3 (37.5)	0 (0)	3 (23.1)
4b	1 (9.1)	0 (0)	1 (6.6)	0 (0)	0 (0)	0 (0)
N classification (%)						
0	5 (45.5)	1 (25.0)	6 (40.0)	6 (75.0)	2 (40.0)	8 (61.5)
1	2 (18.2)	1 (25.0)	3 (20)	1 (12.5)	2 (40.0)	3 (23.1)
2	4 (36.3)	2 (50.0)	6 (40.0)	1 (12.5)	1 (20.0)	2 (15.4)
Tumor stage (%)						
1	1 (9.1)	1 (25.0)	2 (13.4)	3 (37.5)	1 (20.0)	4 (30.7)
2	0 (0)	0 (0)	0 (0)	1 (12.5)	2 (40.0)	3 (23.1)
3	1 (9.1)	1 (25.0)	2 (13.4)	1 (12.5)	2 (40.0)	3 (23.1)
4a	8 (72.7)	2 (50.0)	10 (66.6)	3 (37.5)	0 (0)	3 (23.1)
4b	1 (9.1)	0 (0)	1 (6.6)	0 (0)	0 (0)	0 (0)

Data are presented as n (%), frequencies or mean ± SEM.

maintained between the mouth and condenser microphone (SONY ECM-MS907, SONY Corp., Tokyo, Japan). The program was digitized at a sampling rate of 44.1 Hz and 16-bit quantization. The recording level was fixed at -12 dB. Data were analyzed using Praat, a motor speech software program that is a module of the Computerized Speech Lab model 5105. Maximum phonation time (MPT) and vocal intensity were collected. For MPT measurement, the patients were asked to produce the long vowel /a/ sound. This vocalization was measured 3 times, and the longest MPT was recorded.<sup>31,32</sup> To measure changes in the patient's voice quality, the patient was instructed to speak the vowel /a/ as comfortably as possible. Among the measured intervals, a relatively stable 3-second period of time was analyzed to measure pitch, intensity, jitter, shimmer, and harmonics to noise ratio (HNR). To evaluate the range and the speed of vocal fold movement, each patient was asked to repeat the glottal syllable /a/ as quickly, consistently, and accurately as possible for 5 seconds. The rate of laryngeal diadochokinesis (L-DDK) was measured by calculating the number of syllables spoken.<sup>33-36</sup> Two independent raters with more than 2 years of clinical experience randomly selected a sample of 5 participants from the data and calculated the reliability. The intra-rater reliability of the results was obtained twice by randomly selecting a sample of 5 participants at different times.

### Swallowing Study

Swallowing data were collected as the primary outcomes of this study. Experienced physiatrists performed a video-fluoroscopic swallowing study (VFSS) in a radiography room. The patient and examiner sat across from each other. The patient was positioned appropriately for observation of the anatomical structure and swallowing function. The patient swallowed the bolus, which was mixed with a barium sulfate solution (yogurt powder 4.5 g, Baritop HD power 4.5 g, water 150 mL), while radiographic recordings were acquired fluoroscopically. The tapes of the dynamic radiographic procedures provided useful information for analyzing the patients' anatomical and physiological abnormalities. Two independent raters with more than 2 years of clinical experience evaluated the recordings based on swallowing scales and calculated the reliability. The raters were completely blinded when they were scaling VFSS. The intra-rater reliability was obtained twice from the results of all patients.

### Assessment of Swallowing Function

Videofluoroscopic dysphagia scale (VDS) and dynamic imaging grade of swallowing toxicity (DIGEST) were used to evaluate the swallowing function. VDS is a numerical scale that quantifies the degree of oropharyngeal function

**Table 3.** Vocal Function in Head and Neck Patients With Dysphagia After the Intervention.

Variables	Intervention group		Control group		Time		Group		Time × group	
	Pre	Post	Pre	Post	F	P value	F	P value	F	P value
MPT	12.12 ± 1.91	13.91 ± 2.50	10.17 ± 2.58	10.54 ± 3.04	1.857	.186	0.585	.452	0.799	.381
Pitch	145.60 ± 11.07	148.81 ± 12.56	147.13 ± 16.52	130.57 ± 16.66	0.944	.341	0.202	.657	2.071	.164
Intensity	66.03 ± 2.60	67.87 ± 2.81	69.47 ± 2.13	70.45 ± 1.99	0.930	.345	0.768	.390	0.088	.770
Jitter	0.86 ± 0.27	0.54 ± 0.15	1.20 ± 0.53	0.58 ± 0.18	1.857	.089	0.680	.419	0.680	.419
Shimmer	10.98 ± 2.30	8.55 ± 1.81	9.94 ± 2.78	9.48 ± 2.03	1.563	.224	0.000	.986	0.726	.403
HNR	0.10 ± 0.03	0.06 ± 0.03	0.19 ± 0.08	0.18 ± 0.07	1.430	.244	0.335	.568	0.335	.568
L-DDK	13.60 ± 1.33	16.47 ± 1.38 <sup>††</sup>	13.73 ± 1.34	14.00 ± 1.35	13.715	.001 <sup>**</sup>	0.275	.605	5.559	.027 <sup>*</sup>

Data are presented as frequencies, mean ± SEM.

Abbreviations: MPT, maximum phonation time; HNR, noise-to-harmonics ratio; L-DDK, laryngeal diadochokinesis.

\* $P < .05$ . \*\* $P < .01$  significant effect by two-way repeated measures ANOVA.

†† $P < .01$  significant difference by Wilcoxon signed-ranked test.

observed during VFSS. VDS scale consists of the following 14 items: lip closure, bolus formation, mastication, apraxia, tongue-to-palate contact, premature bolus loss, oral transit time, pharyngeal swallow triggering, vallecular residue, laryngeal elevation, pyriform sinus residue, coating of pharyngeal wall, pharyngeal transit time, and aspiration. The first 7 items (lip closure, bolus formation, mastication, apraxia, tongue-to-palate contact, premature bolus loss, oral transit time) are used for functional assessment of the oral phase, and the other 7 items (pharyngeal swallow triggering, vallecular residue, laryngeal elevation, pyriform sinus residue, coating of pharyngeal wall, pharyngeal transit time, and aspiration) are used to assess the pharyngeal phase. VDS scale has a maximum score of 100. A higher score of VDS indicates a greater impairment of swallowing function.<sup>37-39</sup> DIGEST utilizes safety and efficiency components to quantify pharyngeal bolus transit. A patient's safety profile is scored while accounting for the frequency and quantity of high-grade penetration/aspiration events. The efficiency profile is assigned through the estimation of the maximum percentage of pharyngeal residue. The total DIGEST grade was estimated by combining the safety and efficiency profiles of the patients.<sup>40</sup> A higher grade of DIGEST indicates a greater impairment of swallowing function.

### Statistical Analysis

Statistical analysis was performed using the IBM SPSS (Statistical Package for the Social Science, version 25.0) for Windows program. Each scale was compared from post-test to pre-test. Two-way repeated-measures ANOVA was used to determine interaction between time and group, and main effects of scores of VDS, DIGEST, MPT, pitch, jitter, shimmer, HNR, and L-DDK. Wilcoxon signed-rank test was performed to analyze the differences between pre-test and post-test scores. A  $P < .05$  was considered statistically significant.

## Results

### Clinical Characteristics of Patients

The present study consisted of the intervention group (N=15) and the control group (N=13). Based on the characteristics of HNC treatment, each group was divided into 2 subgroups. The intervention group was divided into 2 subgroups, including the oral cavity cancer group (N=11) and the pharyngeal cancer group (N=4). The control group was also divided into the oral cavity cancer group (N=8) and the pharyngeal cancer group (N=5) (Table 2). Clinical characteristics including gender, age, onset duration, and tumor characteristics were not statistically different between the groups.

### Vocal Function

Vocal functions of patients with HNC were evaluated using MPT, pitch, intensity, jitter, shimmer of voice, HNR, and L-DDK. The inter-rater reliability of MPT, HNR, and L-DDK showed intra-class correlation coefficients (ICC) of .713, .954, and .813, respectively. The intra-rater reliability of the results was obtained twice by randomly selecting a sample of 5 participants at different times by each rater. As a result, each rater showed ICC=.936, .924 for MPT, ICC=.971, .975 for HNR, and ICC=.903, .912 for L-DDK.

In this study, there were no significant differences in scores of MPT, pitch, intensity, jitter, shimmer of voice, and HNR after the intervention. However, L-DDK showed an interaction effect between time and group ( $F_{1,25}=5.559$ ,  $P=.027$ ) and time effect ( $F_{1,25}=13.715$ ,  $P=.001$ ) (Table 3). This indicated that the intervention group showed an improvement in laryngeal elevation with enhanced L-DDK score at post-test compared to the baseline ( $P=.003$  by Wilcoxon signed-rank test). However, the control group did not show the time-dependent change in laryngeal elevation.

**Table 4.** Swallowing Functions in Head and Neck Patients With Dysphagia After the Intervention.

Variables	Intervention group		Control group		Time		Group		Time × group	
	Pre	Post	Pre	Post	F	P value	F	P value	F	P value
<b>VDS</b>										
Oral phase	11.03 ± 2.26	8.33 ± 2.03	13.46 ± 2.45	15.63 ± 2.34	0.025	.875	3.333	.079	4.178	.051
Pharyngeal phase	32.93 ± 4.33	20.80 ± 4.64 <sup>††</sup>	30.54 ± 4.74	34.42 ± 4.16 <sup>†</sup>	2.349	.137	1.203	.283	14.683	.001**
Total score	43.97 ± 5.39	29.13 ± 5.64 <sup>††</sup>	44.00 ± 5.19	50.04 ± 4.18 <sup>†</sup>	1.874	.067	3.006	.095	17.454	<.001***
<b>DIGEST</b>										
Safety grade	1.00 ± 0.31	0.13 ± 0.09 <sup>†</sup>	1.16 ± 0.30	1.08 ± 0.29	6.700	.016*	6.262	.019*	1.823	.045*
Efficiency grade	1.93 ± 0.30	1.00 ± 0.28 <sup>††</sup>	2.08 ± 0.29	2.41 ± 0.19 <sup>†</sup>	2.247	.146	2.400	.133	17.847	<.001***
Total grade	1.87 ± 0.24	0.73 ± 0.18 <sup>††</sup>	2.08 ± 0.19	2.33 ± 0.14	1.389	.249	21.097	<.001***	11.537	.002**

Data are presented as frequencies, mean ± SEM.

Abbreviations: VDS, videofluoroscopic dysphagia scale; DIGEST, dynamic imaging grade of swallowing toxicity.

\* $P < .05$ . \*\* $P < .01$ . \*\*\* $P < .001$  significant effect by two-way repeated measures ANOVA.

<sup>†</sup> $P < .05$ . <sup>††</sup> $P < .01$  significant difference by Wilcoxon signed-rank test.

### Swallowing Function

VDS and DIGEST were scored during the VFSS. The inter-rater reliability of DIGEST and VDS showed ICCs of .920 and .901, respectively, in patients scored by 2 independent scorers. The intra-rater reliability of DIGEST and VDS was obtained from the results conducted to all participants by one rater, with ICCs of .898 and .902, respectively.

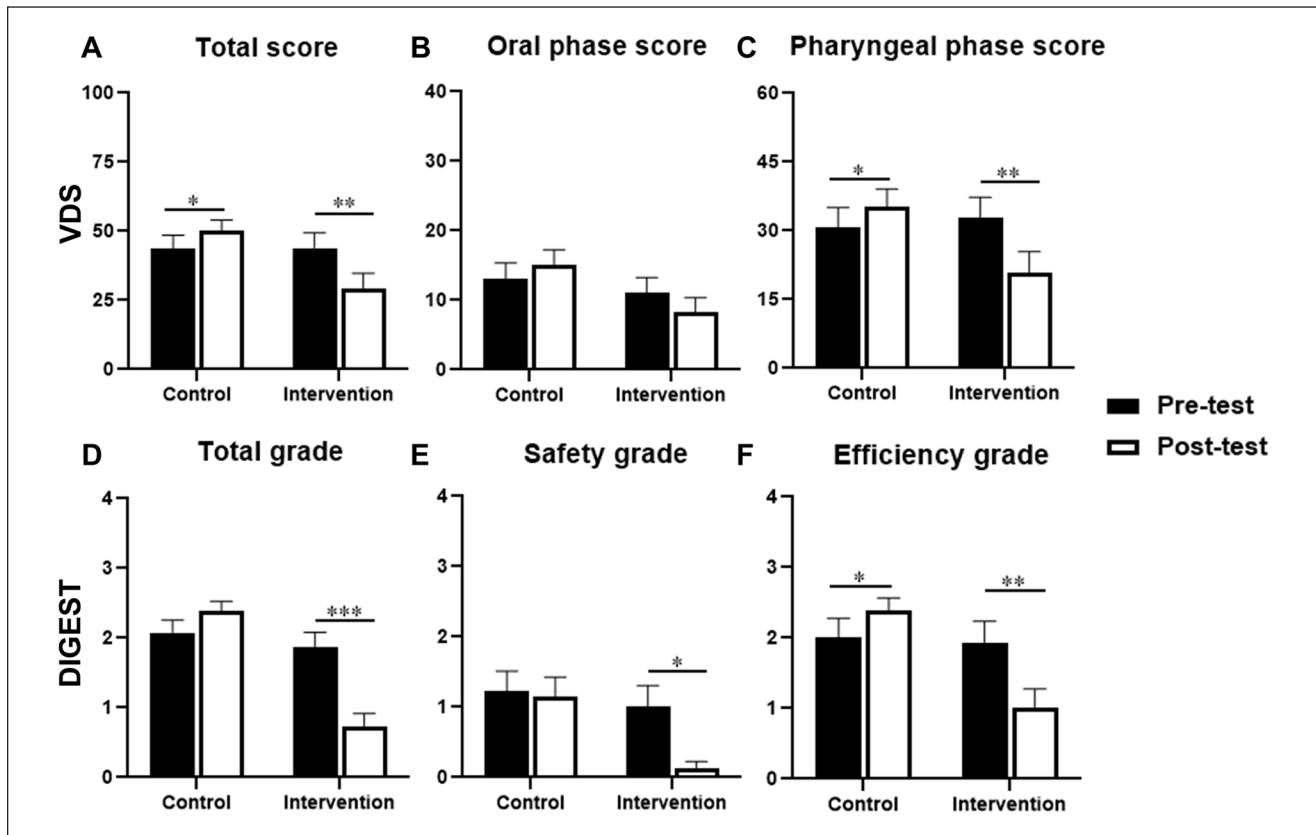
VDS showed an interaction effect between time and group in pharyngeal phase score and total score ( $F_{1,25} = 14.683$ ,  $P = .001$ ;  $F_{1,25} = 17.454$ ,  $P < .001$ ) (Table 4). The results indicated an improvement in swallowing function of the intervention group, especially in the pharyngeal phase, with significant reverse patterns of the control group ( $P = .042$  in the control group;  $P = .008$  in the intervention group by Wilcoxon signed-rank test) (Table 4, Figure 2).

In DIGEST, the safety and efficiency profiles give an overall score which indicates the severity of dysphagia. The safety, efficiency, and total grades showed an interaction effect between time and group ( $F_{1,25} = 1.823$ ,  $P = .045$ ;  $F_{1,25} = 17.847$ ,  $P < .001$ ;  $F_{1,25} = 11.537$ ,  $P = .002$ ). Group effects were shown in safety and total grades ( $F_{1,25} = 6.262$ ,  $P = .019$ ;  $F_{1,25} = 21.097$ ,  $P < .001$ ). Time effect was also found in safety grades ( $F_{1,25} = 6.700$ ,  $P = .016$ ) (Table 4). For safety grade, the intervention group only showed definite improvement in swallowing function ( $P = .016$  by Wilcoxon signed-rank test). The result indicated an improvement in efficiency grade of the intervention group with significant reverse patterns of the control group ( $P = .025$  in the control group;  $P = .006$  in the intervention group by Wilcoxon signed-rank test). For total grade, significant improvement was only found in the intervention group ( $P = .008$  by Wilcoxon signed-rank test) (Table 4, Figure 2).

Each parameter of VDS was also analyzed to identify which parameter in a specific phase was influenced by the intervention in this study. In the oral phase, only oral transit time showed group effect ( $F_{1,25} = 6.380$ ,  $P = .018$ ) with a reverse pattern between groups. However, this should be carefully interpreted due to the lack of statistical significance of time-dependent change in the intervention group. In the pharyngeal phase, 3 parameters, including laryngeal elevation, pharyngeal transit time, and aspiration, showed significant interaction effect between time and group, individually ( $F_{1,25} = 11.607$ ,  $P = .002$ ;  $F_{1,25} = 5.058$ ,  $P = .033$ ;  $F_{1,25} = 10.335$ ,  $P = .003$ ). The results indicated that the swallowing function of the intervention group was significantly improved ( $P = .014$ ;  $P = .046$ ;  $P = .011$  by Wilcoxon signed-rank test), especially in the pharyngeal phase with reverse patterns of the control group (Table 5).

When VDS and DIGEST were analyzed in 2 subgroups of oral cavity cancer and pharyngeal cancer, pharyngeal phase and total VDS scores showed the time effect ( $F_{1,25} = 14.986$ ,  $P = .002$ ;  $F_{1,25} = 17.257$ ,  $P = .001$ ). In addition, safety grade, efficiency grade, and total grade of DIGEST showed that there were the time effects ( $F_{1,25} = 7.875$ ,  $P = .015$ ;  $F_{1,25} = 9.683$ ,  $P = .003$ ;  $F_{1,25} = 9.683$ ,  $P = .008$ ). The results indicated that swallowing function of the pharyngeal cancer group was improved, showing significant time-dependent changes in pharyngeal phase VDS score, safety grade, efficiency grade, and total grade of DIGEST ( $P = .037$ ;  $P = .041$ ;  $P = .034$ ;  $P = .039$  by Wilcoxon signed-rank test) (Table 6).

Furthermore, we analyzed each parameter of VDS to identify which parameter was affected by the intervention in each subgroup. Parameters of the pharyngeal phase, including laryngeal elevation, pharyngeal transit time, pyriform sinus residue and aspiration, showed time effects



**Figure 2.** Videofluoroscopic Dysphagia Scale (VDS) and Dynamic Imaging Grade of Swallowing Toxicity (DIGEST) in Head and Neck Patients With Dysphagia After the Intervention. (A) VDS Total Score. (B) VDS Oral Phase Score. (C) VDS Pharyngeal Phase Score. (D) DIGEST Total Grade. (E) DIGEST Safety Grade. (F) DIGEST Efficiency Grade. \* $P < .05$ . \*\* $P < .01$ . \*\*\* $P < .001$  by Wilcoxon signed-ranked test.

**Table 5.** Videofluoroscopic Dysphagia Scale in Head and Neck Patients With Dysphagia After the Intervention.

VDS	Intervention group		Control group		Time		Group		Time $\times$ group	
	Pre	Post	Pre	Post	F	P value	F	P value	F	P value
Lip closure	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	—	—	—	—	—	—
Bolus formation	2.20 $\pm$ 0.68	1.80 $\pm$ 0.57	3.00 $\pm$ 0.74	3.50 $\pm$ 0.72	0.033	.858	2.469	.128	1.611	.216
Mastication	2.67 $\pm$ 0.84	2.13 $\pm$ 0.77	4.00 $\pm$ 0.98	4.33 $\pm$ 0.92	0.029	.866	2.995	.095	0.725	.402
Apraxia	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	—	—	—	—	—	—
Tongues to palate contact	2.67 $\pm$ 0.96	2.00 $\pm$ 0.82	2.50 $\pm$ 0.75	3.33 $\pm$ 0.94	0.042	.840	0.428	.519	2.045	.165
Premature bolus loss	2.50 $\pm$ 0.32	2.00 $\pm$ 0.32	2.38 $\pm$ 0.47	2.38 $\pm$ 0.39	3.202	.085	0.025	.875	3.202	.085
Oral transit time	1.00 $\pm$ 0.38	0.40 $\pm$ 0.27	1.75 $\pm$ 0.45	2.25 $\pm$ 0.39	0.013	.911	6.380	.018*	3.664	.067
Triggering of pharyngeal swallow	1.20 $\pm$ 0.53	0.60 $\pm$ 0.41	1.13 $\pm$ 0.59	1.13 $\pm$ 0.59	1.592	.218	0.166	.687	1.592	.218
Vallecular residue	3.33 $\pm$ 0.50	3.20 $\pm$ 0.47	3.67 $\pm$ 0.48	3.67 $\pm$ 0.48	0.141	.710	0.294	.592	0.141	.710
Laryngeal elevation	7.80 $\pm$ 0.82	4.20 $\pm$ 1.20 <sup>†</sup>	6.00 $\pm$ 1.28	8.25 $\pm$ 0.75	0.464	.502	0.611	.442	11.607	.002**
Pyriform sinus residue	6.00 $\pm$ 1.05	4.80 $\pm$ 1.03	6.38 $\pm$ 1.17	7.13 $\pm$ 1.03	0.143	.709	0.284	.598	3.571	.070
Coating on the pharyngeal wall	6.60 $\pm$ 1.06	4.80 $\pm$ 1.20	6.38 $\pm$ 1.17	6.75 $\pm$ 1.18	1.034	.319	1.896	.180	2.554	.122
Pharyngeal transit time	2.40 $\pm$ 0.79	0.80 $\pm$ 0.55 <sup>†</sup>	3.50 $\pm$ 0.89	3.50 $\pm$ 0.89	1.264	.271	1.812	.190	5.058	.033*
Aspiration	5.60 $\pm$ 0.92	2.40 $\pm$ 0.79 <sup>†</sup>	3.50 $\pm$ 0.89	4.00 $\pm$ 0.85	2.584	.120	0.464	.502	10.335	.003**

Data are presented as frequencies, mean  $\pm$  SEM.

Abbreviations: VDS, videofluoroscopic dysphagia scale.

\* $P < .05$ . \*\* $P < .01$  significant effect by two-way repeated measures ANOVA.

<sup>†</sup> $P < .05$  significant difference by Wilcoxon signed-ranked test.



**Table 6.** Swallowing Functions in Subgroups of Participants.

Intervention	Variables	Oral cavity cancer		Pharyngeal cancer		Time		Group		Time × group		
		Pre	Post	Pre	Post	F	P value	F	P value	F	P value	
Intervention group	VDS											
	Oral phase	12.00 ± 2.92	9.45 ± 2.55	8.38 ± 2.86	5.25 ± 2.84	2.794	.119	0.718	.412	0.029	.867	
	Pharyngeal phase	30.45 ± 5.76	21.05 ± 5.95	39.75 ± 1.88	20.13 ± 7.13 <sup>†</sup>	14.986	.002**	0.188	.672	1.855	.196	
	Total score	42.45 ± 7.27	30.50 ± 7.15 <sup>†</sup>	43.13 ± 4.00	25.38 ± 9.02 <sup>†</sup>	17.257	.001**	0.001	.982	1.670	.219	
	DIGEST											
	Safety grade	0.91 ± 0.39	0.18 ± 0.12	1.25 ± 0.48	0.00 ± 0.00 <sup>†</sup>	7.875	.015*	0.041	.843	0.550	.471	
	Efficiency grade	1.82 ± 0.40	1.00 ± 0.36	2.25 ± 0.25	1.00 ± 0.41 <sup>†</sup>	9.683	.003**	0.126	.728	0.574	.462	
	Total grade	1.36 ± 0.31	0.73 ± 0.24	1.75 ± 0.25	0.75 ± 0.25 <sup>†</sup>	9.683	.008**	0.246	.628	0.478	.501	
	Control group	VDS										
Oral phase		14.19 ± 3.46	17.81 ± 2.95	12.50 ± 2.76	11.75 ± 2.95	0.496	.497	0.708	.420	1.149	.309	
Pharyngeal phase		27.56 ± 6.85	32.81 ± 6.08	37.63 ± 2.18	41.75 ± 1.79	3.819	.079	1.072	.325	0.055	.819	
Total score		41.75 ± 7.44	50.63 ± 5.72	50.13 ± 3.92	53.50 ± 3.80 <sup>†</sup>	3.357	.097	0.360	.562	0.677	.430	
DIGEST												
Safety grade		1.00 ± 0.38	0.88 ± 0.35	1.60 ± 0.40	1.60 ± 0.40	1.426	.258	4.170	.604	0.453	.506	
Efficiency grade		2.00 ± 0.38	2.38 ± 0.26	2.00 ± 0.45	2.40 ± 0.24	6.611	.026*	0.145	.007**	0.935	.721	
Total grade		2.00 ± 0.27	2.25 ± 0.16	2.20 ± 0.20	2.60 ± 0.24	3.043	.109	0.994	.340	0.695	.556	

Data are presented as frequencies, mean ± SEM.

Abbreviations: VDS, videofluoroscopic dysphagia scale; DIGEST, dynamic imaging grade of swallowing toxicity.

\* $P < .05$ . \*\* $P < .01$  significant effect by two-way repeated measures ANOVA.

<sup>†</sup> $P < .05$  significant difference by Wilcoxon signed-rank test.

( $F_{1,25} = 8.022$ ,  $P = .014$ ;  $F_{1,25} = 6.724$ ,  $P = .022$ ;  $F_{1,25} = 4.765$ ,  $P < .048$ ;  $F_{1,25} = 15.600$ ,  $P = .002$ ). Especially, the pharyngeal cancer group showed significant time-dependent change in aspiration score after the intervention by overcoming poor aspiration condition at baseline ( $P = .049$  by Wilcoxon signed-rank test) (Table 7).

## Discussion

A singing-based intervention can facilitate appropriate laryngeal and pharyngeal muscle movements to produce significant therapeutic effects for patients with swallowing difficulties. Anatomical relationships between breathing, singing, and swallowing imply the integration of laryngeal and pharyngeal muscle movements, and these integrated functions are essential mechanisms for swallowing intervention in the concept of this study.<sup>19,22</sup>

The present study evaluated the effectiveness of therapeutic singing on swallowing function of HNC patients. Our protocol involved muscle exercises targeting the laryngeal elevation and the intrinsic muscle movement of swallowing. All HNC patients received the intervention after the primary cancer treatment. Overall, a rehabilitative approach using singing was effective in patients with HNC who had difficulties in voice and swallowing, as evidenced by the outcomes of L-DDK, VDS, and DIGEST changes in this study.

The inter- and intra-rater reliability of our voice and swallowing data showed high ICCs and demonstrated our data were reliable. The vocal functions of HNC patients were first evaluated in various vocal scales to elucidate the effect of therapeutic singing. Among the vocal measurements, L-DDK score, specifically related to the intrinsic muscle movement of vocal fold and laryngeal muscle movement, showed a significant improvement.<sup>34,41</sup> Since the singing-enhanced swallowing protocol was designed to make patients sing with different pitches, the therapy facilitated the upper esophageal sphincter's width, opening and increasing the extent and duration of laryngeal elevation. It indicates that therapeutic singing mainly focuses on improving the vocal fold and laryngeal movement.

Functional improvements based on statistical significance in VDS and DIGEST scores showed the beneficial effects of music application for HNC patients with dysphagia. Music application, such as singing in different pitches and breathing control with rhythmic cues, can stimulate muscles involved in swallowing from the activation of central and peripheral neural network.<sup>22</sup> During the intervention, singing with different pitches targets the intrinsic muscle movement of the vocal fold and the proper coordination of the muscle for laryngeal elevation when a patient makes a higher pitch sound. When vocalizing in different pitches, intensities generally change while showing different vibrations and strength through acoustic sound.

**Table 7.** Videofluoroscopic Dysphagia Scale in Subgroups of the Intervention Group.

VDS	Oral cavity cancer		Pharyngeal cancer		Time		Group		Time × group	
	Pre	Post	Pre	Post	F	P value	F	P value	F	P value
Lip closure	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	—	—	—	—	—	—
Bolus formation	2.18 ± 0.82	1.91 ± 0.73	2.25 ± 1.44	1.50 ± 0.87	0.783	.392	0.16	.902	0.171	.686
Mastication	2.55 ± 0.98	2.55 ± 0.98	3.00 ± 1.91	1.00 ± 1.00	1.059	.322	0.117	.737	1.059	.322
Apraxia	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	—	—	—	—	—	—
Tongues to palate contact	3.18 ± 1.22	2.27 ± 1.04	1.25 ± 1.25	1.25 ± 1.25	0.347	.566	0.608	.450	0.347	.566
Premature bolus loss	2.73 ± 0.40	2.18 ± 0.42	1.88 ± 0.38	1.50 ± 0.00 <sup>†</sup>	4.357	.057	1.289	.277	0.149	.705
Oral transit time	1.36 ± 0.47	0.55 ± 0.37	0.00 ± 0.00	0.00 ± 0.00	1.300	.275	2.359	.149	1.300	.275
Triggering of pharyngeal swallow	1.64 ± 0.68	0.82 ± 0.55	0.00 ± 0.00	0.00 ± 0.00	0.770	.396	1.686	.217	0.770	.396
Vallecular residue	3.45 ± 0.67	3.45 ± 0.61	3.00 ± 0.58	2.50 ± 0.50	0.502	.491	0.435	.521	0.502	.491
Laryngeal elevation	7.36 ± 1.10	4.09 ± 1.42	9.00 ± 0.00	4.50 ± 2.60	8.022	.014*	0.274	.609	0.200	.662
Pyriform sinus residue	5.73 ± 1.37	5.32 ± 1.33	6.75 ± 1.30	3.38 ± 1.13	4.765	.048*	0.043	.840	2.927	.111
Coating on the pharyngeal wall	5.73 ± 1.37	4.09 ± 1.42	9.00 ± 0.00	6.75 ± 2.25	2.980	.108	1.715	.213	0.074	.789
Pharyngeal transit time	2.18 ± 0.91	1.09 ± 0.73	3.00 ± 1.73	0.00 ± 0.00	6.724	.022*	0.010	.921	1.464	.248
Aspiration	4.36 ± 0.85	2.18 ± 0.91	9.00 ± 1.73	3.00 ± 1.73 <sup>†</sup>	15.600	.002**	3.537	.083	3.397	.088

Data are presented as frequencies, mean ± SEM.

Abbreviation: VDS, videofluoroscopic dysphagia scale.

\* $P < .05$ . \*\* $P < .01$  significant effect by two-way repeated measures ANOVA.

<sup>†</sup> $P < .05$  significant difference by Wilcoxon signed-ranked test.

In this study, HNC patients with dysphagia performed singing with different pitches, which requires vocal fold vibration, including the intrinsic muscle movement of the vocal fold and laryngeal movement in a structured musical behavior. When considering the swallowing difficulties and poor vocal functions in HNC patients with dysphagia,<sup>15</sup> patients with HNC need to enhance laryngeal elevation non-invasively and prevent aspiration by improving the intrinsic muscle movement of vocal folds.

In addition, we also analyzed the swallowing function of the oral cancer group and the pharyngeal cancer group in VDS and DIGEST to identify which parameters of swallowing function were more sensitive according to cancer sites. Especially, the pharyngeal cancer group showed time-dependent changes in pharyngeal phase scores. This suggests that the pharyngeal cancer group showed recovery in swallowing function of the pharyngeal phase, including aspiration after the intervention, even though the group had poor condition in the pharyngeal phase at baseline. These results indicate that patients with pharyngeal cancer had a sensitive response to therapeutic singing since our protocol mainly involved exercises related to laryngeal elevation and intrinsic muscle movement of the vocal folds.

The limitation of the study is that the investigation of patient-reported experiences was not performed to evaluate the effect of therapeutic singing on patients' psychometrical properties. In addition, speech-language pathologists were not involved to measure vocal and swallowing data in the study, even though music therapists trained by experienced physiatrists were involved. Moreover, a further clinical trial with larger sample size is essential to make a definite

conclusion. However, our results may suggest potential benefits of therapeutic singing by improving swallowing functions in HNC patients. Therefore, the present study may shed some light on the rehabilitative approach with a novel intervention for HNC patients with swallowing difficulties after indispensable surgical procedures and radiotherapies.

## Conclusion

The present study showed the potential benefit of therapeutic singing on swallowing function in HNC patients with dysphagia. A significant effect was observed in the pharyngeal phase during the swallowing process. The therapeutic singing was more responsive for pharyngeal cancer group with swallowing problems during the pharyngeal phase. Our protocol involved improving the patients' pharyngeal functions, such as laryngeal elevation movement and intrinsic muscle movement of the vocal fold. Therefore, HNC patients who suffered from dysphagia are recommended to take therapeutic singing to improve their swallowing function.

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## Author contributions

All authors made substantial contributions to this study. Seongmoon Jo, Myung Sun Yeo, Yoon-Kyum Shin, and Ki Hun Shin contributed to the acquisition and interpretation of data and writing of the manuscript. Soo Ji Kim and Sung-Rae Cho designed the study and reviewed and approved the manuscript. They were also responsible for the integrity of the data as co-corresponding authors.

## Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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