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Enhancing swallowing reflexes in patients with dysphagia through interferential current therapy

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Abstract

Background: Dysphagia, often caused by aging or disease, is a major focus for speech-language pathologists. Electrical stimulation therapy, including interferential current (IFC) therapy, has recently gained attention in swallowing rehabilitation. This study investigates the effects of IFC on swallowing-related reflexes.

Methods: Twenty patients with dysphagia were randomized into stimulation and sham groups. We evaluated reflexes (swallowing, cough, pharyngeal) and swallowing functions (repeated saliva swallow test [RSST], tongue pressure, functional oral intake scale [FOIS], Fujishima grade). IFC therapy was applied for 30 minutes daily, alongside conventional training, over one month.

Results: The stimulation group showed significant improvements in cough latency, cough frequency, pharyngeal reflex, RSST, tongue pressure, FOIS, and Fujishima grade. The sham group showed improvement in RSST, FOIS, and Fujishima grade.

Conclusion: IFC therapy combined with conventional rehabilitation significantly improved swallowing function in our cohort of patients with dysphagia, particularly cough and pharyngeal reflexes.

BACKGROUND

Pneumonia, the fourth leading cause of death in Japan, is caused by aspiration pneumonia in more than 70% of cases, and about 70% of these cases are in elderly people ≥75 years old (Ministry of Health, Labour and Welfare, 2019). Many elderly patients present with dysphagia due to aging or cerebrovascular disease, and numerous patients develop pneumonia due to dysphagia.

Swallowing rehabilitation for patients with dysphagia is just one of the rehabilitation practices provided by speech-language pathologists (STs). Dysphagia can be caused by aging or disease, so STs have a wide range of involvement in this field in hospitals and facilities, and it is one of the areas in which their expertise is especially required. In patients presenting with speech-language pathology other than dysphagia, STs should first conduct a swallowing function evaluation and assessment of eating situations to determine whether there are problems with swallowing.

Rehabilitation for dysphagia can be divided into two main categories. Indirect swallowing training is a general term for training that is performed without the use of food. For example, ice massage can be used to induce the swallowing reflex, and head raising training aims to increase muscle strength (Takehara, 2014). Direct swallowing training, meanwhile, involves the use of a meal plan adapted to the patient's dysphagia, ensuring correct posture and the actual ingestion of the food.

Electrical stimulation therapy presents a new type of swallowing rehabilitation. It has been widely used in the United States as a swallowing rehabilitation technique (Giselle, 2013). Electrical stimulation therapy can be divided into two types. Neuromuscular electrical stimulation aims at muscle contraction, targeting the superficial muscles of the hyoid-laryngeal region. It has been reported to result in improved function compared with conventional feeding and swallowing training (Freed, 2001). Similarly, hyoid elevation distance was reportedly improved when it was combined with head raising training (Shaw, 2007). Interferential current therapy (IFC), meanwhile, aims to provide sensory input to nerves, making it possible to stimulate nerves deeper than the muscles. It is also increasingly used in clinical practice as a safe and efficient stimulation method that does not cause the unpleasant sensation of stimulation that can be problematic when performing electrical stimulation therapy.

An interferential current low-frequency treatment device, Gentle Stim (FoodCare, Inc., Kanagawa, Japan) is now available as a treatment device for IFC, offering a different approach to that of conventional neuromuscular electrical stimulation. It uses interference waves to stimulate the sensory nerves in the neck, with the aim of inducing the swallowing reflex or improving airway defense.

Conventional approaches to patients with inability or dysfunction of the swallowing reflex include sensory stimulation input in the form of taste, temperature, touch, and pressure. Ice massage of the throat, for example, involves icing the anterior palatal arch region of the mouth and then encouraging swallowing. It has an immediate effect: the icing triggers the swallowing reflex, although no evidence of long-term effects has been reported (Takehara, 2014).

The center for the triggering of the swallowing reflex is located in the medulla oblongata of the brainstem, where the central pattern generator (CPG) transmits afferent inputs from the swallowing organ to the nucleus pulposus and triggers the swallowing reflex in the reflex arch (Umezaki, 2007). Ice massage aims to lower the threshold for the triggering of the swallowing reflex by providing a peripheral stimulus input to the swallowing organ. Gentle Stim, on the other hand, targets the superior laryngeal nerve for this afferent input. The superior laryngeal nerve is divided into an external and an internal branch. The external branch is responsible for swallowing-related movements, while the inner branch is responsible for sensation distributed in the root of the tongue, the epiglottis, and in laryngeal mucosa. The superior laryngeal nerve is thought to be the only nerve that can independently induce the swallowing reflex by stimulation. Experiments using interference wave electrical stimulation from electrodes just below the cervical skin in deafferented guinea pigs reported that the solitary bundle nucleus of the medulla oblongata and its surrounding swallowing-related neurons were active (Umezaki, 2018). IFC may therefore improve swallowing ability by affecting the swallowing CPG (Umezaki, 2018). In addition, double-blind RCTs of patients with dysphagia have reported improved cough reflex and airway defense (Maeda, 2017) and shortened swallowing reaction time during the pharyngeal phase after interferential wave stimulation at rest (Sugishita, 2015). Efficacy in patients with dysphagia with dementia has also been reported (Hara, 2020), as well as improvement in tongue muscle strength unrelated to sensation (Yoshimatsu, 2022). Improvements in swallowing-related muscle groups that are not related to IFC have also been reported.

On the other hand, regarding sensory function during the pharyngeal period, which is the target of IFC, the elicitation of the swallowing reflex and airway defense have been studied, but there have been no studies on pharyngeal strangulation reflex (hereafter, 'the pharyngeal reflex'). The pharyngeal reflex is a superficial reflex of the pharyngeal musculature with elevation of the root of the tongue that occurs when the middle pharynx is stimulated with a tongue depressor. The afferent path of the reflex arch is the glossopharyngeal nerve, the centrifugal path is the vagus nerve, and the center is the medulla oblongata. The pharyngeal reflex has been suggested by some to be a reflex associated with swallowing (Hirazima, 1996; Linden, 1983). Conversely, there are reports that the pharyngeal reflex is highly associated with subclinical aspiration (Tokuda, 2003), and that the pharyngeal reflex is important as a sensory function related to swallowing. Previous reports have not examined the three reflexes simultaneously in the pharyngeal phase of swallowing, which is the target of IFC: the triggering of the swallowing reflex (hereafter, 'the swallowing reflex'), the airway defense capability (hereafter, 'the coughing reflex'), and the pharyngeal reflex. The current study aims to determine whether the use of IFC improves the three reflexes, to examine the improvement of these reflexes and swallowing function, and to determine the effect of IFC on patients with dysphagia.

METHODS

Subjects

The subjects were patients admitted to Nakatani Hospital of the Yushikai Medical Corporation between October 2022 and December 2023. The attending physician directed the STs to provide feeding and swallowing rehabilitation. Patients were randomly divided into two groups: the stimulation group and the sham group, based on the order in which the physician alternately assigned them to rehabilitation. Patients with pacemakers, tracheotomy cannulas, or those in frail general condition were excluded from the study.

Basic information

Basic information (including sex, length of hospitalization, nutritional status, and cognitive function) was collected from medical records. Nutritional status was assessed using the mini nutritional assessment (short form), with scores of 0-7 indicating malnutrition, 8-11 indicating a risk of malnutrition, and 12-14 indicating normal nutritional status. Cognitive function was evaluated using the *Mini-Mental State Examination*.

Evaluation of swallowing reflex

Swallowing reflex

Swallowing videofluorography was used to evaluate the swallowing reflex. The laryngeal elevation delay time was measured after the patient drank 5 cc of water. We recorded 30 frames of videofluorography while the patient was drinking the water. The time from the first of the contrast medium reaching the convex base of the fossa pellucida to the time the hyoid bone reached its highest position was visually measured in the sagittal section. The time was recorded as the time displayed on the screen.

Cough reflex

A nebulizer (NE-U22; Omron, Kyoto, Japan) was used to generate a 1% citric acid mist, and we measured cough latency and cough frequency after dispersal of the mist. The subject was asked to inhale the mist orally in a 45-degree sitting position, and their nose was blocked with the examiner's finger to ensure oral inhalation. The time from mist exposure to the induction of the first cough was defined as latency (seconds), and the number of coughs per minute after mist exposure was defined as cough frequency. Time was measured by the examiner using a stopwatch.

Pharyngeal reflex

The pharyngeal reflex was assessed using the strangulation reflex evaluation method of the Mann Assessment of Swallowing Ability (Japanese version) score sheet. To evaluate the strangulation reflex, the ST stimulated the root of the subject's tongue once on each side with a tongue depressor. The response was evaluated on a 5-point scale (1: loss of pharyngeal reflex, 2: unilateral loss, 3: unilateral weakening, 4: bilateral weakening, 5: hyperreflexia).

Evaluation of swallowing function

Repeated saliva swallow test

In the repeated saliva swallow test (RSST), subjects were instructed to swallow as many times as possible in a 30-second period. The number of swallows within that 30 seconds was recorded, with the examiner using a stopwatch to measure the time.

Tongue pressure

Tongue pressure, measured using a tongue pressure measuring device (TPM-02E, JMS, Hiroshima, Japan) was defined as the force exerted by the tongue against the maxilla. The subject placed the balloon of the tongue pressure probe, connected to the device, into the oral cavity and compressed the balloon between the tongue and the palate with maximum force. The maximum pressure was measured in kilopascals (kPa).

Functional oral intake scale

The functional oral intake scale (FOIS) is used to evaluate the oral intake ability of patients with dysphagia. It utilizes a simple ordinal scale ranging from level 1 to level 7, with lower scores indicating more severe dysphagia.

Fujishima swallowing grade

The Fujishima swallowing grade is an objective assessment tool for evaluating swallowing ability on a 10-point scale, with 10 representing normal swallowing function and 1 representing severe dysphagia.

Interferential frequency stimulator

The interferential frequency stimulator (IFC) is a device in which electrode pads are placed on the skin, with one set of electrodes outputting 2050 Hz and the other 2000 Hz, crossing each other inside the body to generate a low interference current (50 Hz) in the nerves. The medial branches of the superior laryngeal nerve running through the right and left cervical regions are targeted for stimulation. The interference waves stimulate the nerve, inducing the swallowing reflex. IFC is effective for patients with aspiration after swallowing due to delayed triggering of the swallowing reflex. In this study, we used Gentle Stim, an interferential current low-frequency therapy device (Figure 1), with a beat frequency of 50 Hz and a carrier frequency of 2000 Hz.

Figure 1. Interferential current type low frequency therapy machine gentle stim food care, Inc. Medical device certification number: 227AHBZX00026000

Implementation period

Reflex and swallowing function assessment

Initial evaluations of reflexes and swallowing function were conducted over a 2-day period. The stimulation start date was set one day after the initial evaluation. Re-evaluations were conducted 1 to 3 days after the stimulation ended, following the same 2-day assessment procedure.

Stimulation implementation

In addition to indirect or direct swallowing training provided by an ST, a Gentle Stim pad was applied to both sides of the subject's neck, anterior to the sternocleidomastoid muscle (Figure 2). Interference wave input was applied for 30 minutes per day. The stimulation intensity for the Stimulation Group was 2.5 to 3.0 mA or less, while the Sham Group received 0.1 mA. Stimulation was applied over one month. After reevaluation, the sham group received the same rehabilitation treatment as the stimulation group.

Methods of analysis

All statistical analyses were conducted using SPSS version 28 (IBM, Armonk, NY, USA), with a significance level set at ≤5%. Wilcoxon's signed-rank test was used to compare pre- and post-stimulation means for each reflex item: swallowing reflex (laryngeal elevation delay time), cough reflex (cough latency and cough frequency), pharyngeal reflex, and swallowing function (RSST, tongue pressure, FOIS, and Fujishima swallowing grade). The relative changes from pre- to post-stimulation in both the stimulation and sham groups were calculated, and these relative ratios were statistically analyzed using Mann-Whitney's U test.

Ethical considerations

The purpose and details of this study were explained to the subjects or their families both in writing and orally, and written informed consent was obtained from all participants. This study was conducted with the approval and oversight of Osaka Kawasaki Rehabilitation University Ethics Committee (approval number: OKRU-RA0034), in accordance with the ethical principles outlined in the Declaration of Helsinki.

RESULTS

Baseline characteristics of subjects

The baseline characteristics of the stimulation and sham groups are presented in Table 1; 20 subjects were included in the study, with 10 subjects in each group. The stimulation group consisted of four women and six men, while the sham group consisted of five women and five men. The mean age was 67.8 years in the stimulation group and 72.9 years in the sham group, a slight age difference. The mean duration of hospitalization was comparable between the groups: 111.1 days for the stimulation group and 105.6 days for the sham group. Both groups had significantly lower *Mini-Mental State Examination* scores than the cutoff value, indicating severe cognitive dysfunction. In terms of nutritional status, both body mass index and *Mini Nutritional Assessment-Short Form* scores indicated poor nutrition.

Figure 2. Gentle stim pad application

Table 1. Baseline characteristics of participants in the stimulus and sham groups

Feature	Stimulus group (n=10)	Sham group (n=10)
Age	67.8±11.8	72.9±12.3
Female	4	5
Male	6	5
Length of hospital stay (days)	111.1±23.7	105.6±14.1
MMSE	6.8±4.2	8.1±4.4
BMI (kg/m²)	18.8±2.3	19.1±2.9
MNA-SF	6.9±2.1	7.6±2.4
Swallowing Function		
FOIS	1.2±0.4	1.3±0.5
Swallowing Grade	2.2±0.6	2.4±0.8
Main Disease		
Infarction	3	5
Bleeding	4	3
Personal injury	1	0
Pneumonia	2	2

Reflex response

The within-group differences before and after stimulation are shown in Table 2. Comparison of the pre- and post-stimulation mean values of the swallowing reflex between the stimulation and sham groups is shown in Figure 3. No significant differences were found between the two groups (p = 0.123). However, significant improvements were observed in cough latency (p = 0.042), cough frequency (p = 0.046) (Figure 4), and the pharyngeal reflex (p = 0.024) (Figure 5) in the stimulation group (Table 2). The sham group did not show significant improvements in swallowing reflex (p = 0.263), cough latency (p = 0.138), cough frequency (p = 0.414), or pharyngeal reflex (p = 0.102).

Table 2. Comparison of pre- and post-stimulus measurements and within-group differences

	Stimulus group pre	Stimulus group pos	p-value	Sham group pre	Sham group pos	p-value
Swallowing reflection (LEDT) (sec)	2.01	1.76	0.123	1.48	1.2	0.263
Cough reflex (cough latency) (sec)	43.6	36.2	0.042*	36.4	33.6	0.138
Cough reflex (cough frequency)	0.6	1	0.046*	1	1.2	0.414
Pharyngeal reflex (scale)	1.5	2.4	0.024*	2.5	2.9	0.102
RSST (Scale)	0.7	1.5	0.038*	1	1.4	0.046*
Tongue pressure (Kpa)	14	18.6	0.042*	13.8	16	0.176
FOIS (scale)	1.2	4.1	0.007**	1.3	4.2	0.01**
Fujishima Swallowing Grade (Scale)	2.2	5.7	0.007**	2.4	5.7	0.011*

※Wilcoxon signed-rank test Values are averages.

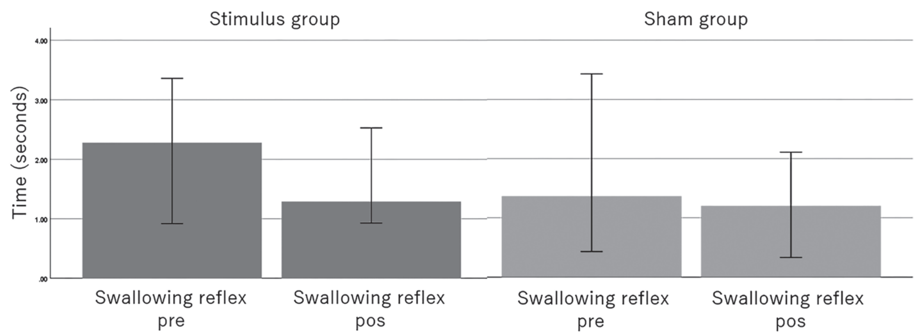

Figure 3. Swallowing reflex, stimulus group, sham group

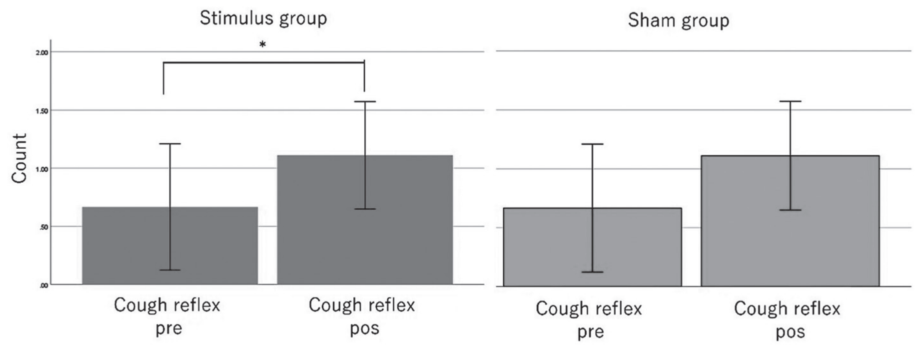

Figure 4. Cough reflex and cough frequency, stimulus group, sham group

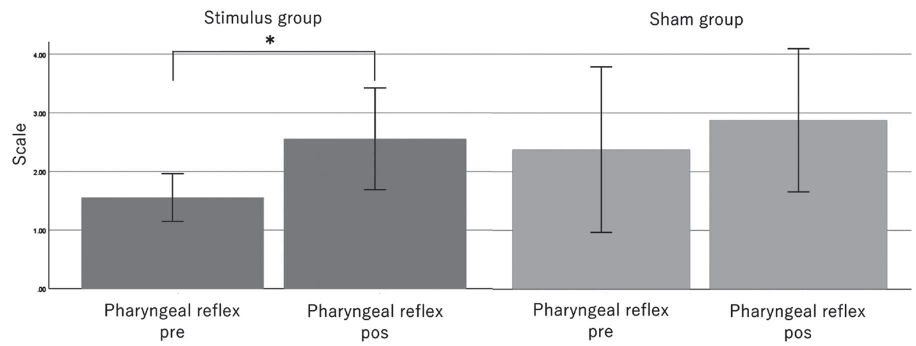

Figure 5. Pharyngeal reflex, stimulus group, sham group

Evaluation of swallowing function

The stimulation group demonstrated significant improvements in all swallowing function measures: RSST ($p = 0.038$), tongue pressure ($p = 0.042$), FOIS ($p = 0.007$), and Fujishima swallowing grade ($p = 0.007$). The sham group also showed improvements, albeit to a lesser extent: RSST ($p = 0.046$), FOIS ($p = 0.01$), and Fujishima swallowing grade ($p = 0.011$) (Table 2).

Comparison between the stimulation and sham groups

The relative changes between the pre- and post-stimulation groups are shown in Table 3. While the stimulation group exhibited greater improvements than the sham group, none of the differences between the groups reached statistical significance (Table 3).

DISCUSSION

Reflex responses

In this study, we applied IFC to patients with dysphagia, dividing them into stimulation and sham groups. In terms of reflex measurements, the stimulation group showed significant improvements in the cough reflex (cough latency and cough frequency) and the pharyngeal reflex before and after stimulation. There were no significant differences in the sham group. Previous IFC studies have demonstrated that sensory input to the superior laryngeal nerve promotes the elicitation of the swallowing reflex (Umezaki, 2018) and that incorporating IFC into direct swallowing training improves swallowing reflex latency (Sugishita, 2018). However, in this study, the stimulation group did not show significant improvement in the swallowing reflex. This may be attributed to most subjects having a Fujishima swallowing grade of 2 or FOIS of Level 1, indicating they were unable to take oral intake, as well as having severe dysphagia with an RSST score of 0, indicating no voluntary swallowing.

On the other hand, there were significant improvements in cough reflex in both cough latency and cough frequency, consistent with findings from a previous randomized controlled trial (Maeda, 2017), where IFC improved the cough reflex and airway defense. The direct effect of IFC on the pharyngeal reflex has not yet been fully clarified, but our stimulation group showed significant improvement in pharyngeal reflex measurements.

Pharyngeal sensation is transmitted to the medulla oblongata via two pathways: the glossopharyngeal nerve and the vagus nerve. Laryngeal sensation is transmitted via the internal branch of the superior laryngeal nerve and the tracheal branch of the recurrent nerve. Thus, while the pharyngeal and cough reflexes are closely related, they form separate reflex arcs at the input stage (Yumoto, 2002). However, one study reported that the loss of the pharyngeal reflex increases the risk of aspiration or laryngeal intrusion, suggesting that the pharyngeal and cough-swallow reflexes may be interrelated, despite differences in their threshold settings (Tokuda, 2003).

The superior laryngeal nerve, targeted by IFC, is divided into internal and external branches. The internal branch is responsible for sensory functions of the tongue root, glottis, and laryngeal mucosa. Although we did not assess whether aspiration occurred after IFC stimulation, some patients with a previously absent pharyngeal reflex developed a unilateral loss. Stimulation of the superior laryngeal nerve has been suggested to provide input to the CPG of swallowing via the nucleus of the solitary tract and the reticular formation (Umezaki, 2018). Also, stimulation input from the superior laryngeal nerve may affect not only

Table 3. Relative proportions (%) before and after stimulation and comparison of differences between groups

	Stimulus group	Sham group	p-value
Swallowing reflection (LEDT)	93.5	84.87	0.772
Cough reflex (cough latency)	79.77	87.12	0.819
Cough reflex (cough frequency)	66.66	26.96	0.457
Pharyngeal reflex	172.22	168.75	0.772
RSST	94.44	87.5	0.858
Tongue pressure	123	81.6	0.819
FOIS	361.11	337.5	0.707
Fujishima Swallowing Grade	272.22	240.06	0.772

※ Mann-Whitney U test Values are averages the CPG of swallowing, but also the CPG of mastication within the reticular formation (Iizumi, 2022).

The nerves responsible for pharyngeal sensation and the pharyngeal reflex, particularly the glossopharyngeal and vagus nerves, are innervated from the medulla oblongata. Traditional methods to improve sensory function typically involve sensory inputs such as taste, temperature, touch, and pressure, but these are ineffective in stimulating deeper sensory input at the tracheal level. The IFC used in this study was able to provide deep stimulation through interference waves, and it is believed that this stimulation of the nerves involved in pharyngeal sensation, along with activation of the CPG in the medulla oblongata, may have contributed to the improvement in the pharyngeal reflex.

Evaluation of swallowing function

In the evaluation of swallowing function, the stimulation group showed significant improvements in RSST, tongue pressure, FOIS, and the Fujishima swallowing grade. Similarly, the sham group showed significant improvements in RSST, FOIS, and the Fujishima swallowing grade, although the improvements were less pronounced. IFC reportedly improves tongue muscle strength in a manner unrelated to sensation (Yoshimatsu, 2022) and the number of spontaneous swallows reportedly increased after IFC in healthy adults (Iizumi, 2022). The significant improvements in RSST and tongue pressure observed in the current study may be due to the increased frequency of swallowing caused by IFC, which may have enhanced the functionality of the tongue musculature and increased tongue pressure.

Combining IFC with direct swallowing training is perhaps beneficial for patients with dysphagia (Sugishita, 2018). In this study, the stimulation group underwent regular swallowing rehabilitation in parallel with IFC. Previous studies have generally focused on patients with mild dysphagia or were single-case studies, while the current study targeted patients with severe dysphagia and found significant improvements in all swallowing-related endpoints. The combination of IFC and conventional swallowing rehabilitation may be effective for patients with severe dysphagia.

Limitations of the study

There are several limitations to this study. First, the sample size was small (20 patients), and additional cases are required to validate the findings. Moreover, there were differences in the age and disease status between the stimulation and sham groups, which may have influenced the results. Additionally, both groups received IFC and conventional swallowing rehabilitation, so the combined effect of the two treatments might have led to the improvements observed. Further studies are needed to isolate and verify the effect of IFC alone. Lastly, the duration of IFC therapy was one month, and although reflex and swallowing function were evaluated post-treatment, it is necessary to assess the long-term persistence of IFC's effects.

CONCLUSION

We applied IFC therapy to patients with dysphagia, divided into stimulation and sham groups. The stimulation group demonstrated significant improvements in both the cough reflex (cough latency and cough frequency) and the pharyngeal reflex following stimulation. Significant improvements were shown across all four swallowing function assessments. A combination of IFC therapy and conventional swallowing rehabilitation may be an effective approach for improving swallowing function in patients with dysphagia.

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The following thesis paper is submitted to the Journal of Aging and Physical Activity.

Masataka Ohki, Kyoko Minehisa, Keiko Sakai, Maki Takei, Masakazu Imaoka, Masatoshi Takeda, Misa Nakamura. Association between balance ability and cognitive function in community-dwelling older adults without cognitive impairment: A cross-sectional study.