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Feasibility of Swallowing Exercises Using a Communication Robot in Older Adults

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Abstract

Background: Maintaining eating and swallowing functions is important to extend the life-span of older adults. This requires continuous swallowing exercises. In this study, a communication robot, manufactured by Unirobot© and named "Unibo" that enables older adults to continuously train themselves in swallowing was developed and its applicability was verified.

Methods: Four swallowing exercise programs were implemented using Unibo: deep breathing, neck exercises, vertical shoulder movements, and vocalization exercises. In this experiment, six participants (age range: 73–93 years; three men and three women) were selected from a daycare center for older adults in Japan. Swallowing exercises were performed by the participants using an independently operated communication robot. This was completed once per person. Immediately after, participants' feedback was obtained by answering questions about their impressions of the robot, it's operability, ease of the exercise, time required for exercise, and the intention to continue exercising with the robot. Data were collected in June 2019.

Results: Two participants experienced frequent coughing while eating. Five participants had experience with swallowing exercises, two of whom performed them at home or in nursing homes. None of the participants had previous experience with living-support robots. Three participants had positive impressions of the robot after the exercise. Regarding their intention to continue exercising alone using the robot, four participants wanted to train with the robot at home. The remaining participants answered, "I want to train alone, I don't want to be commanded by a robot," and "I don't feel that exercise is necessary."

Conclusion: Although the participants had never used the robot before, all of them easily operated the robot, and more than half were willing to continue exercising with the robot. Although the outcome was positive, further examination of the practical use of robots as support apparatus for older adults and user-friendly features should be implemented.

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Introduction

Japan has the highest aging rate worldwide, with those aged 65 years or older accounting for 29.0% of the total population in 2021; this is predicted to increase annually [1]. The number of pneumonia-related deaths in older adults is increasing, with aspiration pneumonia being the most common cause of death [2]. Aspiration pneumonia is caused by an eating and swallowing dysfunction, leading to the inhalation of foreign substances, such as microbes and food, in the oral cavity and pharynx; vaccine prevention is not always effective [3]. Additionally, aspiration pneumonia often develops repeatedly [4]. Maintaining and improving eating and swallowing functions in older adults are important preventive measures against the development of aspiration pneumonia.

Frailty is associated with eating and swallowing dysfunction, irrespective of the age, presence of neurodegenerative diseases, and number of chronic diseases [5]. Older adults with eating and swallowing dysfunction have directly and indirectly decreased activities of daily living [6,7], and could also be undernourished owing to a lack of variety in their diet [8]. Older adults' swallowing function could affect not only the physical aspects of their well-being but also mental aspects [7,9,10]. Studies conducted in Japan reported that patients with aspiration pneumonia have poorer short- and long-term prognoses than those with other types of pneumonia [11,12]. From the above discussion, it is evident that older adults need to maintain effective eating and swallowing functions.

Background

In Japan, training in eating and swallowing functions has been conducted in older adults and its effects have been explained. Ishikawa et al. [13] conducted a one-year training program for older adults in group homes and found that eating and swallowing functions improved for those who underwent training. Ooka et al. [14] noted improvements in eating function and orbicular muscles in the mouths of older adults through simple daily home exercises. In addition, Tamura et al. [15] reported an improvement in the oral symptoms of older adults, such as dry mouth and halitosis, through a six-month sustainable exercise program. Swallowing exercises should be practiced daily, otherwise, there is a risk that the functions will return to their original status [16]. In Japan, swallowing is used as a preparatory exercise before meals and as a basic exercise. Exercise before meals is effective in relaxing and awakening the eating and swallowing muscles of the entire body and neck. Such exercises are often performed in groups at day services, hospitals, and facilities for older adults [17].

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Mieno et al. [18] developed a program that allowed older adults to enjoy exercise, even when alone, so that they could continue exercising. The program was configured to exercise participants by observing both the model (sample video) and their movements on a tablet computer. The older adults who were introduced to electronic devices for the first time had previously undergone this program at a daycare center in Japan. It was difficult for the participants in the program to participate without support because operating the tablet was complicated, and the touch screen did not respond to their dry fingers. Moreover, most participants responded that they preferred not to continue exercising with the program because it was difficult to operate and they did not feel it was necessary. These results indicate that it is necessary to develop a simpler and more user-friendly program for older adults.

Today, devices that use information and communication technology (ICT), such as tablets, have become indispensable to the daily lives of many people. Berner et al. [19] revealed that frail older adults can further improve their lives by connecting with society through information exchange using ICT devices. Therefore, it is necessary to develop equipment that can be easily operated by older adults reluctant to use ICT. In recent years, smart home technologies have been developed to support older adults in several ways [20]. Systems that use physiological and behavioral data, collected by sensors to understand short- and long-term health patterns and respond to emergencies, have been developed [21]. In addition, robotic pets are being created to provide comfort and psychological support that allows older adults to cope better with loneliness and depression [22]. We are developing physical and psychological support robots for older adults that can be easily operated by the user, allowing for continuous swallowing exercises. This study reports the possibility of older adults using these robots.

Objectives

This study aims to develop a robot that enables older adults to independently perform swallowing exercises using programs installed on the robot and further verify its utilization possibilities. Moreover, this study examines the task of developing a user-friendly system that allows older adults to connect socially and enjoy swallowing exercises independently.

Methods and Materials

Development of the robot that supports swallowing exercise

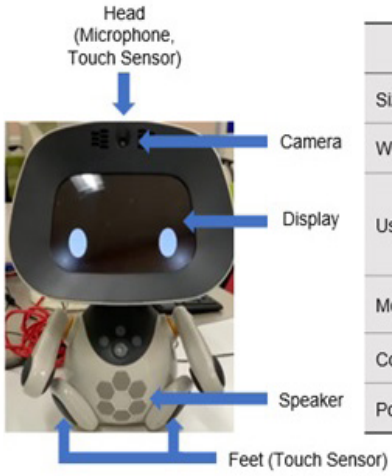
This study used Unirobot's communication robot, called "Unibo" (provided by Fujitsu; Unibo Web site, https://www.unirobot.com/unibo/spec), which has a voice-operated function that can be easily operated by anyone. The appearance and specifications of Unibo are shown in Figure 1.

The display attached to Unibo's head makes it capable of projecting images. Sensors on the head and feet make it easy to operate through touch. It recognizes sounds using a microphone on its head and a speaker on its chest. In this study, we enhanced the function of Unibo by adding actions and auditory guidance for swallowing exercises.

Contents of swallowing exercise

Swallowing exercises have two purposes: relaxation of the swallowing muscles of the whole body and neck and arousal [23]. Swallowing exercises are performed in combination with other exercises. This study combined four types of general exercises: deep breathing, neck exercises, vertical shoulder movements, and vocalization exercises. Deep breathing exercises help improve ventilation efficiency and relaxes the entire body during eating and swallowing [23]. Neck exercises and vertical shoulder movements improve the mobility of the neck and scapula swallowing [23]. Mobility in the neck and scapula is an important function in eating behavior, and impairment of mobility hinders swallowing. Vocalization exercises aim to enable closure and opening of the lips and smooth movement of the entire tongue swallowing [23]. This study adopted the "PATAKALA gymnastic exercises," which are the most popular in Japan. These exercises involve the pronunciation of four sounds: "PA," "TA," "KA," and "LA." The lip and tongue movements during these vocalizations are similar to those used during eating and swallowing.

The flow of the swallowing exercise incorporated into the robot is illustrated in Figure 2. Unibo was programmed to automatically activate 10 min prior to lunch at 12 o'clock; at that time, it directed the user to perform swallowing exercises. The exercise began when



	Specifications
Size	High 32cm, Width 26cm, Depth 16cm
Weigh	2.5 kg
User Interface	Microphone: place in the head Speaker: 4Ω round speaker, place in the chest Camera: 5 million pixels, place in the head Display: 7.0-inch, touch panel
Movement	head: left and right 140 degree, up and down 44 degree Arm: back and forth 90 degree
Communication	Wireless LAN 802.11 b/g/n
Power supply	Lithium-ion battery, drive continuously for 1 hour

Quoted from Unibo HP, https://www.unirobot.com/unibo/spec (Acquired Feb 29, 2024)

Figure 1. Unibo appearance and specifications
Note: The Unibo is a registered trademark of Unirobot Corporation.

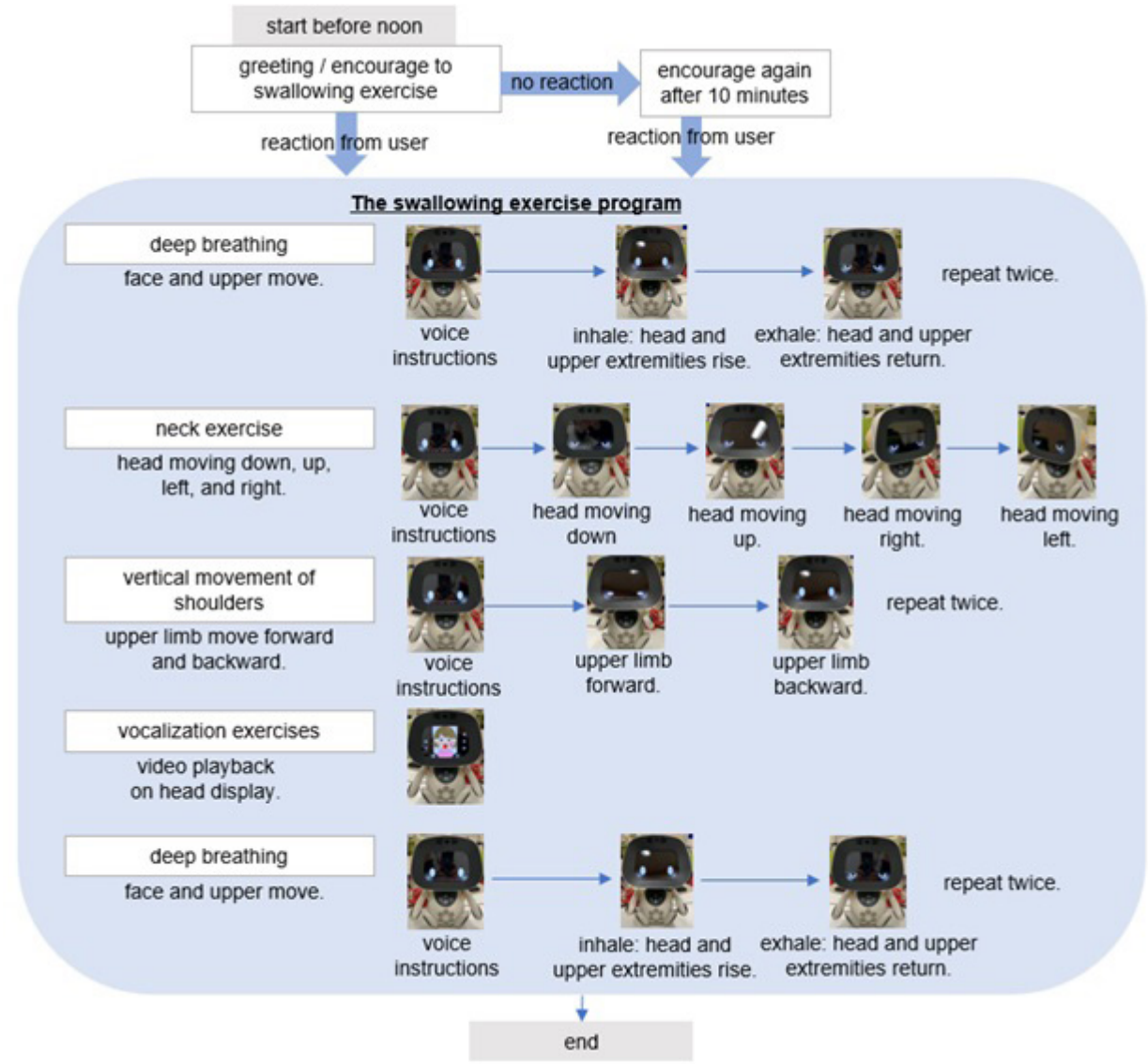


Figure 2: Composition of the swallowing exercise.

a user responded. If there was no response from the user, the robot instructed the user to perform the exercise after 10 min. The swallowing exercises were in the following order: deep breathing, neck exercises, vertical movement of the shoulders, vocalization exercises, and deep breathing. During deep breathing, Unibo gave voice instructions for breathing and demonstrating the timing by moving the head and upper extremities (inhale: head and upper extremities rise; exhale: head and upper extremities return). For the neck exercise, Unibo gave voice instructions to move the face down, up, left, and right and then demonstrated the respective head movements. For the vertical movement of the shoulders, Unibo gave voice instructions for the upper limb up and down, and then demonstrated the upper limb forward and backward. For vocalization exercises, PATAKALA exercises were employed by displaying an example video consisting of original illustrations on Unibo's head. Figure 3 shows part of the vocalization exercise flow. The movement of the character's mouth was displayed and the sounds were pronounced simultaneously. Users could practice while watching the model video. We created 10 types of vocalization exercise menus. The required practice time was approximately seven min.

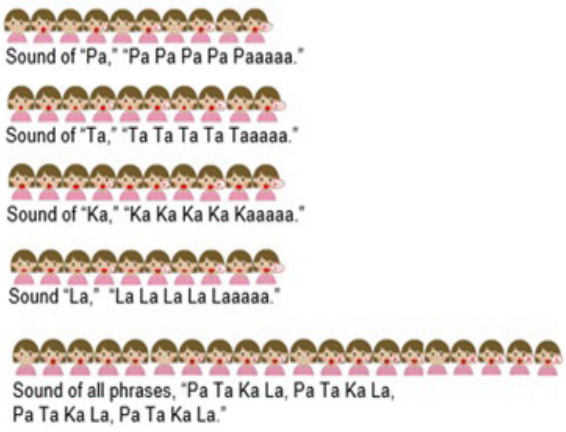


Figure 3: Vocalization exercises, "PATAKALA gymnastic exercises" (one part).

Participants

Six older adults from a daycare center in Japan were selected to examine the applicability of the robot. The inclusion criteria were as follows: 1) ability to follow verbal instructions, 2) ability to maintain a sitting position, and 3) ability to move the upper limbs.

Data collection

The research group provided written and oral information about this study to the head nurse at a daycare center and obtained their consent to participate in the administration of the study procedure. The head nurse selected and referred participants who consented to participate in the study. Prior to use, participants were instructed by the researcher on how to use the device. Subsequently, they performed swallowing exercises using a communication robot that operated independently. This was completed once per person. Immediately following this, their feedback was evaluated by answering questions regarding their impressions of the robot, its operability, ease of exercise, time required for exercise, and intention to continue exercising using the robot. In addition, they answered questions about their own attributes, such as the motor function of their upper limbs, their experience of swallowing exercises, effective implementation of swallowing exercises at home, and their experience of using robots (Table 1). The researchers then reviewed the questions. The researchers asked the questions verbally, according to the questionnaire content, and the participants also answered orally. Questions were asked through semi-structured interviews. The researchers recorded the participants' responses. The survey was conducted on June 26, 2019.

Table 1: Questionnaire content.

1. Age, Sex		
2. Motor function disability of upper limb (especially dominant arm).		
a) No disability	b) No problem with operation	c) Cannot operate
3. Swallowing function disability (subjective).		
a) No disability	b) Frequent coughing	c) Always coughing
4. Do you have experience in swallowing exercises?		
5. Have you implemented the swallowing exercise at home?		
6. Do you have experience using mobile terminals?		
7. What is your impression of the robot?		
8. How is the operability of the robot? a) Possible b) Not possible		
→ If inoperable, which operations were difficult? → How do you think it would be easier to use?		
9. The swallowing exercise takes seven min. Time required is		
a) Just right	b) Short	c) Long
10. Do you think you can continue the swallowing exercise alone with Unibo?		
a) I can continue it alone	b) I can't continue it alone	
11. Is there a function you want in a living robot like Unibo?		
12. Do you have experience using living support robots?		

Ethical considerations

This study was approved by the research ethics committee of the authors' institution (no. 383; June 8, 2019). Participants were informed, both orally and in writing, about the aim and method of the research and were assured that they could refuse to participate at any time. Those who agreed to participate signed a consent form.

Data analysis

Descriptive statistics were used to analyze the closed-ended questions.

Results

All participants were selected by the head nurse who cooperated in this study. The characteristics of the six participants are listed in Table 2. Of the six participants, three were male and three were female. The age range of the participants was 73-93 years, with a mean age of 83.0 years. None of the participants reported upper limb dysfunction. Regarding the swallowing function, two participants experienced frequent coughing. Five participants had previous experience with swallowing exercises, two of whom had performed swallowing exercises at home or in a nursing home. Two participants had experience using mobile terminals.

Table 2: Characteristics of participants (N = 6)

Age, years	
Mean ± SD [range]	83.0 ± 7.2 [73–93]
Sex	
Male	3 (50.0%)
Female	3 (50.0%)
Motor function disability of upper limb	
No disability	4 (66.7%)
No problem with operation	2 (33.3%)
Swallowing function disability	
No disability	4 (66.7%)
Frequent coughing	2 (33.3%)
Experience in swallowing exercise	
Yes	5 (83.3%)
No	1 (16.7%)
Implement swallowing exercise at home	
Yes	2 (33.3%)
No	4 (66.7%)
Experience in using mobile terminals	
Yes	2 (33.3%)
No	4 (66.7%)

Table 3 shows the evaluation results after exercise. None of the participants had any previous experience using living-support robots, such as Unibo. Three participants, two of whom were women, had good impressions of the robot after the exercise. As feedback, participants who had a good impression about the robot said: "The robot was cute," "It was fun to train with the robot," and "The robot's words were easy to understand." The other three participants said: "It takes time to get used to the program," "I do not feel it is necessary," and "I don't want to be commanded by a robot." None of the participants had any problems with the robot's operability. Regarding the ease of exercise, three participants answered, "The timing of vocalization is difficult during vocalization exercises." Regarding the exercise time, four

participants answered, "just right." And two answered, "too short" and wanted to train more with the robot. With regard to their intention to continue exercising alone using the robot, four participants answered that they wanted to train with the robot at home. The other two participants answered, "I want to train alone, I don't want to be commanded by a robot," and "I don't feel that exercise is necessary." As for the functionality they would like to see in living-support robots, such as Unibo, one participant said they would dance and sing together.

Table 3: Comment on using robot and operation status (N = 6).

Impression of the robot	
Good	3 (50%)
Not good	3 (50%)
Operability of the robot (subject)	
Operation possible	6 (100%)
Ease of exercise (subject)	
Timing is difficult during vocalization exercises.	3 (50%)
Time required for program.	
Just right	4 (66.7%)
Short	2 (33.3%)
Want to continue exercise with Unibo	
Yes	4 (66.7%)
No	2 (33.3%)
Function wanted in a living robot like Unibo	
Dance and sing together	1 (17%)
Experience using living support robots	
Yes	0 (0%)
No	6 (100%)

Discussions

In Japan, the development and commercialization of robotic nursing care equipment is being promoted to improve and maintain the quality of life of older adults by supporting their independence and reducing the burden on caregivers [24]. We aim to develop a system that allows older adults to live and talk to robots to help them manage their health and support their lives. We developed an older adult support robot that can perform swallowing exercises using a simple program and further verified the possibility of using this robot for older adults.

Prior to this study, the participants had no experience using communication robots, such as Unibo. After the exercise, half of the participants, especially the women, became accustomed to the robot and wanted to extend their exercises. After the session was completed, four participants answered that they would like to train with a robot at home and responded positively to continuing the swallowing exercise with the robot. Previous studies used tablet computers to perform swallowing exercises [18]. In the study, most respondents said that they could not continue exercising because of difficulties in operating the tablet without assistance. External support from family members is indispensable for older adults using tablet computers [4]. We adopted a robot with a voice-operational system that simplified operation. This resulted in the creation of a system that could easily be operated by older adults unfamiliar with robots. In addition, some participants preferred the robot's appearance. The developed communication robot had a form similar to that of a human and uttered words in the voice of a child. Having a robopet engaging and interacting with older adults could have a positive impact on health outcomes such as loneliness and agitation [22]. The results suggest that a feeling of connection that cannot be achieved with tablet computers is an important requirement in robots to support older adults.

However, some participants had negative opinions, such as: "It takes time to get used to (exercise with a robot)" and "I want to live as I like; [manipulating the robot] is troublesome." This was because communication with the robot was still unfamiliar to the participants. In general, for the robot's communication function, the time required to complete its programming is determined during the process of voice recognition and phonation. In contrast, humans have natural conversations, understand the meaning of other's words while thinking of a response, and react accordingly. When an older adult talks to a robot while imagining a conversation with a human, the timing of the conversation shifts and the user feels that the conversation has not been established, making them feel uncomfortable or strange. Ono et al. [25] noted that reading the mind is essential in human–robot conversations as well as in human–human conversations. By reading the robot's mind and estimating its intention, Ono's study found that humans could understand the robot's meaning even if it had an indistinct voice. The predictability of the robot and its conversation are necessary features that ease the user.

Robotic technology is being developed to support older adults in Japan, which has the world's largest aging population. In this report, we describe a robot that performs swallowing exercises together with older adults. The robot was developed to prevent the decline in eating and swallowing functions believed to be the cause of aspiration pneumonia, a recent problem in Japan. We believe that the newly developed robot can be easily operated by older adults who are unfamiliar with electronic devices and that it will be a method to perform swallowing exercises, either alone or in groups.

Furthermore, one participant replied, "I do not feel the necessity to undergo the swallowing exercise at home." Earlier studies have also reported that some older adults did not feel the need for swallowing exercises [18], which is in agreement with the current results. Hasegawa et al. [26] showed that oral dysfunction was associated with physical vulnerability in older adults. Interventions in oral function improvement programs for older adults delay cognitive decline [2]. The main purpose of swallowing exercises is to prevent deterioration of eating and swallowing functions. Continuous exercise is essential for the self-perception of oral dysfunction. Older adults who find exercising unnecessary may not have experienced aspiration or swallowing dysfunction. Therefore, it is necessary to build a system that allows older adults to understand the importance of actively starting regular exercise before the swallowing function declines.

Limitations and Future Research Directions

This study reports the results of a pilot study involving six participants. Owing to the limited number of participants, one limitation of this study was that it did not control for physical and cognitive function levels. To compensate for this limitation, it is necessary to stratify the level of participants' physical and cognitive functions and conduct research to examine programs that can be utilized at different ability levels.

In addition, the current results are based on only one exercise session in which the participants used the robot. The older adults would feel more familiar with the robot when multiple ongoing exercise sessions were conducted. In the future, the sustainability of exercises using robot should be verified.

Based on the current results, we plan to install the robot in the homes of older adults for a certain period to verify the feasibility of continuing exercise using the robot. Furthermore, we aim to develop a system in which robots can manage and maintain the health of older adults and support them while living with them, similar to family members.

Conclusions

We developed a robot that enables older adults to perform swallowing exercises independently using programs installed in the robot, and verified its utilization possibilities. In the future, it will be necessary to devise further functions such that older adults can operate the program on their own and perform exercises while having a smooth conversation with the robot.

Competing Interests

The authors declare that they have no competing interests.

Author Contributions

AM and KH conceived the concept of the study, all authors contributed to its design. All authors performed data synthesis. AM drafted the manuscript, and all authors commented on subsequent drafts and contributed to the discussion and implications.

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Data Availability Statement

The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request.

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