Original Paper

Chin Tuck Against Resistance Exercise With Feedback to Improve Swallowing, Eating, and Drinking in Frail Older People Admitted to Hospital With Pneumonia (CTAR-SwiFt): Randomized Controlled Feasibility Study

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Abstract

Background: Community-acquired pneumonia in frail older people requiring hospital admission is considered to be commonly associated with swallowing difficulties (dysphagia). A rehabilitation program (chin tuck against resistance [CTAR]) targeting the anterior neck musculature involved in laryngeal movement can improve swallowing safety. We have developed a swallowing exercise rehabilitation intervention (CTAR-SwiFt [Chin Tuck Against Resistance Exercise With Feedback to Improve Swallowing, Eating, and Drinking in Frail Older People Admitted to Hospital With Pneumonia]) by adapting a previously established swallowing exercise. The CTAR-SwiFt intervention consists of a feedback-enabled exercise ball that can be squeezed under the chin, with real-time feedback provided via a mobile app.

Objective: This study aimed to assess the usability of the CTAR-SwiFt intervention and the feasibility of recruiting participants to take part in a larger-scale multicenter randomized controlled trial.

Methods: We recruited participants aged 75 years and older who were admitted with a diagnosis of pneumonia to the acute frailty wards at 2 participating hospitals in the United Kingdom. Patients had to be medically stable. Study participants were randomized to 1 of 3 groups: standard care (control), low intensity (once daily), or high intensity (twice daily) CTAR-SwiFt exercises. The intervention period lasted for 12 weeks; the final follow-up assessment was conducted at 24 weeks. Feasibility outcomes were assessed descriptively and included participant recruitment rate, retention, compliance with the exercise regimen,

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and adverse incidents. The Eating Assessment Tool-10 (EAT-10) and 4 Question Test (4QT) measures were used to screen for oropharyngeal dysphagia. Additionally, we assessed the usability and acceptability of the intervention device and performance of different clinical outcome measures (chin tuck strength, Functional Oral Intake Scale [FOIS], Quality of Life in Swallowing Disorders [SWAL-QOL] questionnaire, EuroQol 5-Dimension 3-Level [EQ-5D-3L] questionnaire, and swallow speed).

Results: A total of 24 participants were recruited, and 21 were randomized at the rate of 0.91 recruits per month (95% CI 0.59-1.0). Of those approached, 32% (24/75) were willing to take part, and of those randomized, 52% (11/21) completed the study. The major reason for failing to complete the study was medical, with people becoming unwell or being readmitted to hospital. The outcome measures assessed suggested that there was an improvement in the EAT-10 and 4QT and a minimal impact on FOIS. Quality of life as measured by the EQ-5D-3L showed improvement with time. The low-intensity intervention demonstrated the best improvement. Participants were able to partake in the CTAR-SwiFt exercises. There was an improvement in the consistency of ball squeeze over the course of the intervention and an increase in maximum chin tuck strength by a mean of 0.8 (SD 0.9) kgf.

Conclusions: The literature supports the benefit of CTAR in improving swallowing in community-dwelling older adults. Our study has demonstrated that older, frail adults are able to perform CTAR and could use the ExerPhager. A future study should investigate the benefits of CTAR-SwiFt in community-dwelling older, frail adults after pneumonia.

Trial Registration: ISRCTN Registry ISRCTN12813363; https://www.isrctn.com/ISRCTN12813363

International Registered Report Identifier (IRRID): RR2-10.1186/s40814-022-01060-w

(JMIR Form Res 2026;10:e79146) doi: 10.2196/79146

KEYWORDS

pneumonia; swallowing; dysphagia; digital health; mobile health; frailty

Introduction

Respiratory infection is a common reason for an acute hospital admission and death in older adults. In the 2020-2021 financial year, 186,705 adults aged 75 years and older were admitted to hospital in England and Wales with a diagnosis of community-acquired pneumonia (CAP) or lower respiratory tract infection [1], and worldwide there are 1 million pneumonia-related deaths annually [2]. Up to 90% of older people admitted with a diagnosis of CAP may have aspirated infected saliva or food [3,4].

It is estimated that there will be 1.5 billion older adults (>65 years) worldwide by 2025 [5]. As people increase in age, swallowing remains safe, but the sequential timing of each phase within the swallowing process becomes more critical [6]. Older people have multiple medical problems, including frailty, sarcopenia, neurological disease (dementia, stroke, motor neuron disease, and Parkinson disease), muscle diseases, autoimmune disease, cancer, oral and pharyngeal infection, and cardiorespiratory disease. Oropharyngeal dysphagia (OD) may be associated with any of these and may occur suddenly following an acute medical event (stroke and acute infection) or gradually with disease progression (dementia, Parkinson disease, motor neuron disease, cancer, and autoimmune disease). OD may present with food refusal, coughing, choking, or recurrent chest infections [7].

Bolus preparation is important before the commencement of the pharyngeal phase of swallowing. Difficulties in bolus preparation may occur with tongue disorders, oral frailty [8,9], and/or sarcopenic dysphagia [10] and contribute to the presence of OD. Physiological changes also occur in the pharyngeal phase of swallowing that may contribute to dysphagia, including reduced laryngeal elevation and rotation, reduced pharyngeal stripping wave strength, and less efficient clearance [11]. This results in a larger residue of food being retained on closure of the upper esophageal sphincter [4,12], increasing the risk of food entering the airway after swallowing.

Presbyphagia most commonly describes these changes in the aged swallow where there appears to be no apparent underlying pathology. Presbyphagia may present incipiently with a slower speed of eating, a reduction in the amount eaten due to fatigue, a change in texture of food due to reduction in bite strength, or changes in the pharyngeal phase of swallowing [4,6,13,14]. In response to incipient presbyphagia, many older adults may make subtle changes to types of food eaten and the time taken to eat it, compensating for any swallow impairment. Consequently, they may deny that they have any problem swallowing because of these adaptations. [4,13]. Frailty and sarcopenia, common in old age, may result in OD, which only becomes apparent when the individual becomes unwell, resulting in a decompensation of the swallow due to a lack of physiological reserve. The swallow may return toward normal as the medical insult subsides [15].

The prevalence of dysphagia in community-dwelling older adults is up to 40%, increasing to 70% in the nursing home setting [7]. Studies have suggested that as many as 75% of older frail adults admitted to acute older adult and medical wards have OD either due to a preexisting impairment or decompensation associated with an acute illness [16-19]. The complications of OD may range from minimal to having a major impact on a person's physical, psychological, and social life, resulting in anxiety and occasionally food phobia, isolation, malnutrition, dehydration, and infection, including pneumonia [20]. Reduced functional capacity, increased institutionalization, and mortality are commonly associated [21,22].

The management of pneumonia in older adults without clinically apparent dysphagia does not routinely include the assessment of the ability to swallow [23,24], despite the suggested high frequency of aspiration [3]. Consequently, there is a failure to identify and correctly manage dysphagia in this population. In

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the context of stroke, Bray et al [25] noted that late assessment and intervention for dysphagia following an acute stroke was associated with a worse outcome.

In the United Kingdom, for many frail patients, the standard management of OD in hospital includes modification of the diet and swallowing maneuvers to alter swallowing physiology rather than rehabilitative exercises to improve the mechanics of swallowing. Momosaki et al [26], using a large Japanese database, demonstrated that those patients with OD who were offered appropriate rehabilitation were more likely to have a total oral intake compared to those not offered oral-pharyngeal rehabilitation (odds ratio [OR] 1.2, $P<.001$).

Frail older adults are frequently sarcopenic, and there is a growing consensus that muscle groups involved in swallowing (anterior neck and suprahyoid complex) may also be affected. Skeletal (arm and leg) muscle weakness, treated with resistance exercise, has been investigated and shown to have a positive effect on muscle strength and bulk [27]. Resistance exercises may prevent loss or improve muscle bulk and strength [28-30]. A logical step, therefore, would be to take the same approach with the muscles involved in swallowing.

There are generally 2 approaches taken to strengthen the swallow: tongue strengthening exercises [31] and isometric resistance exercises of the external pharyngeal musculature such as the Shaker maneuver (head lift exercises) [32]. Both approaches have been shown to improve the mechanics of swallowing. The Shaker maneuver exercise program is conducted in a supine position and consists of 3 isometric head lifts, held for 60 seconds each, followed by rapid neck flexion, 30 times daily for 6 weeks. The exercise program strengthens the suprahyoid muscles, resulting in improved upper esophageal opening, laryngeal anterior excursion, and reduction in postswallow aspiration [32].

In frail older people, the Shaker exercise may not be technically feasible due to core muscle weakness, fatigue, or coexisting morbidities. Sze et al [33] showed that it is possible to do this type of exercise by placing a partially inflated ball beneath the chin and then pressing down against the ball. This exercise—chin tuck against resistance (CTAR)—generated similar electromyography results and greater benefits than the Shaker exercise. Park et al [34] studied patients with stroke and showed positive clinical benefits of CTAR in a small randomized controlled trial, and more recently a Danish study showed benefit in a mixed community population [35]. Rogus-Pulia et al [31] demonstrated an improvement in Functional Oral Intake Scale (FOIS) score (effect estimate 0.4, $P<.02$), reduced incidence of pneumonia, and reduced number of hospital admissions, in a cohort that was mixed in etiology of dysphagia using isometric progressive resistance oropharyngeal therapy.

Effective rehabilitation requires the ability to control the effort exerted to undertake the exercise in a consistent and regulated way. The use of CTAR as applied in previous studies did not incorporate a method to ensure that the exercise is undertaken in a consistent way with controlled effort, because there is no means by which effort can be regulated by the patient. Park's group in South Korea has demonstrated that game theory and chin tuck can be effective in dysphagia rehabilitation [36], but their approach does not provide the feedback required to alter effort applied to provide consistency of effort. We are not aware of any similar exercise (CTAR) device that is able to provide feedback that permits the patient to carefully control their effort. Furthermore, no previous exercise programs allow logging of exercise data for subsequent review by the therapist in the clinic.

We have developed a CTAR exercise program (CTAR-SwiFt [Chin Tuck Against Resistance Exercise With Feedback to Improve Swallowing, Eating, and Drinking in Frail Older People Admitted to Hospital With Pneumonia]), using an exercise ball that can be squeezed under the chin with an implanted pressure transducer (ExerPhager) connected via Bluetooth to a tablet or smartphone app to encourage consistent effort and to log compliance with the program. We have conducted a feasibility study to establish the measurement variability of the tools for assessing outcomes, determine whether patients are willing and able to take part in such a study, and assess the acceptability of the ExerPhager and compliance with its use.

Methods

Overview

The methods have been described in detail previously [37]. Briefly, this was a clinical feasibility study with a multisite (Southeast London and Bristol) randomized controlled design and 3 parallel study arms. The plan was to recruit 60 participants from acute frailty wards at 2 hospitals in the United Kingdom from May 2021 to December 2022 (as per the protocol). Older adults more than 75 years of age admitted to hospital with a diagnosis of CAP who met the inclusion criteria for the study (Textbox 1) were recruited and randomly allocated to a standard care control group, a lower- or a higher-intensity intervention group: exercise rehabilitation "once-per-day" group (EXR1) or "twice-per-day" group (EXR2). Each participant who was allocated to either of the intervention groups was asked to perform CTAR using the investigational device. Any older person with pneumonia who was identified to have OD that required active intervention was excluded from the study. Written informed consent was obtained from all study participants. The CONSORT (Consolidated Standards of Reporting Trials) checklist is available in the Multimedia Appendix 1.

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Textbox 1. Inclusion and exclusion criteria for participants recruited to CTAR-SwiFt randomized controlled study in frail older adults admitted with community-acquired pneumonia [37].

Inclusion criteria

- Admitted with a diagnosis of pneumonia
- Medically stable: systolic blood pressure >110 mm Hg, heart rate >60 bpm, and Modified Early Warning Score ≤ 1
- Aged 75 years or older (although patients who fulfilled the frailty criteria and who were slightly younger than 75 years were considered)
- Clinical Frailty Score of ≥ 4 and < 8
- Montreal Cognitive Assessment (MOCA) > 14
- Able to provide consent (different media provided to patients to enable consent to occur, for example, pictures, speech, and language therapy support)
- No significant breathlessness (St George's chronic obstructive pulmonary disease Score)
- Not requiring oxygen
- No past history of stroke or neurological disease
- No evidence of severe rheumatoid arthritis (risk of neck instability)

Exclusion criteria

- Failure to provide consent to take part in the study
- Progressive medical conditions (eg, due to malignancy or progressive neurological disease)
- MOCA < 14
- Dysphagia requiring active intervention at the time of assessment
- Dysphagia secondary to surgical treatment of head and neck cancer

Intervention Group

Patients were reviewed in their own home at monthly intervals. During these supervised sessions, an assessment of maximum chin tuck strength (MCTS) was performed by a speech and language therapist. This involved 3 chin tuck maneuvers for 3-5 seconds during which the participant was asked to exert as much chin tuck force against the ball as possible. The MCTS value was used to determine an individual safe submaximal target intensity (effort level) for the CTAR-SwiFt exercise, which was set at 30% of MCTS. Patients were then asked to repeat 1-minute CTAR-SwiFt exercise periods at this target intensity, 3 times, with 1 minute of rest in between each.

When performing the CTAR-SwiFt exercise, patients were requested to use the visual feedback provided on the smartphone or tablet to adjust their effort until it matched the individual target intensity. Patients were then requested to maintain this effort for 1 minute. This was done twice more with a 1-minute rest between each effort.

The overall ease with which each exercise session was completed was assessed by asking patients to complete a simple exercise "comfort rating scale" (CR-10) after every single session. This ease of completion rating was used by the patient and clinic staff to ensure that the exercises did not require excessive effort from patients. The effort level was to be maintained at 30% of MCTS (as assessed in the monthly supervised sessions). During the intervention period, it was expected that participants' MCTS would increase, and that the absolute target effort level would also increase accordingly with every reassessment of MCTS. However, it was at the speech and language therapist's discretion to reduce the later target levels to 25% if participants exhibited difficulty with maintaining a 30% target level.

Control Group

Participants in the standard care control group underwent monthly MCTS assessments as participants in the intervention groups but did not conduct daily CTAR-SwiFt exercises. No other dysphagia rehabilitation was offered, as this is not part of standard care when there is no identified clinical problem.

Follow-Up

All participants were followed up for a total of 24 weeks (12 weeks intervention and 12 weeks postintervention). The primary aim of the study was to assess the feasibility of recruiting and retaining participants, compliance with the exercise program, and the safety and acceptability of the ExerPhager to study participants. Clinical swallowing data and quality of life parameters were also collected, but the study was not powered to identify any significant changes between groups.

On completion of the study, qualitative feedback was obtained using a semistructured interview to determine key issues of concern with respect to the running of the study. These were transcribed verbatim. Interview data were analyzed by a postdoctoral speech and language therapist researcher in the software NVivo 12 Pro (QSR International) using a basic thematic analysis [38]. Participants were also invited to complete a survey with closed and open questions on the ease of use of the ExerPhager. Poststudy interviews were conducted with 4 participants.

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Videofluoroscopy

A subgroup of patients were to undergo videofluoroscopy (VF) examination at or soon after study commencement and at week 12. The purpose was to review the effect of CTAR on the physiological movement of the base of the tongue, posterior pharyngeal wall, and laryngeal movement. VF was the chosen modality as it was considered to be the best modality for looking at the function and physiology concurrently. VF was readily available whereas Fiberoptic Endoscopic Evaluation of Swallowing (FEES) was not. We were not using VF as part of a routine clinical assessment.

Assessments

To assess whether a subsequent large-scale randomized controlled trial would be possible, the following parameters were used: 70% recruitment of total eligible candidates, rate of recruitment (per month), attrition rate <30%, and 85% compliance with the exercise program.

We assessed the following outcomes using the listed tools [37]:

- Food intake (FOIS)
- Quality of life (SWAL-QOL and EQ-5D-3L [EuroQol 5-Dimension 3-Level])
- Swallow speed (Timed Water Swallow Test [TWST])
- Swallow screen (EAT-10 and 4QT)
- Standardized swallow assessment delivered by a speech and language therapist trained in dysphagia assessment
- Ease of use and acceptability of the intervention (including the CTAR-SwiFt feedback ball)
- Participants' willingness and ability to undergo VF
- Optimum dose of CTAR-SwiFt training (daily vs twice daily frequency)

Statistical Analysis

Sample Size Justification

This was a feasibility study and as such it was not powered to detect a statistically significant intervention effect. Sixty participants were to be recruited, which was considered to be adequate to identify the possibility of progressing to a larger definitive study. This is a generally recommended sample size for feasibility studies [39]. The objective measures, process mapping, and qualitative data collected were to be used to aid in that decision. Recruitment rate, retention, and attrition are simple percentages of those recruited. The feasibility criteria (willingness to be recruited to the study, study retention [<30% dropout], compliance [80%; daily percentage of exercises undertaken averaged over the intervention period], absence of adverse incidents and acceptability of intervention) were to be used to establish whether it is feasible to progress to a larger-scale multicenter randomized controlled trial.

Analysis

On the completion of the study, the data were cleaned and analyzed. Recruitment rate was estimated accounting for the differences in start-up times for sites by calculating the average of site-specific recruitment periods. The average recruitment rate per month was then calculated as the total number of patients recruited, divided by the number of sites, and then divided by the average number of months recruiting. Willingness and attrition (completion) were calculated as percentages. All calculated percentages were reported with their corresponding 95% CI. All demographic and baseline participants' characteristics were described overall and by treatment arm when planned. Continuous variables were presented as mean and SD, median, IQR, and range, as appropriate for these distributions. Categorical variables were summarized by frequency counts and percentages for the subgroups of interest. No formal statistical test was performed as the study was not powered to identify any significant differences between the groups. Missing data were reported and excluded from the data summarization. All analyses were performed using Stata (version 16.0; StataCorp LLC).

Ethical Considerations

The study protocol was reviewed and approved by the Northwest – Greater Manchester West Research Ethics Committee (ref: 20/NW/0009). Approval was granted on March 3, 2020. All participants provided informed consent. No participants were provided with any remuneration or compensation of any kind (financial or otherwise). At the commencement of the study, all participants were provided with a trial number and all data were stored under this. A separate file was kept and stored securely to prevent the ability to link a particular participant with a particular data file.

Results

Primary Outcomes

Two hundred and thirty-one people were screened as potential participants. After screening, 156 were assessed as not meeting the inclusion criteria and 75 were considered to be eligible. However, 9 failed further screening or were discharged before being approached, and 42 declined to take part in the study. Twenty-four patients consented to take part in the study. Two no longer met the criteria prior to randomization and a third became unwell. Consequently, only 21 were randomized equally between standard clinical care and once-daily or twice-daily CTAR-SwiFt exercises (Figure 1). This represents 35% of the initial recruitment target (21/60). Mean age was 85.8 (SD 6.0) years, and the median (range) clinical frailty score was 5 (4-7; Table 1).

Recruitment was slower than anticipated, at 0.91 participants per month (95% CI 0.59-1.0). Recruitment was hindered by the delay in commencing the study secondary to the COVID-19 pandemic, movement of staff, and illness severity following the first wave of COVID-19.

Seventy-five people were approached; only 24 (32%) agreed to take part in the study (51 declined for various reasons). The main categories of why people declined to participate were: feeling unwell (n=10) and not interested (n=13). Twenty-one were randomized (21/24, 87.5%, 95% CI 67.6-97.3).

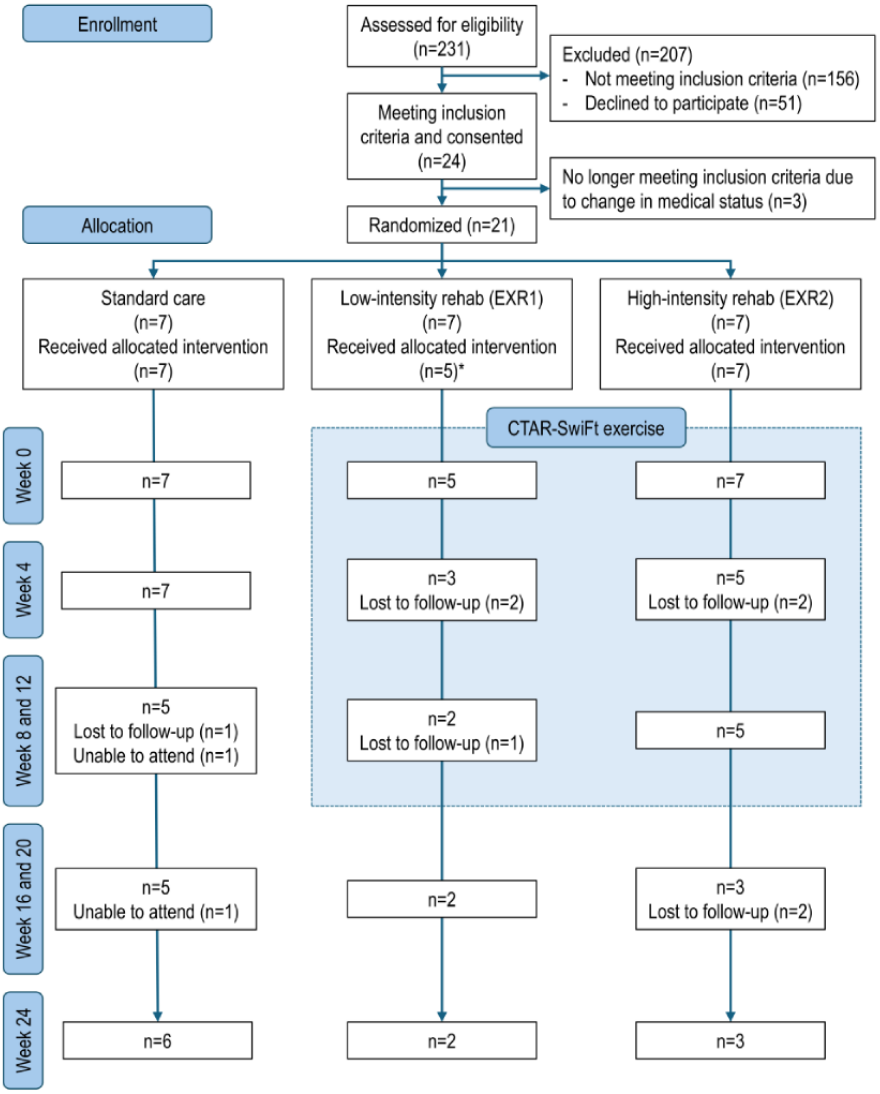
Eleven participants (52.3%, 95% CI 29.8-74.3) completed the study. Out of 10 participants lost to follow-up, 2 failed to start the study after being randomized to the low-intensity arm of the study, 6 withdrew from the study for various medical reasons, 1 lost contact, and 1 died. Four people undertook structured interviews at the end of the study. The lack of

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face-to-face contact and support during the study was highlighted as a concern. There were issues with the power source of the tablet (battery power), which hindered compliance for some. It was difficult to interpret measurement variability due to the number of patients recruited and the number completing the study.

The results for swallowing-related outcomes and quality of life are documented in Tables S1-S5 in Multimedia Appendix 2.

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flow diagram [40]. *Two participants were randomized to low-intensity rehabilitation intervention but did not start the intervention: one of these participants requested it as she felt "too elderly" and "doesn't want to use the materials involved." The other participant no longer met criteria (change in medical status) when we went to start the intervention. No quantitative outcome data were collected at baseline for these 2 participants.



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Table 1. Baseline characteristics of the study sample.

Characteristic	Overall (n=21)	Standard care (n=7)	Low-intensity rehabilitation (EXR1; n=7)	High-intensity rehabilitation (EXR2; n=7)
Sex, n (%)				
Female	12 (57.1)	1 (14.3)	5 (71.4)	6 (85.7)
Male	9 (42.9)	6 (85.7)	2 (28.6)	1 (14.3)
Age (years)				
Mean (SD)	85.8 (6.0)	85.6 (2.8)	85.4 (8.0)	86.3 (6.9)
Median (min-max)	85.0 (75.0-97.0)	86.0 (80.0-89.0)	83.0 (75.0-97.0)	85.0 (78.0-96.0)
Frailty score				
Mean (SD)	5.0 (0.9)	4.9 (0.7)	5.0 (1.0)	5.3 (1.0)
Median (min-max)	5.0 (4.0-7.0)	5.0 (4.0-6.0)	5.0 (4.0-7.0)	6.0 (4.0-6.0)

Data From the ExerPhager

It was not possible to determine MCTS in all patients at all planned assessment time points during the intervention. This was mainly due to technical difficulties relating to the prototype ExerPhager, especially its Bluetooth connectivity to the patient's smartphone or tablet. It was also due to weekly fluctuations in patients' wellness during the COVID pandemic.

It was possible to calculate the mean MCTS in 7 patients before and after the intervention (male = 1, female = 6, mean age 88.3, SD 6.5 years). The mean (SD) MCTS increased by 0.8 (0.9) kgf from 3.8 (2.2) kgf at baseline to 4.6 (2.4) kgf after the 12-week intervention (Figure 2). It was not possible to carry out our intended subanalysis of data from the groups who performed CTAR once versus twice per day in relation to MCTS changes.

The real-time feedback of force exerted on the ExerPhager ball during CTAR exercise (3 × 1-minute exercise periods, with 1 minute of rest in between) allowed us to observe the differences between the target CTAR force and that achieved by patients. As described previously, patients were encouraged to achieve a CTAR force that matched as closely as possible the target CTAR force. The extent to which the patient matched the target was displayed in the app on the patient's smartphone or tablet. Each patient's target was derived from their MCTS and calculated as 30% of MCTS.

Patients were able to match their target during the CTAR exercise to within a mean error margin of ±22% (SD 8%) at the beginning of the intervention (first exercise session). At the end of the intervention, the error margin was narrowed to a mean of ±16% (SD 3.3%), suggesting an improvement in the patients' ability to control force exerted by the chin and neck muscles during CTAR exercise (Figure 3).

For the embedded study of repeated VF with a subgroup of the sample, we were able to recruit 2 participants. Because the study commenced following the first COVID-19 wave, we were unable to ask participants to return to the hospital for either the first or second VF study.

The overall responses to the study were positive. No participants expressed negative views about the study. Participants found the device easy to use, but some difficulties were experienced in being able to read the instructions on the tablet (app) due to the font being too small. Participants would have preferred more face-to-face contact, which had been part of the protocol but was limited as a consequence of COVID-19.

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Figure 2. Maximum chin tuck strength at week 0 and week 12 in both intervention groups combined (n=7). Shown are mean (×), median (-), IQR (box), and range (whiskers).

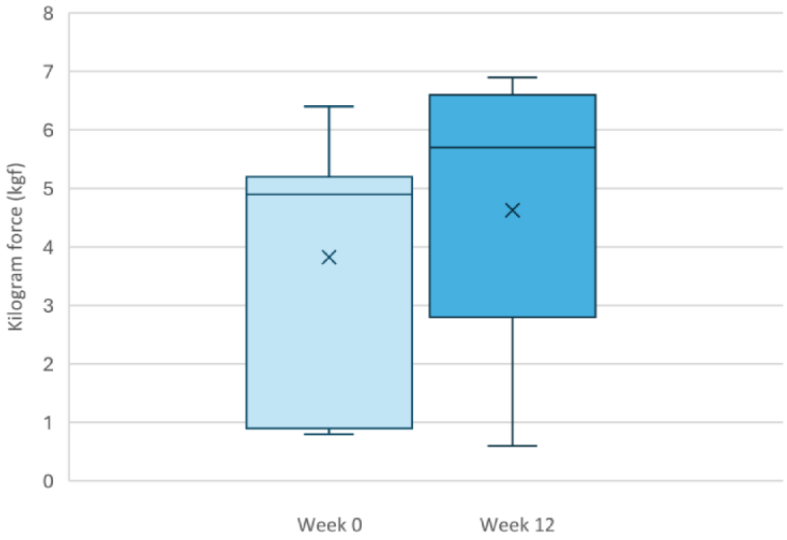
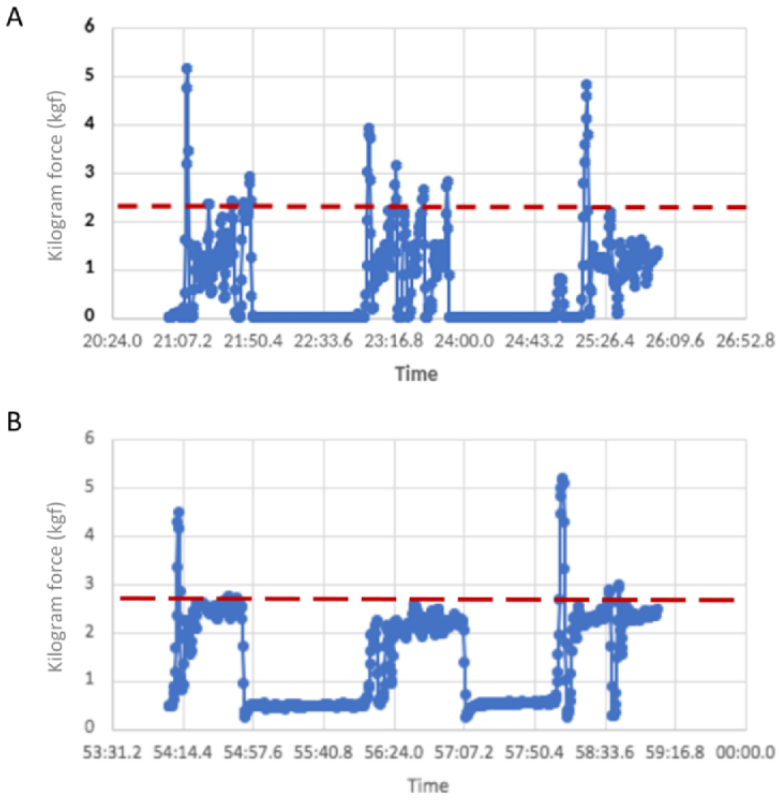


Figure 3. Graphical representation of the ability to maintain chin tuck against resistance (CTAR) target force at baseline (A) and at 12 weeks (B). The difference between the two figures demonstrates a more consistent application of pressure (ball squeeze) occurring at 12 weeks.



Adverse Events

Fifteen adverse events were reported in 13 participants. Out of those, 9 were reported as serious adverse events. Two events related to swallowing occurred but were not secondary to the study intervention or the use of the ExerPhager (Table 2).

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Table 2. Adverse events affecting participants in all groups.

Category and event type	Value, n
Adverse events	
COVID-19	2
Fall	1
Sore throat	1
Urinary tract infection	1
Vison impairment	1
Serious adverse events	
Breast cancer	1
Death	1
Hip dislocation	1
Multiorgan failure	1
Parapneumonic effusion	1
Periprosthetic hip fracture and deep vein thrombosis	1
Possible aspiration or choking	2
Rectal bleeding	1

Discussion

Principal Findings

As people age, there are changes to muscles involved in swallowing, and although the swallow remains safe, the timing between various phases becomes more critical [41]. As a consequence, any mistiming will increase the risk of aspirating saliva or food particles. In normal, robust individuals, this would have no ill effects, but in frail older adults, due to ineffective mechanical airway clearance, inflammation, and poor lung and systemic immunity, pneumonia is more likely to occur [42].

Aspiration of saliva has been suggested to be a major factor in the development of pneumonia in many older adults [3]. Momosaki [43] suggested that swallowing rehabilitation after pneumonia would improve swallowing, improve nutrition, and thus reduce pneumonia incidence and hospital admission. Rehabilitation exercise programs that include resistance training have demonstrated an improved FOIS, reduced incidence of pneumonia, and reduced hospital admissions [31,34,35,44-46].

Kraaijenga et al [46] recruited 10 healthy volunteers and following CTAR and jaw opening against resistance exercises 3 times a day for 6 weeks, found an increase in strength in muscle groups used for swallowing [46]. Park et al [36] compared game-based CTAR to head lift exercises. Those undertaking CTAR pressed their chin against a resistance bar. Maximum pressure was recorded on a computer screen. A total of 70% of the maximum pressure was calculated, and this was set as the target during exercise. This was conducted for 4 weeks and 5 times a week. There was no difference in the FOIS and Penetration Aspiration Scale (PAS) score between the two groups, but those using CTAR had more fun.

Our study has demonstrated that participants are able to undertake a period of rehabilitation training using CTAR with real-time feedback. The study was not able to demonstrate any clinical outcome, as it was not powered to do so. The limited results did show that participants were able to improve and maintain the consistency of “ball squeeze” during a period of resistance training. Jensen et al [35] recruited a mixed cohort of 92 citizens in Denmark, randomized between standardized care and standardized care plus CTAR. All had evidence of oropharyngeal dysphagia on assessment. Those randomized to CTAR were supported by an occupational therapist twice a week. There was a trend toward a better outcome in the CTAR group, but this was not significant. When the CTAR training stopped, any increased recovery ceased. Kim and Park [47] randomized 30 patients with stroke to traditional dysphagia therapy with or without CTAR (chin press against a resistance bar). The group with CTAR improved swallowing safety, food intake (FOIS $P<.001$), and swallow safety (PAS $P<.001$). Liu et al [48] randomized community-dwelling adults with age-related dysphagia to flexibility and progressive CTAR exercise. Those in the progressive CTAR group demonstrated an improvement in their swallow and swallowing-related quality of life but no change in the number of swallows or chews. A systematic review (9 studies) and meta-analysis (8 studies) [49] reported that CTAR was superior to the Shaker maneuver for improved swallow safety and increased oral intake but that there was no change in FOIS. All protocols have the same problem in that there is no means of ensuring consistency of effect; therefore, the final efforts of chin tuck may be less effective than the first.

We were able to recruit 24 (32%) of those approached; only 21 people were randomized and 11 (52%) completed the study. The reasons for failing to complete were due to illness or device failure rather than adverse events. The results suggest that a larger multicenter study with a similar protocol would be feasible. However, participation may be facilitated by recruiting in the recovery phase of pneumonia, probably after hospital discharge.

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Previous studies all recruited people with a pathological swallow, predominantly secondary to stroke [34,44]. The purpose of our study was to recruit older adults without a history of dysphagia who had been admitted with pneumonia rather than a neurological condition. This was the first study to do this for a CTAR intervention. Our study had a feedback element similar to that of Park et al [36], and our protocol prescribed 1 or 2 episodes of exercise daily for 12 weeks as opposed to 5 times a week. We had planned to provide support to all groups, but this was prevented by infection control restrictions secondary to COVID-19. The results from Jensen et al [35] suggest that this would have been very useful for compliance and may have demonstrated positive outcomes. Those participating were able to use the ExerPhager, with dexterity and ease of use improving with study duration. The ExerPhager data demonstrated that participants were able to meet their target compression within a mean error margin of ±22% (SD 8%), and this had improved to ±16% (SD 3.3%) by the end of the intervention.

To the authors' knowledge, this is the first study to quantify chin tuck strength in hospital patients. Thus, there are few previous studies with which to compare chin tuck strength values. Kraaijenga et al [46] assessed chin tuck strength using a handheld dynamometer (Microfet) in older healthy men (median age 60 years, range 52-73). They reported values equivalent to a median of 8.3 kgf before their exercise intervention and 13.4 kgf after it. The patients in whom we were able to measure chin tuck strength were mostly older women (mean age 88.3, SD 6.5 years), and our chin tuck strength values changed from a mean of 3.8 (SD 2.2) kgf at baseline to 4.6 (SD 2.4) kgf after our intervention.

In relation to the improved ability to accurately maintain the target chin tuck pressure on the exercise ball during feedback-regulated CTAR, there are no previous studies that have reported this type of improvement in older hospital patients. In a recent review by Huckabee et al [50], the idea was presented that rehabilitation of the swallow might sensibly focus on muscle-strengthening, but it was also postulated that swallowing is a "skilled purposeful movement" and thus rehabilitation should also focus on "the swallowing motor plan," through increased cortical activation. It might be that feedback-regulated CTAR has the potential to contribute to this type of rehabilitation through improved control of the external swallowing musculature of the neck and jaw.

The delivery of health care is rapidly moving toward the use of apps and wearable devices. Many older frail adults will struggle because of their lack of manual dexterity, cognitive impairment, and visual impairment, coupled with a lack of access to an up-to-date smartphone or tablet. Many studies have shown that these are all barriers to older people, and overcoming these barriers will necessitate a certain degree of digital knowledge and ability as well as health literacy. In our study, it was presumed that most of those recruited would have access to a smartphone [51]. Recent studies have shown that only 61% of those more than 65 years of age have a smartphone [52]. Our study was predicated on many older adults having a smartphone. We had a contingency of providing a tablet, and the uptake was greater than expected. Lamba et al [53] found that only 25% of frail veterans were able to complete a video consultation and many did not have access to a relevant device. Despite the fact that the uptake of smartphones will be greater in the older population in future years, the issue will remain that many of the very old (>85 years) will be very frail, have cognitive impairment, visual and hearing loss, and disabilities reducing manual dexterity, suggesting that without the support of a carer or family member they will not be able to access telehealth and consequently will not be able to partake in some studies.

Limitations

Device limitations became apparent during the study. The power source was not as resilient as prestudy work suggested. As the ExerPhager was being used frequently, the battery emptied faster than anticipated. Any future study should either use a powered device or use a rechargeable battery.

The recruited cohort was frailer and sicker than the cohort in the study by Momosaki et al [26]. This limited the number of people eligible for the study. The length of stay in hospital in the United Kingdom is generally shorter than that in Japan. Participants felt that more home support would have assisted their participation, which is supported by the work of Jensen et al [35]. This was originally part of our protocol. As many of the participants did not have clinical dysphagia, they were less engaged than we would have hoped.

Conclusions

The literature supports the benefit of CTAR in improving swallowing in community-dwelling older adults. Our study recruited older adults (>75 years) who were frail and without overt neurological disease and acutely unwell. The study has demonstrated that older, frail adults are able to perform CTAR and could use the ExerPhager. Participants were randomized to 2 different doses of exercise: once or twice a day. Because there were only small numbers in each group, it is not possible to draw firm conclusions. A future study should include a pilot phase to determine which dose to use, and estimates from this study may be used to estimate future sample size for a full study. Such a study should investigate the benefits of CTAR-SwiFt in community-dwelling frail older adults after pneumonia.

Acknowledgments

We gratefully acknowledge the contribution to this study of Mr. William Oliff who developed the Exerphager smartphone application.

Funding

This study was funded by the UK National Institute for Health and Care Research (NIHR) Research for Patient Benefit (RfPB) Program (grant number PB-PG-1217-20005). SA was supported by the NIHR Biomedical Research Centre based at Guy's and

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St Thomas' NHS Foundation Trust and King's College London. The views expressed are those of the authors and not necessarily those of the National Health Service (NHS), the NIHR or the Department of Health and Social Care.

Data Availability

We have provided details of data as summary tables presented in the main manuscript and in the supplementary material. We do not have patients' consent to allow datasets to be deposited in publicly available repositories. The datasets generated or analyzed during this study are available from the corresponding author on reasonable request.

Generative AI Use

Generative AI tools were not used at any stage in the preparation of this manuscript.

Authors' Contributions

Conceptualization: DGS, IS, SA, A Gambaruto, DH, STK, EL-D
Funding acquisition: DGS, IS, SA, A Gambaruto, DH, STK, EL-D
Formal analysis: SA, A Gambaruto, A Goubar, AS-G, LM
Investigation: DGS, IS, AS-G, LM
Methodology: DGS, IS, SA, A Gambaruto, DH, STK, EL-D
Project administration: AS-G, LM
Software: STK, EL-D
Supervision: DGS, IS, DH
Writing – original draft: DGS
Writing – review & editing: DGS, IS, SA, A Gambaruto, A Goubar, AS-G, LM, DH, STK, EL-D

Conflicts of Interest

None declared.

Multimedia Appendix 1

CONSORT checklist V1.6.2.
[PDF File (Adobe PDF File), 1122 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Results for 4 Question Test, Functional Oral Intake Scale, Timed Up and Go, Eating Assessment Tool-10, EuroQol 5-Dimension 3-Level, Quality of Life in Swallowing Disorders, Clinical Swallow Assessment, and Timed Water Swallow Test.
[PDF File (Adobe PDF File), 597 KB-Multimedia Appendix 2]

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Abbreviations

4QT: 4 Question Test
CAP: community-acquired pneumonia
CONSORT: Consolidated Standards of Reporting Trials
CR-10: comfort rating scale
CTAR: chin tuck against resistance
CTAR-SwiFt: Chin Tuck Against Resistance Exercise With Feedback to Improve Swallowing, Eating, and Drinking in Frail Older People Admitted to Hospital With Pneumonia
EAT-10: Eating Assessment Tool-10
EQ-5D-3L: EuroQol 5-Dimension 3-Level
FEES: Fiberoptic Endoscopic Evaluation of Swallowing
FOIS: Functional Oral Intake Scale
MCTS: maximum chin tuck strength
OD: oropharyngeal dysphagia
OR: odds ratio
PAS: Penetration Aspiration Scale
QoL: quality of life
SWAL-QOL: Quality of Life in Swallowing Disorders
TWST: Timed Water Swallow Test
VF: videofluoroscopy

Edited by J Sarvestan; submitted 16.Jun.2025; peer-reviewed by S Javorszky; comments to author 20.Nov.2025; revised version received 13.Mar.2026; accepted 16.Mar.2026; published 13.Nov.2026

Please cite as:
Smithard DG, Swaine I, Ayis S, Goubar A, Gambaruto A, Stone-Ghariani A, Morgan L, Hansjee D, Kulnik ST, Lloyd-Dehler E
Chin Tuck Against Resistance Exercise With Feedback to Improve Swallowing, Eating, and Drinking in Frail Older People Admitted to Hospital With Pneumonia (CTAR-SwiFt): Randomized Controlled Feasibility Study
JMIR Form Res 2026;10:e79146
URL: https://formative.jmir.org/2026/1/e79146
doi: 10.2196/79146
PMID:

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