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ORIGINAL RESEARCH

# Effect of Inspiratory Muscle Training on Cough Strength in Older People With Frailty: A Single-Blind Randomized Controlled Trial

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**Abstract**

**Objective:** To investigate the effect of inspiratory muscle training (IMT) on cough strength in older people with frailty.

**Design:** Single-blind randomized controlled trial.

**Setting:** Day health care centers at 2 sites.

**Participants:** Older people with frailty (N=60).

**Interventions:** Eligible people were randomly assigned to receive IMT program in addition to general exercise training (IMT group), or general exercise training alone (control group). The IMT group performed training using a threshold IMT device with the load set at 30% of maximum inspiratory mouth pressure in addition to the general exercise training program throughout the 8 weeks. The IMT took place twice a day and each session consisted of 30 breaths.

**Main Outcome Measures:** Primary outcome was cough strength, measured as the cough peak flow (CPF), at the beginning and the end of the program.

**Results:** Data from 52 participants (26 in each group) were available for the analysis. The mean age was 82.6 years; 33% were men. The change in CPF at the end of the program was 28.7±44.4 L/min in the IMT group and −7.4±26.6 L/min in the control group. A linear regression model showed that the presence or absence of IMT was associated with changes in CPF (mean difference between groups, 36.3; 95% confidence interval, 16.7-55.9; effect size, 0.99).

**Conclusions:** IMT may be a useful intervention to improve cough strength in frail older people.

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Pneumonia is a major cause of death worldwide, with higher morbidity and mortality in people aged >70 years.[1] The reporting of respiratory symptoms is less common in older people thus detection of pneumonia is often delayed,[2] and the pneumonia tends to be more severe. In addition, pneumonia in older individuals is important because it is associated with a high risk of readmission due to recurrence[3] and reduced activities of daily living (ADL) during hospitalization.[4] In addition, aspiration pneumonia accounts for 80% of pneumonia in older people.[5] Prevention of pneumonia is especially important for older people with frailty, who are at greater risk of developing pneumonia and are more likely to become severely ill.[6]

Factors that contribute to the development of pneumonia in older people include immune system compromise as well as dehydration, dementia, swallowing impairment, and age-related decline in mucociliary clearance.[7] Among these, adequate cough strength, required for the expectoration of sputum, is one predictor of the onset of pneumonia[8] and can be evaluated by cough peak

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flow (CPF).[9,10] The cough is a complex forced expiratory maneuver, that can be considered in 4 phases: receptorial, inspiratory (maximal inspiration), compressive (increased intrapulmonary pressure), and expiratory (explosive expiration).[11] Respiratory muscle strength, glottal closure, lung function, age, and functional capacity are the factors that determine cough strength, with respiratory muscle strength playing the most important role.[12] Respiratory muscle strength declines with age,[13] and the decline is more rapid in older people with frailty.[14] Therefore, in older people who may be frail, strategies to strengthen the respiratory muscles may improve CPF and have a positive effect on the prevention of pneumonia.

In previous studies pertaining to the effect of training on CPF, expiratory muscle training was often undertaken using an expiratory threshold loading device, and achieved an improvement in CPF even in frail older people.[15,16] However, in older people, factors related to the inspiratory phase, such as inspiratory muscle strength and lung volume are independent contributors to CPF.[17] Therefore, interventions to improve these may lead to enhanced CPF. One such intervention is inspiratory muscle training (IMT), using an inspiratory threshold loading device. The use of IMT in older people with frailty improves inspiratory and expiratory muscle strength and increases diaphragm thickness and motility.[18] The CPF has also been reported to be associated with diaphragm mobility.[19] Based on previous studies,[17-19] it was hypothesized that IMT would improve CPF in older people with frailty. However, there have been no reports of IMT, using inspiratory threshold loading devices, on CPF in this population. Therefore, the aim of this study was to investigate whether IMT improves CPF in older people with frailty.

# Methods

## Trial design

This study was a single-blind randomized controlled trial at 2 sites in Japan. The trial was registered in the clinical trial registry database (University Hospital Medical Information Network). The registry number is UMIN000036924. This trial is reported according to the Consolidated Standards of Reporting Trials statement.[20]

## Participants

Clinically stable community dwelling older people who attended day health care centers at Tagami Hospital and Keijuen special nursing home participated in the study between August 2019 and December 2021. Individuals aged >65 years, who met the criteria for the definition of prefrail or frail as determined by the Japanese version of Cardiovascular Health Study criteria[21] were eligible for this study. Exclusion criteria comprised (1) inability to understand instructions and/or complete assessments owing to cognitive impairment or neurologic disorders, (2) inability to produce a voluntary cough, (3) inability to walk independently, or (4) history of pneumothorax, advanced cancer, or an exacerbation of any existing medical condition within the last 4 weeks. The study was approved by the Human Ethics Review Committee of the study institution (approved number 19021401). Written informed consent was obtained prior to participation in the trial.

***List of abbreviations:***

| | |
|---|---|
| **ADL** | **activities of daily living** |
| **CPF** | **cough peak flow** |
| **IMT** | **inspiratory muscle training** |
| **ITT** | **intention-to-treat** |
| **PEmax** | **maximum expiratory mouth pressure** |
| **PImax** | **maximum inspiratory mouth pressure** |
| **SPPB** | **short physical performance battery** |

## Interventions

The intervention and control groups performed an identical general exercise training program for a duration of 8 weeks, with at least 1 supervised session each week. Interventions were individualized by the physical therapists at each facility. Each session lasted for 60 minutes and comprised lower limb strength and endurance training, and exercises aimed at improving the ability to undertake basic ADL (eg, toileting, bathing). Training intensity was set at a rating of perceived exertion of 11-13 (Borg scale).[22]

Participants in the intervention group performed IMT using a threshold IMT device[a] in addition to the general exercise training program throughout the 8 weeks. The initial training load was set at 30% of maximum inspiratory mouth pressure (PImax) and training intensity was increased based on a reassessment of PImax at 4 weeks after the start of training. The IMT took place daily and a participant was considered to be compliant with the training protocol if they trained on at least 3 days of the week. Each session consisted of 30 consecutive breaths twice a day (≥24 sessions, up to 56 sessions). The IMT was performed in the sitting position. Participants received verbal instruction in the technique for IMT and the first session was supervised by a physiotherapist. Subsequent training was unsupervised with the exception of 1 session each week, which was supervised by the physiotherapist.

Participants completed a training log and recorded any adverse events (dyspnea, palpitations, dizziness, other symptoms) in the diary provided.

## Outcome measurements

The primary outcome was cough strength, measured as the CPF, at the end of the 8-week training period. In this study, the secondary outcomes were lung function, respiratory muscle strength, swallowing function, physical function, and functional status. The assessment of outcome measures was conducted by physical therapists who were not involved in prescription or supervision of the IMT. The physical therapists were trained to assess swallowing function and were blind to group allocation.

### Cough peak flow

The primary outcome was CPF as a measure of cough strength, and a proxy indicator of airway clearance ability.[10] The CPF was measured according to a published protocol[23] using a face mask that was attached to a spirometer.[b] The measurement was performed in a sitting position, and the individual was instructed to take maximum inspiration followed by a voluntary cough. The measurement was performed 3 times and the maximum value was used in the analyses.

### Lung function

Forced vital capacity and forced expiratory volume in 1 second were measured using a spirometer,[b] and the results were compared to predicted values obtained from published reference equations.[24-27]

### Respiratory muscle strength

The PImax and maximum expiratory mouth pressure (PEmax) were assessed using a mouth occlusion pressure meter connected to a spirometer[b] in accordance with published guidelines.[23] Participants performed the maneuvers at least 3 times or until consecutive measures varied by <20%.[23] The highest value of PImax and PEmax was used in the analyses. Predicted values were taken from a reference equation derived in a Japanese sample.[13]

### Swallowing function

This was assessed using the repetitive salvia swallowing test[28] and measurement of tongue pressure.[29] The repetitive salvia swallowing test counts the number of times that saliva is swallowed over 30 seconds. After moistening the oral cavity with a small amount of water, the individual repeatedly swallows as many times as possible in 30 seconds. The test result is positive if the number of swallows is <3 in the 30 seconds, indicating dysphagia is suspected.[28] Tongue pressure was measured using a tongue pressure measuring device comprising a balloon-type disposable probe.[c] The probe was inflated with air to an initial pressure of 19.6 kPa. This pressure was taken as the standard and measurement was performed after zero calibration. Measurements were recorded with the participants seated, and the balloon was placed in their mouths with the participants asked to hold the plastic pipe at the midpoint of their central incisors with closed lips. They were then asked to raise the tongue and compress the small balloon onto the palate for approximately 7 seconds with maximum effort, and the value was recorded. The measurement was repeated 3 times interspersed with a rest period of 30 seconds. The mean value of the 3 measurements was used in the analysis.[29]

### Physical function

Handgrip strength and lower extremity function were assessed as measures of physical function. Hand grip strength was measured with a digital grip strength dynamometer[d] on both hands, and the maximum value obtained from 2 attempts on each side was used. Lower extremity function was assessed using the short physical performance battery (SPPB).[30] The SPPB comprises 4-m gait speed, chair stands, and standing balance. The total score ranges from 0 to 12 with higher scores indicating better performance.[30]

### Functional status

The Barthel index was used to assess ADL performance.[31] This evaluates 10 common ADL with a maximum possible score of 100 points.

## Randomization

Randomization was performed using the Internet Data and Information System for Clinical and Epidemiological Research (Cloud version) provided by the University Hospital Medical Information Network. Individuals were randomly assigned in a 1:1 ratio to receive either IMT with general exercise training (IMT group) or exercise training alone (control group). Randomization was undertaken using a stratified block method, and the allocation factors were the presence or absence of respiratory disease (as diagnosed by a physician and based on information recorded in the medical notes) and the trial site.

## Sample size calculation

Calculations were based on data from a study in which IMT lasting 8 weeks was undertaken by people with neuromuscular disease.[32] In that study, CPF (the primary outcome in the present study) improved by 42±39 L/min (mean ± SD) in those assigned to IMT vs 17± 20 L/min in the control group. Using these data, the sample size required was 25 participants per group (based on a power of 80%, significance level of 5%, and Welch's *t* test). The sample was inflated to 30 per group to allow for a withdrawal rate of 20%.

## Statistical analysis

Descriptive data were expressed as means ± SD for continuous variables and numbers (percentages).

In the primary analysis, the intention-to-treat (ITT) effect of the primary outcome was estimated using a modified ITT population. The modified ITT population excluded participants in the IMT group who undertook training for <3 d/wk and participants in both groups who did not complete all the outcome measures. The effect of the intervention on the primary outcome was assessed with a linear regression model, with the objective variable being the change in the primary outcome, and the explanatory variables being the presence or absence of intervention, coexisting respiratory disease, site of implementation, and initial values of the primary outcome. The effect size was determined using Cohen's d for the difference between groups of the primary outcome.

However, since there were only 2 evaluation time points and the outcome was the magnitude of change, cases with missing final time points were excluded and equal to the per-protocol set. Therefore, the per-protocol effect was also estimated, using the inverse probability of censoring weighting.[33] To estimate the per-protocol effect, a logistic regression model was conducted with the presence or absence of lost to follow-up as the objective outcome and variables that may be associated with lost to follow-up as explanatory variables, and a predicted probability of lost to follow-up was calculated. Then, the inverse of the predicted probability was calculated and weighted, and the effect was estimated using generalized estimating equations in which the objective variable was the change in each outcome and the explanatory variable included the presence or absence of intervention, coexisting respiratory disease, site of implementation, and initial outcomes of each outcome. The same statistical analysis was used for the secondary outcomes.

Statistical analyses were performed using R statistical software version 4.2.2,[e] with significance set at 5%.

# Results

## Individual characteristics

Two-hundred and nineteen older people were screened for eligibility. Sixty individuals met the inclusion criteria and were randomly assigned to the IMT group (30 participants) or control group (30 participants) (fig 1). During the study period, 4 participants from each group were lost to follow-up leaving data from 52 participants (26 in each group) for the analyses.

Baseline characteristics of the participants are shown in table 1. Twenty-nine (55.8%) and 23 (44.2%) participants met the Japanese version of Cardiovascular Health Study criteria for prefrail and frail, respectively. The mean age was 82.6±5.9 years, 17

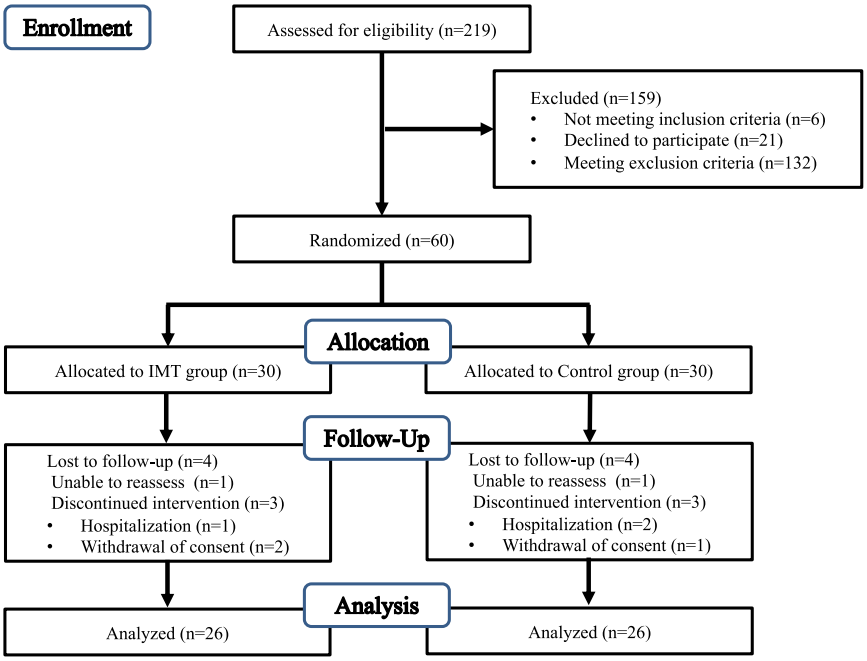


**Fig 1** Consolidated Standards of Reporting Trials flow diagram: number of participants from enrollment to analysis.

**Table 1** Baseline characteristics of the IMT and control group.

| Variable | IMT Group (n=26) | Control Group (n=26) |
|---|---|---|
| Age (y) | 81.9±5.9 | 83.3±6.1 |
| Sex, male (%) | 7 (27) | 10 (39) |
| BMI (kg/m$^2$) | 23.2±2.9 | 23.5±3.2 |
| J-CHS | | |
| Prefrail | 11 (42) | 18 (69) |
| Frail | 15 (58) | 8 (31) |
| Comorbidity | | |
| Cerebrovascular | 6 (23) | 5 (19) |
| Neuromuscular | 4 (15) | 4 (15) |
| Musculoskeletal | 19 (73) | 19 (73) |
| Cardiovascular | 9 (35) | 21 (81) |
| Metabolic | 7 (27) | 4 (15) |
| Respiratory | 5 (19) | 6 (23) |
| MMSE (score, 0-30) | 26.7±2.3 | 28.1±2.8 |
| CPF (L/min) | 250±57 | 245±88 |
| $FEV_1$ (L) | 1.45±0.50 | 1.36±0.45 |
| $FEV_1$ % pred (%) | 89±22 | 84±25 |
| FVC (L) | 1.96±0.71 | 1.79±0.52 |
| FVC % pred (%) | 90±19 | 82±18 |
| $FEV_1$/FVC (%) | 75±8 | 76±12 |
| PImax ($cmH_20$) | 39.0±17.0 | 42.4±24.4 |
| PImax % pred (%) | 85±42 | 87±41 |
| PEmax ($cmH_20$) | 49.9±19.0 | 55.0±29.5 |
| PEmax % pred (%) | 77±35 | 77±30 |
| RSST | 3.3±1.0 | 2.9±1.0 |
| Tongue pressure (kPa) | 29.3±9.9 | 31.3±7.3 |
| SPPB (score, 0-12) | 7.7±3.1 | 7.4±3.1 |
| Grip strength (kg) | 20.0±6.8 | 21.3±8.0 |
| Barthel Index (score, 0-100) | 95.1±6.6 | 91.4±11.0 |

NOTE. Data are presented as mean ± SD or n (%).
Abbreviations: BMI, body mass index; $FEV_1$, forced expiratory volume in 1 second; FVC, forced vital capacity; J-CHS, Japanese version of Cardiovascular Health Study criteria; MMSE, mini-mental state examination; pred, prediction; RSST, repetitive salvia swallowing test.

(32.7%) were men, and 11 (21.2%) had respiratory disease. The frequency of the general exercise training program was not different between the IMT group (2.5±0.9 times/wk) and the control group (2.4±0.9 times/wk).

### Adherence to IMT

In the IMT group, the mean number of training sessions was 49 (87.3%) out of a possible 56. The PImax assessed at week 4 of training showed an increase of 4.1±5.6 $cmH_2O$ (10.5%). No adverse events were reported during IMT.

### Changes in primary outcome

The change in CPF at the end of the program was 28.7± 44.4 L/min in the IMT group and 7.4±26.6 L/min in the control group. A linear regression model showed that the presence or absence of IMT was associated with changes in CPF (mean difference between groups, 36.3 L/min; 95% confidence interval, 16.7-55.9; effect size, 0.99) (table 2; fig 2). Similar results were obtained in the per-protocol effect using inverse probability of censoring weighting (table 3).

### Changes in secondary outcomes

At the end of training, the IMT group showed a significant change in the PImax, PEmax, tongue pressure, and SPPB (table 2). In addition, these outcomes in both the ITT effect and the per-protocol effect revealed that the presence or absence of IMT was associated with changes (tables 2 and 3).

## Discussion

To the authors' knowledge, this is the first randomized controlled trial to investigate the effect of 8 weeks of IMT, combined with general exercise training on cough strength in prefrail and frail older people. It was demonstrated that IMT led to significant improvement in CPF, PImax, PEmax, tongue pressure, and SPPB.

The IMT improved CPF but not lung capacity. The IMT in older people does not improve lung volume but improves inspiratory and expiratory muscle strength and diaphragm mobility.[18,34] Therefore, it is possible that not only the inspiratory phase but also other phases of cough were improved. In contrast to the findings of the present study, it has been reported that IMT undertaken by older people did not improve CPF.[35] This disparity may be because the participants in the earlier study[35] were not frail and had a high baseline CPF. Further, differences in study design include the shorter duration of training (4 vs 8wk), the lack of any supervised IMT sessions during the intervention period, and the lower completion rate (67% vs 87%).

It should be noted that the measurement of CPF may vary depending on the method used and the measurement devices.[23,36] Therefore, it is necessary to be aware of this point when referring to the results of this study, which uses absolute values.

In addition, improvement in PEmax was observed along with improvement in PImax. A meta-analysis[37] reported that IMT in older people is an effective strategy for improving inspiratory muscle strength. It has also been reported that IMT undertaken by older individuals improves not only inspiratory but also expiratory muscle strength,[18] with the increase in expiratory muscle strength being attributed to expiratory effort due to repetitive breathing

**Table 2** Modified ITT effects of IMT on CPF, respiratory function, swallowing function, and physical function.

| Outcomes | IMT Group Mean Change (95% CI) | Control Group Mean Change (95% CI) | Between-Group Difference (95% CI) | *P* Value | Effect Size (Cohen's d) |
|---|---|---|---|---|---|
| Primary outcome | | | | | |
| CPF (L/min) | 28.7±44.4 (10.7 to 46.6) | −7.4±26.6 (−18.2 to 3.3) | 36.3 (16.7 to 55.9) | <.001 | 0.99 |
| Secondary outcomes | | | | | |
| $FEV_1$ (L) | 0.05±0.15 (−0.01 to 0.11) | −0.01±0.1 (−0.05 to 0.03) | 0.06 (−0.003 to 0.13) | .06 | 0.48 |
| FVC (L) | 0.05±0.18 (−0.02 to 0.12) | 0.06±0.18 (−0.01 to 0.13) | −0.01 (−0.11 to 0.09) | .80 | −0.07 |
| PImax ($cmH_20$) | 9.7±11.9 (4.9 to 14.5) | −0.4±6.5 (−3.0 to 2.2) | 10.1 (4.6 to 15.6) | <.001 | 1.06 |
| PEmax ($cmH_20$) | 8.8±10.2 (4.7 to 12.9) | 0.9±12.4 (−4.1 to 5.9) | 7.9 (1.7 to 14.2) | .01 | 0.70 |
| RSST | 0.3±0.6 (0.06 to 0.6) | 0.1±0.5 (−0.1 to 0.3) | 0.3 (−0.1 to 0.6) | .13 | 0.42 |
| Tongue pressure (kPa) | 3.1±3.7 (1.6 to 4.6) | −0.59±3.2 (−1.9 to 0.7) | 3.6 (1.7 to 5.5) | <.001 | 1.07 |
| SPPB (score, 0-12) | 0.7±1.3 (0.1 to 1.2) | −0.1±1.4 (−0.7 to 0.5) | 0.8 (0.03 to 1.5) | .04 | 0.54 |
| Grip strength (kg) | 0.3±1.4 (−0.2 to 0.9) | 0.2±1.7 (−0.5 to 0.9) | 0.1 (−0.7 to 0.9) | .84 | 0.09 |
| Barthel Index (score, 0-100) | 0.5±2.2 (−0.3 to 1.5) | 0±2 (−0.8 to 0.8) | 0.6 (−0.6 to 1.8) | .32 | 0.28 |

NOTE. Data are presented as mean ± SD. Mean between-group differences were estimated using a linear regression model (objective variable: change in each endpoint including the primary endpoint, explanatory variables: presence or absence of intervention, coexisting respiratory disease, site of implementation, and initial endpoints of each endpoint).
Abbreviations: CI, confidence interval; $FEV_1$, forced expiratory volume in 1 second; FVC, forced vital capacity; RSST, repetitive salvia swallowing test.

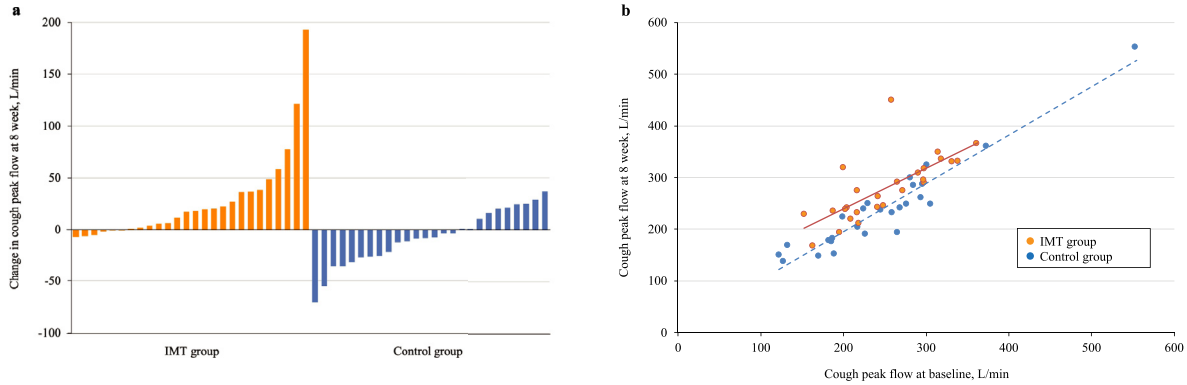


**Fig 2** Change in CPF in IMT and control groups. (**A**) Change in CPF at 8 weeks for each participant. The vertical axis shows the change in CPF after 8 weeks. The line extending upward indicates the increase, and the line extending downward indicates the degree of decrease. (**B**) Change in CPF from baseline to 8 weeks. Each point represents an individual participant. The vertical distance between the 2 regression lines represents the estimated difference between the groups from the analysis of covariance between baseline and 8 weeks later.

exercises during IMT leading to improved neuromuscular recruitment pattern.[18] Hence, in prefrail and frail older people, IMT combined with general exercise training improves both inspiratory and expiratory muscle strength.

On the other hand, the change in PImax was lower than the minimally important difference for chronic obstructive pulmonary disease reported previously.[38,39] This may be due to the older age of our participants and IMT intensity as low as 30% of PImax compared to other studies, which may account for the more modest improvement.

The use of IMT for frail older people was also found to improve tongue pressure. The effect of IMT on tongue pressure has been unclear in previous studies. Tongue pressure reflects the strength of the suprahyoid muscles, the mylohyoid muscles, and the internal tongue muscles.[40] Tongue muscles are activated during spontaneous breathing.[41] Therefore, IMT for pre-flail and frail older people may have strengthened the tongue muscles. In addition, decreased tongue pressure is associated with the risk of dysphagia.[42] In other words, IMT undertaken by prefrail and frail older people may contribute to the swallowing function.

Moreover, IMT in addition to general exercise training may improve SPPB in prefrail and frail older people. Eight weeks of IMT for older people has been shown to improve balance.[43] In this study,[43] improvement in balance may be related to changes in inspiratory muscle strength leading to changes in the phasic contraction of the diaphragm and a change in its ability to increase intra-abdominal pressure. In addition, 6 weeks of IMT for older people has been shown to improve performance on the Sit to Stand Test, an assessment of lower limb muscle strength.[44] In this study,[44] it has been stated that IMT improves respiratory muscle strength and reduces metaboreflex, thereby increasing oxygen supply to peripheral muscles during exercise and improving performance and tolerance. The SPPB is an assessment of lower extremity function, including lower limb muscle strength and balance. Therefore, it is believed that IMT in addition to general exercise training for prefrail and frail older people improves SPPB.

With aging of the population worldwide, mortality from pneumonia is expected to increase in the future.[45] The results of this study are clinically significant, as they indicate the possibility of a new intervention strategy to prevent pneumonia in older people.

## Study limitations

This study had some limitations. First, the number of study sites was small, so these results are based on a limited population whose characteristics may be biased. Therefore, a large-scale, multicenter study is needed. Second, the control group in this study did not undergo sham-IMT. However, the primary outcome,

**Table 3** Per-protocol effects of IMT on CPF, respiratory function, swallowing function, and physical function.

| Outcomes | Regression Coefficient B | 95% CI | *P* Value |
|---|---|---|---|
| CPF (L/min) | 36.3 | 18.8 to 53.8 | <.001 |
| $FEV_1$ (L) | 0.08 | −0.002 to 0.15 | .06 |
| FVC (L) | 0.0003 | −0.10 to 0.10 | .99 |
| PImax ($cmH_20$) | 10.7 | 4.9 to 16.5 | <.001 |
| PEmax ($cmH_20$) | 8.9 | 2.7 to 15.2 | .01 |
| RSST | 0.3 | −0.02 to 0.5 | .07 |
| Tongue pressure (kPa) | 3.6 | 2.0 to 5.3 | <.001 |
| SPPB (score, 0-12) | 0.8 | 0.1 to 1.4 | .02 |
| Grip strength (kg) | 0.1 | −0.7 to 0.8 | .89 |
| Barthel Index (score, 0-100) | 0.6 | −0.4 to 1.5 | .26 |

NOTE. Per-protocol effects were estimated using generalized estimating equations with inverse probability weight of loss-to-follow-up. (objective variable: change in each endpoint including the primary endpoint, explanatory variables: presence or absence of intervention, coexisting respiratory disease, site of implementation, and initial endpoints of each endpoint).
Abbreviations: CI, confidence interval; $FEV_1$, forced expiratory volume in 1 second; FVC, forced vital capacity; RSST, repetitive salvia swallowing test.

CPF, does not seem to have a significant effect on the results, as it is an objective indicator and an assessment made at maximum effort. Finally, this study only investigated changes in CPF and did not look at clinical outcomes such as the development of pneumonia.

## Conclusions

This randomized controlled trial showed that IMT may be a useful intervention to improve cough strength, respiratory muscle strength, swallowing function, and physical function in frail older people. Multicenter trials are needed to validate the present study findings and investigate the long-term effects of IMT on the development of pneumonia in this population.

## Suppliers

a. Threshold IMT; Philips Respironics, Inc.
b. Autospiro AS507; Minato Medical Science Co Ltd.
c. JMS TPM-01; JMS Co Ltd.
d. T.K.K.5401 Grip-D; Takei Scientific Instruments Co Ltd.
e. R statistical software version 4.2.2; R Project for Statistical Computing.

## Keywords

Cough peak flow; Cough strength; Frail older people; Inspiratory muscle training; Randomized controlled trial; Rehabilitation

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