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Research Article

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The Effects of Air Stacking Exercise on Pulmonary Function in Elderly Adults

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| Abstract |

PURPOSE: The aim of this study was to examine the effect of air stacking exercise on lung capacity, activities of daily living, and walking ability in elderly adults.
METHODS: A total of 27 subjects were randomly assigned to an experimental group (EG=13) or a control group (CG=14). Subjects in the experimental group participated in an active pulmonary rehabilitation program. 5 days a week for 4 weeks. The active pulmonary rehabilitation program was composed of an air stacking exercise with an oral nasal mask and manually assisted coughing. Conventional pulmonary rehabilitation exercises, such as, cough exercise, deep breathing, and abdominal muscle strengthening exercises were performed by both groups. Pulmonary function parameters, peak cough flow (PCF), and oxygen saturation were measured and the 6-minute walk test and Korean version of the modified Barthel index (K-MBI) scores were applied.
RESULTS: Significant intergroup differences were observed for forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) results after intervention ($p<.05$), and for 6 minute walk test and PCF results after intervention and at 2-week follow-up visits ($p<.05$). Post hoc test results showed significant differences in K-MBI, 6-minute walk test, and FEV1 in the experimental group after intervention ($p<.05$). FVC values were significantly higher after intervention and at 2-week follow-up visits versus pre-intervention ($p<.05$). PCF values were also significantly higher after intervention and remained significantly higher at 2-week follow-up visits ($p<.05$).
CONCLUSION: Air stacking exercise in elderly adults improves lung capacity and exercise tolerance.

Key Words: Air stacking exercise, Elderly adults, Pulmonary function

Ⅰ. Introduction

Aging is one of the highest risk factors known for most human diseases including cancer, neurodegeneration, diabetes, and metabolic syndrome (Dillin et al., 2014). During aging, respiratory function progressively declines, due to factors like loss of respiratory muscle strength (Hautmann et al., 2000; Dempsey et al., 1990). Reductions in pulmonary functions can be caused by lung tissue related factors, such as, fewer alveoli and capillaries, reduced diffusing capacity or increased residual volume (Sillanpää

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et al., 2014). On the other hand, lung capacity is related to thoracic expansion (Seo et al., 2012). However, the major factor responsible for decline in lung function with age is loss of lung elasticity, which is aggravated by increasing stiffness of the chest wall and reduced respiratory muscle strength (Dyer, 2012). Lung-level changes may further decrease exercise capacity and contribute to muscle strength and power loss. Furthermore, it has been shown muscle power is significantly associated with walking ability (Sillanpää et al., 2014).

Several studies have shown that physical activity may attenuate age-related decline in pulmonary function (Amara et al., 2001; Degens et al., 2013; Pelkonen et al., 2003). Kanitz et al. (2015) reported significant improvements in cardiorespiratory function in older adults after two training programs targeting deep water endurance and strength over a period of 12 weeks. In other studies, high- or low-intensity resistance exercises improved aerobic capacity and treadmill time to exhaustion in older adults (Vincent et al., 2002), and concurrent aerobic and resistance circuit training elicited significant improvements in cardiorespiratory fitness in older adults (Takeshima et al., 2004).

Admission to hospital is a major risk factor of functional decline and reduced health-related quality of life in older people (Haines et al., 2009; Boyd et al., 2008), and this decline is associated with illness and bed rest during hospitalization (Kortebein, 2009). It has also been shown that only a few days of bed rest or a few weeks of inactivity can reduce cardiorespiratory fitness and increase muscle atrophy (de Morton et al., 2007), and Kim et al. showed lung capacity was decreased in the supine position (Kim et al., 2011). Furthermore, cardiopulmonary disease is often associated with poor physical fitness because of the cumulative effects of illness, medication, fatigue, and bed rest (Kortebein, 2009; Murphy et al., 2011).

Pulmonary complications are often encountered when treating elderly adults, and until recently the importance of pulmonary rehabilitation for elderly adults was overlooked (Na et al., 2014).

Air stacking exercise is an inhalation assist exercise. During this exercise, a subject inhales a maximal amount of air and then a therapist passively infuses additional air into the subject's lungs. In a previous study, 4 weeks of active air stacking exercise with manually assisted coughing and functional electrical stimulation in addition to conventional pulmonary rehabilitation in patients with restrictive pulmonary disease caused by a brain lesion were found to improve pulmonary function (Na et al., 2014). In other studies undertaken to evaluate the effects of air stacking on pulmonary function and peak cough flow in patients with cervical spinal cord injury, air stacking exercise for 6 weeks significantly improved pulmonary function and peak cough flow (Jeong and Yoo, 2015). Furthermore, Kim et al. (2010) reported air stacking exercise had positive effects on cough and pulmonary function (lung volume and lung elasticity) improvements in patients with cervical cord injury.

However, studies on air stacking exercise have usually targeted the central nervous system and few studies have been conducted in elderly adults. Accordingly, we evaluated the effects of air stacking exercise and manually assisted coughing intervention on lung capacity, activities of daily living, and walking ability in elderly adults.

Ⅱ. Methods

1. Participants

This study was conducted on 27 elderly living in communities in D City, Korea. The selection criteria employed were as follows: 1) age ≥65 years; 2) no organic lung disease (pneumonia, chronic obstructive pulmonary disease), as determined by; history taking, physical examination, or chest x-ray; 3) an ability to walk independently for more than 10 m without any form of assistance; and 4) the absence of any disease that might affect testing. Candidates with visual impairment, hearing damage, nervous system or vestibular organ problems, and those unable to understand the nature of the experiment were excluded.

Twenty-seven subjects met the study criteria. Information on the study was provided to and written informed consent was obtained from all study subjects, as required by the ethical standards of the Declaration of Helsinki, prior to study commencement. After completion of the initial assessment, subjects were randomly assigned to an experimental group (n=13) or a control group (n=14).

This study was conducted as a double-blind, randomized controlled trial in which the therapist was blinded to treatment. For randomization, sealed envelopes were prepared in advance and marked inside with an A or B, indicating the experimental and control groups, respectively. This randomization was performed by a third party totally unaware of study content. Subject characteristics and all outcome measures before and after treatment were assessed by Physician 1, who was blinded to treatment allocations, and the air stacking exercise was conducted by Physician 2, who was not involved in subject assessments. Conventional pulmonary rehabilitation exercises were performed by Physician 3. Physicians 2 and 3 were instructed not to communicate with subjects about study goals or treatment rationales.

The sample size required for this study was calculated using the G* Power program 3.1.0 (G power program Version 3.1, Heinrich-Heine-University, Dusseldorf, Germany). Based on data from a pilot study, the estimated sample size required to obtain a minimum power of 80% at a significant alpha level of 95% was 22. Accordingly, 27 participants were recruited to cope with a potential dropout rate of 20%.

2. Intervention

Subjects in the experimental and control groups underwent a conventional pulmonary rehabilitation program, but subjects in the experimental group also performed the air stacking exercise after conventional exercises.

1) Conventional pulmonary rehabilitation

All 27 study subjects performed active pulmonary rehabilitation 30 minutes/day, 5 days a week for 4 weeks. During the 4 weeks of the experiment, conventional pulmonary rehabilitation exercises, such as, cough exercise, deep breathing, and abdominal muscle strengthening exercises were performed (Na et al., 2014).

2) Air stacking exercise

The air stacking exercise was performed as follows. After a subject inhaled a maximal amount of air, a therapist infused additional air into the subject’s lungs about 2-3 times using an oral/nasal mask. The subject was then

Table 1. General characteristics of the study subjects

	EG (n=13)	CG (n=14)
Gender (male / female)	7 / 6	7 / 7
Age (years)	68.69±3.22[a]	69.36±3.97
Height (㎝)	163.85±8.48	159.79±7.35
Weight (㎏)	61.23±12.78	60.86±9.22
Body mass index (㎏/㎡)	26.36±3.39	25.34±2.75

[a]Mean±SD.

EG : Air stacking exercise plus conventional pulmonary rehabilitation program; CG : conventional pulmonary rehabilitation program

Table 2. Intra- and inter-group comparisons of outcome measures

	EG (n=13)	CG (n=14)	*t*	*p*
Korean version of the modified Barthel index (score)				
pre	67.69±4.23[a]	68.64±5.12	-.52	.605
4 weeks	79.46±10.38	73.50±10.18	1.51	.145
follow up (2 weeks)	72.31±6.03	70.14±4.38	1.07	.294
F	5.90	.94		
p	.018[a]	.415		
6-minute walk test (m)				
pre	169.77±13.68	165.31±9.88	.98	.338
4 weeks	239.62±40.98	178.21±34.36	4.23	.000**
follow up (2 weeks)	202.92±45.74	172.29±18.76	2.31	.030*
F	18.16	.85		
p	.000[a]	.382		
SaO2: oxygen saturation (%)				
pre	95.46±2.60	97.43±1.83	-1.29	.131
4 weeks	96.31±2.46	97.14±1.88	-1.00	.329
follow up (2 weeks)	96.00±2.45	97.71±1.82	-2.08	.058
F	.30	.94		
p	.745	.709		
FEV1: forced expiratory volume in one second (liter)				
pre	1.47±.33	1.62±.35	-1.10	.282
4 weeks	2.03±.52	1.65±.36	2.20	.037*
follow up (2 weeks)	1.80±.49	1.60±.42	1.15	.260
F	3.72	.84		
p	.048[a]	.920		
FVC: forced vital capacity (liter)				
pre	1.91±.56	1.83±.71	.34	.739
4 weeks	2.98±.48	2.00±.68	4.29	.000**
follow up (2 weeks)	2.32±.38	1.93±.74	1.74	.095
F	10.04	.94		
p	.003[abc]	.417		
PCF: peak cough flow (liter/min)				
pre	243.43±50.70	250.49±50.24	-.36	.720
4 weeks	336.18±67.09	278.18±28.11	2.97	.006**
follow up (2 weeks)	305.17±57.11	258.04±49.01	2.31	.030*
F	12.02	3.41		
p	.002[ab]	.067		

[a]Mean±SD

*p<.05, **p<.01

[a] = pre*4 week, [b] = pre*follow up (2 weeks), [c] = 4 weeks*follow up (2 weeks)

EG : Air stacking exercise plus conventional pulmonary rehabilitation program; CG : conventional pulmonary rehabilitation program allowed to exhale the moment the therapist removed the mask. At that time, the therapist carried out manual assisted coughing by applying pressure to the patient's abdomen. These exercises were conducted 10–15 times per session for two sessions a day in a sitting position (Kang et al., 2007).

3) Outcome measures

(1) Pulmonary function parameters

Pulmonary function testing was conducted using an EasyOne™ diagnostic spirometer (NDD Medical Technologies, Zurich, Switzerland) in a sitting position. FVC and FEV1 were measured by asking subjects to breathe in as much as possible and then to breath out as quickly as possible (Wedzicha et al., 2000).

(2) Peak cough flow (PCF)

In a sitting position with nose held, subjects breathed in as much as possible and then coughed forcefully into the mouthpiece of a Micro Peak™ (Cardinal Health, Kent, UK) peak flow meter. This process was repeated 3 times and the maximum value obtained was recorded (Kulnik et al., 2015).

(3) Oxygen saturation (SaO2)

Oxygen saturation was measured by pulsed oximetry (3300MX, Matrx, USA) immediately after awakening, as previously described (Na et al., 2014). Oxygen saturation

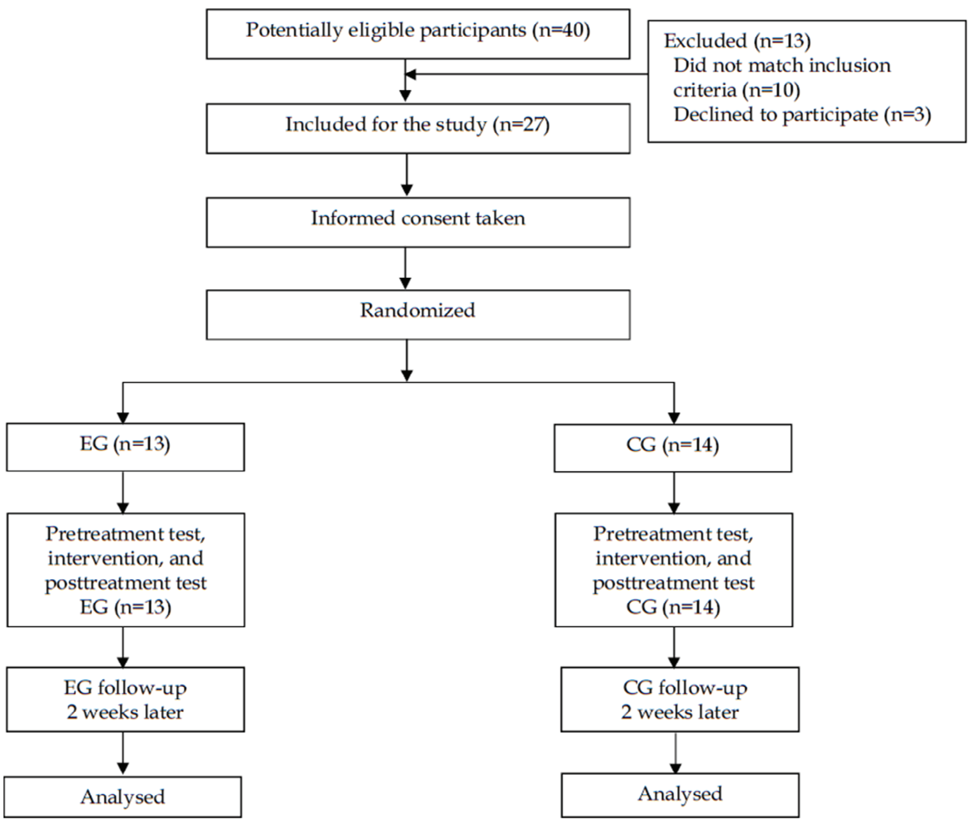

Fig. 1. Study flowchart. EG, Air stacking exercise plus conventional pulmonary rehabilitation; CG, conventional pulmonary rehabilitation

provides is a relative measure of the amount of oxygen that is dissolved or carried in a given medium. It can be measured using a dissolved oxygen probe, such as, an oxygen sensor or an optode in aqueous media. The standard unit of oxygen saturation is percent (%). Oxygen saturation can be measured regionally and noninvasively. Arterial oxygen saturation is commonly measured using pulse oximetry.

(4) The 6-minute walk test

This test is a useful tool for assessing exercise tolerance in deconditioned individuals, and has been reported to have high test–retest reliability with respect to distances travelled by individuals with neurological deficits (ICC=.94) (Mossberg, 2003). Subjects were instructed to walk repeatedly along a 20-m walkway for 6 minutes, with or without a walking aid, and maximum distances walked were then recorded. Rest periods were allowed on request.

(5) Korean version of the modified Barthel index scale

In order to evaluate activities of daily living, the Korean version of the modified Barthel index scale K-MBI was employed. Activities of daily living were divided into 10 items and rated using a 10-point scale. Degree of assistance was rated by awarding up to 10 points were awarded to each of 10 items (10 points=completely independent, zero points=completely dependent). Due to its greater convenience, preciseness, consistency, sensitivity, and compatibility with statistical processing than other evaluation tools, the K-MBI is widely used to generate supportive data for training self-help activities and mobility (Smith, 1993).

4) Statistical Analysis

SPSS 20.0 for Windows (Chicago, IL, USA) was used for the statistical analysis. The chi-square test and the independent t-test were used to analyze intergroup homogeneity before the study. Because outcome measurement data showed parametric distributions, Repeated measures ANOVA was used to examine variances according to intervention period. Least significant difference (LSD) was used for post-hoc analysis. Intergroup comparisons of post-test differences in variance were performed using the independent t-test. *P* values of $<.05$ were considered statistically significant.

Ⅲ. Results

Forced expiratory volume in one second (FEV1) ($p<.05$) and forced vital capacity (FVC) ($p<.05$) were significantly different in the experimental and control groups results after intervention ($p<.05$). Six-minute walk test ($p<.05$) peak cough flow (PCF) ($p<.05$) results were significantly improved in the 2 groups after intervention and at 2-week follow-up visits. In the experimental group, post hoc analysis showed significant differences between KMBI ($p<.05$), 6-minute walk test ($p<.05$), and FEV1 ($p<.05$) values after intervention ($p<.05$). In addition, FVC results were significantly improved after intervention, at after intervention versus 2-week follow-ups, and at follow-up versus pre-intervention ($p<.05$), and PCF values were significantly improved after intervention and after intervention versus at follow-up ($p<.05$).

Ⅳ. Discussion

This study was undertaken to document the effects of an active pulmonary rehabilitation program, composed of air stacking and manually assisted coughing exercises in addition to a conventional pulmonary rehabilitation program, on pulmonary function, activities of daily living, and walking ability in elderly adults. After intervention, significant improvements were noted in 6-minute walk test and in FEV1, FVC, and PCF results in the experimental group as compared with the control group, members of which underwent conventional pulmonary rehabilitation program alone.

Previous studies have shown that air stacking exercise significantly improves pulmonary function and peak cough flow in patients with restrictive pulmonary disease caused by a brain lesion (Na et al., 2014). In the present study, after 4 weeks of active pulmonary rehabilitation consisting of air stacking and a manually assisted cough exercise added to a conventional pulmonary rehabilitation program, FVC increased from 1.9 to 2.7 liters, FEV1 from 1.5 to 1.8 liters, and PCF increased to 349.1 liter/min in the experimental group, and all these increases were significant. Furthermore, these The results concur with previously reported of results.

Another study evaluated the effects of air stacking on pulmonary function and peak cough flow in patients with cervical spinal cord injury. In this previous study, the experimental group performed 20 repetitions of air stacking twice a day and trained for 5 days a week, for 6 weeks. After intervention, FVC and PCF were found to have increased significantly more in the experimental group than in the control group, and in the experimental group, PCF increased by 27.3% (Jeong and Yoo, 2015). These results are in accord with our results. Marques et al. (2014) instructed 18 patients with neuromuscular disease (NMD) to perform routine air stacking at home for 4-6 months and after intervention found PCF increased significantly by 9.9% and FVC also increased.

The significant FVC and FEV1 improvements observed in our experimental group were considered to be the result of expanding lungs to maximum volume and of increasing chest wall compliance by air stacking, which is explained as follows. During aging, elastic elements of the lung degenerate, parenchymal tissue is lost, alveolar ducts and bronchioles dilate, intercostal muscle mass and force are reduced, gas exchange surface area shrinks, and chest wall compliance decreases (Lalley, 2013). It has also been reported thoracic compliance determines the elastic load during inspiration (Sharma and Goodwin, 2006). Furthermore, insufficient expansion of the thorax leads to low thorax compliance, which in turn reduces vital capacity. Thus, a patient that cannot expand his/her lungs sufficiently must expand lung to maximum volume periodically to maintain thorax compliance, and by infusing additional air, lung recoil and thorax compliance can be increased (Na et al., 2014).

In present study, PCF significantly improved in the experimental group. This variable has been used as a measure of huff strength and largely determines the effectiveness of airway clearance (Sasaki, 2007). The three phases of coughing can be classified as inspiration, compression, and expiration. During the inspiration phase, normal subjects have pre-cough volumes of 85－90% of inspiratory capacity (McCool, 2006). However, lung expansion dysfunction results in insufficient inhalation before coughing, inadequate elimination of airway secretions, and lower air flow (Na et al., 2014). On the other hand, air stacking exercise maintains pulmonary compliance by inflating lungs maximally (Jeong and Yoo, 2015).

The higher the maximum insufflation capacity (MIC) is, the greater a patient’s coughing ability, and thus, coughing ability may be improved by increasing the amount of additional air supplied during air stacking (Bach et al., 1993). Kang and Bach (2000a) reported that daily air stacking exercise in patients with neuromuscular disease increased maximum insufflation capacity and assisted peak cough flow. Furthermore, by regularly inflating lungs maximally, maximum insufflation capacity and dynamic lung compliance may be increased (Kang and Bach, 2000b). In the present study, K-MBI, which is an ordinal scale used to measure performance at the activities of daily living (O’Sullivan et al., 2007), was 67.69 before the program and increased non-significantly to 79.46 after the program. In a previous study conducted on air stacking in patients with restrictive pulmonary disease due to a brain lesion, mean K-MBI was 57.5 before a 4-week rehabilitation and significantly increased to 75.8 after intervention (Na et al., 2014).

We believe the reason why changes in pulmonary function related K-MBI scores were not significant despite significant increases in pulmonary functions was that among the items of the K-MBI, which include eating a meal, personal hygiene, bathing, dressing, relieving oneself, controlling micturition and defecation, moving a chair/bed, gait/using a chair car, and climbing stairs, only climbing stairs requires lung capacity. On the other hand, our six meter walk test results were closely related with pulmonary capacity, and these test results increased significantly after intervention.

Previous authors have argued healthy elderly people show a correlation between VC and ADL when performing difficult motions, such as, climbing stairs, and that healthy elderly with better respiratory functions are better able to climb stairs (Yoon et al., 2012). To the best of our knowledge, no previous study has evaluated the effect of air stacking exercise on lung capacity and gait in elderly adults, and the results of the present study support our primary hypothesis that air stacking exercise in elderly subjects improves lung capacity and gait function.

Nonetheless, the present study has some limitations that required consideration. First, the sample size was small, which reduced statistical power, and second, the outcome assessor was not blinded, which might have led to measurement bias.

Ⅴ. Conclusion

Our study shows 4 weeks of air stacking exercise induces significant therapeutic effects in elderly adults. More specifically, air stacking exercise improved lung capacity and exercise tolerance.

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