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Original Article

Association between knee extensor strength and pulmonary function in the female elderly

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Abstract. [Purpose] The purpose of this study is to study the impact of knee extensor strength, which is an index of the degree of physical activity on lung capacity in older women. [Subjects and Methods] Thirty-three older women who participated in the exercise program hosted by a senior citizen center and S University located in Busan. Force vital capacity (FVC) was measured with digital spirometry (Pony FX, COSMED Inc., Italy). Three rounds of measurements were taken for each participant, with one-minute rests between the tests. The means were computed for analysis. Knee extensor strength was measured with a hand-held dynamometer (HHD, MicroFET2®, Hogan Health Industries, Inc., UT, USA). Three rounds of measurements were taken for each knee extensor muscle, after which the mean of the measurements was taken for each side. The higher knee extensor muscle strength value was used for the analysis. [Results] Knee extensor muscle strength had significant positive correlations with Forced vital capacity (FVC), Forced expiratory volume in 1 second (FEV_1), Peak expiratory flow (PEF), and Forced expiratory flow (FEF 25–75%). Association between knee extensor muscle strength and pulmonary function suggested that weakening of the elderly's knee extensor muscle strength has an adverse effect on pulmonary function, although the explanatory power was weak. [Conclusion] Knee extensor muscle weakness in elderly females restricts their physical activity and mobility, thereby serving as a key factor in decreasing their lung capacity.

Key words: Knee extensor strength, Pulmonary function, Physical activity

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INTRODUCTION

Aging is strongly associated with older adults' respiratory disturbances, and pulmonary function decreases as aging progresses[1)]. Aging decreases the size of the thoracic cage and weakens respiratory muscles, which in turn diminishes total lung capacity and coughing ability. Such changes limit one's ability to expectorate, inducing problems such as respiratory diseases[2)]. Nam and Moon[3)] reported that the prevalence of acute respiratory diseases is the highest among elderly females aged 65 years and older. Further, about 33.3% of all elderly females aged 65 years and above are obese, with 43.7 days of limited activity per year, 24.4 days of bed rest per year, and 15.9% of the population with limitations of physical activities.

The vicious cycle of respiratory disturbance among the elderly is directly related to their physical activity. Weakened respiratory muscles impair their mobility, and prolonged sedentary lifestyle and reduced walking speed caused by mobility impairment have an impact on moderate or more severe respiratory disturbance. Respiratory disturbance and dyspnea among the elderly are general symptoms, and they are highly associated with physical inactivity and reduced mobility[4)]. Hence, it is important to assess older adults' inactivity, one method of which is muscle strength testing. The elderly's inactive physical activity is highly related to their upper and lower limb muscle strength. Limb muscle strength is positively correlated with physical activity in older women, and handgrip and knee extensor muscle strength are positively correlated with physical activity in older men. Such degrees of muscle strength are key indices used to assess older adults' physical ability[5)]. There

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have been several studies that investigated the association between physical activity and lung capacity. In a study on the correlation between grip and respiratory function in the elderly, Kim[6] found a high correlation between grip and forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and peak expiratory flow (PEF). Kim et al.[7] reported that FVC and activity fitness are significantly correlated in the elderly aged 65 years or older, and that among components of activity fitness, grip is most strongly positively correlated, followed by knee flexor strength, push-ups, and knee extensor strength. Prior studies report that the elderly's muscle strength and lung capacity are significantly correlated, but there is no data to prove a direct causal relationship between older women's lower limb muscle strength and pulmonary function. Studies report that a degree of physical activity is highly associated with limb muscle strength in the elderly as well as with respiratory disturbance. Therefore, this study is aimed at investigating the impact of knee extensor strength, which is an index of the degree of physical activity, on lung capacity in older women.

SUBJECTS AND METHODS

Thirty-three elderly women, who were attending in the K senior citizen center and in the S University lifelong education center which located in Busan, participated in this study. The inclusion criteria were non-smoking older women aged 60 years or older who are capable of following the investigator's directions. Candidates with lung disease or who experienced pain in the leg when measuring knee extensor muscle strength were excluded from the study. This study complied with the ethical standards of the Declaration of Helsinki, and written informed consent was obtained from each participant. The mean age of the participants was 71.8 ± 8.8 years, with a mean height of 153.2 ± 6.5 cm, weight of 57.0 ± 7.6 kg, and body mass index (BMI) of 23.8 ± 4.3 kg/m^2.

FVC was measured with a digital spirometry (Pony FX, COSMED Inc., Italy). The measurement was taken with the participant sitting upright on a chair with the nose blocked with a clip while slightly biting on the mouthpiece. After taking 3–4 tidal breaths, the participant takes a deep breath in, as large and quick as possible, then quickly breathing out for 6 seconds[8]. Three rounds of measurements were taken for each participant, with one-minute rests between the tests. The means were computed for analysis. Knee extensor strength was measured with a hand-held dynamometer (HHD, MicroFET2®, Hogan Health Industries, Inc., UT, USA). HHD is a useful portable device that measures muscle strength in units of kilogram-force (kgf)[9]. To measure knee extensor strength, the participant sat on a table high enough so that the legs do not touch the floor, and both arms were fixed onto the table. The HHD was fixed midway between both malleolus, and the participant slightly bent the knees from a complete extension to prevent knee injury from excessive extension. With the knee extension slightly relaxed, the participants were instructed to extend their knees with maximal force while the investigator fixed participants' hands to prevent displacement of the hands[10]. Three rounds of measurements were taken for each knee extensor muscle, after which the mean of the measurements was taken for each side. The higher knee extensor muscle strength value was used for the analysis. We performed the Pearson correlation analysis to analyze the correlation between knee extensor muscle strength and pulmonary function of the elderly women. Any association between the two was verified with simple regression analysis. Statistical analyses were performed using the SPSSWIN (ver. 22.0), with a significance level α=0.05.

RESULTS

Knee extensor muscle strength had significant positive correlations with FVC, FEV_1, PEF, and FEF 25–75% ($p<0.01$). These results suggest that the stronger the knee extensor muscle is, the greater the lung capacity is in older adults (Table 1).

The elderly's knee extensor muscle strength had a significant impact on FVC, with an explanatory power of 32% (R^2=0.323, $p<0.01$). Knee extensor muscle strength had a significant impact on FEV_1, with an explanatory power of 30% (R^2=0.300, $p<0.01$). Knee extensor muscle strength had a significant impact on PEF, with an explanatory power of 25% (R^2=0.250, $p<0.05$). Knee extensor muscle strength had a significant impact on FEF 25–75%, with an explanatory power of 23% (R^2=0.234, $p<0.05$). The findings suggested that weakening of the elderly's knee extensor muscle strength has an adverse effect on pulmonary function, although the explanatory power was weak (Table 2).

DISCUSSION

This study examined the effects of knee extensor muscle strength on pulmonary function in female elderly and found that knee extensor muscle strength has significant positive correlations with FVC, FEV_1, PEF, and FEF 25–75%, confirming that elevated knee extensor muscle strength is highly correlated with elevated pulmonary function in older women. Simple regression analysis to investigate the effects of knee extensor muscle strength on lung capacity showed that weakening of the knee extensor muscle has an adverse effect on lung capacity, though the explanatory power was weak. These findings can be explained through a reduction of physical activity as a result of sarcopenia in the elderly. Ikezoe et al.[11] measured the thickness of 17 muscles in the trunk and lower limb via ultrasound in the elderly to examine sarcopenia, and verified changes of thickness 12 weeks later. They found that the loss of muscle mass was the greatest in the erector spinae, followed by rectus femoris, vastus lateralis, vastus intermedius, and tibialis anterior, and that the thickness of vastus lateralis is significantly associated with maximal walking velocity. Garcia et al.[12] reported that calf circumference, walking speed, hand grip, and

Table 1. Correlation between knee extensor strength and pulmonary function (Unit)

Variable	FVC (l)	FEV_1 (l)	PEF (l)	FEF25–75%
KES (kg)	0.57**	0.55**	0.50**	0.48**

*p<0.05, **p<0.01. KES: Knee extensor strength; FVC: Forced vital capacity; FEF25–75%: Forced expiratory flow between; FEV_1 Forced expiratory volume in 1 second; PEF: Peak expiratory flow.

Table 2. The effect of knee extensor strength on pulmonary function (Unit)

Model	Unstandardized coefficients		Standardized coefficients	T	F	R^2
	B	SE	β			
FVC (l)	2.97	0.77	0.57	3.85**	14.80**	0.32
FEV_1 (l)	3.26	0.89	0.54	3.65**	13.31**	0.30
PEF (l)	0.99	0.31	0.50	3.21*	10.32*	0.25
FEF25–75%	2.22	0.72	0.48	3.08*	9.48*	0.23

*p<0.05, **p<0.01. FVC: Forced vital capacity; FEF25–75%: Forced expiratory flow between; FEV_1 : Forced expiratory volume in 1 second; PEF : Peak expiratory flow.

average knee extensor muscle strength decreases with aging in adults in their 60s, 70s, and 80s, and that knee extensor muscle strength is significantly correlated with calf circumference and walking speed. Prior studies suggest that weakening of lower limb muscles and the resulting limitations in activity, such as mobility, have an adverse impact on lung capacity. Such vicious cycle is particularly more evident in the elderly with pulmonary diseases. Compared to healthy controls, older adults with chronic obstructive pulmonary disease (COPD) walk a shorter distance in the 6-minute walk test and have reduced grip. In addition, the distance of the 6-minute walk test and hand grip are the main factors associated with an elevation of static hyperinflation in older adults with COPD[13]. In a follow-up of male and female elderly with COPD, those who showed weakening of the quadriceps femoris muscle had significantly higher 5 year mortality than those with normal quadriceps femoris muscle strength. Moreover, quadriceps femoris muscle strength is a simpler and more accurate indicator of the prognosis of patients with COPD than are age, BMI, and FEV_1[14]. Restriction of elderly's mobility and daily living takes a toll on their activity, which in turn accelerates muscle atrophy, further restricting their daily living in a vicious cycle[15].

In conclusion, weakening of the knee extensor muscle strength in older women restricts their physical activity and mobility, thereby serving as a key factor in decreasing their lung capacity. Therefore, breathing exercise programs for the elderly should include knee extensor strengthening exercise, which plays a key role in older adults' physical activity. Future studies should investigate changes in lung capacity induced by knee extensor muscle strengthening exercises.

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