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Original Article

Influence of Restrictive Ventilation Impairment on Physical Function and Activities of Homebound Elderly Persons†

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SUMMARY

Background: Examinations of respiratory function and respiratory muscle strength are evaluation methods for stamina factors, but instantaneous ability evaluation is disproportionately emphasized in evaluations of elderly persons.
Methods: The participants were 290 persons who were capable of undergoing respiratory examinations. The participants were firstly divided into two groups; 42 persons in a normal group (percentage of forced vital capacity ≥80%) and 42 patients in a restrictive group (percentage of forced vital capacity <80%). The participants were then subcategorized into three groups; 21 participants were randomly selected from the normal group (normal-1), 20 regularly exercising restrictive participants were assigned to a restrictive training group (RTG), and 22 participants who did not exercise were assigned to a restrictive nontraining group (RNTG). The measured parameters were respiratory function, cognitive function, spinal alignment, muscle strength, skeletal muscle volume, gait evaluation, subjective feelings of life, and active ability.
Results: Six-minute walk test was significantly lower in the restrictive group compared with the normal group ($p < 0.05$). Walking time of the 10-m obstruction course in the normal-1 group differed significantly from the RTG ($p < 0.05$) and RNTG ($p < 0.01$). Highest walking speed, Timed Up and Go test, and 6-minute walk test did not significantly differ between the normal-1 group and RTG, but significant differences were observed between the normal-1 group and RNTG ($p < 0.01$, $p < 0.05$, and $p < 0.05$, respectively).
Conclusions: Although patients with restrictive ventilation impairment were unlikely to be aware of their disorder, degradation in systemic stamina had already commenced. It appears that maintaining exercise habits prevented degradation of not only instantaneous walking ability but also of systemic stamina.

1. Introduction

Upper and lower extremity muscle strength and balancing ability are related to the action speed, safety, and stability of elderly persons and are therefore considered to be important factors in determining action in daily life (ADL) and quality of life (QOL). Stamina factors are also important determinants of ADL and QOL. Examinations of respiratory function and respiratory muscle strength are evaluation methods for stamina factors, but instantaneous ability evaluation is disproportionately emphasized in evaluations of elderly persons. Objective evaluations of stamina are rarely conducted in elderly care and prevention programs or in fall-prevention programs in local communities. This may be because the participants for traditional evaluation of systemic stamina have been elderly patients with defects in the oxygen transportation system, such as respiratory and cardiovascular diseases; and because most of the elderly persons in local communities display normal ADL. This suggests that walking and self-care are considered to be normal activities, but this does not ensure active ability in elderly persons. The disproportionate emphasis on instantaneous ability evaluations may reveal a superficial understanding of the situation that has never been questioned.

Examinations of respiratory function and respiratory muscle strength do not require huge and expensive facilities, special knowledge, or special skills. Simple evaluations are possible outside

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the facilities of a specialized institution[1,2], but they have rarely been conducted on patients with no medical history or symptoms of respiratory disease[3–5]. Objective investigations and reports on the influence of decreased vital capacity on physical function and activities in homebound elderly persons have also rarely been carried out.

In this study, respiratory function was examined in homebound elderly persons who had no medical history of a respiratory disease (not-yet-diagnosed or treated) to investigate the influence of decreased forced vital capacity (FVC) or so-called restrictive ventilation impairment on physical function and activities. Healthy persons and patients with restrictive ventilation impairment objectively were compared. The influence of the presence or absence of daily voluntary training (exercise) on physical function and abilities in patients with restrictive ventilation impairment was also investigated. The usefulness of respiratory function examinations and respiratory muscle strength examinations, appropriate physiotherapy programs in elderly care and prevention programs, and fall-prevention programs in local communities are discussed.

2. Participants and Methods

2.1. Participants

Written informed consent to voluntary participation in this study was obtained after explaining the objectives and methods of the study both orally and by written materials to 634 homebound elderly persons who had registered for a mini day-service program in Community A. Two-hundred ninety participants for respiratory function examination were selected from 309 homebound elderly persons. The participants were assigned into a group of 61 persons with %FVC lower than 80% and a normal group of 229 persons with %FVC of 80% or greater. Forty-two of the patients with %FVC lower than 80% were assigned to the restrictive ventilation impairment group. Nineteen patients with restrictive ventilation impairment whose forced expiratory volume $(FEV)_{1.0}\%$ was less than 70% were excluded from the study. Forty-two persons were chosen from the normal group of 229 persons to match the age and sex of those in the restrictive group.

To investigate the influence of exercise habits, participants were further assigned to three subgroups. Twenty persons in the restrictive group who had exercised for 30 minutes or more a day for 3 days a week or more, and for 6 months or longer, were subcategorized into a restrictive training group (RTG). The remaining 22 participants in the restrictive group were assigned to a restrictive nontraining group (RNTG). Twenty-one participants from the normal group were randomly selected and assigned to a normal-1 group for comparison (Fig. 1).

"Exercise" was defined as exercising for a training purpose additional to normal ADL. "Participants for exclusion" were persons who had a painful disease or a severe comorbid disease, who were already diagnosed to have a respiratory or articular disease, who had significant physical functional disorder, and who could not understand the objectives and methods of the study.

2.2. Methods

The measured parameters were sex, age, height, body weight, body mass index, respiratory function, cognitive function, spinal alignment, muscle strength (upper extremity, lower extremity, trunk, and respiratory), skeletal muscle volume, gait evaluation (walking time of 10-m obstacle course), highest walking speed, Timed Up and Go test (TUG), and 6-minute walk test (6MWT), subjective feelings of life, and active ability indicators.

2.2.1. Respiratory function evaluation

Respiratory function evaluation was conducted by measuring flow volume with an Autospiro AS507 (Minato Medical Science Co. Ltd., Japan) to obtain %FVC and $FEV_{1.0}\%$. Measurements were taken twice and the better value was used.

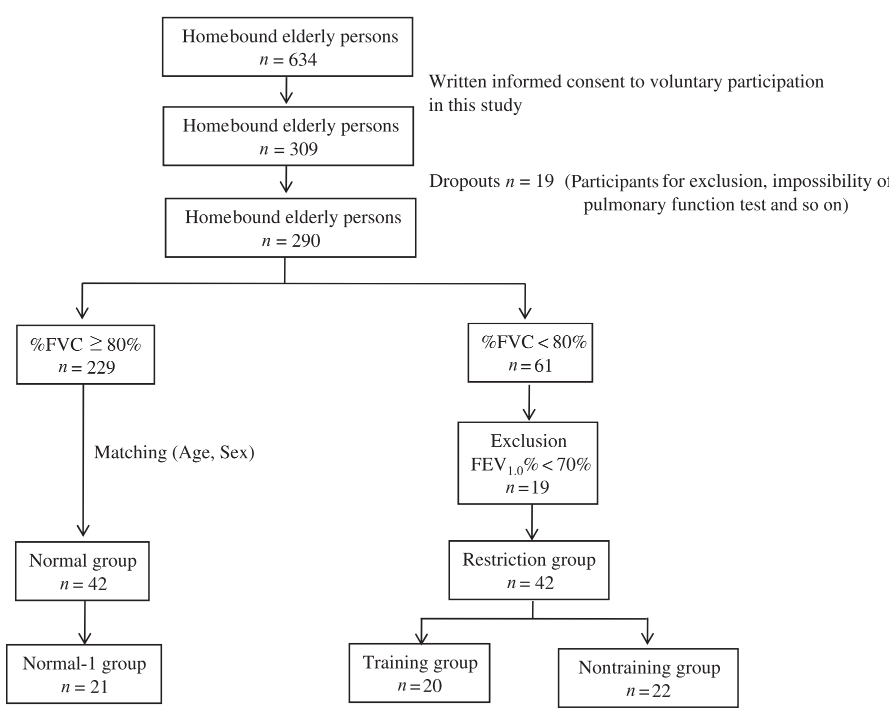

Fig. 1. Selection of participants and study protocol.

2.2.2. Cognitive function evaluation

Cognitive function evaluation was conducted using Mini Mental State Examination (MMSE), which is widely recognized simple evaluation scale of dementia[6,7].

2.2.3. Spinal alignment evaluation

Spinal alignment was evaluated with a Spinal Mouse (Index Ltd., Japan) by measuring from Cervical Spine 7 to Lumbosacral Spine 3 on a paravertebral line in a standing position with both legs open. The thoracic vertebral posterior curve angle was determined as the total of all angles that are made by the adjacent upper and lower vertebrae from Thoracic Vertebrae 1–5. The lumbar vertebral anterior curve angle was determined as the total of all angles that are made by adjacent upper and lower vertebrae from Lumbar Vertebrae 1–12. Spinal alignment evaluation was conducted three times and the average value was used.

2.2.4. Muscle strength evaluation

Upper extremity muscle strength was measured as grasping power (kilogram) with a digital grip dynamometer (Takei Scientific Instruments Co. Ltd., Japan). Lower extremity muscle strength was measured as the isometric maximum muscle strength of the femoral quadriceps muscle (kilogram) while sitting in a chair with the hip joints and knee joints at right angles, using a hand-held dynamometer μTAS MT-1 (Anima Co., Japan), which was fixed to the chair. Trunk muscle strength was measured by counting sit-ups (both the elbows should touch the thighs with the arms crossed in front of the chest and then the back should touch the floor) completed in 30 seconds in a supine position with the knees bent and the knee joints fixed. Respiratory muscle strength was evaluated by measuring maximal inspiration intraoral pressure (cmH_2O) and maximal expiration intraoral pressure (cmH_2O) with a micro respiratory pressure meter (Micro Medical Ltd., UK). Sit-ups were counted once. The other parameters were each measured twice and the better value was used.

2.2.5. Skeletal muscle volume

Skeletal muscle volume was measured with a four-electrode dual frequency composition detector DC-320 (Tanita Corporation, Japan) using the bioelectricity impedance analytic method. Signals from electric currents (500 μA) with frequencies of 6.25 kHz and 50 kHz were analyzed. The currents were applied to both legs while the participants were in a stationary standing position on the measuring instrument.

2.2.6. Gait evaluation

The walking time of a 10-m obstacle course was measured by setting six sponge obstacles which were 20 cm in height on a straight 10-m line at intervals of 2 m. Highest walking time (meter/second) was measured by instructing participants to walk the length of the line at the fastest possible speed and measuring the shortest time to the point 5 m from the starting point with a stopwatch. TUG-test was conducted by measuring the time (seconds) taken to stand from a seated position in a chair, turning to the direction of an eye-marked spot 3 m from the starting point, and then to sit in the chair again. The 6MWT was the longest distance (meter) the participants could walk in 6 minutes. The 6MWT was measured once. The other items were each measured twice and the better value was used.

2.2.7. Evaluations of subjective feelings of life and active ability indicators

Subjective feelings of life were evaluated with four measures, "health status," "satisfaction of living," "purpose in life," and "human relationships," with a visual analog scale. The scale of 100 mm is graded with 0 for the most negative answer and 100 for the most positive answer, and the distance (millimeter) from 0 to the point, which showed the current status, was measured[8–10]. Active ability indicators were measured using the Rouken style "questions for daily life," which consists of 13 items and the number of "yes" answers was counted (Fig. 2)[11].

1. Can you go out on a bus and a train?	Yes or No
2. Can you do the shopping of daily necessities?	Yes or No
3. Can you prepare the meal by yourself?	Yes or No
4. Can you do the payment of the bill?	Yes or No
5. Can you do bank deposits, the receipts, and payments of the postal savings by oneself?	Yes or No
6. Can you write documents, such as pensions by yourself?	Yes or No
7. Do you read a newspaper?	Yes or No
8. Do you read a book and a magazine?	Yes or No
9. Are you interested in an article about the health and a program?	Yes or No
10. Do you visit your friends' house?	Yes or No
11. Do you advice your family and friends?	Yes or No
12. Can you visit a sick person?	Yes or No
13. Do you talk to a young person from oneself?	Yes or No

Number of "Yes" (   )

Fig. 2. Questions of daily life.

2.3. Statistical analysis

The measured values in the normal group and restrictive group were compared by Student *t* test or Welch *t* test after conducting Levene's test of homoscedasticity. Differences between the normal-1 group, RTG, and RNTG were detected by one-way analysis of variance and Turkey's multiple comparison tests were used for *post hoc* comparisons of the groups. The significance level was defined to be less than 5% ($p < 0.05$) and the statistical software package SPSS Version 17 for Windows (SPSS, Inc., Chicago, IL, USA) was used for the analysis.

3. Results

3.1. Comparison of the normal group and the restrictive group

The normal group and the restrictive group differed with regard to %FVC ($p < 0.001$) and MMSE ($p < 0.05$) (Table 1). The number of sit-ups, which indicates trunk muscle strength, was significantly higher in the normal group ($p < 0.05$), but no significant difference was observed in upper and lower extremity muscle strength,

Table 1
Characteristics of study group

Characteristics	Normal group ($n = 42$)	Restriction group ($n = 42$)
Sex (M/F)	9/33	9/33
Age (yr)	74.1 ± 0.9	74.4 ± 6.3
Height (cm)	150.1 ± 7.7	151.1 ± 8.1
Weight (kg)	53.4 ± 8.1	53.8 ± 10.3
BMI	23.6 ± 2.8	23.5 ± 3.3
%FVC (%)	99.6 ± 16.3	69.8 ± 7.8*
$FEV_{1.0}$% (%)	76.3 ± 7.3	78.2 ± 6.7
MMSE	27.2 ± 2.5	25.4 ± 3.5**

FEV = forced expiratory volume; $FEV_{1.0}\% = FEV_{1.0}/FVC$; %FVC = FVC/FVC predicted; FVC = forced vital capacity; MMSE = Mini Mental State Examination; SD = standard deviation.
Data are presented as mean ± SD.
*$p < 0.001$; **$p < 0.05$.

Table 2
Comparison of vertebral column alignment and muscle strength between normal group and restriction group

Parameters	Normal group	Restriction group
Thoracic kyphosis angle	37.4 ± 10.9	39.0 ± 11.5
Lumbar lordosis angle	−9.5 ± 11.9	−8.7 ± 12.8
Muscle strength (grasping power) (kg)	24.8 ± 6.8	23.6 ± 6.1
Muscle strength (quadriceps) (kg)	19.8 ± 7.0	18.8 ± 6.8
Counting sit-ups (times)	4.4 ± 4.6	1.9 ± 2.9*
MIP (cmH_2O)	53.5 ± 29.1	43.8 ± 22.7
MEP (cmH_2O)	52.9 ± 21.1	54.4 ± 26.9
Muscle mass (kg)	35.0 ± 5.6	34.5 ± 6.1

MEP = maximal inspiratory pressure; MIP = maximal inspiratory pressure; SD = standard deviation.
Data are presented as mean ± SD.
*$p < 0.01$.

respiratory muscle strength, or skeletal muscle volume. No significant difference was observed in spinal alignment as shown by thoracic vertebral posterior curve angle and lumbar vertebral anterior curve angle (Table 2). With regard to gait evaluation, no significant difference was observed in highest walking speed and TUG, but significant differences were found in walking time of the 10-m obstacle course and 6MWT ($p < 0.05$, $p < 0.05$). No significant difference was found in any of the measures of subjective feelings of life and active ability indicators (Table 3).

3.2. Comparisons of the normal group, RTG, and RNTG

Walking time of the 10-m obstacle course in the normal group differed significantly from the RTG ($p < 0.05$) and the RNTG ($p < 0.01$). The normal group and RTG did not differ significantly with regard to highest walking speed, TUG, and 6MWT, but these measures differed significantly between the normal group and RNTG ($p < 0.01$, $p < 0.05$, $p < 0.05$, respectively) (Fig. 3). No significant difference was found in any of the measures of subjective feelings of life and active ability indicators (Table 4).

4. Discussion

This study objectively investigated the influence of restrictive ventilation impairment on physical function and activities in homebound elderly persons. Participants were firstly categorized into a normal group and a restrictive group. The restrictive group was then subcategorized into two groups depending on the presence (RTG) or absence (RNTG) of exercise habits, and a subset of the normal group (normal-1) was used for comparisons with these groups. The normal group differed significantly from the restrictive group with regard to the number of sit-ups, 10-m walking obstacle course time, and 6MWT. In comparisons of normal-1 group with RTG and RNTG, significant differences were observed in walking time of a 10-m obstacle course between normal-1 group and both RTG and RNTG, and in highest walking speed, TUG, and 6MWT between normal-1 group and RNTG.

Table 3
Comparison of walking test and rating of daily activity between normal group and restriction group

Parameters	Normal group	Restriction group
Walking time of 10m-obstacle course (m/sec)	7.3 ± 2.2	8.3 ± 2.3*
Highest walking time (sec)	1.9 ± 0.5	1.7 ± 0.5
TUG (sec)	5.5 ± 1.2	6.0 ± 1.8
6MWT (m)	442.5 ± 82.1	395.2 ± 128.9*
Visual analog scale		
Sense of health (mm)	55.9 ± 15.6	57.5 ± 19.9
Sense of satisfaction of life (mm)	61.1 ± 20.9	63.6 ± 23.9
Purpose of life (mm)	69.9 ± 17.1	65.1 ± 23.5
Human relationship (mm)	74.1 ± 18.6	75.2 ± 24.5
Daily activity	11.6 ± 1.8	11.3 ± 2.3

6MWT = 6-minute walk test; SD = standard deviation; TUG = Timed Up and Go test.
Data are presented as mean ± SD.
*$p < 0.05$.

This study could have been affected by selection bias because participants with low motivation might concentrate in the RNTG. However, 309 participants were chosen from a total of 634 volunteers so that possible selection bias for participants with low motivation could be avoided. Furthermore, the ages and sexes of the normal group were matched to those of the restrictive group. Thus, the participants were well matched across the two groups with no bias in characteristics except %FVC. A significant difference in MMSE was observed, but because the average score in both groups was high and the difference of the averages was a mere 1.8 points, it would not significantly influence the results of this study.

Comparison of the normal group and the restrictive group revealed no significant difference in spinal alignment, and the thoracic vertebral posterior curve angle or lumbar vertebral anterior curve angle were not considered to be the cause of the decreased FVC in the restrictive group. Many studies have been published on the relationship between spinal alignment and vital capacity in elderly patients with rounded back or osteoporosis[12−17]. In this study, patients with a significantly painful disease were excluded, and it is therefore very possible that patients with greatly deformed spinal alignment were excluded. This may explain the absence of an observed relationship between spinal alignment and vital capacity. Decreased trunk muscle strength and aging lungs might be the cause of decreased FVC because no significant difference between the groups was found in the upper and lower extremity muscle strength; but there was significant difference in the number of sit-ups, which is an indicator of trunk muscle strength. Therefore, trunk muscle strength might be reduced in elderly patients with decreased FVC, which then leads to decreased muscle strength in the upper and lower limbs. This suggests that evaluation of trunk muscle strength is important for the provision of programs to prevent degradation of trunk muscle strength for elderly persons.

With regard to upper and lower extremity, and respiratory muscle strength, no significant difference was observed between the normal group and the restrictive group in grasping power, femoral quadriceps muscle power, maximal inspiratory pressure, maximal expiratory pressure, and skeletal muscle volume. Because these measures of muscle strength are influenced by instantaneous factors, decreased FVC is unlikely to influence instantaneous muscle power.

With regard to gait evaluation, no significant difference was found between the normal group and the restrictive group in highest walking speed and TUG, which largely consist of instantaneous factors. A significant difference was found between the normal group and the restrictive group in walking time of the 10-m obstacle course, but the difference was about 1 second on average, which is not thought to influence exercise capability. It is unlikely that a decrease in FVC influences walking ability, which consists of instantaneous factors. On the other hand, 6MWT, which is a gait evaluation of stamina factors, was significantly low in the restrictive group at around 50 m[18], which was considered to be clinically meaningful. This indicates that a decrease in FVC may influence the stamina factors of gait ability.

However, no significant difference was observed between the normal group and the restrictive group in all the measures of subjective feelings of life and active capacity indicators, indicating that the participants were not aware that degradation in systemic

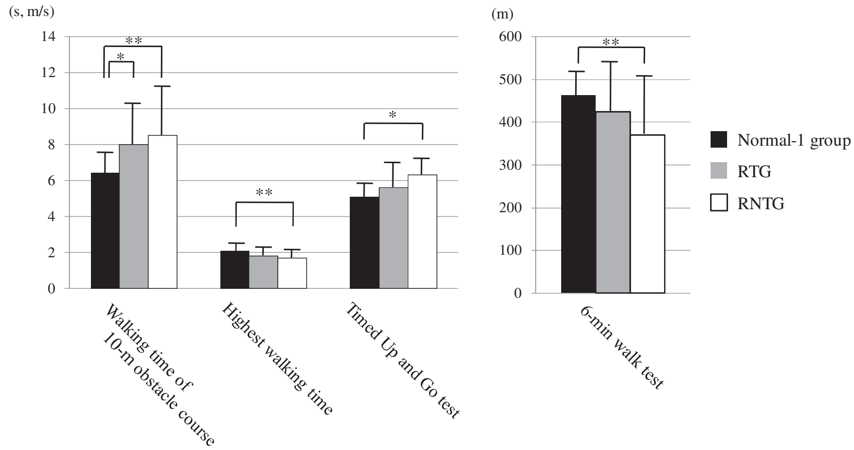

Fig. 3. Comparison of walking test between normal-1 group and restrictive training group and restrictive nontraining group. $*p < 0.05$, $**p < 0.01$. RNTG = restrictive nontraining group; RTG = restrictive training group.

stamina had already commenced. Because it was reported by Yernault[19] that feeling of breathing difficulty in elderly persons were because of decreased sensitivity, it is significant that an unconscious decrease in stamina may affect ADL.

With regard to physical function and activities, the above results indicate that patients with restrictive ventilation impairment may be unaware of any abnormality in subjective feelings of life and active capability indicators, and their QOL is similar to that of healthy persons because the disease does not affect abilities, which include instantaneous factors. Lombardi et al[20] reported that although elderly female patients with osteoporosis had decreased FVC, it did not affect their QOL.

Regardless of the presence or absence of organic factors, such as respiratory diseases, patients with restrictive ventilation impairment are unlikely to be aware of the abnormality in their physical function and activities, which may hamper early detection and early treatment. The objective data of this study indicate that systemic stamina starts decreasing gradually before patients with restrictive ventilation impairment become aware of it. Thus, regular respiratory function examinations may enable early detection of restrictive ventilation impairment and prevent the degradation of stamina.

Finally, comparison of normal-1 group with RTG and RNTG revealed no significant differences in spinal alignment, upper and lower extremity and trunk muscle strength, skeletal muscle volume, subjective feelings of life, and active ability indicators, suggesting that exercise habits may not affect these. However, a significant difference in walking time of a 10-m obstacle course was observed between the normal-1 group and RTG and RNTG. No significant difference was observed in highest walking speed, TUG, and 6MWT between normal-1 group and RTG, but a significant difference was found between normal-1 group and RNTG, indicating that exercise habits of patients with restrictive ventilation may affect walking ability.

The above results indicate that the walking ability of patients with restrictive ventilation impairment can be kept at the same level as that of healthy persons if they exercise, and their instantaneous and systemic stamina walking abilities are degraded if they do not exercise. Degradation of systemic stamina in patients with restrictive ventilation disorder but no subjective symptoms, as in the participants in this study, is assumed to be caused by muscle metabolism disorder, rather than ventilation impairment. Because walking is a low-load type exercise that is likely to be conducted very frequently, it may influence muscle stamina, but not instantaneous muscle power. Thus, it is possible that systemic stamina is significantly degraded in patients with restrictive ventilation impairment and no exercise habit.

Regular respiratory function examinations can determine the presence or absence of restrictive ventilation impairment early. When impairment is found, patients can be advised to engage in voluntary gait training (walking) to sustain instantaneous walking ability and also to prevent degradation of systemic stamina.

It has been reported that high-load training could improve FVC in patients with chronic obstructive pulmonary disorder[21].

Table 4
Comparison of muscle strength and walking test between normal group and restriction group (training group and nontraining group)

Parameters	Normal-1 group ($n = 21$)	Restriction group	
		Training group ($n = 20$)	Nontraining group ($n = 22$)
Muscle strength (grasping power) (kg)	24.3 ± 6.2	24.5 ± 5.7	22.9 ± 6.4
Muscle strength (quadriceps) (kg)	20.2 ± 6.4	19.4 ± 7.4	18.2 ± 6.3
Counting sit-ups (times)	4.2 ± 4.3	1.7 ± 2.3	2.1 ± 3.5
MIP (cmH_2O)	48.8 ± 24.6	47.9 ± 22.4	40.1 ± 23.0
MEP (cmH_2O)	49.6 ± 16.5	58.1 ± 30.3	51.1 ± 23.6
Muscle mass (kg)	34.8 ± 6.1	34.7 ± 5.9	34.3 ± 6.4
Walking time of 10-m obstacle course (m/s)	6.4 ± 1.2	8.0 ± 2.1	8.5 ± 2.5[a,b]
Highest Walking time (s)	2.1 ± 0.3	1.8 ± 0.4	1.7 ± 0.52[b]
TUG (s)	5.1 ± 0.8	5.6 ± 1.2	6.4 ± 2.1[c]
6MWT (m)	461.8 ± 48.3	423.8 ± 107.9	369.1 ± 142.8[b]

6MWT = 6-minute walk test; MEP = maximal inspiratory pressure; MIP = maximal inspiratory pressure; SD = standard deviation; TUG = Timed Up and Go test.
Data are presented as mean ± SD.
[a] Normal-1 group vs. training group, $p < 0.05$.
[b] Normal-1 group vs. nontraining group, $p < 0.01$.
[c] Normal-1 group vs. nontraining group, $p < 0.05$.

However, in a systematic review of many patients with respiratory failure, training was reported to have a negative impact on respiratory function[22–26]. Previous studies indicate that rebuilding decreased vital capacity by training is difficult in patients with restrictive ventilation impairment.

Conducting stamina evaluations in elderly care and prevention programs and fall-prevention programs for elderly persons in local communities is important. In this study, respiratory function examination and respiratory muscle strength examination were selected as useful evaluation methods related to stamina factors, but no clear conclusion could be made with regard to respiratory muscle strength examinations. However, it was concluded that regular respiratory function examinations in these programs could enable early detection of respiratory ventilation impairment. This can contribute to the development of physiotherapy programs to prevent degradation of ADL and QOL of elderly persons whose systemic stamina is potentially already decreasing.

5. Conclusion

Homebound elderly persons were categorized into a normal group and a restrictive group. The restrictive group was then further categorized into RTG and RNTG to compare with a normal group subset (normal-1). Patients with restrictive ventilation impairment are unlikely to be aware of the disorder because no difference in instantaneous ability is found compared with the normal group, but degradation of systemic stamina may have already started. Furthermore, it appears that even patients with restrictive ventilation impairment can prevent degradation of systemic stamina if they exercise. However, if they do not exercise, their systemic stamina may further decrease. Thus, respiratory function examinations in local community programs for homebound elderly persons can contribute to early detection of restrictive ventilation impairment and help encourage engagement in exercise. The number of participants will be increased in further studies to clarify the influence of the presence or absence of exercising habit.

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