

**Original Research****Upper and Lower Limb Skeletal Muscle Mass Index as a Novel Evaluation Index in Patients with Chronic Obstructive Pulmonary Disease**

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***Running Head: USMI and LSMI as Skeletal Muscle Indices in COPD***

***Keywords:*** chronic obstructive pulmonary disease; upper limb skeletal muscle mass index; lower limb skeletal muscle mass index

***Abbreviations:*** COPD= Chronic Obstructive Pulmonary Disease; IL-6=interleukin-6; TNF- $\alpha$ =tumor necrosis factor- $\alpha$ ; SMI=Skeletal Muscle mass Index; USMI=Upper Limb Skeletal Muscle Mass Index; LSMI=Lower Limb Skeletal Muscle Mass Index; Ex=exercise; METs=Metabolic Equivalents of Task; ISWD=Incremental Shuttle Walking Distance; ADL=Activities of daily living; NRADL=the Nagasaki University Respiratory ADL questionnaire; FEV<sub>1</sub>=forced expiratory volume in one second; FEV<sub>1</sub>%=forced expiratory volume percentage in one second; SMM=Skeletal Muscle mass.

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## Abstract

### [Objective]

The objective of this study was to examine the relationships and usefulness of physical activity, physical performance, and physical function in patients with chronic obstructive pulmonary disease (COPD), focusing on two newly proposed skeletal muscle indices: the upper limb skeletal muscle mass index (USMI) and lower limb skeletal muscle mass index (LSMI).

### [Methods]

Eighty stable patients with COPD who participated in outpatient pulmonary rehabilitation at Osaka Fukujuji Hospital were enrolled. The primary measurements were USMI, LSMI, and Skeletal Muscle Index (SMI). The explanatory measurements included physical activity, Incremental Shuttle Walking Distance (ISWD), quadriceps strength, handgrip strength, the Nagasaki University Respiratory Activities of Daily Living Questionnaire (NRADL), and pulmonary function. Pearson's correlation coefficient and stepwise multiple regression analysis were used for the statistical analyses.

### [Results]

USMI showed no significant correlations with physical activity parameters or ISWD. In contrast, LSMI was significantly correlated with weekly exercise volume ( $r = 0.42, p < 0.01$ ), daily exercise volume ( $r = 0.42, p < 0.01$ ), time spent in activities  $\geq 3$  Metabolic Equivalents of Task (METs) ( $r = 0.40, p < 0.01$ ), and ISWD ( $r = 0.46, p < 0.01$ ). Multiple regression analysis

identified ISWD as an independent factor for USMI, LSMI and SMI.

[Conclusion]

This study demonstrated that LSMI, similar to SMI, was associated with physical activity and exercise capacity in patients with COPD. These findings highlight the importance of evaluating, maintaining, and strengthening lower limb skeletal muscle mass and suggest that LSMI may serve as a useful clinical evaluation index.

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## 1. Introduction

Chronic obstructive pulmonary disease (COPD) is known to cause systemic impairments that extend beyond the lungs. Therefore, COPD is recognized as a respiratory disease and a systemic inflammatory disorder. This systemic involvement is mediated by inflammatory cytokines such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- $\alpha$ ), which contribute to skeletal muscle dysfunction<sup>1)</sup>. Among these systemic changes, patients with COPD have been reported to have significantly lower fat-free mass and fat-free mass index compared with individuals without COPD<sup>2)</sup>. Furthermore, regardless of the severity of dyspnea or degree of airflow limitation, decreased quadriceps strength<sup>3)</sup> and reduced quadriceps cross-sectional area<sup>4)</sup> have been reported. Regarding upper limb function, handgrip strength—a representative indicator of upper limb muscle strength—has not always been found to differ significantly between patients with COPD and those without COPD after adjusting for age, sex, and height<sup>5)</sup>. However, during acute exacerbations, patients with COPD demonstrate lower grip strength compared with individuals with stable COPD or without COPD<sup>6)</sup>. Muscle fiber alterations, such as a reduction in type I fibers and an increase in type II fibers, have also been reported<sup>7)</sup>. Moreover, depletion of skeletal muscle mass (SMM) has been associated with prognosis, as reductions in SMM are linked to higher in-hospital mortality during exacerbations<sup>8-9)</sup>. SMM is an important parameter in evaluating muscle loss associated with aging and disease. In fact, the assessment of appendicular skeletal muscle mass index (SMI) is

a mandatory criterion for the diagnosis of sarcopenia<sup>10)</sup>. Previous studies have reported that the prevalence of sarcopenia among patients with COPD is 21.6%<sup>11)</sup>, emphasizing the clinical importance of SMM assessment. Given this background, the evaluation of appendicular SMM is considered crucial in pulmonary rehabilitation. Handgrip strength, as an indicator of upper limb muscle strength, has been shown to be associated with physical activity and exercise capacity<sup>12-14)</sup>. Furthermore, decreased handgrip strength has been linked to an increased risk of acute exacerbations<sup>15)</sup> and poorer prognosis<sup>16)</sup>. Similarly, lower limb muscle strength has also been reported to be associated with physical activity and exercise capacity<sup>17-18)</sup>. In clinical practice, pulmonary rehabilitation often emphasizes interventions targeting the lower limbs, including strength training and aerobic exercise. Aerobic training, typically consisting of walking and cycle ergometer exercise, primarily engages the lower limbs. Because daily activities are largely based on ambulation, lower limb training is prioritized in pulmonary rehabilitation programs. Although reports have linked upper and lower limb muscle strength with physical activity and exercise capacity, no studies to date have specifically examined the relationships between upper and lower limb skeletal muscle mass and these outcomes in patients with COPD. Clarifying these relationships may provide new perspectives in pulmonary rehabilitation and highlight the importance of evaluating SMM. Bioelectrical impedance analysis, a method used to measure SMM, offers a simple and feasible screening tool in clinical practice. In addition, assessing physical activity not only by step count but also

by including exercise volume and intensity may enhance patient education strategies aimed at improving physical activity levels. Therefore, the objective of this study was to investigate the relationships and usefulness of physical activity, physical performance, and physical function in patients with COPD, focusing on two newly proposed skeletal muscle indices: the upper limb skeletal muscle mass index (USMI) and the lower limb skeletal muscle mass index (LSMI).

## 2. Participants and Methods

### 1) Participants

The participants were 80 stable outpatients with COPD who were enrolled in a pulmonary rehabilitation program at Osaka Fukujuji Hospital (mean age,  $75.4 \pm 7.9$  years; 71 men and 9 women). Inclusion criteria were: a diagnosis of stable COPD, regardless of disease stage or sex, and the ability to provide informed consent. Exclusion criteria were: (1) presence of a pacemaker, (2) less than one month since last exacerbation, (3) impaired mobility, (4) severe medical comorbidities, (5) inability to understand the study purpose or procedures, and (6) incomplete data.

### 2) Methods

#### (1) Measurement indices

The primary measurements included the USMI, LSMI, and the overall Skeletal Muscle mass

Index (SMI). These parameters were measured using a bioelectrical impedance analyzer (InBody270®, InBody Japan, Tokyo, Japan). Explanatory measurements included physical activity, which was assessed using a triaxial accelerometer (Active style Pro®, Omron Corporation, Kyoto, Japan). The device recorded step counts, walking time, weekly exercise (Ex) volume, daily Ex volume, walking Ex volume, lifestyle Ex volume, time spent in activities <3 Metabolic Equivalents of Task (METs), and time spent in activities  $\geq 3$  METs. Physical performance and function were assessed using upper limb skeletal muscle mass, lower limb skeletal muscle mass, and the Incremental Shuttle Walking Distance (ISWD) test. Lower limb muscle strength was measured as maximal isometric knee extension force ( $\mu$ Tas F-1®, ANIMA, Tokyo, Japan). Upper limb muscle strength was measured using maximal handgrip strength measured with a digital handgrip meter (Digital Hand Grip Meter®, Takei Scientific Instruments, Niigata, Japan). Activities of daily living (ADL) were evaluated using the Nagasaki University Respiratory ADL questionnaire (NRADL). Pulmonary function was assessed by forced expiratory volume in one second (FEV<sub>1</sub>), % predicted FEV<sub>1</sub> and the percentage of forced expiratory volume in one second relative to forced vital capacity (FEV<sub>1</sub>%).

## (2) Calculation of USMI and LSMI

The USMI was calculated as the sum of the skeletal muscle mass of the left and right upper limbs(kg), measured using a body composition analyzer, divided by height squared (m<sup>2</sup>).

Similarly, the LSMI was calculated as the sum of the skeletal muscle mass of the left and right lower limbs divided by height squared ( $m^2$ ). These indices adjusted for body size and were used to evaluate region-specific skeletal muscle mass.

### (3) Measurement of physical activity

Each participant was instructed to wear a triaxial accelerometer continuously for one month, after which the device was collected. To avoid intentional increases in physical activity, the device display was configured so that step counts and other metrics were not visible to participants. The accelerometer was attached to the waistband of the trousers and worn throughout the day, except during bathing and sleeping. Data were analyzed using dedicated software, and days with less than 360 min of wear time were excluded from the analysis.

### (4) Nagasaki University Respiratory ADL questionnaire

The NRADL is a respiratory disease-specific ADL questionnaire developed in Japan. It evaluates activities of daily living in four categories: movement speed, dyspnea, oxygen flow rate, and continuous walking distance. Each item is scored on a scale from 0 to 3 (except for continuous walking distance, which is scored from 0 to 10). The total score ranges from 0 to 100, with higher scores indicating greater independence in ADL.

### (5) Statistical analysis

Associations between USMI, LSMI, SMM variables, and explanatory measures were examined using Pearson's correlation coefficients. A correlation coefficient  $\geq 0.40$  was considered clinically relevant<sup>19</sup>). To identify independent determinants of USMI, LSMI and SMI, multiple regression analyses with stepwise selection were performed. Independent variables included step counts, weekly Ex volume, time spent in activities  $\geq 3$  METs, ISWD, %FEV<sub>1</sub>, and age<sup>11, 20-21</sup>). Statistical significance was defined as  $p < 0.05$ . Analyses were conducted using SPSS version 30 (IBM Corp., Armonk, NY, USA).

### (6) Ethical considerations

This study was a retrospective study using date obtained from routine clinical practice and was conducted in an opt-out manner. In addition, this study was approved by the Research Ethics Committee of Kyoto Tachibana University (approval number: 25-4).

## 3. Results

The participant flow is shown in Figure 1. A total of 61 participants were included in the final analysis. Baseline characteristics are presented in Table 1. The mean age was  $75.3 \pm 7.8$  years, and 54 participants (88.5%) were male. The mean body mass index (BMI) was  $21.3 \pm 3.4 \text{ kg/m}^2$ . Distribution across the Global Initiative for Chronic Obstructive Lung Disease (GOLD)

categories was balanced, with 21 participants in group A, 20 in group B, and 20 in group C.

Table 2 shows the results of primary and explanatory measurements. The mean values were as

follows: USMI,  $1.6 \pm 0.4$ ; LSMI,  $4.9 \pm 0.7 \text{ kg/m}^2$ ; upper limb skeletal muscle mass,  $4.3 \pm 1.1$

kg; lower limb skeletal muscle mass,  $13.4 \pm 2.6 \text{ kg}$ ; and SMI,  $6.5 \pm 1.0$ . Regarding physical

activity, the mean step count was  $2587.8 \pm 2153.5 \text{ steps/day}$ , weekly Ex volume was  $15.1 \pm$

$10.4 \text{ Ex/week}$ , time spent in activities  $<3 \text{ METs}$  was  $617.0 \pm 142.9 \text{ min/day}$ , and time spent in

activities  $\geq 3 \text{ METs}$  was  $35.6 \pm 24.9 \text{ min/day}$ . The mean ISWD was  $327.5 \pm 168.8 \text{ m}$ , and

the  $\% \text{FEV}_1$  was  $57.1 \pm 27.2\%$ . Table 3 presents correlations between skeletal muscle indices

and physical activity. USMI was not significantly correlated with any physical activity

variables. LSMI was significantly correlated with weekly Ex volume ( $r = 0.42, p < 0.01$ ), daily

Ex volume ( $r = 0.42, p < 0.01$ ), and time spent in activities  $\geq 3 \text{ METs}$  ( $r = 0.40, p < 0.01$ ). Upper

limb skeletal muscle mass was correlated only with lifestyle Ex volume ( $r = 0.40, p < 0.01$ ).

Lower limb skeletal muscle mass was significantly correlated with weekly Ex volume ( $r = 0.44,$

$p < 0.01$ ), daily Ex volume ( $r = 0.44, p < 0.01$ ), and time spent in activities  $\geq 3 \text{ METs}$  ( $r = 0.43,$

$p < 0.01$ ). SMI was significantly correlated with weekly Ex volume ( $r = 0.43, p < 0.01$ ), daily

Ex volume ( $r = 0.43, p < 0.01$ ), lifestyle Ex volume ( $r = 0.42, p < 0.01$ ), and time spent in

activities  $\geq 3 \text{ METs}$  ( $r = 0.42, p < 0.01$ ). Table 4 shows correlations between skeletal muscle

indices and functional outcomes. USMI was significantly correlated with knee extension

strength ( $r = 0.58, p < 0.01$ ), grip strength ( $r = 0.55, p < 0.01$ ), and  $\text{FEV}_1$  ( $r = 0.44, p < 0.01$ ).

LSMI was correlated with ISWD ( $r = 0.46, p < 0.01$ ), knee extension strength ( $r = 0.69, p < 0.01$ ), grip strength ( $r = 0.58, p < 0.01$ ), and FEV<sub>1</sub> ( $r = 0.41, p < 0.01$ ). Upper limb skeletal muscle mass was correlated with ISWD ( $r = 0.48, p < 0.01$ ), knee extension strength ( $r = 0.64, p < 0.01$ ), grip strength ( $r = 0.63, p < 0.01$ ), and FEV<sub>1</sub> ( $r = 0.50, p < 0.01$ ). Lower limb skeletal muscle mass was correlated with ISWD ( $r = 0.51, p < 0.01$ ), knee extension strength ( $r = 0.67, p < 0.01$ ), grip strength ( $r = 0.61, p < 0.01$ ), and FEV<sub>1</sub> ( $r = 0.44, p < 0.01$ ). SMI was correlated with ISWD ( $r = 0.45, p < 0.01$ ), knee extension strength ( $r = 0.73, p < 0.01$ ), grip strength ( $r = 0.65, p < 0.01$ ), and FEV<sub>1</sub> ( $r = 0.50, p < 0.01$ ). Table 5 presents the results of stepwise multiple regression analyses for USMI, LSMI and SMI. ISWD was identified as an independent determinant for all three indices. For USMI, ISWD was a significant predictor ( $B = 0.001, \beta = 0.41, 95\% \text{ confidence interval [CI]: } 0.000\text{--}0.001, p = 0.02$ ), with an adjusted R<sup>2</sup> of 0.15. For LSMI, ISWD was also a significant predictor ( $B = 0.002, \beta = 0.48, 95\% \text{ CI: } 0.001\text{--}0.003, p < 0.01$ ), with an adjusted R<sup>2</sup> of 0.21. In addition, for SMI, ISWD was identified as a significant predictor ( $B = 0.002, \beta = 0.47, 95\% \text{ CI: } 0.001\text{--}0.004, p < 0.01$ ), with an adjusted R<sup>2</sup> of 0.21. Across all analyses using USMI, LSMI, and SMI, independent variables such as step counts and weekly Ex volume were expected to be correlated. However, in the final models, only ISWD was retained, and the variance inflation factor (VIF) was 1.00, indicating that multicollinearity was not an issue.

#### 4. Discussion

This study examined the associations and usefulness of the USMI and LSMI with physical activity, physical performance and physical function in patients with COPD. While previous studies have commonly used SMM or the SMI<sup>22</sup>, our study newly introduced USMI and LSMI as region-specific indices. The findings demonstrated that USMI was not significantly correlated with physical activity or exercise tolerance. Upper limb skeletal muscle mass was correlated only with lifestyle Ex volume. In contrast, LSMI and SMI showed significant correlations with weekly Ex volume, daily Ex volume, and time spent in activities  $\geq 3$  METs. Similarly, unadjusted lower limb skeletal muscle mass also demonstrated significant associations. LSMI demonstrated correlations comparable to those of SMI, suggesting that LSMI may possess validity equivalent to the established SMI while more accurately reflecting its associations with physical activity. This suggests that LSMI may serve as a more reliable indicator than absolute muscle mass when assessing patients with different body constitutions. These results reflect the fact that daily activities in COPD predominantly involve lower limb–driven movements such as walking, while upper limb muscle mass contributes less to overall activity. Therefore, interventions aimed at improving physical activity should prioritize the preservation and enhancement of lower limb muscle mass. LSMI, a novel index developed to reflect lower limb skeletal muscle mass, has not yet been investigated for its clinical utility in patients with COPD. However, the present findings suggest that it may represent a clinically

meaningful indicator in the assessment of physical activity in this population. Step count, a conventional measure of physical activity, was not significantly correlated with USMI, LSMI or SMI. However, significant associations were observed with Ex volume and time spent in activities  $\geq 3$  METs. This finding indicates that quantitative walking measures alone are insufficient and activity intensity and overall daily activity must also be considered. Previous studies have shown that patients with COPD exhibit reduced activity intensity compared with healthy individuals<sup>23)</sup>, and the present results further emphasize the importance of promoting intensity-based activities. Thus, pulmonary rehabilitation and patient education should address not only increasing step count but also Ex volume and activity intensity. Regarding exercise tolerance, USMI was not correlated with ISWD, whereas LSMI and SMI demonstrated significant correlations and were independently associated with ISWD in multiple regression analysis. The magnitude of this association was greater for LSMI and SMI than for USMI, suggesting a closer relationship between LSMI and SMI and exercise tolerance. Prior studies have reported associations between fat-free mass and exercise capacity<sup>24-25)</sup>, and our findings support this by showing a correlation between SMI and ISWD. However, the absence of an association with USMI and the presence of a strong association with LSMI and SMI indicate that lower limb muscle mass, rather than upper limb muscle mass, plays a central role in exercise tolerance in COPD. This is consistent with the fact that aerobic training in pulmonary rehabilitation primarily involves lower limb activities such as walking and cycling, and that a

decline in LSMI may directly contribute to reduced exercise tolerance. While upper limb muscles are important for activities of daily living such as grooming, eating, and household tasks, they have limited influence on endurance and walking ability. The independent association between LSMI and SMI with ISWD observed in this study underscores the critical importance of lower limb muscle mass in maintaining and improving exercise tolerance in COPD. This study has some limitations. First, most participants were men, which prevented an adequate evaluation of sex-specific effects. As men generally have greater muscle mass than women, this imbalance may have influenced the results. Second, the cross-sectional design precludes causal inference. Longitudinal studies are warranted to confirm these findings. In addition, it will be important to further examine these relationships in patients with severe COPD, who are known to have reduced skeletal muscle mass. Furthermore, to facilitate clinical application, interventional studies incorporating pulmonary rehabilitation should be conducted to determine how changes in LSMI contribute to improvements in physical activity and exercise tolerance. In conclusion, this study demonstrated that LSMI, similar to SMI is associated with physical activity and exercise tolerance in patients with COPD. Incorporating simple assessments of LSMI into pulmonary rehabilitation programs may facilitate individualized exercise prescription and strengthen patient education.

## 5. Conclusion

This study demonstrated that the LSMI is associated with both physical activity and exercise tolerance in patients with COPD, similar to the SMI. In particular, LSMI was significantly related to activity measures that accounted for intensity as well as to exercise tolerance, whereas the USMI showed no such associations. These findings highlight the importance of evaluating lower limb muscle mass in pulmonary rehabilitation and suggest that LSMI, similar to SMI, may serve as a valuable clinical index for individualized patient assessment.

## 6. Acknowledgements

### Author contributions

J.O. conceived and designed the study, collected the data, performed the statistical analyses, and drafted the manuscript. S.K. contributed to data collection and assisted with data analysis. S.K. contributed to data collection. J.H. contributed to data collection, provided supervision of the study, and critically reviewed the manuscript. All authors read and approved the final manuscript.

### English Language Editing

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## 7. Declaration of Interest

The authors declare no conflicts of interest related to this study.

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Table 1. Baseline Characteristics of the Participants

Variables	Measurements
n	61
Age years	75.3± 7.8
Sex male/female	54/7
Height m	1.6± 0.1
Weight kg	58.0± 10.4
BMI kg/m <sup>2</sup>	21.3± 3.4
Body fat percentage %	24.2± 7.9
MRC scale grade0/1/2/3/4	7/18/15/15/6
GOLD category A/B/E	21/20/20
GOLD stage / / /	12/12/22/9
MNA-SF points	11.5± 2.1
MMSE points	28.1± 1.9
MOCA-J points	24.3± 3.6
HOT yes/no	25/36

Values are presented as mean ± standard deviation.

BMI: Body mass index, mMRC scale: The Modified Medical Research Council Dyspnea Scale,

GOLD: Global Initiative for Chronic Obstructive Lung Disease, MNA-SF: Mini Nutritional

Assessment Short Form, MMSE: Mini-Mental State Examination, MOCA-J: Japanese Version

of The Montreal Cognitive Assessment, HOT: Home Oxygen Therapy.

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Table 2. Results of Primary and Explanatory Measurements

Variables	Measurements
Primary measurements	
USMI kg/m <sup>2</sup>	1.6± 0.4
LSMI kg/m <sup>2</sup>	4.9± 0.7
SMI kg/m <sup>2</sup>	6.5± 1.0
Explanatory measurements (physical activity)	
Step counts step/d	2587.8± 2153.5
Walking time min/d	43.1± 25.5
Weekly Ex volume Ex/w	15.1± 10.4
Daily Ex volume Ex/d	2.2± 1.5
Walking Ex volume Ex/d	0.7± 0.8
Lifestyle Ex volume Ex/d	1.4± 0.9
<3METs min/d	617.0± 142.9
3METs min/d	35.6± 24.9
Explanatory measurements (physical performance and function)	
UL skeletal muscle mass kg	4.3± 1.1

LL skeletal muscle mass kg	13.4± 2.6
ISWD m	327.5± 168.8
Knee extension kgf	32.2± 10.6
Handgrip strength kg	32.1± 7.7
NRADL points	77.8± 21.5
FEV <sub>1</sub> L	1.47± 0.8
%FEV <sub>1</sub> %	57.1± 27.2
FEV <sub>1</sub> % %	54.0± 15.4

Values are presented as mean ± standard deviation.

USMI: Upper limb Skeletal Muscle mass Index, LSMI: Lower limb Skeletal Muscle mass

Index, SMI: Skeletal Muscle mass Index, Ex: Exercise, METs: Metabolic Equivalents of Tasks,

UL: Upper Limb, LL: Lower Limb, ISWD: Incremental Shuttle Walking Distance, NRADL:

The Nagasaki University Respiratory ADL questionnaire, FEV<sub>1</sub>: Forced expiratory volume in one second, FEV<sub>1</sub>: % Forced expiratory volume in one second, FEV<sub>1</sub>%: Forced expiratory volume % in one second.

Table 3. Correlation Analysis between USMI, LSMI, Upper Limb Muscle Mass, Lower Limb Muscle Mass, SMI, and Physical Activity

	USMI		LSMI		UL skeletal		LL skeletal		SMI	
	r	p	r	p	r	p	r	p	r	p
step counts	0.17	0.19	0.33	<0.0	0.24	0.06	0.37	<0.0	0.30	0.02
walking			0.04	<0.0				<0.0		<0.0
time	0.26	0.04	0.38	<0.0	0.31	0.02	0.39	<0.0	0.38	<0.0
Weekly Ex			<0.0	<0.0				<0.0		<0.0
volume	0.33	0.33	0.42	0.42	0.39	0.44	0.44	0.43	0.43	0.43
Daily Ex			<0.0	<0.0				<0.0		<0.0
volume	0.33	0.33	0.42	0.42	0.39	0.44	0.44	0.43	0.43	0.43
walking Ex			<0.0	<0.0				<0.0		<0.0
volume	0.18	0.16	0.34	0.34	0.25	0.06	0.37	0.30	0.30	0.02
lifestyle			<0.0	<0.0				<0.0		<0.0
Ex volume	0.38	0.38	0.37	0.37	0.40	0.38	0.38	0.42	0.42	0.42
<3 METs	-0.23	0.07	-0.23	0.08	-0.22	0.08	0.43	-0.27	0.38	
								1		

	<0.0			<0.0			<0.0		
3METs	0.32	0.01	0.40	0.38		0.43	0.42		
	1			1		1	1		1

USMI: Upper limb Skeletal Muscle mass Index, LSMI: Lower limb Skeletal Muscle mass

Index, UL: Upper Limb, LL: Lower Limb, SMI: Skeletal Muscle mass Index, Ex: Exercise,

METs: Metabolic Equivalents of Tasks.

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Table 4. Correlation Analysis between USMI, LSMI, Upper Limb Muscle Mass, Lower Limb Muscle Mass, SMI, and Physical Performance and Physical Function

	USMI		LSMI		UL skeletal		LL skeletal		SMI			
	r	p	r	p	r	p	r	p	r	p		
ISWD	0.39	<0.0	0.46	<0.0	0.48	<0.0	0.51	<0.0	0.45	<0.0		
		1		1		1		1		1		
knee extensio	0.58	<0.0	0.69	<0.0	0.64	<0.0	0.67	<0.0	0.73	<0.0		
		1		1		1		1		1		
n handgri	0.55	<0.0	0.58	<0.0	0.63	<0.0	0.61	<0.0	0.65	<0.0		
		1		1		1		1		1		
strength	0.32	0.01	0.31	0.01	0.35	<0.0	0.33	0.01	0.34	0.01		
						1						
NRADL	0.44	<0.0	0.41	<0.0	0.50	<0.0	0.44	<0.0	0.50	<0.0		
		1		1		1		1		1		
%FEV <sub>1</sub>	0.34	0.01	0.28	0.04	0.31	0.02	0.23	0.09	0.36	0.01		
FEV <sub>1</sub> %	0.32	0.02	0.17	0.21	0.31	0.02	0.16	0.25	0.30	0.03		

USMI: Upper limb Skeletal Muscle mass Index, LSMI: Lower limb Skeletal Muscle mass Index, UL: Upper Limb, LL: Lower Limb, SMI: Skeletal Muscle mass Index, ISWD: Incremental Shuttle Walking Distance, NRADL: The Nagasaki University Respiratory ADL questionnaire, FEV<sub>1</sub>: Forced expiratory volume in one second, FEV<sub>1</sub>: % Forced expiratory volume in one second, FEV<sub>1</sub>%: Forced expiratory volume % in one second.

Table 5. Stepwise Multiple Regression Analyses for USMI, LSMI and SMI

n=61							
Dependent variable	USMI	B	$\beta$	95% CI		p	VIF
Independent variables	ISWD	0.001	0.41	0.0003	0.001	0.02	1.00
$R^2$			0.17				
Adjusted $R^2$			0.15				
Dependent variable	LSMI	B	$\beta$	95% CI		p	VIF
Independent variables	ISWD	0.002	0.48	0.001	0.003	p<0.01	1.00
$R^2$			0.23				
Adjusted $R^2$			0.21				
Dependent	SMI						

variable	95% CI				p	VIF
	B	$\beta$	Lower	Upper		
<b>Independent</b>						
ISWD	0.002	0.47	0.001	0.004	p<0.01	1.00
variables						
R <sup>2</sup>		0.22				
Adjusted R <sup>2</sup>		0.21				

Independent variables: step counts, weekly Ex volume, activity  $\geq 3$  METs, ISWD, %FEV<sub>1</sub>, Age.

USMI: Upper limb Skeletal Muscle mass Index, LSMI: Lower limb Skeletal Muscle mass

Index, ISWD: Incremental Shuttle Walking Distance, 95% CI: 95% Confidence Interval, VIF:

Variance Inflation Factor.

Figure 1

Figure

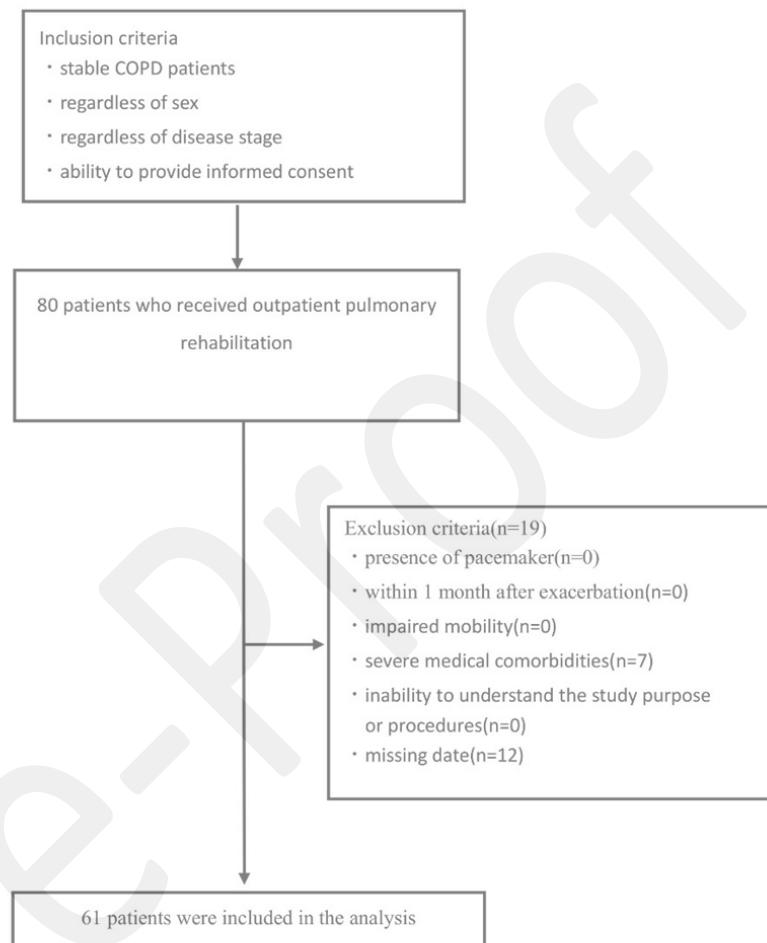


Figure 1. Study Flowchart