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Original Article

The association between the body composition and lifestyle affecting pulmonary function in Japanese workers

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Abstract. [Purpose] The purpose of this study was to identify factors related to physical characteristics and lifestyle that affect pulmonary function. [Subjects and Methods] Ninety seven healthy male workers were recruited for this study, and basic information and details about lifestyle were collected. Body composition analyzer and visceral fat measuring device were conducted as measurements. Pulmonary function was measured using spirometer. A multiple stepwise linear regression analysis was performed with pulmonary function as the dependent variable. Variables with a significant association with pulmonary function on univariate analysis were imputed as independent variables. [Results] Height, fat free mass, upper extremity muscle mass, lower extremity muscle mass, and trunk muscle mass had significant positive correlations with FEV1 and FVC. Age, percentage of body fat, and visceral fat area were negatively correlated with FEV1 and FVC. Regarding the association between pulmonary function and lifestyle, a significant difference was found between the smoking index and the presence or absence of metabolic syndrome risk factors and both FEV1 and FVC. The multiple stepwise linear regression analysis with FEV1 as the dependent variable, adjusted for age and height, revealed that visceral fat area and fat free mass were significantly associated with FEV1. A similar analysis, FVC as the dependent variable identified visceral fat area. [Conclusion] FEV1 was independently associated with visceral fat area and fat free mass. FVC was independently associated with visceral fat area. These results may be valuable in preventing the decrease in respiratory function and, hence, in further preventing the onset of COPD.

Key words: Pulmonary function, Visceral fat area, Worker

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INTRODUCTION

In recent years, the incidence of chronic obstructive pulmonary disease (COPD) has been increasing, and according to the World Health Organization, COPD will become the third common cause of death by 2030[1)]. An epidemiological survey in Japan, in 2004, found that the prevalence of COPD among Japanese adults, aged 40 years or older, was 8.6%, corresponding to approximately 5,300,000 persons[2)]. The prevention of COPD onset is an urgent public health issue in Japan as the incidence is expected to rise further.

Body composition undergoes significant changes with aging and, specifically, there is a decrease in muscle mass while

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fat mass, particularly visceral fat mass, increases[3–5]. The accumulation of visceral fat is associated with insulin resistance and impaired glucose tolerance, elevated blood pressure, and disorder of lipid metabolism, such as metabolic syndrome (MetS)[6] and is considered a risk factor of arteriosclerotic[7]. Furthermore, a recent study reported that abdominal obesity is associated with a decreased respiratory function and the onset of COPD[8–10]. Abdominal obesity is characterized by visceral fat and subcutaneous fat components. Visceral fat is associated with greater systemic inflammation and insulin resistance than subcutaneous fat[11, 12], however no studies have examined the independent association of visceral fat with the respiratory function by distinguishing between visceral fat and subcutaneous fat[13].

Furthermore, reduced physical activity, which causes visceral fat accumulation, is associated with COPD, because shortness of breath, a cardinal symptom for COPD, results in diminished physical activity. It has been suggested that physical activity affects prognosis, in terms of increased mortality, in COPD[14, 15], and that it also affects the risk of onset of COPD[16]. Therefore, it is crucial to determine the association between lifestyle, such as the physical activity, and respiratory function in the workers in order to prevent the future onset of COPD.

Sarcopenia, the age-related loss of muscle mass and muscle strength[17], is an important risk factor for frailty, leading to falls and bedridden status[18–20]. Respiratory function also decreases with age[21, 22] and it is postulated that this is related to respiratory function and muscle mass. However, although studies for patients with COPD have shown that systemic inflammation and skeletal muscle disorders are associated with reduced physical activity[23, 24], there are limited reported studies on the association between respiratory function and muscle mass in the working age population in the abscence of COPD[25].

This study analyzes the association among respiratory function, parameters of body composition, such as muscle mass and the visceral fat area (VFA), and lifestyle parameters that are assumed to be associated with body composition. The aim of this study was to identify factors related to physical characteristics and lifestyle that affect the pulmonary function.

SUBJECTS AND METHODS

Respiratory function measurement was carried out for 127 men employed in 2 companies followed by the health measurement conducted by the research center for the Health Promotion and Employment Support, Kyushu Rousai Hospital in 2015. Following the provision of information on the purpose of the study and on privacy protection of participants, consent was obtained from 120 subjects. Exclusion criteria were subjects with blanks to self-administered questionnaires, pulmonary disease or a history of pulmonary disease, and forced expiratory volume in one second percent (FEV1/FVC)<0.7 . A total of 97 healthy male workers were therefore recruited for this study. The average age was 45.5 ± 9.2 (years), weight was 73.5 ± 11.3 (kg), and height was 171.5 ± 5.4 (cm). The breakdown, according to the type of industry, and based on the International Standard Classification of Occupations (Major Groups)[26] was as follows: managers (33); professionals, technicians and associate professionals (22) ; clerical support workers (30) ; service and sales workers (9) ; craft and related trades workers (1) ; and others (9). The study complied with guidelines set out by the Ethics Committee of the Kyushu Nutrition Welfare University, Higashi Chikushi Junior College.

Self-administered questionnaire was used to collect the following information: age, height, disease under treatment, and prevalence of MetS risk factors (hypertension, dyslipidemia, diabetes, obesity). Information on smoking habits and physical activity, as a part of lifestyle information, was also collected via self-administered questionnaires. The subject smoking habit was described by the smoking index (pack-years), calculated by multiplying the number of years the person has smoked by the mean number of cigarettes smoked per day. Physical ativity was evaluated using the short version of the International Physical Activity Questionnaire (IPAQ), Japanese edition. The reliability and validity of this questionnaire has previously been established[27, 28]. Physical activity was calculated physical activity (Mets.mins) by multiplying the intensity of the physical activity by the time, according to high strength, moderate strength, and locomotor intensity of the exercise in IPAQ. This method was shown by Murase et al[28]. Weight, body mass index, waist circumference, percentage of body fat, fat free mass, and waist to hip ratio were measured by body composition analyzer (InBody 720, InBody Co., Ltd., Seoul, Korea) using bioelectric impedance analysis. Measurements were taken in the standing position over 90 seconds. Upper extremity muscle mass, lower extremity muscle mass, upper extremity fat mass, and lower extremity fat mass were calculated from relevant measurements of muscle and fat mass (left upper extremity, right upper extremity, left lower extremity, right lower extremity). The skeletal muscle index (SMI)[29], one of the diagnostic indexes for sarcopenia, was calculated as an appendicular skeletal muscle mass divided by squared height. Using a visceral fat measuring device (HDS-2000 DUALSCAN, OMRON HEALTHCARE Co., Ltd., Kyoto, Japan), the VFA and the subcutaneous fat area (SFA) were measured. Measurements were performed in the supine position.

Spirometry test was performed according to guidelines developed by the Committee of Pulmonary Physiology of the Japanese Respiratory Society[30]. The measurement was performed in the sitting position. Forced expiratory volume in one second (FEV1), forced vital capacity (FVC), forced expiratory volume in one second percent (FEV1/FVC) were measured by an electronic spirometer (Autospiro AS-507, MINATO MEDICAL SCIENCE Co., Ltd., Osaka, Japan). Predicted FEV1 and predicted FVC were calculated using the equation developed by the Japanese Respiratory Society[31].

The values were described as mean ± standard deviation or median (interquartile range 25–75%), for normally and not normally distributed data, respectively. Categorical data were expressed as a frequency and percentage. Analyses were performed using IBM SPSS Statistics 22.0 (IBM Japan, Ltd., Tokyo, Japan). The p-values of <0.05 were considered statisti-

Table 1. The characteristics of analysis subjects

Variables	Values
Basic information	
Age (years)	46.0 (39.0–53.0)
Height (cm)	171.5 ± 5.4
No MetS risk factors	82 (84.5)
Lifestyle information	
Smoking index (Pack-years)	120.0 (0.0–400.0)
High strength time (min)	0.0 (0.0–480.0)
Moderate strength time (min)	0.0 (0.0–420.0)
Locomotor intensity time (min)	396.0 (115.5–693.0)
Physical activity (Mets.mins)	960.0 (495.0–1485.0)
Body Composition	
Weight (kg)	71.9 (66.6–81.3)
Body mass index (kg/m^2)	24.8 (22.6–27.4)
Waist circumference (cm)	83.8 (77.8–92.2)
Percentage of body fat (%)	22.6 (18.4–28.8)
Fat free mass (kg)	55.7 ± 5.3
Waist to Hip ratio	0.9 (0.8–0.9)
Upper extremity muscle mass (kg)	6.0 ± 0.8
Lower extremity muscle mass (kg)	18.1 ± 1.9
Trunk muscle mass (kg)	24.4 ± 2.5
Upper extremity fat mass (kg)	1.8 (1.3–2.7)
Lower extremity fat mass (kg)	5.1 (4.0–6.7)
SMI (kg/m^2)	8.2 ± 0.6
Visceral fat area (cm^2)	81.8 (62.5–106.4)
Subcutaneous fat area (cm^2)	169.0 (127.1–218.3)
Pulmonary Function	
FEV1 (L)	3.6 ± 0.5
FEV1 %predicted	96.6 ± 10.4
FVC (L)	4.4 ± 0.6
FVC %predicted	101.3 ± 10.9
FEV1/FVC (%)	82.1 ± 4.8

The values were described as mean ± standard deviation or median (interquartile range 25–75%), for normally and not normally distributed data, respectively. Categorical data were expressed as a frequency and percentage. MetS: Metabolic Syndrome, SMI: Skeletal Muscle Index, FEV1: Forced Expiratory Volume in one second, FVC: Forced Vital Capacity

Table 2. The correlation between pulmonary function and lifestyle

	FEV1 (L)	FVC (L)
Smoking index (Pack-years)	−0.208 *	−0.200 *
High strength time (min)	0.183	0.197
Moderate strength time (min)	0.024	0.003
Locomotor intensity time (min)	−0.090	−0.120
Physical activity (Mets.mins)	0.031	0.007

* $p<0.05$. All were analyzed using Spearman correlation coefficient.

Table 3. The difference in pulmonary function according to prevalence of MetS risk factors

Prevalence of MetS risk	FEV1 (L)	FVC (L)
	Values	Values
No	3.6 ± 0.5 *	4.4 ± 0.5 *
Yes	3.3 ± 0.4	4.0 ± 0.6

*$p<0.05$ (vs. Yes).
This was analyzed using Two sample t-test. MetS: Metabolic Syndrome

cally significant.

Correlations between respiratory function and body composition, basic information, and lifestyle were analyzed using Pearson's correlation coefficient for continuous variables or Spearman correlation coefficient for ordinal variables. Two groups, identified according to prevalence of MetS risk factors, were compared using two-sample t-test or Mann-Whitney test, according to the distribution.

A multiple stepwise linear regression analysis was performed with the pulmonary function as the dependent variable. Variables with a significant association with pulmonary function on univariate analysis were imputed as independent. Age and height were imputed as adjustment variables. It was confirmed that the variance inflation factor (VIF) of independent variables was less than 10 to avoid the potential issue of multicollinearity.

RESULTS

Table 1 shows the characteristics, pulmonary function, body composition, and lifestyle of the subjects included in the study.

Table 4. The correlation coefficient between pulmonary function and body composition

	FEV1 (L)	FVC (L)
Age (year)[b]	−0.578 **	−0.511 **
Height (cm)[a]	0.501 **	0.552 **
Weight (kg) [b]	0.149	0.149
Body mass index (kg/m^2) [b]	−0.064	−0.087
Waist circumference (cm) [b]	0.004	0.002
Percentage of body fat (%)[a]	−0.227 *	−0.240 *
Fat free mass (kg) [a]	0.407 **	0.390 **
Waist to hip ratio [b]	−0.058	−0.051
Upper extremity muscle mass (kg) [a]	0.306 **	0.268 **
Lower extremity muscle mass (kg) [a]	0.411 **	0.418 **
Trunk muscle mass (kg) [a]	0.342 **	0.310 **
Upper extremity fat mass (kg) [b]	−0.164	−0.165
Lower extremity fat mass (kg) [b]	−0.134	−0.143
SMI (kg/m^2) [a]	0.156	0.100
Visceral fat area (cm^2) [b]	−0.252 *	−0.275 **
Subcutaneous fat area (cm^2) [b]	−0.063	−0.083

*p<0.05, **p<0.01. [a]Pearson's correlation coefficient. [b]Spearman correlation coefficient.
SMI: Skeletal Muscle Index

Table 5. The multiple stepwise linear regression analysis that assumed FEV1 as a dependent variable with being adjusted by age and height

	Partial regression coefficient	Standard partial regression coefficient	95% confidence interval	VIF
(Constant)	0.453		−2.453 to 3.359	
Age	−0.023	−0.413**	−0.032 to −0.014	1.252
Height	0.019	0.195	−0.001 to 0.039	2.101
Percentage of body fat		0.033		3.847
Fat free mass	0.023	0.239*	0.000 to 0.046	2.693
Upper extremity muscle mass		−0.022		11.305
Lower extremity muscle mass		−0.163		12.546
Trunk muscle mass		0.033		13.846
Visceral fat area	−0.004	−0.290**	−0.007 to −0.002	1.542
Smoking index		−0.030		1.214
No MetS risk factors		0.041		1.127

*p<0.05, **p<0.01. ANOVA<0.001. R=0.720, R^2=0.518, adjusted R^2=0.497. VIF: Variance Inflation Factor, MetS: Metabolic Syndrome

The correlation between pulmonary function and lifestyle are shown in Table 2. Both FEV1 and FVC were negatively associated with the smoking index (p<0.05). No significant associations among other variables were observed. Table 3 shows the difference in pulmonary function according to prevalence of MetS risk factors of the individuals. A significant difference was observed with respect to presence or absence of MetS risk factors according to the FEV1 and FVC, the absence of MetS risk factors (p<0.05) was significantly associated with higher FEV1 and FVC.

Table 4 shows the correlation coefficient and p-values between pulmonary function and body composition. Significant positive correlations were observed between FEV1 and height (p<0.001), fat free mass (p<0.001), upper extremity muscle mass (p<0.005), lower extremity muscle mass (p<0.001), and trunk muscle mass (p<0.001), respectively. Age (p<0.001), percentage of body fat (p<0.05), VFA (p<0.05) were negatively correlated with FEV1. Height (p<0.001), fat free mass (p<0.001), upper extremity muscle mass (p<0.01), lower extremity muscle mass (p<0.001), and trunk muscle mass (p<0.005) correlated positively with FVC. Age (p<0.001), percentage of body fat (p<0.05), and VFA (p<0.01) correlated negatively with FVC.

The results of the multiple stepwise linear regression analysis that assumed FEV1 and FVC as dependent variables, adjusted by age and height, are shown in Tables 5 and 6. From the results of FEV1 as dependent variable, VFA and fat free

Table 6. The multiple stepwise linear regression analysis that assumed FVC as a dependent variable with being adjusted by age and height

	Partial Regression coefficient	Standard partial regression coefficient	p value	95% confidence interval	VIF
(Constant)	−2.511		0.130	−5.774 to 0.751	
Age	−0.024	−0.361	0.000**	−0.034 to −0.014	1.117
Height	0.048	0.422	0.000**	0.030 to 0.066	1.109
Percentage of body fat		0.092	0.532		3.815
Fat free mass		0.185	0.131		2.693
Upper extremity muscle mass		0.129	0.232		2.081
Lower extremity muscle mass		0.110	0.471		4.119
Trunk muscle mass		0.156	0.186		2.467
Visceral fat area	−0.004	−0.216	0.005**	−0.006 to −0.001	1.017
Smoking index		0.025	0.764		1.196
No MetS risk factors		0.101	0.202		1.116

*p<0.05, **p<0.01. ANOVA<0.001. R=0.695, R^2=0.482, adjusted R^2=0.466. VIF: Variance Inflation Factor, MetS: Metabolic Syndrome

mass were identified. The multiple regression model was significant, and the adjusted R^2 was 0.497. From the results of FVC as dependent variable, VFA was identified. The multiple regression model was significant, and the adjusted R^2 was 0.466.

DISCUSSION

Among diseases that are associated with aging, COPD is the main cause of morbidity and mortality in the elderly people[32]. Specifically, the decrease in FEV1 has been shown as an independent factor associated with increased mortality[33]. Thus, prevention of pulmonary function decline in younger population is important because the age-related decrease in pulmonary function results in the onset of COPD and in an increased risk of death in elderly people. The purpose of this study was to examine the workers and identify factors related to physical characteristics and lifestyle that affect the pulmonary function.

This study found that VFA and percentage of body fat are associated with a decreased pulmonary function in multiple regression analysis, adjusted by age and height. Previous studies on the association between pulmonary function and physical characteristics have shown that an index of central obesity, including waist circumference and waist to Hip ratio, and abdominal height expressing visceral fat accumulation[34] were associated with a decreased respiratory function[9, 10, 35]. Diaphragmatic movement is limited in obesity while abdominal pressure is increased, particularly with the accumulation of visceral fat[36]. Therefore, it is postulated that a reduction in expiratory reserve volume, FEV1, and FVC is due to a mechanical limitation of air flow, regardless of respiratory tract inflammation[37, 38]. Visceral fat has the function of an endocrine organ and secretes interleukin-6, TNF-α, and leptin. These are associated with systemic inflammation[12, 39, 40]. Furthermore, C-reactive protein is elevated in obese subjects. Systemic inflammation is shown to be associated with pulmonary function[41, 42], and this study shows that systemic inflammation combined with the presence of visceral fat may have an influence on decreased pulmonary function.

Conversely, lifestyle factors affecting pulmonary function in the working generation were not identified. The smoking habit also was not identified as a variable associated with the pulmonary function by the multiple regression analysis although the correlation was observed between smoking habit and pulmonary function. According to the guidelines of the Japanese Respiratory Society[43], COPD is defined as "an inflammatory disease of the lungs that is caused by long-term inhalation exposure to noxious substances such as tobacco smoke". The most important factor causing COPD is cigarette smoke (smoking and passive smoking). Specifically, smoking promotes the exacerbation of pulmonary function decline with aging, and the decrease in pulmonary function is greater compared to that in nonsmokers[44]. Therefore, future lifestyle changes are important because respiratory function decreases and the risk of COPD onset increases with time even if the smokers of the working population have good respiratory function at present. Both active and passive smoking should be taken into account. It cannot be examined that the effects of passive smoking because the history of passive smoking is not assessed in this study. Previous studies have shown that passive smoking is independently associated with COPD onset[45] from other factors, and that parental smoking habits influence the development of the respiratory function in children[46]. Therefore, it is necessary to investigate further the association between cigarette smoke, including a history of passive smoking, and respiratory function.

Studies in elderly people have shown that fat free mass, muscle in the trunk and low extremity are associated with respiratory function[9, 10, 25]. In addition, it has been reported that sarcopenia, an age-related reduction in muscle mass[47], causes breathing muscle weakness. Furthermore, it has been reported that skeletal muscle disorders associated with systemic inflammation and a reduction in physical activity may occur in patients with COPD[23]. However, upper extremity muscle mass, lower extremity muscle mass, trunk muscle mass, and SMI were not identified as the key factors affecting pulmonary function in multiple regression analysis. SMI calculated by using upper extremity muscle mass and lower extremity muscle mass except the trunk muscle mass was unrelated to a pulmonary function even by univariate analysis. It has been suggested that in a working population, SMI cannot be an index for respiratory function because SMI, as an index of sarcopenia, is unrelated to pulmonary function. Conversely, it is postulated that muscle mass decline with aging affects respiratory function because of the association between muscle mass and respiratory function is in elderly people and the patients with COPD. There may be the need to promote maintenance and improvement of muscle mass in the working population in order to reduce the risk of future respiratory function deterioration and COPD onset. It will be necessary to examine the effects of a reduction in age-related muscle mass on pulmonary function.

This study examined factors to affecting pulmonary function in the working population in order to prevent decreased pulmonary function. It was found that FEV1 was associated with VFA and fat free mass, and that FVC was associated with VFA independently of age and height. These results may be valuable in preventing the decrease in respiratory function and, hence, in further preventing the onset of COPD. Guidance on the prevention of visceral fat accumulation is important, and in future, it will be necessary to examine how body composition and lifestyle of the working population affect age-related change in respiratory function.

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