[Original]

Frequency of Exposure to Secondhand Smoke Outside the Home Is Associated with a Lower FEV_1/FVC in Male Workers Regardless of Smoking Status

Atsushi INOMOTO[1,2*], Hiroshi YAMATO[3], Ryoma MICHISHITA[4], Ying JIANG[3], Shingo NISHIYAMA[3], Rika FUKUDA[5] and Junko DEGUCHI[5]

[1] *Faculty of Rehabilitation, Kyushu Nutrition Welfare University. Kokuraminami-ku, Kitakyushu 811-0298, Japan*
[2] *Graduate School of Occupational Health, University of Occupational and Environmental Health, Japan. Yahatanishi-ku, Kitakyushu 807-8555, Japan*
[3] *Department of Health Development, Institute of Industrial Ecological Sciences, University of Occupational and Environmental Health, Japan. Yahatanishi-ku, Kitakyushu 807-8555, Japan*
[4] *Faculty of Sports and Health Science, Fukuoka University. Jonan-ku, Fukuoka 814-0180, Japan*
[5] *Kyushu Rosai Hospital Research Center for the Promotion of Health and Employment Support. Kokuraminami-ku, Kitakyushu 800-0296, Japan*

Abstract **:** Decreased respiratory function associated with aging leads to the onset of chronic obstructive pulmonary disease (COPD) and increased risk of death in the elderly. Prevention of a decline in respiratory function from a young age is important. This study aimed to clarify the factors that affect decreased forced expiratory volume in one second (FEV_1)/forced vital capacity (FVC), an index of obstructive respiratory disorder caused by airway obstruction, by considering the influence of body composition and lifestyle. We recruited 262 employed adult men and determined their lifestyle-related factors, including smoking status, past or current secondhand smoke (SHS) exposure, exposure to SHS outside the home, and physical activity (PA). Body composition and respiratory function were also measured. The data were then compared with those of non-smokers using logistic regression analysis, adjusting for age. We also investigated factors influencing FEV_1/FVC using multiple regression analysis, adjusting for age, height, smoking status, and lifestyle. Current smokers and heavy smokers exhibited significantly lower amounts of PA and had a higher body fat%, visceral fat area, prevalence of cohabitation with smokers, and frequency of SHS exposure outside the home, and FEV_1/FVC was significantly lower in heavy smokers. A multiple regression analysis revealed that FEV_1/FVC was associated only with the frequency of SHS exposure outside the home. It is important for occupational health personnel of a company to advise both non-smokers and smokers to avoid SHS to prevent chronic obstructive pulmonary disease onset. This needs to be coupled with encouragement to quit smoking, especially for heavy smokers.

Keywords **:** body composition, lifestyle, respiratory function, secondhand smoke, workers.

(Received August 9, 2018, accepted November 15, 2018)

*Corresponding Author: Atsushi INOMOTO, Faculty of Rehabilitation, Kyushu Nutrition Welfare University, 1-5-1 Kuzuharatakamatsu, Kokuraminami-ku, Kitakyushu 811-0298, Japan, Tel: +81-93-471-7939, Fax: +81-93-471-8123, E-mail: inomoto@knwu.ac.jp

Introduction

The prevalence of chronic obstructive pulmonary disease (COPD) has increased worldwide in recent years. According to estimates by the World Health Organization, COPD will be the third leading cause of death globally in 2030 [1]. Meanwhile, 8.6% of adults over 40 years old in Japan have COPD (approximately 5.3 million), according to an epidemiological survey conducted in 2004 [2]. Thus, COPD is a major disease that requires urgent examination and countermeasures against declining respiratory function among working-age people. Clarifying the factors related to decreased respiratory function is an urgent task needed to inform prevention efforts.

The Guidelines of the Japan Respiratory Society define COPD as a "disease of the lungs that is caused by long-term inhalation exposure to noxious substances such as tobacco smoke" [3]. Importantly, the primary cause of COPD development is tobacco smoke. Tobacco smoke is divided into mainstream smoke, inhaled directly by the smoker, and secondhand smoke (SHS), which is inhaled by the surrounding people; the respiratory function of the smoker decreases due to, for example, cigarette smoke adversely affecting the muscles [4-6]. Exposure to SHS has also been reported to be a risk factor for COPD, bronchial asthma, and respiratory infection, including reduced respiratory function [7]. Therefore, avoidance of SHS is recommended to prevent the decline of respiratory function. It is recommended that smokers modify their own smoking habits.

Recent reports have indicated that smokers not only have increased abdominal obesity, but also decreased physical activity (PA) and poor nutritional balance [8-12]. In particular, abdominal obesity has been shown to be associated with decreased respiratory function, which is the subject of this study [13]. To the authors' knowledge, however, no comprehensive previous studies have considered these variables. The purpose of this study was to comprehensively analyze the factors that affect forced expiratory volume in one second (FEV_1)/forced vital capacity (FVC), an index of obstructive respiratory disorder caused by airway obstruction, by considering the influence of body composition and lifestyle, and to present effective preventive measures of COPD in workers.

Participants and Methods

Participant recruitment

To perform this study, the respiratory function of male employees from five companies was measured over the course of two years, beginning in the 2016 fiscal year. These measurements were performed at the health assessments conducted by the Kyushu Rosai Hospital research center for the promotion of health and employment support. Of the 324 individuals who were approached, 320 provided written informed consent after being informed of the purpose of the study and being assured that their data would be anonymous. Of these, three participants with cardiovascular disease, two with cerebrovascular disease, three with cancer, 39 with respiratory disease (either past or present), and 11 participants who submitted incomplete self-administered questionnaires were excluded. Thus, a total of 262 healthy male workers were included in this study. With regard to the type of industry in which the participants worked (classified according to the international standard classification of occupations (major groups) [14]), the study cohort comprised the following: managers (n=89); professionals, technicians, and associate professionals (n=133); clerical support workers (n=29); services and sales workers (n=6); craft and related trade workers (n=2); and others (n=3).

The study was approved by the ethics committee of medical research, University of Occupational and Environmental Health, Japan (No. H28-049).

Participant information and lifestyle

Self-administered questionnaires were used to obtain the following information: age, height, receiving treatment for a disease, prevalence of metabolic syndrome (METS) risk factors (hypertension, dyslipidemia, diabetes, and obesity), smoking status, prevalence of cohabitation with smokers (from birth to present), frequency of exposure to SHS outside the home, drinking habits, average duration of sleep on weekdays, and PA. In terms of smoking status, participants were classified as "non-smokers," "ex-smokers," or "current smokers" [15]. The smoking index of ex-smokers and current smokers was calculated by multiplying the number of years of smoking by the average number of cigarettes smoked/day. As done in a previous study [16], current smokers were classified as heavy smokers if they smoked more than 20 cigarettes/day. Regarding the frequency of exposure to SHS outside the home, the participants were asked "Do you go to places that smell of cigarettes?" If the answer was "Yes", the frequency of exposure to SHS was classified as the frequency with which participants visited places where smoking is common, such as a Japanese upright pinball game, restaurants, and pubs. Drinking habits were estimated as the total amount of alcohol consumed in a week (g/week), calculated on the basis of the type of alcohol consumed and the frequency of consumption. PA was evaluated using the short version of the international physical activity questionnaire (IPAQ), Japanese edition, for which reliability and validity have been confirmed in previous studies [17, 18]. PA (kcal) was determined using the PA intensity calculation developed by Murase *et al* [18]. Each participant's weekly average PA was calculated by multiplying PA duration by intensity (low, moderate, or vigorous, determined using the IPAQ), then the weekly average was divided by seven to calculate the daily average. Total PA (kcal/day) was calculated using energy/m*l* of oxygen intake (= 0.005 kcal) and 1 metabolic equivalent = 3.5 m*l*/kg/min.

Body composition

Body weight, body mass index, body fat%, fat-free mass, and regional muscle mass were measured using a body composition analyzer (InBody 720, InBody Co., Ltd., Seoul, Korea) that performed bioelectric impedance analysis. This measurement was conducted while participants were in a standing position and took approximately 90 seconds. Upper limb muscle mass and lower limb muscle mass were calculated using the results of regional muscle mass.

A visceral fat measuring device (HDS-2000 Dualscan, Omron Healthcare Co., Ltd., Kyoto, Japan) was used to measure visceral fat. This instrument measures the visceral fat area (VFA) using the dual impedance method, and has been found to show a high correlation with measurements made using X-ray computed tomography [19]. For the present study, the measurements were obtained with the participants in a supine position, and VFA was measured by examining the cross-sectional area of the abdomen, fat-free area, and subcutaneous fat area.

Respiratory function

Spirometry was performed in accordance with guidelines specified by the committee of pulmonary physiology of the Japanese Respiratory Society [20]. FVC, FEV_1, and FEV_1/FVC were measured using an electronic spirometer (Autospiro AS-507, Minato Medical Science Co., Ltd., Osaka, Japan) while the participants were in a seated position. Predicted FVC and predicted FEV_1 were calculated using an equation developed by the Japanese Respiratory Society [21].

Statistical analysis

For statistical analysis, we examined differences between ex-smokers, current smokers, heavy smokers, and non-smokers in terms of participant age, using the Mann-Whitney *U* test. Information on each smoking participant, except age, lifestyle, body composition, and respiratory function, was compared with that of non-smokers as age-adjusted variables, using multiple logistic regression analysis; odds ratios (OR) and 95% confidence intervals (95%CI) were also calculated.

The relationships between participant information, lifestyle, body composition and FEV_1/FVC were then analyzed for each level of smoking status using Pearson's correlation coefficient and Spearman's rank correlation coefficient for continuous variables. Additionally, differences in FEV_1/FVC between groups based on the prevalence of METS risk factors and cohabitation with smokers, respectively, were examined using a two-sample *t*-test and the Mann-Whitney *U* test.

In order to investigate factors affecting FEV_1/FVC, multiple stepwise linear regression analysis was performed, with FEV_1/FVC as the dependent variable. In Model 1, age, height, and smoking status (non-smokers, ex-smokers, and all current smokers) were set as adjustment variables. In Model 2, cohabitation with smokers at birth, cohabitation with smokers at present, drinking habits, average duration of sleep on weekdays, total PA, and PA according to the intensity of activity were added as adjustment variables. In order to avoid potential issues of multicollinearity, we confirmed that the variance inflation factor (VIF) of independent variables was less than 10. All analyses were performed using SPSS Statistics 25.0 (IBM Co., Armonk, NY). *P*-values less than 0.05 were considered statistically significant.

Results

Characteristics of participants

The values obtained through analysis are described below as mean ± standard deviation or median (interquartile range 25−75%) for normally and not normally distributed data, respectively. Categorical data are expressed as frequencies and percentages. Table 1 shows the information, body composition, lifestyle, and respiratory function of the 262 participants.

Difference based on smoking status

The difference between each indicator in terms of the smoking status of the participants is shown in Table 2. First we determined that the ex-smokers and heavy smokers were significantly older than the non-smokers. Consequently, we decided to conduct multiple logistic regression analysis adjusted for age to compare each indicator with that of the non-smoking group.

As a result, the presence of dyslipidemia and body fat% were found to be significantly higher in the ex-smokers than the non-smokers. For current smokers, body fat%, VFA, cohabitation rate with current smokers, and frequency of exposure to SHS were significantly higher, and total PA and vigorous PA were significantly lower. The same was true of heavy smokers, and FEV_1/FVC was significantly lower.

Correlation analysis between FEV_1/FVC and other factors

Table 3 shows the correlation between FEV_1/FVC and other factors for each smoking status. For the non-smokers, FEV_1/FVC showed a significant negative correlation with both age and alcohol consumption. For ex-smokers, FEV_1/FVC had a significant negative correlation with age only. Finally, for current smokers, there was a significant negative correlation with age, smoking index, and alcohol consumption in terms of FEV_1/FVC. Additionally, among the current smokers, heavy smokers had a significant positive correlation with body fat%.

Table 1. Participant information: body composition, lifestyle, and respiratory function

Variables	Male n=262
Participant information	
Age (years)	48.5 (40.8−57.0)
Height (cm)	170.7±5.8
METS risk n, (%)	59 (22.5)
Hypertension n, (%)	34 (13.0)
Dyslipidemia n, (%)	25 (9.5)
Diabetes n, (%)	13 (5.0)
Obesity n, (%)	3 (1.1)
Body composition	
Weight (kg)	68.2 (61.8−75.6)
Body mass index (kg/m^2)	23.4 (21.5−25.4)
Body fat% (%)	22.5 (18.5−25.9)
Fat-free mass (kg)	53.1 (49.7−56.7)
Upper limb muscle mass (kg)	5.6 (5.1−6.1)
Lower limb muscle mass (kg)	17.4±2.1
Trunk muscle mass (kg)	23.2±2.6
Visceral fat area (cm^2)	67.7 (48.0−89.3)
Lifestyle	
Smoking index	11.0 (0.0−380.0)
Smoking status	
Non-smokers n, (%)	123 (46.9)
Ex-smokers n, (%)	77 (29.4)
Current smokers n, (%)	62 (23.7)
Cohabitation with smokers at birth n, (%)	147 (56.1)
Cohabitation with smokers at present n, (%)	12 (4.6)
Frequency of exposure to SHS out the home (times/month)	0.7 (0.0−4.0)
Alcohol consumption (g/wk)	96.0 (0.0−197.7)
Average duration of sleep on weekdays (hours/day)	6.0 (6.0−7.0)
Total physical activity (kcal/day)	108.2 (57.0−238.8)
Low physical activity (kcal/day)	49.3 (0.0−97.6)
Moderate physical activity (kcal/day)	0.0 (0.0−40.3)
Vigorous physical activity (kcal/day)	0.0 (0.0−90.8)
Respiratory function	
FVC (*l*)	4.1 (3.8−4.6)
FVC (% pred.)	99.2±10.9
FEV_1 (*l*)	3.4 (3.1−3.8)
FEV_1 (% pred.)	93.8±10.1
FEV_1/FVC (%)	81.2±5.8

Values are described as mean ± standard deviation or median (interquartile range 25−75%) for normally or not normally distributed data, respectively. Categorical data are expressed as frequency and %. METS: metabolic syndrome, SHS: secondhand smoke, FVC: forced vital capacity, FEV_1: forced expiratory volume in one second.

Relationship between FEV_1/FVC and other factors

The relationships between FEV_1/FVC and other factors in terms of smoking status are shown in Table 4. For current smokers, a higher METS risk, indicated through high levels of factors such as hypertension and diabetes, was found to be related to a decrease in FEV_1/FVC.

Table 2. Differences in each indicator based on smoking status

Variables	Non-smokers n=123	Ex-smokers n=77			Current smokers n=62					
					All current smokers n=62			Heavy smokers n=37		
	Values	Values	OR	95% CIs	Values	OR	95% CIs	Values	OR	95% CIs
Participant information										
Age (years)	47.0 (36.0−57.0)	52.0 (44.5−60.0)**			48.0 (35.0−55.3)			54.0 (45.0−57.0)*		
Height (cm)	171.3±6.1	170.1±5.6	0.98	0.93−1.03	170.1±5.4	0.97	0.92−1.02	170.5±4.7	0.99	0.93−1.06
METS risk n, (%)	21 (17.1)	22 (28.6)	1.39	0.67−2.90	16 (25.8)	1.77	0.80−3.93	11 (29.7)	1.38	0.56−3.45
Hypertension n, (%)	15 (12.2)	9 (11.7)	0.60	0.24−1.52	10 (16.1)	1.39	0.55−3.51	8 (21.6)	1.29	0.47−3.56
Dyslipidemia n, (%)	5 (4.1)	14 (18.2)	4.10	1.38−12.1*	6 (9.7)	2.53	0.73−8.78	3 (8.1)	1.59	0.35−7.17
Diabetes n, (%)	4 (3.3)	5 (6.5)	1.46	0.37−5.81	4 (6.5)	2.03	0.48−8.56	4 (10.8)	2.79	0.65−12.0
Obesity n, (%)	2 (1.6)	1 (1.3)	1.04	0.09−12.1	0 (0.0)			0 (0)		
Body composition										
Weight (kg)	67.4 (60.1−76.1)	68.5 (62.4−75.7)	1.01	0.98−1.05	68.7 (61.9−75.1)	1.01	0.98−1.04	69.0 (64.0−76.8)	1.02	0.99−1.06
Body mass index (kg/m^2)	23.0 (21.4−24.7)	23.7 (21.8−25.7)	1.09	0.98−1.21	23.9 (21.2−26.3)	1.07	0.97−1.19	24.1 (21.5−26.3)	1.12	0.98−1.27
Body fat percentage (%)	21.1±5.6	23.4±6.0	1.06	1.01−1.12*	23.5±6.0	1.08	1.02−1.14**	24.2±5.9	1.09	1.02−1.17*
Fat-free mass (kg)	53.6±6.3	53.0±5.3	0.99	0.94−1.04	52.6±5.9	0.97	0.93−1.02	53.0±5.6	1.00	0.93−1.06
Upper limb muscle mass (kg)	5.6±0.9	5.6±0.8	1.04	0.74−1.47	5.6±0.9	0.97	0.69−1.36	5.6±0.8	1.11	0.72−1.70
Lower limb muscle mass (kg)	17.7±2.3	17.3±1.9	0.94	0.82−1.08	17.1±2.0	0.88	0.76−1.02	17.2±1.9	0.94	0.79−1.12
Trunk muscle mass (kg)	23.2±2.8	23.2±2.3	1.01	0.90−1.13	23.1±2.7	0.99	0.88−1.11	23.3±2.5	1.03	0.89−1.19
Visceral fat area (cm^2)	61.2 (41.8−84.2)	72.1 (55.0−91.0)	1.01	1.00−1.02	68.5 (51.0−107.0)	1.01	1.00−1.02*	74.4 (57.0−113.0)	1.01	1.00−1.03*
Lifestyle										
Smoking index	—	225.0 (150.0−445.0)			490.0 (132.5−725.0)			700.0 (530.0−825.0)		
Cohabitation with smokers at birth n, (%)	67 (54.5)	42 (54.5)	0.98	0.55−1.76	38 (61.3)	1.32	0.71−2.46	23 (62.2)	1.34	0.62−2.88
Cohabitation with smokers at present n, (%)	2 (1.6)	1 (1.3)	0.44	0.04−5.08	9 (14.5)	10.4	2.15−49.9**	7 (18.9)	11.6	2.23−60.6**
Frequency of exposure to SHS out the home (times/month)	0.0 (0.0−2.0)	0.5 (0.0−2.8)	1.02	0.95−1.10	4.0 (1.0−9.0)	1.15	1.08−1.24***	4.0 (1.0−9.7)	1.17	1.08−1.26***
Alcohol consumption (g/wk)	50.0 (0.0−146.0)	100.0 (29.0−233.0)	1.00	1.00−1.00	136.0 (35.0−254.0)	1.00	1.00−1.00	150.0 (27.0−376.0)	1.00	1.00−1.00
Average duration of sleep on weekdays (hours/day)	6.0 (6.0−7.0)	6.0 (6.0−7.0)	1.04	0.72−1.50	6.0 (5.8−7.0)	0.88	0.58−1.34	6.0 (5.0−7.0)	0.78	0.46−1.32
Total physical activity (kcal/day)	112.5 (63.4−263.2)	162.2 (71.7−285.8)	1.00	1.00−1.00	58.2 (0.0−131.5)	0.99	0.99−1.00***	47.5 (0.0−105.4)	0.99	0.99−1.00***
Presence of low physical activity n, (%)	93 (75.6)	59 (76.6)	0.91	0.45−1.81	36 (58.1)	0.44	0.23−0.85*	21 (56.8)	0.39	0.18−0.86*
Low physical activity (kcal/day)	58.7 (12.6−97.1)	48.9 (11.7−114.3)	1.00	1.00−1.00	24.3 (0.0−85.8)	1.00	0.99−1.00	34.1 (0.0−79.8)	0.99	0.99−1.00*
Presence of moderate physical activity n, (%)	41 (33.3)	31 (40.3)	1.18	0.64−2.16	10 (16.1)	0.39	0.18−0.83*	2 (5.4)	0.09	0.02−0.42**
Moderate physical activity (kcal/day)	0.0 (0.0−42.2)	0.0 (0.0−66.6)	1.00	1.00−1.01	0.0 (0.0−0.0)	0.99	0.99−1.00	0.0 (0.0−0.0)	0.99	0.98−1.00*
Presence of vigorous physical activity n, (%)	48 (39.0)	32 (41.6)	1.17	0.65−2.12	11 (17.7)	0.34	0.16−0.71**	5 (13.5)	0.24	0.09−0.66**
Vigorous physical activity (kcal/day)	0.0 (0.0−107.1)	0.0 (0.0−149.9)	1.00	1.00−1.00	0.0 (0.0−0.0)	0.99	0.99−1.00**	0.0 (0.0−0.0)	0.99	0.99−1.00*
Respiratory function										
FVC (*l*)	4.2 (3.8−4.7)	4.0 (3.8−4.6)	0.94	0.54−1.63	4.1 (3.9−4.6)	0.88	0.51−1.52	4.1 (3.8−4.5)	0.96	0.48−1.92
FVC (% pred.)	98.9±10.2	99.5±10.4	1.00	0.97−1.03	99.5±12.8	1.00	0.98−1.03	99.6±13.1	1.00	0.97−1.04
FEV_1 (*l*)	3.5 (3.1−3.8)	3.3 (3.0−3.7)	0.77	0.38−1.57	3.3 (3.0−3.8)	0.62	0.31−1.23	3.2 (2.9−3.5)	0.52	0.21−1.27
FEV_1 (% pred.)	94.3±9.4	93.6±9.5	0.99	0.96−1.03	93.1±12.1	0.99	0.96−1.02	91.7±12.9	0.97	0.94−1.01
FEV_1/FVC (%)	82.1±5.7	80.2±5.1	0.97	0.91−1.03	80.5±6.6	0.94	0.89−1.00	78.3±5.6	0.90	0.83−0.97**

Values are presented as mean ± standard deviation or median (interquartile range 25−75%). ***: $P<0.001$, **: $P<0.01$, *: $P<0.05$. Age versus non-smokers assessed by Mann-Whitney *U* tests to compare continuous variables. Multiple logistic regression analysis adjusting for age was performed to estimate odds ratios (OR) and 95% confidence intervals (CIs) versus non-smokers. METS: metabolic syndrome, SHS: secondhand smoke, FVC: forced vital capacity, FEV_1: forced expiratory volume in one second

Table 3. Correlation analysis between FEV1/FVC and other factors for each smoking status

Variables	Non-smokers n=123	Ex-smokers n=77	Current smokers n=62	
			All current smokers n=62	Heavy smokers n=37
Age (years)	−0.51†††	−0.33††	−0.53†††	−0.07
Height (cm)	0.04	−0.02	−0.07	−0.15
Weight (kg)	0.09	−0.07	−0.01	0.19
Body mass index (kg/m^2)	0.05	−0.10	0.03	0.27
Body fat% (%)	−0.07	0.05	0.02	0.34*
Fat − free mass (kg)	0.01	−0.12	−0.05	−0.02
Upper limb muscle mass (kg)	−0.06	−0.13	−0.07	0.01
Lower limb muscle mass (kg)	0.04	−0.14	−0.07	−0.06
Trunk muscle mass (kg)	−0.04	−0.10	−0.06	0.01
Visceral fat area (cm^2)	−0.04	−0.07	−0.12	0.24
Smoking index	—	−0.20	−0.49†††	−0.19
Frequency of exposure to SHS out the home (times/month)	−0.01	−0.09	−0.08	−0.13
Alcohol consumption (g/wk)	−0.26††	0.08	−0.27†	−0.20
Average duration of sleep on weekdays (hours/day)	0.09	0.05	−0.13	0.00
Total physical activity (kcal/day)	−0.06	−0.18	0.04	−0.17
Low physical activity (kcal/day)	−0.10	−0.13	−0.11	−0.19
Moderate physical activity (kcal/day)	−0.17	−0.11	0.22	−0.17
Vigorous physical activity (kcal/day)	0.05	0.02	0.06	−0.20

*: $P<0.05$ assessed by Pearson correlation coefficient, †††: $P<0.001$, ††: $P<0.01$ and †: $P<0.05$ assessed by Spearman's rank correlation coefficient. SHS: secondhand smoke, FVC: forced vital capacity, FEV1: forced expiratory volume in one second

Table 4. Relationship between FEV1/FVC and other factors based on smoking habit

Variables	Non-smokers n=123		Ex-smokers n=77		Current smokers n=62			
					All current smokers n=62		Heavy smokers n=37	
	n	FEV1/FVC (%)	n	FEV1/FVC (%)	n	FEV1/FVC (%)	n	FEV1/FVC (%)
METS risk								
Yes	21	81.0 ± 4.8	22	80.1 ± 3.7	16	77.5 ± 6.2*	11	76.8 ± 5.2
No	102	82.3 ± 5.8	55	80.2 ± 5.6	46	81.6 ± 6.4	26	79.0 ± 5.8
Hypertension								
Yes	15	81.6 ± 4.0	9	81.3 ± 2.4	10	76.0 ± 4.5*	8	75.0 ± 4.4
No	108	82.2 ± 5.9	68	80.0 ± 5.4	52	81.4 ± 6.6	29	79.2 ± 5.7
Dyslipidemia								
Yes	5	79.6 ± 7.7	14	80.6 ± 3.9	6	79.5 ± 4.7	3	81.6 ± 4.4
No	118	82.2 ± 5.6	63	80.1 ± 5.4	56	80.6 ± 6.7	34	78.0 ± 5.7
Diabetes								
Yes	4	84.6 ± 3.2	5	80.2 ± 3.0	4	72.8 ± 4.3*	4	72.8 ± 4.3*
No	119	82.0 ± 5.7	72	80.2 ± 5.3	58	81.1 ± 6.4	33	79.0 ± 5.5
Obesity								
Yes	2	85.4 (83.5 – 87.2)	1	—	0	—	0	—
No	121	81.3 (78.5 – 85.6)	76	80.2 ± 5.2	62	80.5 ± 6.6	37	78.3 ± 5.6
Cohabitation with smokers at birth								
Yes	67	80.8 (78.7 – 85.3)	42	79.8 (77.3 − 83.3)	38	80.7 ± 5.5	23	79.2 ± 5.3
No	56	81.8 (77.9 – 85.9)	35	80.7 (78.2 − 82.8)	24	80.3 ± 8.1	14	76.8 ± 6.1
Cohabitation with smokers at present								
Yes	2	79.4 (78.2 – 80.6)	1	—	9	79.4 ± 6.6	7	77.5 ± 6.2
No	121	81.6 (78.6 – 85.8)	76	80.2 ± 5.2	53	80.7 ± 6.6	30	78.5 ± 5.6

Values are described as mean ± standard deviation or median (interquartile range 25−75%). *: $P<0.05$ versus no by two sample *t* tests. METS: metabolic syndrome, FVC: forced vital capacity, FEV1: forced expiratory volume in one second

Table 5. Result of multiple regression analysis with FEV_1/FVC as the dependent variable

Variable	Model 1		Model 2	
	Standardized coefficient	95% CI	Standardized coefficient	95% CI
Frequency of exposure to SHS out the home	−0.148**	−0.30 − −0.05	−0.143*	−0.30 − −0.04

**: $P<0.01$, *: $P<0.05$, Model 1: age, height, and smoking status were adjusted. Model 2: age, height, smoking status, cohabitation with smokers at birth, cohabitation with smokers at present, alcohol consumption, average duration of sleep on weekdays, total physical activity, and physical activity according to the intensity of activity were adjusted, CI: confidence interval, SHS: secondhand smoke, FVC: forced vital capacity, FEV_1: forced expiratory volume in one second

Result of multiple regression analysis with FEV_1/FVC as the dependent variable

Table 5 shows the results of multiple regression analysis in which FEV_1/FVC was a dependent variable, and adjustments were made for age, height, and smoking status. The results showed that only frequency of exposure to SHS outside the home was a significant related factor; similar results were obtained for Models 1 and 2. The multiple regression models for all conditions were significant.

Discussion

Through this study, the current smokers were shown to burn fewer calories and engage in less PA, and to have a higher body fat% and VFA than did the non-smokers. This result was similar to the findings of previous studies [10−12]. Another study showed that VFA temporarily increases following smoking cessation, but thereafter decreases as smoking cessation continues [22]. Because PA is expected to reduce visceral fat, it may be helpful to provide current smokers with smoking cessation guidance to help them improve their PA. A novel finding in this study was that current smokers are highly likely to reside with other smokers, and also to have a high frequency of exposure to SHS outside the home. The unfavorable tendency regarding these body compositions and lifestyle was particularly marked in the heavy smokers.

In particular, this study showed that the frequency of exposure to SHS outside the home was related to a decrease in FEV_1/FVC, regardless of one's smoking status. Preventing a decrease in FEV_1/FVC is important, particularly among younger people, given that FEV_1/FVC is an index of obstructive respiratory disorder. Hagstad *et al* reported that as exposure to passive smoking, such as in the home or workplace, increased, so did the risk of COPD, independently of other factors [23]. Thus, this study result clarifying the influence of the frequency of exposure to SHS outside the home seems to be of great significance.

Secondhand smoke exposure in the workplace has decreased in recent years in Japan, due to the establishment of designated smoking rooms and smoke-free buildings in the workplace [24]. There were also no cases of SHS exposure in the office at the five companies surveyed in this research. Owing to the decrease in Japanese citizens' overall smoking rate [25] and increased social awareness regarding SHS, the number of smokers who do not smoke inside their homes is also increasing [25]. Therefore, non-smokers presumably have little exposure to SHS in closed spaces, except when regularly visiting restaurants that take inadequate or no measures against SHS. For this reason, this study has sensitively detected the influence of SHS outside the home in non-smokers. Meanwhile, unexpected results were obtained even in smokers: the exposure to SHS outside the home influences respiratory function. Owing to smokers frequenting smoking areas, this group is exposed to both SHS from other smokers and mainstream smoke, which is inhaled directly by the smoker. Therefore, it is inferred that smokers cannot ignore the influence of SHS on respiratory function.

These results provide the basis for minimizing exposure to SHS for non-smokers. Another interesting observation is that SHS also poses an increased risk of obstructive respiratory function even in smokers. Thus, it is important for occupational health personnel to advise both non-smokers and smokers to avoid SHS.

A previous study has reported that parents' smoking habits affect the development of children's respiratory function [26]. However, this study did not extract cohabitation with smokers at birth as a factor affecting FEV_1/FVC. The study excluded potential participants with respiratory diseases such as bronchial asthma and COPD; therefore, passive smoking history at birth may not be related to respiratory function.

There are two limitations in this study. First, at only five, few companies were targeted for the study, and this may limit generalizability. Moreover, since one out of the five companies used a closed smoking room, and four companies had an open smoking area outdoors, it was not possible to unify the situation of passive smoking during work hours. In addition, as the smoking rate of men in their 30s to 50s in Japan ranges from 37 to 42% [25], the smoking rate in the five companies was clearly low at 23.7%. Future studies should be conducted using companies with a unified measure against SHS, as well as companies with a smoking rate similar to the average of same age workers. Second, this research was cross-sectional. In future, we will perform prospective longitudinal studies on the factors related to respiratory function mentioned in this study, and we will construct a strategy for preventing respiratory depression through intervention. Specifically, we will take muscle mass and frequency of exposure to SHS into consideration.

Conclusion

A high frequency of exposure to SHS outside the home was extracted as a factor influencing the decline in FEV_1/FVC, regardless of an individual's smoking status. Avoiding SHS outside the home is a primary preventive measure not only for non-smokers but also for smokers. It is important for occupational health personnel of a company to advise both non-smokers and smokers to avoid SHS to prevent chronic obstructive pulmonary disease onset. This needs to be coupled with encouragement to quit smoking, especially for heavy smokers.

Acknowledgments

I would like to express my heartfelt thanks to Dr. Toshihiro Toyonaga, who offered extensive support and encouragement during the planning and performance of this research.

Conflicts of Interest

The authors declare that they have no conflict of interest.

References

1. World Health Organization (2008): World Health Statistics 2008. World Health Organization, Geneva 30 pp
2. Fukuchi Y, Nishimura M, Ichinose M *et al* (2004): Chronic obstructive pulmonary disease (COPD) in Japan: the Nippon COPD Epidemiology study. Respirology 9: 458–465
3. Committee for the fifth edition of the COPD guidelines of the Japanese respiratory society (2018): Guidelines for the diagnosis and treatment of COPD. 5th *ed*. Medical Review Co., Ltd, Tokyo p 10 (in Japanese)
4. Degens H, Gayan-Ramirez G & van Hees HW (2015): Smoking-induced skeletal muscle dysfunction: from evidence to mechanisms. Am J Respir Crit Care Med 191: 620–625
5. Omori H, Nonami Y & Morimoto Y (2005): Effect of smoking on FEV decline in a cross-sectional and longitudinal study of a large cohort of Japanese males. Respirology 10: 464–469
6. Osaka D, Shibata Y, Abe S *et al* (2010): Relationship between habit of cigarette smoking and airflow limitation in healthy Japanese individuals: the Takahata study. Intern Med 49: 1489–1499
7. Office on Smoking and Health (2006): Respiratory effects in children from exposure to secondhand smoke. *In*: The health consequences of involuntary exposure to tobacco smoke. Centers for Disease Control and Prevention, Atlanta pp 537–568
8. Chiolero A, Faeh D, Paccaud F & Cornuz J (2008): Consequences of smoking for body weight, body fat distribution, and insulin resistance. Am J Clin Nutr 87: 801–809
9. Dyer AR, Elliott P, Stamler J, Chan Q, Ueshima H, Zhou BF & INTERMAP Reseach Group (2003): Dietary intake in male and female smokers, ex-smokers, and never smokers: the Intermap study. J Hum Hypertens 17: 641–654
10. Furlanetto KC, Mantoani LC, Bisca G, Morita AA, Zabatiero J, Proenca M, Kovelis D & Pitta F (2014): Reduction of physical activity in daily life and its de-

terminants in smokers without airflow obstruction. Respirology 19: 369−375
11. Kim JH, Shim KW, Yoon YS, Lee SY, Kim SS & Oh SW (2012): Cigarette smoking increases abdominal and visceral obesity but not overall fatness: an observational study. PLoS One 7: e45815
12. Komiya H, Mori Y, Yokose T & Tajima N (2006): Smoking as a risk factor for visceral fat accumulation in Japanese men. Tohoku J Exp Med 208: 123−132
13. Inomata M, Kawagishi Y, Taka C *et al* (2012): Visceral adipose tissue level, as estimated by the bioimpedance analysis method, is associated with impaired lung function. J Diabetes Investig 3: 331−336
14. International Labour Office (2012): Structure of the international standard classification of occupations. *In*: International standard classification of occupations. International Labour Organization, Geneva pp 66−67
15. Ministry of Health and Welfare (1998): Field study regarding smoking and health in 1998. Ministry of Health and Welfare, Tokyo https://www.mhlw.go.jp/www1/houdou/1111/h1111-2_11.html [accessed Nov 4, 2017] (in Japanese)
16. Takashima N, Miura K, Hozawa A *et al* (2010): Cigarette smoking in middle age and a long-term risk of impaired activities of daily living: NIPPON DATA80. Nicotine Tob Res 12: 944−949
17. Craig CL, Marshall AL, Sjöström M *et al* (2003): International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 35: 1381−1395
18. Murase N, Katsumura T, Ueda C, Inoue S & Shimomitsu T (2002): Reliability and validity of the Japanese version of the international physical activity questionnaire. Kousei no Shihyou 49(11): 1−9 (in Japanese)
19. Fukui T, Maruyama M, Yamauchi K, Miyamoto Y & Fukami T (2012): Usefulness of measurement of visceral fat area by dual impedance method and points for attention in interpretation of results -from viewpoint of diagnosis of metabolic syndrome and early-stage atherosclerosis-. Ningen Dock 27: 719−728 (in Japanese)
20. The Committee of Pulmonary Physiology of the Japanese Respiratory Society (2004): Spirometry and flow volume curve. *In*: Guidelines for Pulmonary Function Tests -Spirometry, flow-volume curve, diffusion capacity of the lung-. Medical Review Co., Ltd, Tokyo pp 1−23 (in Japanese)
21. Sasaki H, Nakamura M, Kida K *et al* (2001): Reference values for spirogram and blood gas analysis in Japanese adults. JJRS 39: S1−S17 (in Japanese)
22. Matsushita Y, Nakagawa T, Yamamoto S, Takahashi Y, Noda M & Mizoue T (2011): Associations of smoking cessation with visceral fat area and prevalence of metabolic syndrome in men: the Hitachi health study. Obesity (Silver Spring) 19: 647−651
23. Hagstad S, Bjerg A, Ekerljung L, Backman H, Lindberg A, Rönmark E & Lundbäck B (2014): Passive smoking exposure is associated with increased risk of COPD in never smokers. Chest 145: 1298−1304
24. Teikoku DataBank (2017): Awareness survey on smoking in companies. Teikoku DataBank, LTD., Tokyo https://www.tdb.co.jp/report/watching/press/pdf/p171005.pdf [accessed July 23, 2018] (in Japanese)
25. Ministry of Health, Labour and Welfare (2017): Conditions related to drinking and smoking. *In*: The national health and nutrition survey in Japan, 2016. Ministry of Health, Labour and Welfare, Tokyo pp 51−53 (in Japanese)
26. Office on Smoking and Health (2006): Respiratory effects in children from exposure to secondhand smoke. *In*: The health consequences of involuntary exposure to tobacco smoke. Centers for Disease Control and Prevention, Atlanta pp 257−420

男性勤労者において家庭外の受動喫煙の曝露頻度は喫煙状況に関係なく１秒率の低下に影響する

井元　淳[1,2]，大和　浩[3]，道下　竜馬[4]，姜　英[3]，西山　信吾[3]，福田　里香[5]，出口　純子[5]

[1] 九州栄養福祉大学　リハビリテーション学部　理学療法学科
[2] 産業医科大学大学院　医学研究科　産業衛生学専攻
[3] 産業医科大学　産業生態科学研究所　健康開発科学
[4] 福岡大学　スポーツ科学部
[5] 九州労災病院　治療就労両立支援センター

要　　旨：加齢に伴う呼吸機能の低下は慢性閉塞性肺疾患（COPD）の発症や高齢者の死亡リスクに繋がるため, 若い世代からの呼吸機能低下の予防が求められる．本研究では身体組成や生活習慣の影響を考慮した上で, 気道の閉塞によって引き起こされる閉塞性換気障害の指標である1秒率に影響を与える要因を検討することを目的とした．5企業の男性従業員262名を対象とし, 喫煙状況, 現在や過去の受動喫煙の有無, 家庭外での受動喫煙の曝露頻度, 身体活動量（PA）などを含む生活習慣を聴取した．また身体組成や呼吸機能を測定した．統計学的分析は得られたデータについて非喫煙者との比較をロジスティック回帰分析で年齢を調整して検討した．さらに, 年齢, 身長, 喫煙状況, また生活習慣を調整変数とした重回帰分析により1秒率に影響を与える要因を検討した．年齢で調整したロジスティック回帰分析の結果, 現喫煙者と重喫煙者は体脂肪率, 内臓脂肪面積, 喫煙者との同居率, 家庭外での受動喫煙の曝露頻度が有意に高かった．またPAは現喫煙者と重喫煙者で有意に低く, 1秒率は重喫煙者で有意に低かった．重回帰分析の結果, 1秒率に関連する因子として家庭外での受動喫煙の曝露頻度のみが抽出された．COPD発症の予防策として企業内で健康管理に従事するものは喫煙者, 特に重喫煙者への禁煙指導とともに, 喫煙者, 非喫煙者に関係なくすべての勤労者に受動喫煙を避けることを心がけるよう指導することが重要である．

キーワード：身体組成, 生活習慣, 呼吸機能, 受動喫煙, 勤労者.

J UOEH（産業医大誌）41（1）：15 − 24（2019）