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Physical Function Traits of Long-term Officially Acknowledged Victims of Pollution-related Illnesses Compared with Elderly Patients with Chronic Obstructive Pulmonary Disease

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Abstract. [Purpose] To examine the long-term effects of air pollution on the physical functioning of a group of officially acknowledged victims of pollution-related illnesses (Victims group) who were exposed to air pollution more than 50 years ago, we compared them with age-matched patients with chronic obstructive pulmonary disease (COPD group). [Subjects and Methods] The Victims group comprised 34 subjects and the COPD group 24, all of whom were aged over 65 years. Respiratory function, muscle strength, exercise capacity and physical activity were measured and compared between the groups. [Results] The Victims group had significantly higher forced expiratory volume in the first second (FEV_1), proportion of predicted FEV_1, proportion of predicted vital capacity (VC), and ratio of FEV_1 to forced VC than the COPD group. Surprisingly, the muscle strength of the Victims group was significantly weaker, their incremental shuttle walking test distance was significantly shorter, and their physical activity was significantly less than those of the COPD group. [Conclusion] Although the pulmonary function of Victims was better than that of the COPD group, their physical functioning was worse. Exposure to air pollution 50 years ago appears to continue to adversely affect their physical function. It is particularly important to offer Victims rehabilitation to improve their exercise performance and physical activity.
Key words: Pollution-related disease, Exercise capacity, Physical activity

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INTRODUCTION

Air pollution is a global problem. In 2011 the World Health Organization reported that 1.3 million people die each year as a result of diseases caused by outdoor air pollution[1)]. After World War II, industrialization progressed rapidly in Japan, causing pollution. Air pollution is associated with impaired lung function[2, 3)]. Many residents of areas in Japan affected by air pollution have complained of poor health as a result. In Japan, persons who suffer from ill health as a consequence of pollution are officially acknowledged as victims of pollution-related diseases. Registered victims must meet the following conditions as determined by the Public Relief System, in accordance with the Pollution-Related Health Damage Compensation Law (1973): (1) they must have resided or been active in an area specified as having significant air pollution (Table 1), and (2) must have been diagnosed with chronic bronchitis or asthma by a doctor. Registered victims are entitled to various forms of compensation. The proportion of victims over 60 years of age, who were exposed to air pollution in the 1960s and are now receiving compensation, reached 43% at the end of March 2012. The pulmonary function of women who had lived in these communities has declined as they have aged, and decline of pulmonary function is associated with a decline in physical function[4)]. Pulmonary diseases are an increasingly serious problem for officially acknowledged victims of pollution-related illness as they age, a phenomenon that is becoming a major economic and social concern. An investigation conducted by the Japanese Ministry of the Environment in 2004 found that the cost burden for healthcare providers was very large and growing, that nursing care insurance was insufficient, and that most victims of pollution-related illnesses were elderly, lived in households of one or two, and required substantial assistance with activities of daily living.

Many studies have examined the short-term influence of air pollution on pulmonary function[5–8)]. Our previous longitudinal study showed that the lung function of victims enrolled in compensation schemes does not return to normal

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Table 1. Time required for certification of pollution-related illness

Illness	a)	b)	c)
Chronic bronchitis	24 months	48 months	36 months
Asthma	12 months	30 months	18 months

a) Individual who resided in a designated area prior to 1973
b) Individual who did not reside in a designated area, but spent at least 8 hours per day in a designated area
c) Individual who resided in a designated area, then relocated but continued to work in a designated area for at least 8 hours per day

Table 2. Characteristics of the subjects

	Victims (n=34)	COPD (n=24)
Age (years)	73.5 ± 6.6	73.2 ± 8.4
Gender***		
Male/Female (n)	23/29	22/2
Height (cm) **	152.6 ± 8.5	158.6 ± 3.9
Weight (kg) *	56.8 ± 3.5	54.2 ± 7.4
BMI (kg/m^2) **	24.3 ± 4.3	21.6 ± 3.5

Data are presented as the mean ± SD. *p<0.05, **p<0.01, ***p<0.001 compared to the COPD value

even after improvements in air quality[9, 10]. However, there are no data on the late effects of air pollution on physical function in officially acknowledged victims of pollution-related illness.

The purpose of this study was to compare the physical function of officially acknowledged victims of pollution-related illness with age-matched patients with chronic obstructive pulmonary disease (COPD), so as to clarify the late effects of air pollution to which victims were exposed more than 50 years beforehand.

SUBJECTS AND METHODS

Subjects

We recruited 34 officially acknowledged victims of pollution-related illness who were exposed to air pollution 50 years beforehand, who had also been diagnosed with chronic bronchitis. Their mean disease duration was 32.3 ± 9.9 years. The subjects were entitled to various forms of compensations, including monthly consultation with a doctor, prescriptions for expectorants and bronchodilators, and annual assessments of respiratory symptoms using a detailed questionnaire and respiratory function testing, in accordance with the Public Nuisance Countermeasures Law to ensure tertiary prevention by all possible means. Twenty-four age-matched subjects diagnosed with COPD were recruited as a control group. All the participants were aged 65 years or more. All provided their informed consent to participation in this study which was approved by the Human Ethics Review Committee of Nagasaki University Graduate School of Biomedical Science (approval number: 08072424-2).

Methods

Height, weight, lung function, muscle strength (hand grip and quadriceps force), exercise capacity (incremental shuttle walking test, ISWT) and physical activity were assessed. Lung function was measured using an electronic spirometer (FUDAC 70; Fukuda Sangyo Inc.; Chiba, Japan). Forced expiratory volume in the first second (FEV_1), forced vital capacity (FVC), and vital capacity (VC) were recorded, and predicted values [the proportion expressed as a percentage (%) of normal values for individuals of the same age, sex and weight] were calculated in accordance with a standard protocol[11]. The measurements were repeated until at least three reproducible forced expiratory curves had been obtained.

Quadriceps force (QF) was measured using a hand-held dynamometer with a fixing belt (μTas F-1; Anima Corporation; Tokyo, Japan) as peak force developed during a maximal isometric knee extension maneuver on the dominant side. The highest value of three attempts was recorded. Handgrip force (HF) of the dominant hand was measured three times and the highest value was recorded.

The ISWT was used to assess exercise capacity, and was conducted following to current guidelines[12]. The test was performed twice and the maximum value was recorded.

Physical activity was measured with a uni-axial accelerometer (Lifecorder GS; Suzuken Corporation; Nagoya, Japan) for two weeks. The accelerometer records vertical acceleration as counts and activity times per day. Subjects were told to wear the accelerometer on a belt around the waist and to take it off when sleeping and showering. Recordings from the first and last days were excluded from the analysis, as these days were incomplete.

The Shapiro-Wilk test was used to examine the distribution of data. Non-normally distributed data were analyzed using non-parametric tests. Differences between groups were assessed using the Mann-Whitney U test and the χ^2 test. All analyses were performed using the PASW software package, version 18 (SPSS, Japan Inc., Tokyo, Japan). A two-tailed value of $p < 0.05$ was considered statistically significant.

RESULTS

The characteristics of both groups are shown Table 2. There were significantly more women in the Victims group ($p < 0.001$). The comparison of the groups is shown in Table 3. The Victims group had significantly higher FEV_1, $FEV_{1\%}$ predicted, VC % predicted and FEV_1/FVC ratio (all $p < 0.001$) than the COPD group. Furthermore, HF ($p < 0.05$) and QF ($p < 0.001$) were significantly weaker, the distance covered in the ISWT was significantly shorter ($p < 0.01$), and physical activity was significantly lower ($p < 0.01$) in the Victims group.

DISCUSSION

Our main finding is that officially acknowledged victims of pollution-related illness exposed to air pollution at least 50 years previously, who continue to receive various forms

Table 3. Comparison of Victims and COPD

	Victims (n=34)	COPD (n=24)
Pulmonary function		
FEV_1 (l)***	1.49 ± 0.60	0.85 ± 0.40
FEV_1 % predicted (%)***	73 ± 24	35 ± 17
FVC (l)	2.23 ± 0.76	2.06 ± 0.70
VC (l)	2.58 ± 0.71	2.36 ± 0.78
VC % predicted (%)***	94 ± 26	76 ± 16
FEV_1/FVC (%)***	65 ± 13	41 ± 13
MMRC (n)*		
0/1/2/3/4	2/9/12/8/3	0/4/6/8/6
Muscle force		
HF (kg)*	18.3 ± 6.2	24.7 ± 7.9
QF (kgf)***	18.9 ± 6.6	50.8 ± 14.3
ISWT		
Distance (m)**	160.5 ± 93.8	256.7 ± 84.9
Physical activity		
Mean activity counts (counts/day)**	3415 ± 1058	4726 ± 1017
Mean activity times (min/day)**	41 ± 28	76 ± 26

Values are presented as mean ± SD or number (%). FEV_1: forced expiratory volume in 1 second; FVC: forced vital capacity; VC: vital capacity; FEV_1/FVC: forced expiratory volume in 1 second/forced vital capacity; MMRC: Modified Medical Research Council Dyspnea scale; HF: handgrip force; QF: quadriceps force; ISWT: Incremental Shuttle Walking Test.
Victims versus COPD: Mann-Whitney U test. *p<0.05, **p<0.01, ***p<0.001 compared to the the COPD value

of compensation from the government, exhibited diminished physical function compared to patients with COPD. Nevertheless, we found that FEV_1, $FEV_{1\%}$ predicted, VC % predicted and FEV_1/FVC ratio of the Victims group were significantly greater than the respective values of age-matched controls with COPD. We had expected that exposure to high concentrations of air pollutants in the 1960s would result in substantial reductions in pulmonary function, and were surprised to find that the Victims group had better lung function than the COPD group. This may be explained by improvements in the environment, tertiary prevention and medical interventions over the past 50 years. Despite this, physical functions, such as muscle strength, exercise capacity and physical activity, were significantly lower in the Victims group.

Significant associations between air pollution and decreased physical exercise capacity and physical activity have previously been reported[5, 13–16]. Inhalation of air pollutants has also been shown to cause decreased heart rate variability[17, 18]. Elevated plasma concentrations of endothelin-1, a vasoconstrictor peptide, might impair muscle performance by compromising oxygen delivery through muscle arterioles[15, 19]. Local arteriolar endothelial dysfunction may compromise muscle reperfusion, and vasoconstriction of pulmonary arterioles could reduce oxygen delivery to the working muscles and affect muscle performance[17, 19]. Our findings suggest that inhalation of air pollution may exert an adverse effect on skeletal muscles, which manifests as decreased exercise performance, and that these effects may persist for many years in officially acknowledged victims of pollution-related illnesses.

Other potential mechanisms include the effects of systemic inflammation on skeletal muscle strength[20, 21], and secondary disuse atrophy resulting from the breathlessness caused by respiratory diseases. Officially acknowledged victims of pollution-related illnesses who have experienced many years of dyspnea at rest are also likely to have anxieties about performing physical activity, provoking a vicious cycle of increasing dyspnea with decreasing levels of physical activity with concomitant deconditioning, depression and fearful avoidance of actual physical activity. In a previous study of patients with occupational-related respiratory disease, exercise capacity was significantly associated with a poorer psychological status[22]. We previously reported that officially acknowledged victims of pollution-related illness had low health-related quality of life and a high rate of depression[23]. Although we did not specifically study the relationship between mood and physical activity, we believe that they are likely to be closely associated in officially acknowledged victims of pollution-related illness.

It is striking that officially acknowledged victims of pollution-related illnesses exposed to air pollution more than 50 years ago are still suffering from impaired physical functioning. It is important to find means to intervene and address these deficiencies, and victims should be prioritized for rehabilitation to improve physical activity, exercise performance and dyspnea.

Our study had some limitations. First, the number of subjects was small. Second, many of the subjects were women. Third, depression status was not evaluated. Therefore, additional research is necessary to ensure that our findings can be generalized to wider populations.

In conclusion, we investigated the physical functioning of officially acknowledged victims of pollution-related illnesses who were exposed to air pollution more than 50 years ago and found that muscle strength, exercise capacity and physical activity were lower than the respective values of patients with COPD. It is important that victims are offered rehabilitation to improve physical function as much as possible, and are offered assistance when improvements cannot be made.

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