

Relationship between predicted oxygen uptake and cigarette smoking in Japanese men

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ABSTRACT

The link between cigarette smoking and predicted oxygen uptake was investigated using data for 149 Japanese men not taking medication. Cigarette smoking habits were obtained through interviews by well-trained staff. The influence of cigarette smoking on predicted oxygen uptake, predicted work rate and predicted heart rate were evaluated. Predicted oxygen uptake decreased with age. Predicted oxygen uptake and predicted work rate in men who smoked cigarettes was significantly lower than in subjects who did not, after adjusting for age. The differences in parameters did not reach significant levels after adjusting for age and physical activity evaluated by Σ [metabolic equivalents \times h per week (METs \cdot h/w)] (predicted oxygen uptake: $p = 0.0632$, predicted work rate: $p = 0.0873$). Cigarette smoking might be a modifiable factor for improving the aerobic exercise level in Japanese men.

Keywords: Cigarette Smoking; Predicted Oxygen Uptake; Metabolic Equivalents

1. INTRODUCTION

Regular physical activity has been shown to increase high density lipoprotein (HDL) cholesterol and reduce resting blood pressure, triglycerides, abdominal fat, fasting blood sugar, and insulin responses to the oral glucose challenge test [1-5]. In addition, Sandvik L. *et al.* reported that physical fitness was a graded, independent, long-term predictor of mortality from cardiovascular causes in healthy, middle-aged men [6]. Maximal oxygen uptake is generally considered an accurate and reliable parameter. In the Exercise and Physical Activity Refer-

ence for Health Promotion 2006, established by the Ministry of Health Labour and Welfare Japan in 2006, maximal oxygen uptake was considered to be the most significant element of physical fitness related to health promotion and the recommended reference value for maximal oxygen uptake to prevent lifestyle-related disease was reported [7].

Cigarette smoking has become an important public health challenge, and it has been reported that 39.4% of men and 11.0% of women are current smokers in Japan [8]. Cigarette smoking is also a strong risk factor for atherosclerosis and cardiovascular disease in a dose dependent manner [9]; however, the relationship between cigarette smoking and aerobic exercise level defined by maximal oxygen uptake has not been fully discussed.

The aim of this study was to explore the link between cigarette smoking and predicted oxygen uptake in Japanese men.

2. SUBJECTS AND METHODS

2.1. Subjects

We used data for 149 Japanese men (44.1 ± 14.1 years) who met the following criteria from April 2007 to March 2010 at Okayama Southern Institute of Health, Okayama, Japan: 1) underwent anthropometric and predicted oxygen uptake measurements and evaluation of cigarette smoking voluntarily; 2) receiving no medications for diabetes, hypertension and/or dyslipidemia; and 3) provided written informed consent (Table 1).

Ethics approval for the study was obtained from the Ethics Committee of Okayama Health Foundation.

2.2. Anthropometric and Body Composition Measurements

Anthropometric and body compositions were evaluated based on the following parameters: height, body

Table 1. Clinical profiles of enrolled men.

	Mean \pm SD	Minimum	Maximum
Number of subjects	149		
Age	44.1 \pm 14.1	21	69
Height (cm)	170.2 \pm 5.6	158.1	187.3
Body weight (kg)	66.4 \pm 8.8	48.3	96.4
Body mass index (kg/m ²)	22.9 \pm 2.9	17.2	34.7
Abdominal circumference (cm)	81.3 \pm 8	63.9	104.9
Body fat percentage (%)	19.8 \pm 5.6	27.3	60.4
Predicted oxygen uptake (ml/kg/min)	37.2 \pm 8.7	16.5	61.9
Predicted work rate (watt)	200.8 \pm 49.1	91	354
Predicted heart rate (beat/min)	178.6 \pm 23.2	106	230
Daily step counts (steps/day)	8588.7 \pm 3601.4	973.0	20910.9
METs·h/w	14.5 \pm 10.8	0.0	63.4
Σ [metabolic equivalents \times h per week (MET·h/w)]			

weight, abdominal circumference and body fat percentage. Abdominal circumference was measured at the umbilical level in standing subjects after normal exhalation [10]. Body fat percentage was measured by dual energy X-ray absorptiometry (DEXA) (QDR4500; Hologic Inc., Waltham, MA, USA), which is used as an accurate standard [11]. The DEXA measurement consisted of a whole body scan using an array beam [12]. Subjects removed all metal objects and were positioned in the supine position with hands placed prone on either side of the body and with legs held 10 cm apart according to the specifications of the manufacturer. All scans were analyzed according to the manufacturer's instructions [13].

2.3. Exercise Testing

Predicted oxygen uptake was measured using a maximal graded exercise test with bicycle ergometers (Excalibur V2.0; Lode BV, Groningen, Netherlands). The initial work load was 30 - 60 watt, and the work rate was increased thereafter by 15 watt/min until the subject could not maintain the required pedaling frequency (60 rpm) [14]. During the latter stages of the test, each subject was verbally encouraged by the test operators to make their maximal effort. In addition, ECG was monitored continuously together with recording of the heart rate (HR). Expired gas was collected and rates of oxygen consumption (VO₂) and carbon dioxide production (VCO₂) were measured breath-by-breath using a cardiopulmonary gas exchange system (Oxycon Alpha; Mijnhardt b.v., Netherlands). Achievement of predicted oxygen uptake was accepted if two of the following con-

ditions were met: subject's maximal HR was >95% age-predicted maximal HR (220 - age), and the VO₂ curve showed a leveling off.

2.4. Cigarette Smoking

Data on cigarette smoking were obtained at interviews by well-trained hired staff, such as a public health nurse, in a structured way. The subjects were asked if they currently or had previously smoked cigarettes for at least 6 months and/or 100 cigarettes. When the answer was "yes", they were classified as cigarette smokers (+). When the answer was "no", they were classified as cigarette smokers (-).

2.5. Physical Activity

Physical activity was measured by the Kenz Life-corder (LC; SUZUKEN Co Ltd, Nagoya, Japan) which is a recent addition to the growing number of uniaxial accelerometer options; it offers comparable instrument outputs with several potentially attractive features for researchers and practitioners. The LC displays reasonable estimates of physical activity intensity and energy expenditures under controlled conditions on a treadmill [15], over 24 h of typical daily activities undertaken in a respiratory chamber [15], and in a free-living environment using double-labeled water as the criterion method [16]. Furthermore, when compared with many other accelerometers, the LC can potentially simplify the data interpretation process by reducing the time spent and the need for advanced technical expertise or software programs [17]. The subjects were taught how to use the in-

strument, and were told to wear it on their belt or waist band at the right midline of the thigh from the moment they got up until they went to bed except while bathing or swimming, for seven consecutive days [18]. The activity monitor was firmly attached to their clothes at the waist by a clip.

2.6. Statistical Analysis

All data are expressed as the mean \pm standard deviation (SD). Statistical analysis was performed using the unpaired *t* test and covariance analysis, with $p < 0.05$ considered significant. We used the unpaired *t* test to compare parameters between subjects who did and did not smoke cigarettes. Pearson's correlation coefficients were calculated and used to test the significance of the linear relationship between continuous parameters.

3. RESULTS

The measurements of parameters in men are shown in **Table 1**. Predicted oxygen uptake in enrolled subjects

was 37.2 ± 8.7 ml/kg/min. Physical activity evaluated by LC according to Σ [metabolic equivalents \times h per week (METs·h/w)] was 14.5 ± 10.8 METs·h/w. Seventy-eight men (52.3%) were defined as having a smoking habit (**Table 2**).

We evaluated the relationship between age and clinical parameters such as predicted oxygen uptake, predicted work rate, predicted heart rate, daily step counts and METs·h/w (**Table 3**). Predicted oxygen uptake, predicted work rate and predicted heart rate were significantly correlated with age (**Table 3, Figure 1**).

In men, there was significant difference in age between subjects who did and did not smoke cigarettes. Predicted oxygen uptake [smoking habit (+): 34.1 ± 7.5 ml/kg/min, smoking habit (-): 40.7 ± 8.7 ml/kg/min], predicted work rate and predicted heart rate in men who smoked cigarettes were significantly lower than in men who did not (**Table 4**). Significant differences of daily step counts and METs·h/w were not noted between men who did and did not smoke cigarettes. To avoid the influence of age on parameters, we used age as a covariate

Table 2. Prevalence of subjects who smoked cigarettes.

	20s	30s	40s	50s	60s	Total (%)
Smoking habit (+)	4 (13.3)	13 (43.3)	20 (66.7)	20 (64.5)	21 (75.0)	78 (52.3)
Smoking habit (-)	26 (86.7)	17 (56.7)	10 (33.3)	11 (35.5)	7 (25.0)	71 (47.7)

Table 3. Relationship between age and clinical parameters.

	r	p
Predicted oxygen uptake (ml/kg/min)	-0.554	<0.0001
Predicted work rate (watt)	-0.554	<0.0001
Predicted heart rate (beat/min)	-0.719	<0.0001
Daily step counts (steps/day)	0.114	0.1657
METs·h/w	0.124	0.1305
Σ [metabolic equivalents \times h per week (METs·h/w)]		

Table 4. Comparison of aerobic exercise level between men with and without a cigarette smoking habit.

	Smoking habit (+)	Smoking habit (-)	p	After adjusting for age	After adjusting for age and METs·h/w
Age	49.4 ± 12.4	38.3 ± 13.7	<0.0001		
Predicted oxygen uptake (ml/kg/min)	34.1 ± 7.5	40.7 ± 8.7	<0.0001	0.0415	0.0632
Predicted work rate (watt)	184.4 ± 40.8	218.9 ± 51.3	<0.0001	0.0351	0.0873
Predicted heart rate (beat/min)	172.5 ± 22.0	185.3 ± 22.6	0.0006	0.9942	0.6278
Daily step counts (steps/day)	8401.0 ± 3922.6	8794.9 ± 3227.3	0.5067	0.9655	0.9639
METs·h/w	14.6 ± 11.7	14.4 ± 9.8	0.9171	0.7842	
Σ [metabolic equivalents \times h per week (METs·h/w)]					

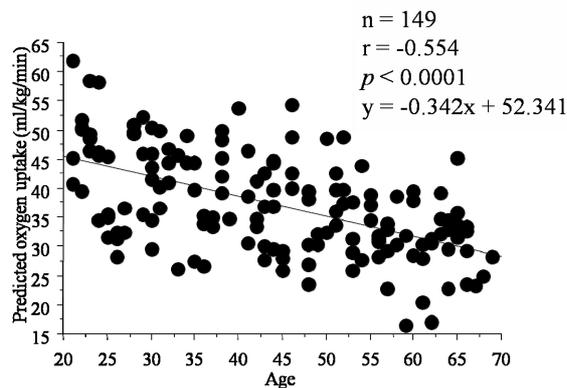


Figure 1. Simple correlation analysis between predicted oxygen uptake and age.

and compared parameters using covariance analysis. In addition, predicted oxygen uptake and predicted work rate with cigarette smoking were significantly lower than in men who did not smoke cigarettes even after adjusting for age (**Table 4**).

It is well known that the aerobic exercise level is closely linked to exercise habits [19]. To avoid the influence of age and exercise habits evaluated by METs·h/w on cigarette smoking, we finally used age and METs·h/w as covariates and compared parameters using covariance analysis. Significant differences of predicted oxygen uptake and predicted work rate between men with and without smoking habits were attenuated after adjusting for age and METs·h/w (predicted oxygen uptake: $p = 0.0632$, predicted work rate: $p = 0.0873$) (**Table 4**).

4. DISCUSSION

Impairment of pulmonary oxygen exchange [20,21], down regulation of adrenergic receptors [22] and long-term cardiac damage caused by stimulation of catecholamine by smoking [23] may also in part explain the lower maximal oxygen uptake in men who smoked cigarettes. Some cross sectional studies show that cigarette smoking is correlated with cardiovascular fitness [24-27]. Rotstein *et al.* reported that smoking retards physiological responses to submaximal exercise immediately after smoking three cigarettes [24]. Hirsch *et al.* evaluated the immediate effects of cigarette smoking on aerobic exercise capacity, which resulted in a significantly lower VO_2 max and higher heart rate after 3 cigarettes/h for 5 hours [25]. Marti *et al.* also showed that, among army conscripts, the distance covered in a 12-min endurance run was inversely related to daily cigarette consumption and years of smoking [26]. Bolinder *et al.* reported that significantly lower maximal oxygen uptake was found for smokers than non-smokers [27]. We also reported that oxygen uptake at the ventilatory threshold (VT) in women and work rate at VT in men who smoked cigarettes

were significantly lower than in subjects who did not smoke cigarettes, after adjusting for age [28]. The differences of parameters at VT did not reach significant levels after adjusting for age and exercise habits in both sexes [28]. In longitudinal analysis, Sandvik L. *et al.* showed that decline in physical fitness and lung function was greater among smokers than among non-smokers among 1393 men over 7 years [29]. Moreover, moderate to heavy smoking was longitudinally and negatively related to maximal oxygen uptake, maximum treadmill slope, heat rate at sub-maximal exercise and maximum heat rate, and with increasing age, the negative relationship between smoking and the parameters described above became stronger in men [30]. In this study, we solely evaluated the relationship between cigarette smoking and the aerobic exercise level defined by predicted oxygen uptake in Japanese men. Physical activity was accurately evaluated by LC and the aerobic exercise level was also accurately measured by predicted oxygen uptake compared to our previous studies [28]. Predicted oxygen uptake and predicted work rate in men who smoked cigarettes were lower than in men who did not smoke cigarettes after adjusting for age and METs·h/w, but not at a significant level. Taken together, a combination of increased physical activity and giving up cigarette smoking might be considered for improving predicted oxygen uptake in Japanese men.

Potential limitations remain in this study. First, our study was a cross sectional and not a longitudinal study. Second, the 149 men in our study voluntarily underwent measurements; they were therefore more likely to be more health-conscious than the average person. Third, we could not show a clear relationship between cigarette smoking and predicted oxygen uptake because of the small sample size in this study. Fourth, the relationship between cigarette smoking and predicted oxygen uptake was not investigated in women; however, it seems reasonable to suggest that giving up smoking and increasing physical activity might ameliorate the aerobic exercise level in some Japanese men. To show this, further prospective studies of Japanese are needed.

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