Low Vital Capacity is Associated with Diabetes Despite Inverse Relationships with Metabolic Risk Factors in Lean Japanese Men

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Abstract

Background There is no study examining the relationships between vital capacity and diabetes or metabolic risk factors in lean subjects.

Methods Cross-sectional relationships between % vital capacity (%VC) and diabetes and metabolic risk factors were examined in Japanese subjects using medical check-up data from 2,079 men and 1,215 women. Subjects were divided into lean ($\text{BMI} < 23 \text{ kg/m}^2$) and obese ($\text{BMI} \geq 23 \text{ kg/m}^2$) groups and then subdivided into lower %VC ($\leq 95\%$) and higher %VC ($\geq 96\%$) subgroups by gender. Metabolic risk factors and prevalence of diabetes and MS were compared between the subjects in each group, and then excluding current smokers and between subjects with the lowest quartile of %VC and those with the highest quartile of %VC in the lean men group. Spearman's correlation coefficients between %VC and metabolic risk factors were calculated separately in obese subjects and in lean subjects by gender.

Results The prevalence of diabetes, but not metabolic syndrome, was significantly higher in subjects with the lower %VC than in those with the higher %VC in the lean men despite the fact that age, obesity parameters, systolic and diastolic blood pressures were significantly lower in subjects with the lower %VC than in those with the higher %VC and triglycerides, high-density lipoprotein cholesterol, high-sensitivity C-reactive protein, white blood cell count, and heart rate were not significantly different between the two groups.

Conclusion Low vital capacity was significantly associated with diabetes in lean Japanese men despite inverse relationships with metabolic risk factors.

Key words: vital capacity, diabetes, metabolic syndrome, lean men

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Introduction

While low vital capacity was reported as a predictor of insulin resistance or diabetes in Western countries where the prevalence of obesity is high (1-5), there are few reports on the relationship between respiratory function and metabolic syndrome (MS) or diabetes in Japanese where the prevalence of obesity is very low. We investigated cross-sectional relationships between % vital capacity (%VC) and diabetes and MS-related risk factors in lean Japanese men and women.

Methods

Subjects

Between April 1 and December 29, 2008, 2,136 men and 1,255 women visited our medical check-up center for a nationwide general medical check-up program named "Ningen Dock", one of the programs prepared by our Medical Check-up Center. Visitors were all required to fill out a questionnaire prepared by the Ministry of Health, Labor, and Welfare including questions about history of cardiovascular disease, smoking status, antihypertensive and hypoglycemic

medication, and alcohol consumption. Among these persons, 13 men and 15 women without signed consent, 11 men and 14 women without respiratory function data, a man and a woman without renal function data, 28 men and 9 women with serum levels of high-sensitivity C-reactive protein (hs-CRP) higher than 10 mg/L, and 4 men and 1 woman without body fat % (BF%) data were excluded resulting in 2,079 men and 1,215 women. The protocol for the present study was approved by the ethics committee of Tachikawa Medical Center and signed informed consent was obtained from each subject.

Measurements

After an overnight fast, blood samples were obtained to measure serum levels of routine medical check-up tests. Plasma glucose, serum triglycerides, high-density lipoprotein (HDL) cholesterol, total cholesterol, low-density lipoprotein (LDL) cholesterol, hemoglobin A1c, uric acid, blood cell counts, electrolytes, liver and kidney function tests, and amylase were measured at BML Nagaoka (Nagaoka, Japan) using routine laboratory methods, except for hs-CRP which was measured at BML General Laboratory (Tokyo, Japan) with nephelometry using N-latex CRP-2 (Siemens Healthcare Japan, Tokyo, Japan). The measurement limit of hs-CRP was 0.02 mg/L and the value of hs-CRP less than the measurement limit was considered as 0.01 mg/L. Respiratory function tests including %VC and forced expiratory volume in 1 second (FEV1) divided by forced vital capacity (FVC) (FEV1%) were performed with the Autospirometer System 7 (Minato Medical Science, Osaka, Japan). BF% was measured with bioelectrical impedance analysis using TBF-210 (TANITA, Tokyo, Japan). Heart rate was automatically recorded by an electrocardiogram with the subjects in a supine position. Average systolic blood pressure (SBP) and diastolic blood pressure (DBP) were calculated from two measurements with the subjects in a sitting position after 5 min rest. Body weight was measured with the subjects wearing lightweight clothing provided by our center and the weight of the clothing was subtracted from the measured body weight. Waist circumference (WC) was measured at the level of the umbilicus. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Estimated glomerular filtration rate (eGFR) was calculated as $eGFR (mL/min/1.73 m^2) = 194 \times \text{creatinine}^{-1.094} \times \text{age}^{-0.287}$ in men, and $194 \times \text{creatinine}^{-1.094} \times \text{age}^{-0.287} \times 0.739$ in women according to the guideline of the Japanese Society of Nephrology.

Data analysis

Diabetes was defined as fasting plasma glucose levels ≥ 126 mg/dL or those receiving hypoglycemic medication. MS was defined by the revised National Cholesterol Education Program (NCEP) criteria (6) where the cut-off point of WC was modified for Japanese as ≥ 90 cm in men and ≥ 80 cm in women according to the recommendation by the International Diabetes Federation (7). Subjects receiving antihyper-

tensive or hypoglycemic medication were considered to have the respective MS component. Subjects were divided into a lean (BMI < 23 kg/m²) and an obese (BMI ≥ 23 kg/m²) groups by gender, then, subdivided into a lower %VC ($\leq 95\%$) and a higher %VC ($\geq 96\%$) subgroups. MS-related risk factors and prevalence of diabetes and MS were compared between subjects with the lower %VC and those with the higher %VC separately in the lean group and the obese group, then, compared excluding current smokers in the lean men group. MS-related risk factors and prevalence of diabetes and MS were also compared between subjects with the lowest quartile of %VC (Q1) and those with the highest quartile of %VC (Q4) in the lean men. Spearman's correlation coefficients between %VC and MS-related risk factors were calculated separately in obese subjects and in lean subjects using Dr SPSS-2. P values less than 0.05 were considered to be statistically significant.

Results

Basal data stratified by BMI

Basal data stratified by the BMI cut point of 23 kg/m² is presented in Table 1. BF%, WC, SBP, DBP, fasting plasma glucose, triglycerides, hs-CRP, white blood cell count (WBC), gamma glutamyltransferase (GGT), and the prevalence of both diabetes and MS were significantly higher and HDL cholesterol and eGFR were significantly lower in obese subjects than in lean subjects both in men and women. Heart rate was significantly higher in obese subjects than in lean subjects only in men and age was significantly higher and FEV1% was significantly lower in obese subjects than in lean subjects only in women.

Results in obese subjects

Data in obese subjects are presented in Table 2. BMI, BF%, WC, SBP, DBP, fasting plasma glucose, triglycerides, hs-CRP, WBC, heart rate, FEV1%, and the prevalence of both diabetes and MS were significantly higher and HDL cholesterol was significantly lower in subjects with the lower %VC than in those with the higher %VC in men. WC, fasting plasma glucose, hs-CRP, WBC, FEV1%, and the prevalence of both diabetes and MS were significantly higher in subjects with the lower %VC than in those with the higher %VC in women.

Results in lean subjects

Data in lean subjects are presented in Table 3. Age, BMI, BF%, WC, SBP, and DBP were significantly lower but FEV1% and the prevalence of diabetes were significantly higher in subjects with the lower %VC than in those with higher %VC in men. Age, BMI, BF%, WC, and fasting plasma glucose were significantly lower and heart rate and FEV1% were significantly higher in subjects with the lower %VC than in those with the higher %VC in women. The prevalence of diabetes was not significantly different between

Table 1. Basal Data Stratified by BMI

	men			women		
	BMI < 23 kg/m ²	BMI ≥ 23 kg/m ²	p	BMI < 23 kg/m ²	BMI ≥ 23 kg/m ²	p
n	1027	1052		872	343	
age (year)	51.0 ± 9.3	51.4 ± 8.9	ns	50.5 ± 9.6	52.5 ± 9.2	<0.001
BMI (kg/m ²)	21.0 ± 1.4	25.5 ± 2.3	<0.0001	20.2 ± 1.6	25.5 ± 2.5	<0.0001
body (fat %)	19.0 ± 3.7	25.3 ± 4.3	<0.0001	24.0 ± 3.7	33.5 ± 4.6	<0.0001
waist circumference (cm)	78.7 ± 5.4	89.9 ± 6.4	<0.0001	75.1 ± 6.0	88.2 ± 6.8	<0.0001
systolic blood pressure (mmHg)	117 ± 16	127 ± 17	<0.0001	109 ± 15	120 ± 18	<0.0001
diastolic blood pressure (mmHg)	75 ± 10	80 ± 10	<0.0001	68 ± 10	74 ± 10	<0.0001
fasting plasma glucose (mg/dL)	93.9 ± 15.0	98.4 ± 16.1	<0.0001	87.8 ± 8.4	92.7 ± 13.9	<0.0001
triglycerides (mg/dL)	102 ± 61 (88)	141 ± 92 (121)	<0.0001	77.4 ± 45.0 (68)	99.7 ± 52.5 (88)	<0.0001
HDL cholesterol (mg/dL)	62.4 ± 15.0	52.9 ± 11.9	<0.0001	69.5 ± 14.5	61.2 ± 13.1	<0.0001
high-sensitivity CRP (mg/L)	0.47 ± 0.85 (0.23)	0.79 ± 1.12 (0.42)	<0.0001	0.36 ± 0.64 (0.18)	0.67 ± 0.93 (0.39)	<0.0001
white blood cell count (/L ⁻⁶)	5330 ± 1445	5799 ± 1475	<0.0001	4717 ± 1288	5160 ± 1152	<0.0001
gamma glutamyltransferase (U/L)	45.8 ± 46.9(31)	57.9 ± 54.5 (42)	<0.0001	21.8 ± 19.9 (17)	27.1 ± 20.2 (21)	<0.0001
eGFR (mL/min/1.73m ²)	79.5 ± 12.6	76.9 ± 13.0	<0.0001	80.7 ± 13.3	77.8 ± 12.5	<0.001
heart rate (/min)	58.9 ± 9.1	60.2 ± 8.9	<0.001	61.1 ± 8.2	60.8 ± 8.4	ns
%vital capacity (%)	96.3 ± 11.0	96.0 ± 11.6	ns	96.2 ± 11.9	97.6 ± 11.6	ns
FEV1% (%)	80.4 ± 6.8	80.6 ± 5.5	ns	82.7 ± 6.0	81.8 ± 4.4	<0.01
diabetes	4.7	7.3	<0.05	0.6	3.8	<0.0001
metabolic syndrome	3.1	26.1	<0.0001	1.9	21.3	<0.0001
antihypertensive medication	13.3	23.8	<0.0001	6.9	15.7	<0.0001
hypoglycemic medication	3.2	4.4	ns	0.2	3.2	<0.0001
stroke	1.5	2.0	ns	1.3	1.2	ns
ischemic heart disease	3.3	4.9	ns	1.5	1.5	ns
current smoker	34.0	33.9	ns	6.7	6.7	ns

Data are mean ± SD (median) or percent. eGFR: estimated glomerular filtration rate, FEV1%: forced expiratory volume in 1 second divided by forced vital capacity

Table 2. Data Stratified by % Vital Capacity (%VC) in Subjects with BMI≥23 kg/m²

	men			women		
	%VC ≤ 95	%VC ≥ 96	p	%VC ≤ 95	%VC ≥ 96	p
n	512	540		144	199	
% vital capacity (%)	86.4 ± 6.1	105.1 ± 7.5	<0.0001	86.9 ± 7.0	105.4 ± 7.2	<0.0001
age (year)	51.5 ± 9.0	51.3 ± 8.8	ns	53.2 ± 9.4	52.0 ± 9.0	ns
BMI (kg/m ²)	25.9 ± 2.7	25.1 ± 1.9	<0.0001	25.6 ± 2.4	25.4 ± 2.5	ns
body (fat %)	26.2 ± 4.5	24.5 ± 3.9	<0.0001	33.9 ± 4.6	33.2 ± 4.6	ns
waist circumference (cm)	90.9 ± 7.0	89.0 ± 5.7	<0.0001	89.2 ± 6.5	87.5 ± 6.9	<0.05
systolic blood pressure (mmHg)	128 ± 17	125 ± 17	<0.01	121 ± 18	118 ± 17	ns
diastolic blood pressure (mmHg)	81 ± 11	79 ± 10	<0.05	75 ± 11	74 ± 10	ns
fasting plasma glucose (mg/dL)	100.5 ± 18.5	96.5 ± 13.2	<0.0001	95.4 ± 17.3	90.8 ± 10.5	<0.01
triglycerides (mg/dL)	152 ± 98 (131)	131 ± 84 (113)	<0.001	102 ± 56 (93)	98 ± 50 (86)	ns
HDL cholesterol (mg/dL)	51.5 ± 11.6	54.3 ± 12.0	<0.001	60.5 ± 12.3	61.7 ± 13.7	ns
high-sensitivity CRP (mg/L)	0.91 ± 1.24 (0.50)	0.67 ± 0.99 (0.37)	<0.001	0.85 ± 1.25 (0.49)	0.54 ± 0.57 (0.34)	<0.01
white blood cell count (/L ⁻⁶)	5954 ± 1525	5652 ± 1411	<0.001	5379 ± 1220	5003 ± 1075	<0.01
heart rate (/min)	61.0 ± 9.1	59.5 ± 8.7	<0.01	60.6 ± 8.3	61.0 ± 8.4	ns
FEV1% (%)	81.4 ± 5.5	79.8 ± 5.5	<0.0001	82.4 ± 4.5	81.3 ± 4.2	<0.05
diabetes	10.5	4.3	<0.001	6.3	2.0	<0.05
metabolic syndrome	34.0	18.7	<0.001	28.5	16.1	<0.01
antihypertensive medication	27.9	19.8	<0.01	22.9	10.6	<0.01
hypoglycemic medication	6.6	2.2	<0.001	5.6	1.5	<0.05
stroke	2.0	2.0	ns	1.4	1.0	ns
ischemic heart disease	6.4	3.5	<0.05	2.1	1.0	ns
current smoker	36.9	31.1	<0.05	6.9	6.5	ns

Data are mean ± SD (median) or percent. Abbreviations are the same as in Table 1.

subjects with the lower %VC and those with the higher %VC in women. Triglycerides, HDL cholesterol, hs-CRP, WBC, and the prevalence of MS were not significantly different between the two groups both in men and in women.

Detailed analysis in lean men

Table 4 shows data in lean men excluding current smokers. Age, BMI, BF%, WC, SBP, DBP, and the prevalence of MS were significantly lower but FEV1% and the prevalence of diabetes were significantly higher in subjects with the lower %VC than in those with higher %VC in nonsmokers.

Table 5 shows data by the quartile of %VC in lean men. Age, BMI, BF%, WC, SBP, and DBP were significantly lower but fasting plasma glucose, FEV1%, and the prevalence of diabetes were significantly higher in Q1 than in Q4.

Correlations between %VC and MS-related risk factors in lean subjects and in obese subjects Spearman's correlation coefficients between %VC and MS-related risk factors are presented in Table 6 separately in the obese and in the lean groups. While BMI, BF%, WC, SBP, DBP, fasting plasma glucose, triglycerides, hs-CRP, WBC, and GGT were significantly negatively and HDL cholesterol was significantly

Table 3. Data Stratified by % Vital Capacity (%VC) in Subjects with BMI<23 kg/m²

	men			women		
	%VC ≤ 95	%VC ≥ 96	p	%VC ≤ 95	%VC ≥ 96	p
n	495	532		434	438	
% vital capacity (%)	87.2 ± 6.1	104.7 ± 7.0	<0.0001	86.5 ± 6.4	105.7 ± 7.5	<0.0001
age (year)	50.2 ± 9.7	51.9 ± 8.9	<0.01	49.3 ± 10.1	51.7 ± 9.0	<0.001
BMI (kg/m ²)	20.7 ± 1.6	21.2 ± 1.3	<0.0001	19.8 ± 1.7	20.6 ± 1.5	<0.0001
body (fat %)	18.6 ± 3.8	19.3 ± 3.5	<0.01	23.5 ± 3.8	24.4 ± 3.5	<0.001
waist circumference (cm)	78.0 ± 5.7	79.3 ± 5.1	<0.001	74.2 ± 6.3	75.9 ± 5.6	<0.0001
systolic blood pressure (mmHg)	116 ± 17	119 ± 17	<0.01	108 ± 16	109 ± 15	ns
diastolic blood pressure (mmHg)	74 ± 10	76 ± 10	<0.01	68 ± 10	68 ± 9	ns
fasting plasma glucose (mg/dL)	94.7 ± 17.4	93.2 ± 12.2	ns	87.2 ± 8.2	88.3 ± 8.5	<0.05
triglycerides (mg/dL)	101 ± 57 (88)	103 ± 64 (87)	ns	76.5 ± 51.6 (66)	78 ± 37 (70)	ns
HDL cholesterol (mg/dL)	62.3 ± 15.7	62.5 ± 14.3	ns	69.4 ± 13.8	69.6 ± 15.1	ns
high-sensitivity CRP (mg/L)	0.48 ± 0.83 (0.24)	0.45 ± 0.87(0.22)	ns	0.39 ± 0.62 (0.20)	0.33 ± 0.67(0.17)	ns
white blood cell count(/L ⁻⁶)	5340 ± 1418	5321 ± 1471	ns	4735 ± 1260	4698 ± 1316	ns
heart rate (/min)	59.2 ± 9.1	58.6 ± 9.0	ns	61.9 ± 8.7	60.2 ± 7.7	<0.01
FEV1% (%)	81.3 ± 7.5	79.6 ± 5.9	<0.0001	83.8 ± 6.4	81.7 ± 5.3	<0.0001
diabetes	6.9	2.6	<0.01	0.5	0.7	ns
metabolic syndrome	2.2	3.9	ns	1.4	2.5	ns
antihypertensive medication	13.3	13.3	ns	6.7	7.1	ns
hypoglycemic medication	5.3	1.3	<0.001	0.2	0.2	ns
stroke	1.2	1.7	ns	1.8	0.7	ns
ischemic heart disease	3.8	2.8	ns	0.9	2.1	ns
current smoker	36.2	32.0	ns	6.0	7.3	ns

Data are mean ± SD (median) or percent. Abbreviations are the same as in Table 1.

Table 4. Data Stratified by % Vital Capacity (%VC) in Men with BMI<23 kg/m² Excluding Current Smokers

	%VC ≤ 95	%VC ≥ 96	p
n	316	362	
% vital capacity (%)	87.2 ± 6.4	105.1 ± 7.3	<0.0001
age (year)	49.9 ± 10.3	52.5 ± 9.2	<0.001
BMI (kg/m ²)	20.7 ± 1.6	21.3 ± 1.2	<0.0001
body (fat %)	18.6 ± 3.9	19.5 ± 3.4	<0.01
waist circumference (cm)	77.9 ± 5.8	79.5 ± 5.1	<0.001
systolic blood pressure (mmHg)	116 ± 17	121 ± 17	<0.01
diastolic blood pressure (mmHg)	74 ± 11	77 ± 11	<0.01
fasting plasma glucose (mg/dL)	93.5 ± 14.4	93.3 ± 10.9	ns
triglycerides (mg/dL)	95.3 ± 53.8 (84)	100 ± 61 (85)	ns
HDL cholesterol (mg/dL)	63.7 ± 15.3	63.7 ± 14.2	ns
high-sensitivity CRP (mg/L)	0.44 ± 0.83 (0.22)	0.35 ± 0.54 (0.19)	ns
white blood cell count(/L ⁻⁶)	4966 ± 1144	4939 ± 1092	ns
heart rate (/min)	59.1 ± 9.3	58.9 ± 9.5	ns
FEV1% (%)	82.7 ± 7.0	80.1 ± 6.1	<0.0001
diabetes	5.4	2.2	<0.05
metabolic syndrome	1.3	3.9	<0.05
antihypertensive medication	14.6	14.4	ns
hypoglycemic medication	4.1	1.1	<0.05
stroke	1.9	2.2	ns
ischemic heart disease	4.1	3.0	ns

Data are mean ± SD (median) or percent. Abbreviations are the same as in Table 1.

positively correlated with %VC in the obese men, BMI, BF %, WC, SBP, DBP, and age were, unexpectedly, significantly positively and only hs-CRP and WBC were significantly negatively correlated with %VC in the lean men. While WC, SBP, fasting plasma glucose, hs-CRP, WBC, and GGT were significantly negatively correlated with %VC in the obese women, BMI, BF%, WC, SBP, DBP, triglycerides, and age were, unexpectedly, significantly positively and only hs-CRP and heart rate were significantly negatively corre-

lated with %VC in the lean women.

Discussion

Lazarus et al found that FVC, FEV1, and maximal mid-expiratory flow rate were predictors of insulin resistance (1). Engstrom and Janzon (2) reported that low FVC and FEV1 predicts diabetes independent of adiposity and that the incidence of cardiovascular disease is significantly increased

Table 5. Data by the Quartile of % Vital Capacity (%VC) in Men with BMI<23 kg/m²

%VC quartiles	Q1 54 - 88 %	Q2 89 - 96 %	Q3 97 - 103 %	Q4 104 - 142 %	P*
n	261	270	242	254	
% vital capacity (%)	82.9 ± 5.1	92.6 ± 2.2	100 ± 2.0	110.5 ± 5.9	<0.0001
age (year)	50.5 ± 10.3	50.1 ± 9.1	50.9 ± 8.7	52.7 ± 8.9	<0.01
BMI (kg/m ²)	20.5 ± 1.7	20.9 ± 1.4	21.1 ± 1.4	21.4 ± 1.2	<0.0001
body fat (%)	18.4 ± 3.9	18.9 ± 3.5	19.1 ± 3.7	19.5 ± 3.5	<0.01
waist circumference (cm)	77.6 ± 6.0	78.6 ± 5.2	79.0 ± 5.4	79.7 ± 4.8	<0.0001
systolic blood pressure (mmHg)	116 ± 17	117 ± 17	119 ± 16	119.5 ± 17	<0.01
diastolic blood pressure (mmHg)	73.7 ± 10	74.3 ± 11	76 ± 10	76 ± 10	<0.01
fasting plasma glucose (mg/dL)	96.2 ± 19.0	93.7 ± 17.3	92.9 ± 10.7	92.6 ± 10.2	<0.01
triglycerides (mg/dL)	99.5 ± 54.3 (87)	103 ± 67.4 (88.5)	106 ± 64.8 (89.5)	99.2 ± 54.8 (86)	ns
HDL cholesterol (mg/dL)	61.6 ± 16.4	62.9 ± 15.0	61.5 ± 13.9	63.5 ± 14.6	ns
high-sensitivity CRP (mg/L)	0.57 ± 1.01 (0.26)	0.38 ± 0.53 (0.23)	0.48 ± 0.93 (0.22)	0.44 ± 0.88 (0.20)	ns
white blood cell count (/L ⁻⁶)	5486 ± 1523	5196 ± 1276	5407 ± 1454	5239 ± 1509	ns
heart rate (/min)	59.4 ± 9.2	58.9 ± 9.1	58.3 ± 9.0	58.8 ± 9.0	ns
FEV1% (%)	81.2 ± 8.5	81.3 ± 6.0	80.5 ± 5.8	78.6 ± 5.9	<0.0001
diabetes	8.4	5.2	2.9	2.0	<0.01
metabolic syndrome	3.4	1.1	5.0	3.1	ns
antihypertensive medication	15.3	10.7	12.8	14.6	ns
hypoglycemic medication	7.3	3.0	1.2	1.2	<0.001
stroke	1.9	0.4	1.2	2.4	ns
ischemic heart disease	5.4	1.9	4.1	2.0	<0.05
current smoker	37.9	34.4	35.1	28.3	<0.05

Data are mean ± SD (median) or percent. *P values are comparisons between Q1 and Q4. Abbreviations are the same as in Table 1.

Table 6. Spearman's Correlation Coefficients between % Vital Capacity and Metabolic Risk Factors

	men				women			
	BMI<23		BMI≥23		BMI<23		BMI≥23	
	r	p	r	p	r	p	r	p
n	1027		1052		872		343	
age	0.094	<0.01	-0.006	ns	0.148	<0.0001	-0.079	ns
BMI	0.210	<0.0001	-0.141	<0.0001	0.270	<0.0001	-0.073	ns
body fat %	0.104	<0.001	-0.198	<0.0001	0.134	<0.0001	-0.098	ns
waist circumference	0.132	<0.0001	-0.144	<0.0001	0.180	<0.0001	-0.157	<0.01
systolic blood pressure	0.104	<0.001	-0.083	<0.01	0.083	<0.05	-0.155	<0.01
diastolic blood pressure	0.094	<0.01	-0.067	<0.05	0.085	<0.05	-0.122	<0.05
fasting plasma glucose	0.011	ns	-0.100	<0.01	0.065	ns	-0.205	<0.001
triglycerides	-0.004	ns	-0.146	<0.0001	0.076	<0.05	-0.053	ns
HDL cholesterol	0.059	ns	0.171	<0.0001	-0.049	ns	0.055	ns
high-sensitivity CRP	-0.098	<0.01	-0.189	<0.0001	-0.074	<0.05	-0.166	<0.01
white blood cell count	-0.065	<0.05	-0.133	<0.0001	-0.010	ns	-0.132	<0.05
gamma glutamyltransferase	0.010	ns	-0.105	<0.001	0.024	ns	-0.117	<0.05
heart rate	-0.05	ns	-0.057	ns	-0.069	<0.05	-0.005	ns

r: Spearman's correlation coefficients. Other abbreviations are the same as in Table 1.

among subjects with low %VC who developed insulin resistance (Engstrom et al, 3). Ford and Mannino found that restrictive lung disease is significantly associated with the incidence of diabetes but not obstructive lung disease (4). Yeh et al also concluded that lower vital capacity predicts the development of diabetes and that the association between respiratory function and diabetes is stronger in never smokers and it appears to be specific to vital capacity, since FEV1% was not at all related to diabetic risk and that the subjects with lower vital capacity had many features of MS or insulin resistance at baseline (5). There are a few cross-sectional studies on the association between respiratory function and metabolic risk factors in Japanese (8, 9). Previously, we found that %VC is significantly lower in MS subjects than in non-MS subjects in Japanese men, but not in women and

the prevalence of MS and diabetes is significantly higher in Q1 than in Q4 in Japanese men, but not in women (10). We thought that the number of subjects with diabetes was too small to detect a statistical significance in women and paradoxically positive correlations between %VC and obesity parameters in women might result from the leanness rather than obesity in Japanese women.

In the present study, we examined cross-sectional relationships between %VC and diabetes and MS-related risk factors separately in the lean subjects and the obese subjects. The relationships between %VC and diabetes and MS-related risk factors were in accord with the previous reports (1-5) in both the obese men and women. In the lean men, the prevalence of diabetes, but not MS, was significantly higher in subjects with the lower %VC than in those with

the higher %VC despite the fact that age, BMI, BF%, WC, SBP, and DBP were significantly lower in subjects with the lower %VC than in those with the higher %VC and triglycerides, HDL cholesterol, hs-CRP, WBC, and heart rate were not significantly different in the two groups. In the lean women, the prevalence of diabetes was not significantly different between subjects with the lower %VC and those with the higher %VC and the results were essentially the same after excluding current smokers (data not shown). But, the result was not conclusive because the number of diabetic subjects in the lean women was only 5. In Tables 3, 4, fasting plasma glucose was not significantly different between men with lower vital capacity and men with higher vital capacity. The reason may be the small sample size insufficient to detect statistically significant differences and the confounding effect of hypoglycemic medication because fasting plasma glucose is significantly higher in Q1 than in Q4 in Table 5.

The underlying mechanisms linking low vital capacity and diabetes in lean men are not clear. MS-related risk factors were inversely related with reduced %VC in lean men and the prevalence of MS was significantly lower in subjects with the lower %VC than those with the higher %VC when current smokers were excluded. It is possible that unknown mechanisms different from insulin resistance is involved. Decreased insulin secreting capacity (11) rather than insulin resistance (12) or a simple genetic linkage may be a possible link. Reduced vital capacity in lean men may be a result of diabetes (13, 14), not a predictor of diabetes. However,

hs-CRP and WBC were significantly negatively correlated with %VC even in lean men. Therefore, inflammation, which is closely linked to insulin resistance (15-17), may be involved in the association between vital capacity and diabetes even in lean men.

Limitations

Regrettably, we did not measure insulin levels. We are planning the next study to detect whether the relationship between vital capacity and insulin secreting function or insulin resistance is different between lean and obese diabetic men. If the relationship is similar between lean and obese diabetic men, then, it means that insulin resistance dissociates from metabolic syndrome in lean diabetic men. If lower vital capacity is associated with lower insulin secreting capacity in lean diabetic men, then, there may be some common mechanisms between insulin secreting capacity of pancreatic beta-cells and vital capacity which may be related to the surfactant protein secreting capacity of pulmonary alveolar cells (18) or contractile strength of respiratory muscles (19).

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