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Blood rheological properties are strongly related to the metabolic syndrome in middle-aged Chinese

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Abstract

The current investigation sought to evaluate the relation between hemorheological properties and the metabolic syndrome. 1400 office workers aged 35 to 59 years were enrolled in this study. Waist circumference and blood pressure were determined. Plasma high-density lipoprotein (HDL cholesterol), triglyceride, fasting blood glucose, plasma insulin and whole blood viscosity (WBV) at a high-shear rate of 200 s^{-1} were measured at the attendance. Metabolic syndrome was defined according to National Cholesterol Education Program (NCEP)/ATP III guidelines. The metabolic syndrome was identified in 18% of this sedentary population. Mean WBV was 4.71 ± 0.56 mPa s. One-way ANOVA indicated WBV increased across subjects with 0–4 metabolic syndrome components ($F=3.86$, $p<0.01$). The highest vs. lowest quartiles of WBV occurred significantly more often among subjects as the number of metabolic syndrome components increased. Across five categories of the metabolic syndrome, the frequencies of the occurrence of the highest vs. lowest quartiles were: 0.40, 0.87, 1.31, 1.92, and 4.80, respectively, showing a significant correlation ($R=0.817$, $p<0.05$). Univariate logistic regression analysis showed that the prevalence of hyperviscosity was predicted positively by waist circumference (OR = 1.018, 95% CI: 1.002–1.035, $p<0.05$) and negatively by HDL cholesterol (OR = 0.295, 95% CI: 0.133–0.680, $p<0.01$), independently of age, sex, and smoking status. In summary, this study has shown that WBV is strongly related to the severity of the metabolic syndrome. We suggest that the hemorheological parameters could potentially be used as an additional indicator of the metabolic syndrome.

Keywords: Metabolic syndrome; Blood viscosity; Vascular disease; Risk factors

1. Introduction

The metabolic syndrome is a cluster of generally accepted cardiovascular risk factors such as impaired glucose metabolism, elevated blood pressure, dyslipidemia, and central obesity. The underlying abnormality has been suggested as insulin resistance. The metabolic syndrome is now regarded as a major risk factor for cardiovascular disease (CVD). The global increase in this syndrome has led researchers to focus on the prevention of both the metabolic syndrome and its consequences.

Blood rheology is a major determinant in the initiation of atherosclerosis [1] and is associated with cardiovascular events [2]. Atherosclerosis preferentially affects areas where blood flow changes direction and where longitudinal forces exert stress on the arterial wall. Hemodynamic forces, primarily circumferential strain and shear stress, have been implicated in the localization of atherosclerotic lesions at susceptible sites [3].

Accumulating evidence suggests that the components of the metabolic syndrome may induce hemorheological abnormalities. Hypertension [4], dyslipidemia [5], obesity, hyperglycemia [6], and insulin resistance [7] have been implicated in deterioration in rheological properties. Recently, Wang et al. [8] found that increased erythrocyte count was associated with a variety of the metabolic syndrome. We have therefore hypothesised that hyperviscosity of blood is related to the severity of metabolic syndrome and this has been investigated in a cohort of sedentary office workers.

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2. Methods

2.1. Participants

This study was performed during March to May 2004. 1400 office staff aged 35 to 59 years who underwent a thorough health check in Tianjin 254th hospital were enrolled. Physical examination (waist circumference and blood pressure) and plasma high-density lipoprotein (HDL cholesterol), insulin and fasting glucose were measured at the attendance. Participants were asked to complete a self-administered questionnaire, that included personal characteristics (age, sex, and smoking status). Insulin sensitivity (HOMA-IR) was calculated according to the following equation: FI (NU/mL) × FG (mmol/L)/22.5, where FI is fasting plasma insulin and FG is fasting blood glucose.

2.2. Classification of metabolic status

The metabolic syndrome was defined according to National Cholesterol Education Program (NCEP)/ATP III guidelines [9] with the presence of at least three of the following: (1) fasting glucose ≥6.1 mmol/L, (2) waist circumference >80 cm in women or >90 cm in men (Asian WHO), (3) systolic blood pressure ≥130 mm Hg or diastolic blood pressure ≥85 mm Hg, (4) plasma triglycerides ≥1.7 mmol/L, and (5) HDL cholesterol <1.3 mmol/L in women or <1.04 mmol/L in men, respectively. Participants who reported using medications for diabetes or hypertension were classified as having met the criterion for elevated glucose or blood pressure.

2.3. Measurement of rheological profile

Rheological measurement was carried out at 37 °C. Fasting blood samples were obtained from the antecubital vein between 0800 to 1000 h and were anticoagulated with EDTA. Whole blood viscosity (WBV) was measured using a cone-plate automated viscometer (LG-R-80 Steellex, Beijing, China) at a high-shear rate of 200 s^{-1}. The hyperviscosity state was identified when WBV was in the highest quartile (≥5.15 mPa s).

2.4. Statistical analysis

Data on characteristics of the participants are reported as means ± S.D. Probabilities of significant differences were compared by one-way ANOVA for quantitative variables. Linear regression analysis was used to relate WBV distribution across quartiles for the number of metabolic syndrome components. Univariate logistic regression analysis was performed to assess the predictive power of metabolic syndrome components for the occurrence of hyperviscosity, independently of age, sex, and smoking status. Odds ratios (ORs), 95% CI: for odds ratio, and p values were calculated. Data were analysed using SPSS 10.0 (SPSS Inc, Chicago), and figures were prepared with SigmaPlot 8.02 (SPSS Inc, Chicago).

3. Results

3.1. Clinical and biochemical characteristics of the participants are shown in Table 1

The numbers of subjects with 0,1,2,3, and 4 components of the metabolic syndrome were: 420 (30%), 433 (31%), 295 (21%), 181 (13%) and 71 (5%) but none possessed 5 components. Among all components of the metabolic syndrome, high waist circumference occurred most frequently (in 44% of the study population) (Table 1).

3.2. The relation between the severity of the metabolic syndrome and WBV

Mean (SD) of all WBV measurement was 4.71 mPa s (0.56 mPa s), and the values at the 25th, 50th, and 75th percentiles were 4.25, 4.70 and 5.15 mPa s, respectively. One-way ANOVA indicated that there were significant differences in WBV levels with increasing severity of metabolic syndrome ($F=3.86$, $p<0.01$; Fig. 1).

The highest vs. the lowest quartiles of WBV occurred 4.8 times more frequently among subjects with 4 metabolic syndrome components and less than half as frequently in those with none of the components. Across the five categories of the metabolic syndrome, the proportions of

Table 1
Demographic data of subjects

Factor	Mean ± S.D.
Age, years	46.9 ± 6.6
Male, *n* (%)	1136 (81)
Current smoking, *n* (%)	588 (42)
Triglyceride, mmol/L	1.56 ± 1.31
High triglyceride (≥1.7 mmol/L), *n* (%)	335 (24)
HDL cholesterol, mmol/L	1.58 ± 0.40
Low HDL cholesterol (<1.3 mmol/L in women or <1.04 mmol/L in men), *n* (%)	39 (3)
Systolic blood pressure, mm Hg	116.5 ± 35.2
Diastolic blood pressure, mm Hg	74.1 ± 24.7
High blood pressure[a] (systolic blood pressure ≥130 mm Hg or diastolic blood pressure ≥85 mm Hg), *n* (%)	551 (39)
Average waist, cm	85.9 ± 10.7
High waist circumference (>80 cm in women or >90 cm in men), *n* (%)	611(44)
Fasting glucose, mmol/L	5.49 ± 1.21
Hyperglycaemia (fasting glucose ≥6.1 mmol/L) or diabetic, *n* (%)	314 (22)
Fasting insulin, NU/mL	8.9 ± 7.6
HOMA-IR	1.74 ± 1.12
WBV, mPa s	4.71 ± 0.56

**Data are expressed as mean ± SD.
[a] Including participants who were diagnosed with hypertension and reported using anti-hypertensive medication.