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Association of hematological parameters with metabolic syndrome in Beijing adult population: a longitudinal study

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Abstract	The purposes of the study were to estimate the incidence of metabolic syndrome (MetS) and to systematically evaluate the relationship between hematological parameters and MetS in a 5-year follow-up of Beijing adult population. The longitudinal study included 3,180 adults, aged 20–65 years, who attended health check-ups

in Beijing Tongren Hospital in 2007 and 2012. Multivariate logistic regression was conducted to explore the associations between hematological parameters and MetS. The 5-year cumulative incidence of MetS in this sample was 10.82 % (14.22 % for males and 7.59 % for females). Among all the hematological parameters, white blood cell count (WBC) was positively associated with MetS for 20–35-year-old (male OR 1.482, 95 % CI 1.169–2.974; female OR 1.398, 95 % CI 1.145–3.011), and 36–50-year-old (male OR 2.012, 95 % CI 1.290–4.010; female OR 3.400, 95 % CI 1.818–4.528) male and female subjects. Alanine aminotransferase (ALT) was significantly associated with the incidence of MetS for males (20–35-year-old OR 2.080, 95 % CI 1.371–3.159; 36–50-year-old OR 2.421, 95 % CI 1.335–3.412; 51–65-year-old OR 4.267, 95 % CI 1.161–6.781). Low-density lipoprotein cholesterol (LDL-C) was positively associated with MetS for 51–65-year-old (male OR 3.078, 95 % CI 2.468–5.131; female OR 2.140, 95 % CI 1.524–4.359) for male and female subjects. WBC is positively associated with MetS for young adults, while LDL-C is positively associated with MetS for elderly people. ALT is positively associated with MetS for males. Our findings provide further evidence in support of using hematological markers for early detection of individuals at risk for MetS.

Keywords (separated by '-')	Hematological parameters - Metabolic syndrome - Association - Longitudinal study
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Association of hematological parameters with metabolic syndrome in Beijing adult population: a longitudinal study

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Keywords Hematological parameters · Metabolic syndrome · Association · Longitudinal study

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Introduction

Metabolic syndrome (MetS) is a cluster of risk factors that include abdominal obesity, hyperglycemia, raised blood pressure (BP), low high-density lipoprotein cholesterol (HDL-C), and high triglycerides (TG). Since prevalence of MetS is rapidly growing and it is associated with an increased risk of insulin resistance, diabetes, cardiovascular disease (CVD), and total mortality [1–3], the identification for biomarkers of MetS is of pivotal importance.

The prevalence of MetS increased with age for both sexes [4]. Several non-inflammatory biomarkers have been

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associated with MetS and its components in different populations, including growth factors [5], micro albuminuria [6], and uric acid (UA) [7, 8]. Elevated white blood cell (WBC) count is intimately linked to the prevalence and future development of MetS in populations of working subjects [9, 10]. Insulin resistance and/or hyperinsulinemia have been shown to correlate with WBC counts [11]. Elevated liver enzymes, especially alanine aminotransferase (ALT) may be related with and a better predictor for MetS [12–14]. Other hematological parameters including platelet counts (PLT), hemoglobin (HGB), hematocrit concentrations (HCT), C-reactive protein, and serum bilirubin increased with increasing numbers of MetS components [15–18]. To the best of our knowledge, there have been few studies conducting systematic evaluation for relationship between hematological parameters and MetS for different age groups of males and females in a large Beijing adult population.

Therefore, the aims of this study were to estimate the incidence of MetS and to investigate prospective associations between blood parameters and MetS in a Beijing adult population.

Materials and methods

Subjects

A total of 3,832 subjects aged 20–65 years who attended health check-ups in Beijing Tongren Hospital, China, in 2007 and 2012 were enrolled in the study. Individuals with a previous diagnosis of CVD, cerebral infarction or gastric cancer, or those who had undergone coronary artery bypass surgery, coronary stenting surgery or gastrectomy, or those who had MetS at baseline were excluded. The remaining 3,180 subjects were included in the final analysis. The study was approved by the Ethics Committee of Capital Medical University (approval number: 2013SY26). Written informed consent was obtained from all the participating subjects.

Measurements

Information about medication use was gathered by trained medical staff during a standardized interview. Subjects who reported taking anti-hypertensive, anti-dyslipidemic, or anti-diabetic drugs were considered to have elevated BP, elevated TG, reduced HDL-C, or elevated fasting plasma glucose (FPG).

The participants underwent routine physical examinations that included the measurement of height, weight, BP, and overnight fasting blood sampling. Weight and height were measured without shoes, and body mass index (BMI) was calculated as weight (kg) divided by squared height (m). BP was measured on the right arm of subjects seated and at rest for at least 5 min by a trained nurse. During the 30 min preceding the measurements, the subjects were required to refrain from smoking or consuming caffeine. A standard mercury sphygmomanometer was used with one of four cuff sizes (pediatric, regular adult, large adult, or thigh) based on the participant's arm circumference. Three readings each of systolic and diastolic BPs were recorded, with an interval of 1 min at least, and the average of the last two measurements was used for data analysis.

Blood samples were obtained from antecubital vein into tubes containing EDTA in the morning after an overnight fasting period. Red blood cell (RBC), WBC, lymphocyte, neutrophil, mean corpuscular hemoglobin (MCH), PLT, mean platelet volume (MPV), platelet distribution width (PDW), and HGB were measured by an autoanalyzer (Sysmex SE-9000, Kobe, Japan). HDL-C, TG, FPG, ALT, aspartate aminotransferase (AST), UA, and LDL-C were measured by enzymatic method using a chemistry analyzer (Beckman LX 20, USA) at the central laboratory of the hospital. All analyses were performed in accordance with the manufacturer's recommendations.

Definitions

MetS was diagnosed if the subjects had three or more risk determinants according to the Joint Interim Statement criteria [19]. However, in this study, waist circumference (WC) was not measured because of limited health check-up site, and BMI was taken as a substitute for the component of obesity [20]. The determinants were as follows:

(1) Obesity: BMI $\geq$ 28 kg/m^2. (2) Elevated TG (drug treatment for elevated TG is an alternate indicator): $\geq$150 mg/dL (1.7 mmol/L). (3) Reduced HDL-C (drug treatment for reduced HDL-C is an alternate indicator): <40 mg/dL (1.0 mmol/L) in males, <50 mg/dL (1.3 mmol/L) in females. (4) Elevated BP (antihypertensive drug treatment in a patient with a history of hypertension is an alternate indicator): systolic $\geq$130 mmHg and/or diastolic $\geq$85 mmHg, and (5) Elevated FPG (drug treatment of elevated glucose is an alternate indicator): $\geq$100 mg/dL.

Statistical analysis

Data were expressed as mean $\pm$ standard deviation (SD) or, for non-normally distributed variables, as median and interquartile range. To compare the differences between groups, student's t test or Wilcoxon rank sum test was used for continuous variables, and χ^2 test or Fisher's exact test was used for categorical variables. Log transformations were applied to skewed data prior to parametric analyses. Multiple logistic regression analysis was used to assess the

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relationship between hematological parameters and MetS after adjusting for medication use. Data were analysed using the SAS software package (version 9.2; SAS Institute, Chicago, IL, USA), and $P < 0.05$ was considered significant.

Results

The incidence of MetS and prevalence of its components by age and gender

The sample of this study represents 3,180 subjects, including 1,547 males and 1,633 females aged 20–65 years old. The sex- and age-specific incidence of MetS, prevalence of its components, and medical use are shown in Table 1 and Figs. 1 and 2.

Overall, the 5-year cumulative incidence of MetS among all subjects was 10.82 %, with 14.22 % of males and 7.59 % of females having MetS. Of note, the 5-year cumulative incidence of MetS among 36–50-year-old male subjects was the highest (15.40 %). And the 20–35-year-old female subjects had the lowest incidence (4.13 %). While among female subjects, the 51–65-year-old subjects had the highest 5-year cumulative incidence of MetS (14.05 %).

The prevalence of MetS components is shown in Fig. 2. The prevalence of elevated BP and elevated FPG increased with age for male subjects, while the prevalence decreased with age for reduced HDL-C and elevated BMI for male subjects. The highest prevalence of elevated TG was presented in 36–50-year-old group among males. For female

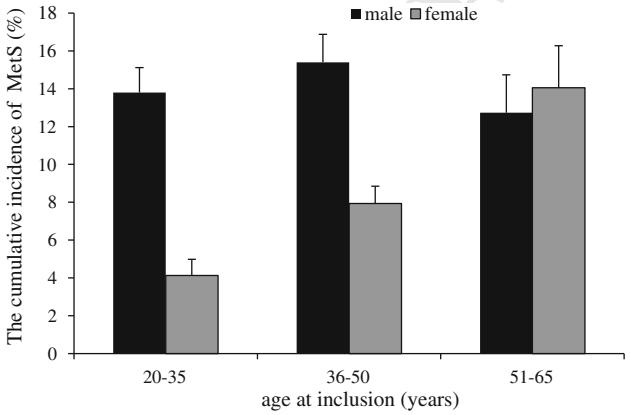

Fig. 1 The 5-year cumulative incidence of MetS. *MetS* metabolic syndrome

Table 1 The incidence of MetS, prevalence of its components and medication use

Gender	Variables	Age at inclusion (years)			*P* value
		20–35	36–50	51–65	
Male	*N*	681	591	275	
	MetS, *n* (%)	94 (13.80)	91 (15.40)	35 (12.73)	0.5296
	Elevated BP, *n* (%)	190 (27.90)	202 (34.18)	118 (42.91)	<0.0001
	Elevated TG, *n* (%)	216 (31.72)	208 (35.19)	75 (27.27)	0.0623
	Reduced HDL-C, *n* (%)	170 (27.96)	111 (18.78)	42 (15.27)	0.0011
	Elevated BMI, *n* (%)	104 (15.27)	75 (12.69)	27 (9.82)	0.0682
	Elevated FPG, *n* (%)	62 (18.36)	203 (35.36)	87 (46.55)	<0.0001
	Anti-hypertensive drugs, *n* (%)	5 (0.73)	70 (11.81)	51 (18.55)	<0.0001
	Anti-dyslipidemic drugs, *n* (%)	41 (6.02)	82 (13.87)	37 (13.45)	<0.0001
	Anti-diabetic drugs, *n* (%)	31 (4.55)	74 (12.61)	37 (13.45)	<0.0001
Female	*N*	533	858	242	
	MetS, *n* (%)	22 (4.13)	68 (7.93)	34 (14.05)	0.0023
	Elevated BP, *n* (%)	42 (7.88)	151 (17.60)	78 (32.23)	<0.0001
	Elevated TG, *n* (%)	41 (7.69)	144 (16.78)	52 (21.49)	<0.0001
	Reduced HDL-C, *n* (%)	140 (26.27)	211 (24.59)	56 (23.14)	0.6141
	Elevated BMI, *n* (%)	17 (3.19)	52 (6.06)	16 (6.61)	0.0363
	Elevated FPG, *n* (%)	125 (11.63)	209 (23.66)	128 (35.97)	<0.0001
	Anti-hypertensive drugs, *n* (%)	6 (1.13)	50 (5.83)	47 (19.42)	<0.0001
	Anti-dyslipidemic drugs, *n* (%)	2 (0.38)	11 (1.28)	15 (6.20)	<0.0001
	Anti-diabetic drugs, *n* (%)	16 (3.00)	38 (4.43)	28 (11.57)	<0.0001

MetS metabolic syndrome, *BP* blood pressure, *TG* triglycerides, *HDL-C* high-density lipoprotein cholesterol, *BMI* body mass index, *FPG* fasting plasma glucose

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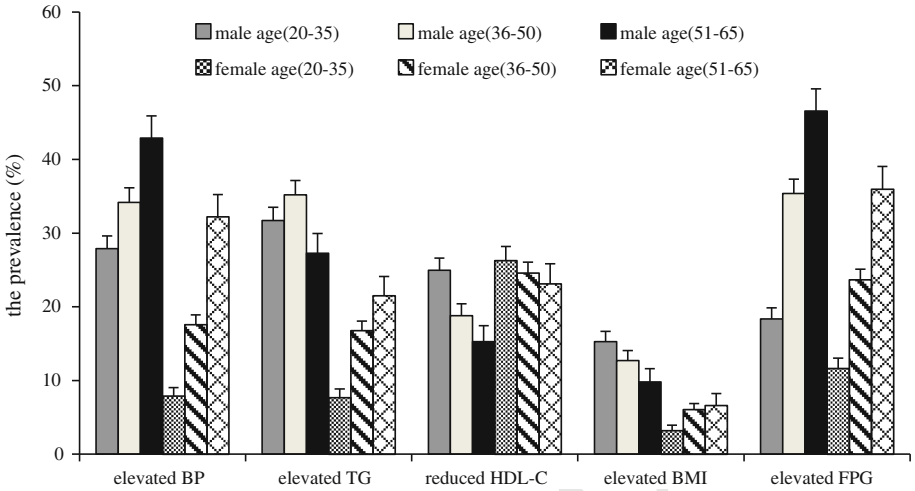

Fig. 2 The prevalence of MetS components. *BP* blood pressure, *TG* triglycerides, *HDL-C* high-density lipoprotein cholesterol, *BMI* body mass index, *FPG* fasting plasma glucose

subjects, the prevalence of elevated BP, elevated TG, elevated BMI, and elevated FPG increased with age, whereas the descending trend was presented in the prevalence of reduced HDL-C. Male subjects had higher prevalence of elevated BP, elevated TG, elevated BMI, and elevated FPG levels than female subjects, whereas female subjects had a higher prevalence of reduced HDL-C level for all age groups than male subjects.

Basic characteristics and hematological parameters of subjects by age and gender

The basic characteristics and hematological parameters of 20–35-year-old subjects are displayed in Table 2. Besides the five MetS components, significant difference was found in ALT, AST, UA, WBC, lymphocytes, neutrophils, HGB, LDL-C levels, and the prevalence of taking anti-dyslipidemic drugs between MetS and non-MetS group for males. As for female subjects, significant difference was observed between the MetS group and non-MetS group for BMI, HDL-C, TG, FPG, SBP, ALT, AST, and LDL-C levels.

The basic characteristics and hematological parameters for 36–50-year-old subjects are presented in Table 3. Significant difference was found in BMI, HDL-C, TG, FPG, ALT, AST, UA, RBC, WBC, lymphocyte, neutrophil, HGB, LDL-C levels, and the prevalence of taking anti-dyslipidemic drugs between MetS and non-MetS group for males. While for females, significant difference was found in BMI, HDL-C, TG, FPG, SBP, DBP, ALT, UA, RBC, WBC, lymphocyte, neutrophil, PLT, MPV, HGB, and LDL-C levels between MetS and non-MetS group.

The basic characteristics and hematological parameters for 51–65-year-old subjects are shown in Table 4. Significant difference was found in BMI, HDL-C, TG, UA, and LDL-C levels between MetS and non-MetS group for males. As for females, significant difference was found in BMI, HDL-C, TG, FPG, UA, HGB, and LDL-C levels between MetS and non-MetS group.

Associated risk factors for MetS by age and gender

Logistic regression analysis was used to determine associations between blood parameters and incidence of MetS after adjusted for the presence of anti-hypertensive, anti-dyslipidemic, and anti-diabetic medication use (Table 5; Fig. 3).

For 20–35-year-old subjects, hematological parameters positively associated with MetS were ALT (OR 2.080, 95 % CI 1.371–3.159), UA (OR 2.135, 95 % CI 1.294–3.614), and WBC (OR 1.482, 95 % CI 1.169–2.974) for males. While neutrophils (OR 1.059, 95 % CI 1.023–1.453), WBC (OR 1.398, 95 % CI 1.145–3.011), and UA (OR 1.523, 95 % CI 1.040–3.147) were positively associated with MetS for females.

As for 36–50-year-old subjects, ALT (OR 2.421, 95 % CI 1.335–3.412), WBC (OR 2.012, 95 % CI 1.290–4.010), and HGB (OR 1.045, 95 % CI 1.018–2.020) were positively associated with MetS for males. While WBC (OR 3.400, 95 % CI 1.818–4.528), and PLT (OR 2.616, 95 % CI 1.432–3.033) were positively associated with MetS for females.

Hematological parameters associated with MetS for 51–65-year-old male subjects were ALT (OR 4.267, 95 % CI 1.161–6.781) and LDL-C (OR 3.078, 95 % CI 2.468–5.131). However, UA (OR 1.025, 95 % CI 1.011–1.321), HGB (OR 1.256, 95 % CI 1.145–3.105), and LDL-C (OR 2.140, 95 % CI 1.524–4.359) were positively associated with MetS for 51–65-year-old females.

Discussion

The study investigated the cumulative incidence of MetS and systematically evaluated the prospective associations

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Table 2 Basic characteristics and hematological parameters of 20–35-year-old subjects

Variables	Male ($N = 681$)			Female ($N = 533$)		
	MetS	Non-MetS	*P* value	MetS	Non-MetS	*P* value
N	94	587	–	22	511	–
BMI (kg/m^2)	26.56 ± 2.84	23.76 ± 3.13	<0.0001[a]	24.99 ± 3.22	20.87 ± 2.64	<0.0001[a]
HDL-C (mmol/L)	1.17 ± 0.23	1.32 ± 0.27	<0.0001[a]	1.32 (1.16–1.47)	1.60 (1.40–1.82)	<0.0001[b]
TG (mmol/L)	1.49 (1.13–2.32)	1.04 (0.72–1.59)	<0.0001[b]	1.01 (0.55–1.59)	0.67 (0.49–0.91)	0.0065[b]
FPG (mmol/L)	5.30 (4.97–5.49)	5.06 (4.80–5.33)	0.0003[b]	5.41 (4.85–5.49)	4.99 (4.74–5.24)	0.0002[b]
SBP (mmHg)	120 (110–130)	115 (110–120)	0.0007[b]	110 (100–120)	100 (100–110)	0.0116[b]
DBP (mmHg)	80 (70–90)	75 (70–80)	<0.0001[b]	70 (70–80)	70 (60–75)	0.1419[b]
ALT (U/L)	29.00 (22.00–49.00)	22.00 (17.00–33.00)	<0.0001[b]	16.00 (15.00–20.00)	14.00 (11.00–17.00)	0.0101[b]
AST (U/L)	31.00 (27.00–38.00)	28.00 (25.00–33.00)	0.0014[b]	29.00 (24.00–32.00)	26.00 (23.00–29.00)	0.0387[b]
UA (μmol/L)	390.00 (353.00–421.00)	355.00 (320.00–396.00)	<0.0001[b]	252.00 (236.00–312.00)	254.00 (220.00–282.00)	0.4441[b]
RBC ($\times 10^{12}$/L)	5.22 ± 0.30	5.15 ± 0.34	0.0626[a]	4.45 ± 0.32	4.44 ± 0.29	0.5051[a]
WBC ($\times 10^9$/L)	6.90 (5.87–7.90)	6.20 (5.40–7.20)	0.0006[b]	6.30 (4.92–7.50)	5.80 (5.02–6.70)	0.1887[b]
Lymphocyte ($\times 10^9$/L)	2.45 ± 0.64	2.26 ± 0.58	0.0054[a]	2.06 ± 0.39	2.11 ± 0.52	0.6173[a]
Neutrophil ($\times 10^9$/L)	3.90 (3.40–4.60)	3.47 (2.87–4.20)	0.0012[b]	3.95 (2.80–4.70)	3.39 (2.78–4.00)	0.0516[b]
MCH (pg)	29.80 (29.30–30.80)	30.10 (29.20–30.80)	0.5710[b]	29.75 (28.40–31.60)	29.80 (28.90–30.70)	0.7727[b]
PLT ($\times 10^9$/L)	228.85 ± 50.99	220.37 ± 47.48	0.1140[a]	248.60 ± 54.79	227.36 ± 49.89	0.0522[a]
MPV (fl)	9.88 ± 0.91	9.80 ± 1.00	0.3984[a]	9.75 ± 0.85	9.81 ± 1.01	0.7700[a]
PDW (%)	11.60 (10.90–12.90)	11.70 (10.70–12.90)	0.4810[b]	11.65 (11.10–13.00)	11.80 (10.80–12.90)	0.7978[b]
HGB (g/L)	156.00 ± 7.60	154.15 ± 8.99	0.0348[a]	134.50 (132.00–138.00)	131.00 (126.00–137.00)	0.1098[b]
LDL-C (mmol/L)	3.12 ± 0.63	2.85 ± 0.70	0.0006[a]	2.91 (2.71–3.10)	2.46 (2.12–2.88)	0.0002[b]
Anti-hypertensive drugs						
n (%)	2 (2.13)	3 (0.51)	0.1426[d]	1 (4.55)	5 (0.98)	0.2244[d]
Anti-dyslipidemic drugs						
n (%)	11 (11.70)	30 (5.11)	0.0126[c]	1 (4.55)	1 (0.98)	0.0809[c]
Anti-diabetic drugs						
n (%)	5 (5.32)	26 (4.43)	0.6026[d]	2 (9.09)	14 (2.74)	0.1376[d]

SBP systolic blood pressure, *DBP* diastolic blood pressure, *ALT* alanine aminotransferase, *AST* aspartate aminotransferase, *UA* uric acid, *RBC* red blood cell count, *WBC* white blood cell count, *MCH* mean corpuscular hemoglobin, *PLT* platelet count, *MPV* mean platelet volume, *PDW* platelet distribution width, *HGB* hemoglobin, *LDL-C* low-density lipoprotein cholesterol

[a] The result of student's *t* test

[b] The result of Wilcoxon rank sum test

[c] The result of χ^2 test

[d] The result of Fisher's exact test

between several common hematological parameters and MetS by age and gender in a Beijing adult population.

The overall prevalence of MetS ranges from 6 to 38 % of the general population in the United States, Europe and Asia, including Korea [21–23]. A cohort study conducted in a Taiwanese health-screening population aged 35–74 years showed that the 5-year cumulative incidence of MetS was 11.37, 14.95 % for males and 9.89 % for females [24]. In our study, the 5-year cumulative incidence of MetS among all subjects was 10.82 %, with 14.22 % of males and 7.59 % of females having MetS after 5-year follow-up.

Previous cross-sectional studies found that sex and age were associated with prevalence of MetS [25, 26]. It is well established that the prevalence of MetS rises from young to old ages [27, 28]. Compared with males, females had a significantly higher prevalence of central obesity and reduced HDL-C, whereas males had a significantly higher

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Table 3 Basic characteristics and hematological parameters of 36–50-year-old subjects

Variables	Male ($N = 591$)			Female ($N = 858$)		
	MetS	Non-MetS	*P* value	MetS	Non-MetS	*P* value
N	91	500	–	68	790	–
BMI (kg/m^2)	26.44 ± 2.16	24.18 ± 2.54	<0.0001[a]	25.64 ± 3.07	22.57 ± 2.62	<0.0001[a]
HDL-C (mmol/L)	1.14 (1.06–1.33)	1.32 (1.15–1.52)	<0.0001[b]	1.36 ± 0.23	1.66 ± 0.34	0.0257[a]
TG (mmol/L)	1.83 (1.41–2.83)	1.20 (0.87–1.73)	<0.0001[b]	1.23 (1.02–1.65)	0.86 (0.64–1.20)	<0.0001[b]
FPG (mmol/L)	5.53 (5.26–5.90)	5.32 (5.03–5.61)	0.0061[b]	5.39 (5.11–5.78)	5.18 (4.90–5.47)	<0.0001[b]
SBP (mmHg)	120 (110–125)	113 (105–120)	0.1598[b]	120 (108–125)	110 (100–120)	<0.0001[b]
DBP (mmHg)	80 (70–85)	80 (70–85)	0.2980[b]	80 (70–80)	70 (70–80)	<0.0001[b]
ALT (U/L)	29.00 (22.00–39.00)	22.00 (18.00–31.00)	<0.0001[b]	17.00 (14.00–22.00)	15.00 (12.00–20.00)	0.0117[b]
AST (U/L)	33.00 (29.00–39.00)	30.00 (26.00–34.00)	0.0015[b]	28.00 (25.00–31.00)	27.00 (24.00–30.00)	0.2298[b]
UA (μmol/L)	355.00 (324.00–399.00)	338.00 (301.00–377.00)	0.0007[b]	275.50 (243.50–305.50)	244.00 (213.00–280.00)	0.0002[b]
RBC ($\times 10^{12}$/L)	5.14 ± 0.31	5.03 ± 0.34	0.0026[a]	4.56 ± 0.28	4.39 ± 0.32	<0.0001[a]
WBC ($\times 10^9$/L)	6.80 (5.80–8.03)	6.10 (5.25–7.30)	<0.0001[b]	6.45 (5.70–7.70)	5.70 (4.90–6.60)	<0.0001[b]
Lymphocyte ($\times 10^9$/L)	2.30 (2.00–2.70)	2.10 (1.70–2.50)	0.0043[b]	2.17 (1.90–2.50)	1.90 (1.60–2.20)	<0.0001[b]
Neutrophil ($\times 10^9$/L)	4.10 (3.40–5.00)	3.50 (2.90–4.30)	<0.0001[b]	3.90 (3.45–4.62)	3.40 (2.76–4.10)	<0.0001[b]
MCH (pg)	30.53 ± 1.45	30.42 ± 1.79	0.5371[a]	29.60 (28.65–30.90)	30.10 (29.10–30.90)	0.2029[b]
PLT ($\times 10^9$/L)	214.10 ± 46.17	213.06 ± 46.11	0.8438[a]	262.30 ± 60.03	228.68 ± 50.00	<0.0001[a]
MPV (fl)	9.40 (8.90–10.10)	9.40 (8.70–10.10)	0.4320[b]	9.20 (8.65–10.00)	9.50 (8.90–10.20)	0.0265[b]
PDW (%)	11.50 (10.80–12.80)	11.40 (10.30–12.70)	0.3026[b]	11.15 (10.40–12.00)	11.60 (10.60–12.80)	0.0501[b]
HGB (g/L)	156.80 ± 9.43	152.47 ± 8.76	<0.0001[a]	136.00 (130.00–139.00)	131.00 (125.00–137.00)	0.0009[b]
LDL-C (mmol/L)	3.29 ± 0.78	3.10 ± 0.72	0.0249[a]	3.07 (2.63–3.32)	2.77 (2.42–3.31)	0.0119[b]
Anti-hypertensive drugs						
n (%)	15 (16.48)	55 (11.00)	0.1365[c]	7 (10.29)	43 (5.44)	0.1059[d]
Anti-dyslipidemic drugs						
n (%)	19 (20.88)	63 (12.60)	0.0356[c]	1 (1.47)	10 (1.27)	0.5990[d]
Anti-diabetic drugs						
n (%)	17 (18.68)	57 (11.40)	0.0536[c]	6 (8.82)	32 (4.05)	0.1125[d]

SBP systolic blood pressure, *DBP* diastolic blood pressure, *ALT* alanine aminotransferase, *AST* aspartate aminotransferase, *UA* uric acid, *RBC* red blood cell count, *WBC* white blood cell count, *MCH* mean corpuscular hemoglobin, *PLT* platelet count, *MPV* mean platelet volume, *PDW* platelet distribution width, *HGB* hemoglobin, *LDL-C* low-density lipoprotein cholesterol

[a] The result of student's *t* test

[b] The result of Wilcoxon rank sum test

[c] The result of χ^2 test

[d] The result of Fisher's exact test

prevalence of raised BP compared with females [29]. Our results are roughly consistent with these observations. In this study, the incidence of MetS increased with age for females, while the same trend was not found for males. The prevalence of elevated BP and FPG increased with age for male subjects, and the prevalence of elevated BP, TG, BMI, and FPG increased with age for female subjects, whereas the descending trend was presented in the prevalence of reduced HDL-C for female subjects. Information from our study suggests that males are more prone to be affected by MetS compared to females for young and middle-age people, while females are at higher risk for MetS for elderly people. The incidence of MetS and prevalence of its components in this population underlines the need to screen for associated hematological factors for MetS.

Several reports have demonstrated that altered hematological status in patients is a high risk factor for MetS.

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Table 4 Basic characteristics and hematological parameters of 51–65-year-old subjects

Variables	Male ($N = 275$)			Female ($N = 242$)		
	MetS	Non-MetS	*P* value	MetS	Non-MetS	*P* value
N	35	240	–	34	208	–
BMI (kg/m^2)	26.36 ± 2.63	24.50 ± 2.85	0.0009[a]	25.97 ± 2.95	23.32 ± 2.59	<0.0001[a]
HDL-C (mmol/L)	1.18 (1.09–1.29)	1.30 (1.13–1.51)	0.0070[b]	1.42 ± 0.30	1.69 ± 0.34	<0.0001[a]
TG (mmol/L)	1.89 (1.28–3.43)	1.24 (0.87–1.65)	<0.0001[b]	1.58 (1.30–1.85)	1.10 (0.78–1.55)	<0.0001[b]
FPG (mmol/L)	5.47 (4.97–6.04)	5.44 (5.11–5.83)	0.8788[b]	5.57 (5.22–6.06)	5.37 (5.00–5.77)	0.0428[b]
SBP (mmHg)	120 (110–125)	120 (105–125)	0.2890[b]	120 (110–130)	120 (105–125)	0.2501[b]
DBP (mmHg)	75 (70–85)	80 (70–85)	1.0000[b]	80 (70–85)	80 (70–80)	0.4339[b]
ALT (U/L)	21.50 (18.00–31.00)	20.00 (17.00–28.00)	0.2591[b]	20.00 (15.00–29.00)	18.00 (14.00–23.00)	0.1268[b]
AST (U/L)	27.50 (25.00–33.00)	29.00 (26.00–35.00)	0.2247[b]	28.50 (25.00–32.00)	29.00 (26.00–33.00)	0.6593[b]
UA (μmol/L)	364.30 ± 65.78	340.21 ± 66.90	0.0471[a]	295.20 ± 51.90	270.30 ± 58.50	0.0204[a]
RBC ($\times 10^{12}$/L)	5.00 (4.79–5.21)	4.88 (4.65–5.12)	0.1854[b]	4.41 (4.34–4.76)	4.42 (4.21–4.61)	0.1263[b]
WBC ($\times 10^9$/L)	7.13 (5.90–7.72)	6.30 (5.30–7.40)	0.0830[b]	6.09 (5.00–6.71)	5.53 (4.80–6.68)	0.2791[b]
Lymphocyte ($\times 10^9$/L)	2.40 (1.73–2.70)	2.10 (1.70–2.60)	0.2712[b]	2.15 (1.90–2.60)	2.00 (1.69–2.40)	0.1411[b]
Neutrophil ($\times 10^9$/L)	4.20 (3.20–4.80)	3.60 (3.00–4.56)	0.1119[b]	3.15 (2.63–4.01)	3.20 (2.50–3.90)	0.5432[b]
MCH (pg)	31.00 (29.80–31.40)	30.80 (29.90–31.80)	0.6847[b]	30.05 (29.30–31.10)	29.95 (29.10–30.90)	0.4624[b]
PLT ($\times 10^9$/L)	196.00 (175.00–239.00)	205.00 (180.00–242.00)	0.9187[b]	214.00 (185.00–249.00)	218.00 (189.00–256.00)	0.7302[b]
MPV (fl)	9.30 (8.80–9.80)	9.30 (8.60–9.90)	0.8346[b]	9.55 (8.80–10.30)	9.40 (8.90–10.10)	0.7320[b]
PDW (%)	11.40 (10.40–12.40)	11.30 (10.30–12.30)	0.7369[b]	11.25 (10.70–12.40)	11.55 (10.60–12.40)	0.9842[b]
HGB (g/L)	152.60 ± 8.94	151.30 ± 8.87	0.4173[a]	135.90 ± 8.65	131.39 ± 9.25	0.0091[a]
LDL-C (mmol/L)	3.46 ± 0.86	3.16 ± 0.70	0.0266[a]	3.67 (3.38–4.31)	3.43 (2.86–3.90)	0.0227[b]
Anti-hypertensive drugs						
n (%)	9 (25.71)	42 (17.50)	0.2428[c]	10 (29.41)	37 (17.79)	0.1576[d]
Anti-dyslipidemic drugs						
n (%)	4 (11.43)	33 (13.75)	1.0000[d]	3 (8.82)	12 (5.77)	0.4496[d]
Anti-diabetic drugs						
n (%)	6 (17.14)	31 (12.92)	0.4388[d]	6 (17.65)	22 (10.58)	0.2477[d]

SBP systolic blood pressure, *DBP* diastolic blood pressure, *ALT* alanine aminotransferase, *AST* aspartate aminotransferase, *UA* uric acid, *RBC* red blood cell count, *WBC* white blood cell count, *MCH* mean corpuscular hemoglobin, *PLT* platelet count, *MPV* mean platelet volume, *PDW* platelet distribution width, *HGB* hemoglobin, *LDL-C* low-density lipoprotein cholesterol

[a] The result of student's *t* test

[b] The result of Wilcoxon rank sum test

[c] The result of χ^2 test

[d] The result of Fisher's exact test

Elevated ALT was found to be predictive of MetS among adolescents and young adults in mainland China [30]. The prevalence of MetS increases with the increase in blood levels of ALT even through the normal range of ALT in Japanese men and women [31]. Our results showed that ALT was significantly associated with the incidence of MetS only for males. The result indicated that the association between ALT and MetS was gender-specific.

There are significant associations among UA, CVD, and MetS [32, 33], partly explained by the activation of the renin–angiotensin system by obesity [34] or vascular dysfunction including inflammation. In addition, nutritional factors are speculated to affect the occurrence of MetS and also of UA. Significant association between UA and MetS was found in 20–35-year-old males and females, and 51–65-year-old females.

Jesri et al. [35] reported that subjects with MetS had higher PLT and WBC counts than controls, and these two parameters linearly increased as the number of MetS components increased. WBC was associated with MetS

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Table 5 Associated risk factors of MetS by gender and age

Gender	Age at inclusion	Parameter	Estimate	Standard error	*P* value	OR	95 % CI for OR	
							Lower	Upper
Male	20–35	ALT	0.733	0.213	0.0006	2.080	1.371	3.159
		UA	0.758	0.326	0.0004	2.135	1.294	3.614
		WBC	0.393	0.154	0.0071	1.482	1.169	2.974
	36–50	ALT	0.884	0.306	0.0039	2.421	1.335	3.412
		WBC	0.699	0.208	0.0021	2.012	1.290	4.010
		HGB	0.044	0.018	0.0480	1.045	1.018	2.020
	51–65	ALT	1.451	0.664	0.0289	4.267	1.161	6.781
		LDL-C	1.124	0.584	0.0176	3.078	2.468	5.131
Female	20–35	neutrophil	0.349	0.169	0.0356	1.059	1.023	1.453
		WBC	0.335	0.116	0.0124	1.398	1.145	3.011
		UA	0.421	0.211	0.0341	1.523	1.040	3.147
	36–50	WBC	1.224	0.642	0.0038	3.400	1.818	4.528
		PLT	0.962	0.697	0.0133	2.616	1.432	3.033
	51–65	UA	0.005	0.003	0.0298	1.025	1.011	1.321
		HGB	0.228	0.012	0.0164	1.256	1.145	3.105
		LDL-C	0.761	0.247	0.0231	2.140	1.524	4.359

Model was adjusted for the presence of anti-hypertensive, anti-dyslipidemic, and anti-diabetic medication use

ALT alanine aminotransferase, *UA* uric acid, *WBC* white blood cell count, *PLT* platelet count, *HGB* hemoglobin, *LDL-C* low-density lipoprotein cholesterol

and its individual components [36]. In this study, WBC was found to be associated with MetS in 20–35-year-old and 36–50-year-old groups for males and females. It is indicated that WBC is strongly associated with MetS for young adults. In this study, young adults have higher prevalence of elevated TG, reduced HDL-C, and obesity than elderly people.

Several studies showed that both obesity and dyslipidemia were the major precursors for development of MetS, and perivascular white adipose tissue can release proinflammatory cytokines [37, 38], such as IL-8, leading to elevated WBC, especially monocytes and granulocytes. In addition, TNF-α is shown to be constitutively expressed by adipose tissue, and this proinflammatory cytokines leads to elevated WBC [39, 40]. Therefore, the total WBC was positively associated with MetS. And many studies have shown the similar results. One study conducted on a Japanese population showed that the correlation between WC and CRP was significantly stronger in younger men than in older men [36]. And, another study displayed a correlation between serum CRP and WBC and some CVD risk factors among young adults [41]. Significant correlation of CRP with BMI and WC was discovered in adolescents and young adults in one study conducted in Asian Indians [42].

RBC counts and HGB were associated with MetS and its components in men and women [43]. Our results showed that HGB was positively associated with MetS for 36–50-year-old male subjects and 51–65-year-old female subjects.

Neutrophil counts were significantly increased in MetS [44]. In this study, significant association between neutrophil counts and the incidence of MetS was found in 20–35-year-old female subjects.

Park et al. [45] reported that PLT and MPV might be a surrogate marker associated with clustered MetS in women. PLT counts may be a potential marker associated with MetS components [17], and our results showed the same association between PLT and MetS for 36–50-year-old female subjects.

Subjects with MetS had elevated levels of oxidized LDL [46]. Circulating oxidized LDL seems to express the level of oxidative stress and associate with the risk factors of MetS [47]. A strongly positive association between LDL-C and MetS was found for 51–65-year-old male and female subjects. It indicates that LDL-C is strongly associated with MetS for elderly people.

Although several reports have demonstrated that there is a close relationship between RBC, MPV, and MetS [48–50], no positive associations between these hematological parameters and MetS were found in our study.

There were some limitations to this study. First, hematological parameters were assessed from a single blood sample in the study, and therefore intra-individual variation cannot be taken into account. Second, information about

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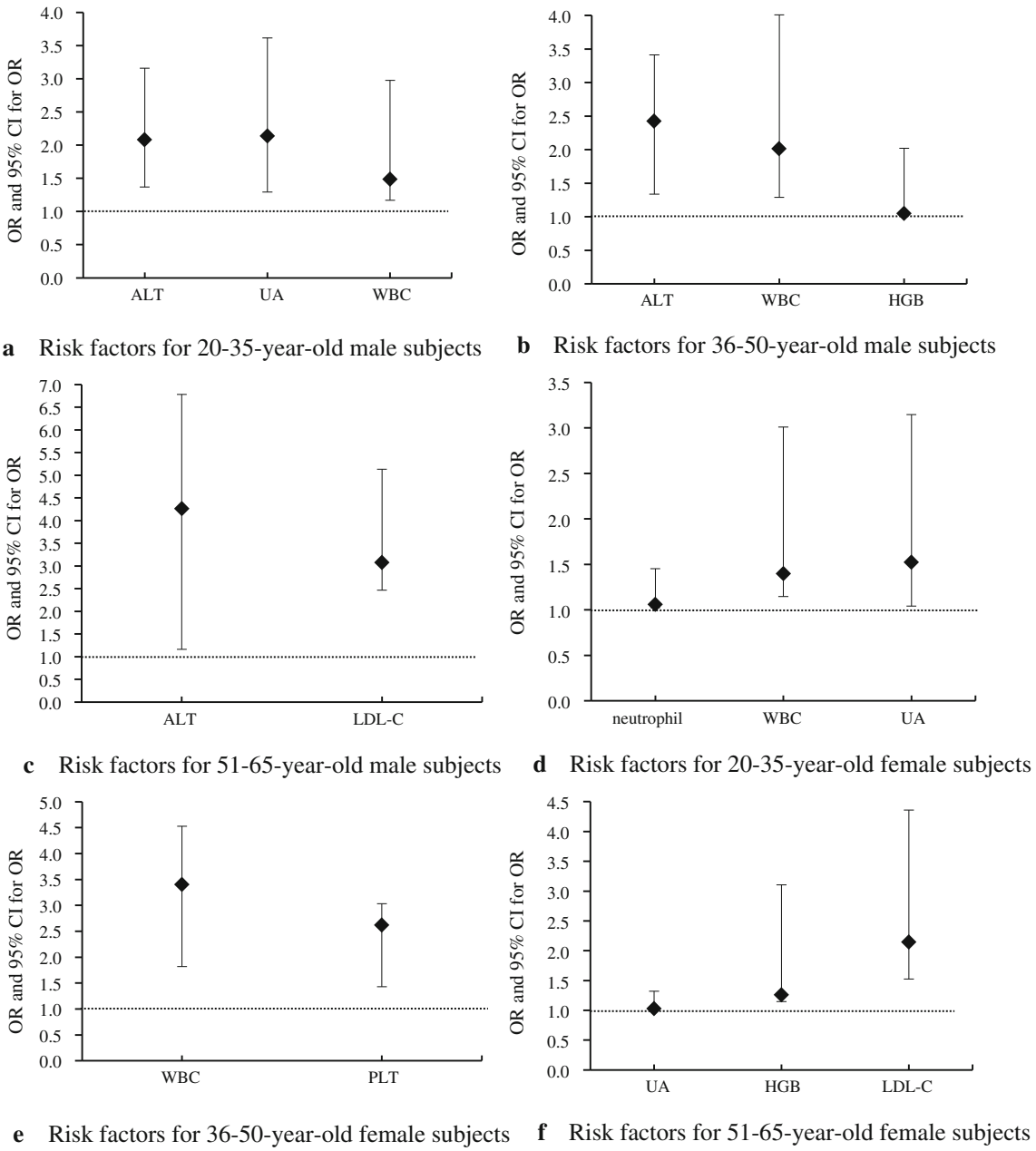

Fig. 3 OR and 95 % CI for risk factors of MetS. *ALT* alanine aminotransferase, *UA* uric acid, *WBC* white blood cell count, *HGB* hemoglobin, *LDL-C* low-density lipoprotein cholesterol, *PLT* platelet count, *OR* odds ratio, *CI* confidence interval

lifestyles was not available, and the multivariate model was not adjusted for these factors. But the lifestyle variables will be included in further studies. Third, as Beijing Tongren Hospital is located in the urban area of Beijing, selection bias may be that there were more people with modern life style recruited for the research. In addition, the study was based on a population attending for routine health check-up from one single hospital. Therefore, the demographics and referral source may limit the generalization of the results. And further studies using the general population would be desirable.

Conclusions

Our study sample showed that the 5-year cumulative incidence of MetS was 10.82 %, with 14.22 % of males and 7.59 % of females having MetS after 5-year follow-up. Among all the hematological parameters, WBC is positively associated with MetS for young adults, while LDL-C is positively associated with MetS for elderly people. ALT is positively associated with MetS for males only. The association between WBC, LDL-C, and MetS was age-specific. While the association between ALT and MetS was

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gender-specific. The study provides further evidence in support of using hematological markers for early detection of different age groups of individuals at risk of MetS.

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Conflict of interest The authors declare no conflict of interest.

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