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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

Footnote Information

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

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Keywords Hematological parameters · Metabolic
syndrome · Association · Longitudinal study 40
41

Introduction 42

Metabolic syndrome (MetS) is a cluster of risk factors that 43
include abdominal obesity, hyperglycemia, raised blood 44
pressure (BP), low high-density lipoprotein cholesterol 45
(HDL-C), and high triglycerides (TG). Since prevalence of 46
MetS is rapidly growing and it is associated with an 47
increased risk of insulin resistance, diabetes, cardiovascu- 48
lar disease (CVD), and total mortality [1–3], the identifi- 49
cation for biomarkers of MetS is of pivotal importance. 50

The prevalence of MetS increased with age for both 51
sexes [4]. Several non-inflammatory biomarkers have been 52

53 associated with MetS and its components in different
54 populations, including growth factors [5], micro albumin-
55 uria [6], and uric acid (UA) [7, 8]. Elevated white blood
56 cell (WBC) count is intimately linked to the prevalence and
57 future development of MetS in populations of working
58 subjects [9, 10]. Insulin resistance and/or hyperinsulinemia
59 have been shown to correlate with WBC counts [11].
60 Elevated liver enzymes, especially alanine aminotransfer-
61 ase (ALT) may be related with and a better predictor for
62 MetS [12–14]. Other hematological parameters including
63 platelet counts (PLT), hemoglobin (HGB), hematocrit
64 concentrations (HCT), C-reactive protein, and serum bili-
65 rubin increased with increasing numbers of MetS compo-
66 nents [15–18]. To the best of our knowledge, there have
67 been few studies conducting systematic evaluation for
68 relationship between hematological parameters and MetS
69 for different age groups of males and females in a large
70 Beijing adult population.

71 Therefore, the aims of this study were to estimate the
72 incidence of MetS and to investigate prospective associa-
73 tions between blood parameters and MetS in a Beijing
74 adult population.

75 Materials and methods

76 Subjects

77 A total of 3,832 subjects aged 20–65 years who attended
78 health check-ups in Beijing Tongren Hospital, China, in
79 2007 and 2012 were enrolled in the study. Individuals with
80 a previous diagnosis of CVD, cerebral infarction or gastric
81 cancer, or those who had undergone coronary artery bypass
82 surgery, coronary stenting surgery or gastrectomy, or those
83 who had MetS at baseline were excluded. The remaining
84 3,180 subjects were included in the final analysis. The
85 study was approved by the Ethics Committee of Capital
86 Medical University (approval number: 2013SY26). Written
87 informed consent was obtained from all the participating
88 subjects.

89 Measurements

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

96 The participants underwent routine physical examina-
97 tions that included the measurement of height, weight, BP,
98 and overnight fasting blood sampling. Weight and height
99 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 cri-
teria [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 ≥ 28 kg/m². (2) Elevated TG (drug
treatment for elevated TG is an alternate indicator):
 ≥ 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 ≥ 130 mmHg and/or diastolic
 ≥ 85 mmHg, and (5) Elevated FPG (drug treatment of ele-
vated glucose is an alternate indicator): ≥ 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

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

154 Results

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

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

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

169 had the highest 5-year cumulative incidence of MetS
170 (14.05 %).

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

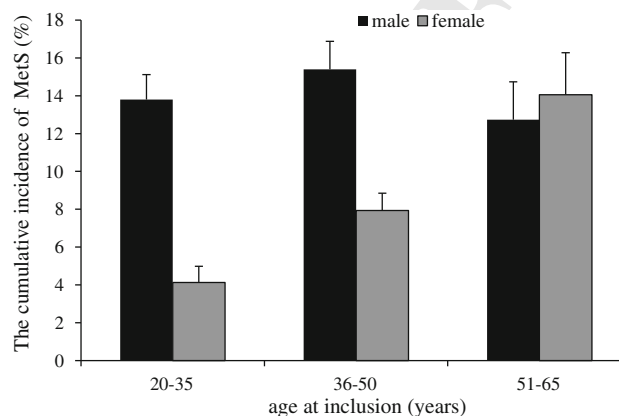


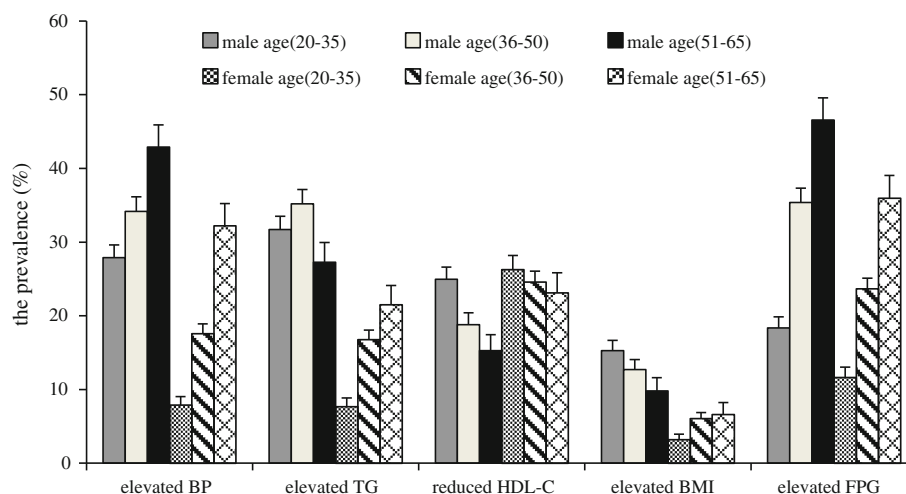
Fig. 1 The 5-year cumulative incidence of MetS. *MetS* metabolic syndrome

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

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



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

185 Basic characteristics and hematological parameters
186 of subjects by age and gender

187 The basic characteristics and hematological parameters of
188 20–35-year-old subjects are displayed in Table 2. Besides
189 the five MetS components, significant difference was found
190 in ALT, AST, UA, WBC, lymphocytes, neutrophils, HGB,
191 LDL-C levels, and the prevalence of taking anti-dyslipi-
192 demic drugs between MetS and non-MetS group for males.
193 As for female subjects, significant difference was observed
194 between the MetS group and non-MetS group for BMI,
195 HDL-C, TG, FPG, SBP, ALT, AST, and LDL-C levels.

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

207 The basic characteristics and hematological parameters
208 for 51–65-year-old subjects are shown in Table 4. Signif-
209 icant difference was found in BMI, HDL-C, TG, UA, and
210 LDL-C levels between MetS and non-MetS group for
211 males. As for females, significant difference was found in

BMI, HDL-C, TG, FPG, UA, HGB, and LDL-C levels
212 between MetS and non-MetS group. 213

Associated risk factors for MetS by age and gender 214

Logistic regression analysis was used to determine asso-
215 ciations between blood parameters and incidence of MetS
216 after adjusted for the presence of anti-hypertensive, anti-
217 dyslipidemic, and anti-diabetic medication use (Table 5;
218 Fig. 3). 219

For 20–35-year-old subjects, hematological parameters
220 positively associated with MetS were ALT (OR 2.080,
221 95 % CI 1.371–3.159), UA (OR 2.135, 95 % CI
222 1.294–3.614), and WBC (OR 1.482, 95 % CI 1.169–2.974)
223 for males. While neutrophils (OR 1.059, 95 % CI
224 1.023–1.453), WBC (OR 1.398, 95 % CI 1.145–3.011),
225 and UA (OR 1.523, 95 % CI 1.040–3.147) were positively
226 associated with MetS for females. 227

As for 36–50-year-old subjects, ALT (OR 2.421, 95 % CI
228 1.335–3.412), WBC (OR 2.012, 95 % CI 1.290–4.010), and
229 HGB (OR 1.045, 95 % CI 1.018–2.020) were positively
230 associated with MetS for males. While WBC (OR 3.400, 95 %
231 CI 1.818–4.528), and PLT (OR 2.616, 95 % CI 1.432–3.033)
232 were positively associated with MetS for females. 233

Hematological parameters associated with MetS for
234 51–65-year-old male subjects were ALT (OR 4.267, 95 %
235 CI 1.161–6.781) and LDL-C (OR 3.078, 95 % CI
236 2.468–5.131). However, UA (OR 1.025, 95 % CI
237 1.011–1.321), HGB (OR 1.256, 95 % CI 1.145–3.105), and
238 LDL-C (OR 2.140, 95 % CI 1.524–4.359) were positively
239 associated with MetS for 51–65-year-old females. 240

Discussion 241

The study investigated the cumulative incidence of MetS
242 and systematically evaluated the prospective associations 243

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 (×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 (×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 (×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 (×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 (×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

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

246 The overall prevalence of MetS ranges from 6 to 38 %
247 of the general population in the United States, Europe and
248 Asia, including Korea [21–23]. A cohort study conducted
249 in a Taiwanese health-screening population aged
250 35–74 years showed that the 5-year cumulative incidence
251 of MetS was 11.37, 14.95 % for males and 9.89 % for
252 females [24]. In our study, the 5-year cumulative incidence

253 of MetS among all subjects was 10.82 %, with 14.22 % of
254 males and 7.59 % of females having MetS after 5-year
255 follow-up.

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

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 (×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 (×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 (×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 (×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 (×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

262 prevalence of raised BP compared with females [29]. Our
263 results are roughly consistent with these observations. In
264 this study, the incidence of MetS increased with age for
265 females, while the same trend was not found for males. The
266 prevalence of elevated BP and FPG increased with age for
267 male subjects, and the prevalence of elevated BP, TG,
268 BMI, and FPG increased with age for female subjects,
269 whereas the descending trend was presented in the preva-
270 lence of reduced HDL-C for female subjects. Information

from our study suggests that males are more prone to be
271 affected by MetS compared to females for young and
272 middle-age people, while females are at higher risk for
273 MetS for elderly people. The incidence of MetS and
274 prevalence of its components in this population underlines
275 the need to screen for associated hematological factors for
276 MetS.
277

Several reports have demonstrated that altered hemato-
278 logical status in patients is a high risk factor for MetS.
279

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 (×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 (×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 (×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 (×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 (×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

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

288 There are significant associations among UA, CVD, and
289 MetS [32, 33], partly explained by the activation of the

290 renin-angiotensin system by obesity [34] or vascular dys-
291 function including inflammation. In addition, nutritional
292 factors are speculated to affect the occurrence of MetS and
293 also of UA. Significant association between UA and MetS
294 was found in 20–35-year-old males and females, and
295 51–65-year-old females.

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



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	
	neutrophil	0.349	0.169	0.0356	1.059	1.023	1.453	
Female	20–35	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
		WBC	1.224	0.642	0.0038	3.400	1.818	4.528
	36–50	PLT	0.962	0.697	0.0133	2.616	1.432	3.033
		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
	51–65	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 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

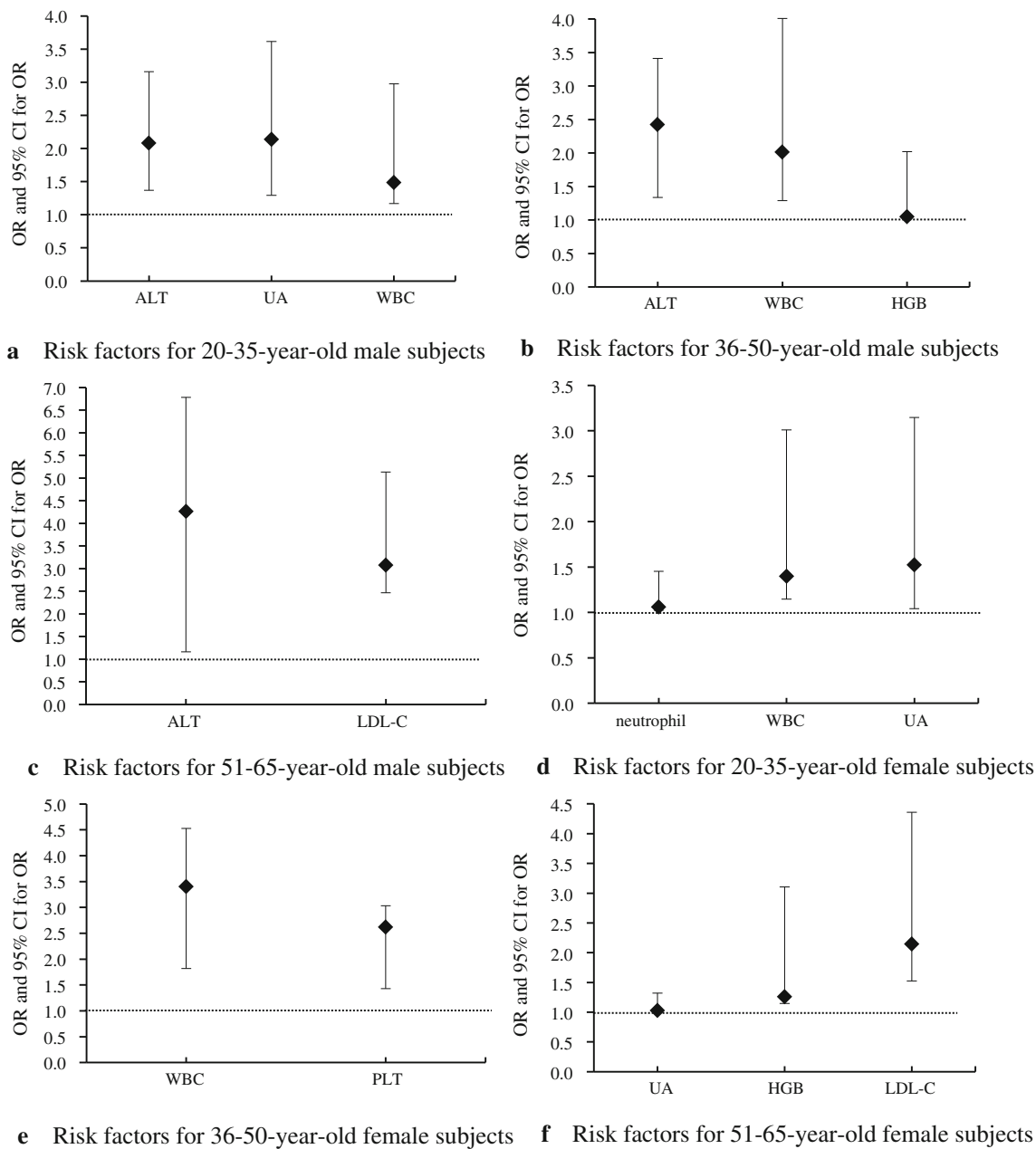


Fig. 3 OR and 95 % CI for risk factors of MetS. ALT alanine aminotransferase, UA uric acid, WBC white blood cell count, HGB hemoglobin, LDL-C low-density lipoprotein cholesterol, PLT platelet count, OR odds ratio, CI confidence interval

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

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

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387

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