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ORIGINAL ARTICLE

The Association of Hematological Parameters and Metabolic Syndrome in an Older Population: A Cross-sectional and Longitudinal Study

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Objective: Hematological parameters play a significant role in metabolic syndrome (MetS) and its development in the elderly, but the association and different ability of each parameter to predict MetS have not been investigated in the very old populations. **Subjects and Methods:** This cross-sectional and longitudinal study included 18,907 participants aged over 65 years and followed up until MetS development with a mean duration of 4 years from the entry date. MetS was diagnosed according to the latest harmonized criteria with modification for waist circumference. Correlations between hematological parameters and MetS were analyzed and operating characteristic curves were compared among each parameter. Stratification was conducted by gender and age as follows: young-old (65–74 years), old-old (75–84 years), and oldest-old (85–94 years). **Results:** White blood cell count (WBC) and hemoglobin (Hb) levels in both genders of young-old (65–74 years) and old-old (75–84 years) and platelet (PLT) in young-old (65–74 years) males were independent factors for risk of MetS. However, only WBC ($P < 0.001$) and Hb level ($P < 0.001$) in young-old (65–74 years) males and Hb level ($P = 0.03$) in old-old (75–84 years) females were independent factors of future MetS development. For predicting MetS, WBC and Hb levels were better markers than PLT in the old-old (75–84 years) and young-old (65–74 years) males group. In young-old (65–74 years) females, WBC was the most sensitive marker. **Conclusions:** Hematological parameters were associated with MetS, showing gender and age effects. These findings can be used for risk estimation of MetS development in the older population.

Key words: Hemoglobin, metabolic syndrome estimation, platelet, the elderly, white blood cell count

INTRODUCTION

Metabolic syndrome (MetS) is defined as a group of metabolic abnormalities including elevated blood pressure, impaired fasting glucose, dyslipidemia, and central obesity. This syndrome was first described by the National Cholesterol Education Program-Adult Treatment Panel III[1] and is known to be a risk factor for type 2 diabetes (T2D) and cardiovascular disease (CVD) development.[2] The growing prevalence of MetS has become an important health issue not only in Taiwan but also in other countries. Furthermore, older age is correlated with a higher prevalence of MetS, and the estimated prevalence is 44.5% of males and 57.3% of females in Taiwan[3] in participants aged older than 60 years.

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The older population, which is defined as persons aged 65 years or older, representing 12.5% of the Taiwanese population in 2015.[4] This population tends to show metabolic trait abnormalities and is prone to a higher incidence of T2D and CVD. Therefore, the early identification of the MetS is an important issue worldwide. The pathogenesis of MetS is complex and associated with the chronic systemic inflammatory response.[5] Several surrogate markers, such as uric acid, interleukin (IL)-1beta, and adiponectin, were used as markers of MetS.[6,7] The hematogram is a feasible examination to conduct in clinical practice. The strong associations between MetS and the hematogram in different ethnic and age populations have been described in previous reports.[8-19] Discrepancies in the results may be attributed to the different ethnic population, gender, and age factors examined. Several studies have explored this association among participants of the elderly population.[13-17] Kawamoto *et al*. suggested a positive association between hemoglobin (Hb) level and MetS in 1696 Japanese participants with a mean age > 60 years.[18] Our previous studies also confirmed the independent role of white blood cell count (WBC) and platelet (PLT) on MetS development in the elderly population both in cross-sectional and longitudinal studies.[14,15,17,19] However, no studies have explored this association in the very aged population. Therefore, in this study, we divided the older population into three groups as follows: young-old (65–74 years), old-old (75–84 years), and oldest-old (85–94 years). We investigated the correlations between MetS and hematological parameters among the different elderly groups. Furthermore, whether the single parameters were sufficiently sensitive for predicting MetS development was evaluated.

SUBJECTS AND METHODS

Study population

Eligibility criteria were detailed previously.[20] There were two stages of the study. In Stage I for cross-sectional analysis, we randomly selected 36,169 participants who were over 65 years of age during the sampling time from 1999 to 2008. We excluded 3347 participants who visited the clinic only once during the sampling periods. Participants with a history of hypertension, T2D, cardiovascular events, and cancer as well as those who were taking medications known to affect MetS components, such as statin and steroid, were excluded (n = 11,562) from the study. In addition, we excluded participants with missing data for MetS components, hematogram, and other demographic data (n = 2353). A total of 18,907 participants were eligible for further analysis. In Stage II for longitudinal analysis, participants without MetS at baseline were followed for 2–10 years to evaluate the factors influencing MetS development. We divided the participants by age into three groups of young-old (65–74 years), old-old (75–84 years), and oldest-old (85–94 years).

Anthropometric measurements and general data

All medical history, physical examinations, and measurement were performed in the MJ Health Screening Centers, the senior nursing staff in the clinic used a questionnaire to obtain the participant's medical history including any current medications. Then, complete physical examinations were performed. Waist circumference (WC) was measured horizontally at the level of the natural waist, which was identified as the level at the hollow molding of the trunk when the trunk was laterally concave. Body mass index (BMI) was calculated as the participant's body weight (kg) divided by the square of the participant's height (m). Both systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured by the nursing staff using a standard mercury sphygmomanometer fitted on the right arm of each participant when seated. Laboratory measurements after the participant fasted for 10 h; blood samples were drawn from the antecubital vein for biochemical analysis. The method of analysis was as detailed previously.[20]

Definition of metabolic syndrome

We used the latest harmonized criteria of MetS in 2009[21] with modifications. The WC criteria were equal or >90 and 80 cm in Taiwanese men and women, respectively.[22] The other four criteria were the same: SBP ≥130 mmHg or DBP ≥85 mmHg, triglyceride (TG) ≥150 mg/dL, fasting plasma glucose (FPG) ≥100 mg/dL, and high-density lipoprotein cholesterol (HDL-C) ≤40 and 50 mg/dL in men and women or taking related medications. Participants had to fulfill at least three criteria to be diagnosed with MetS.

Statistical analysis

The data in this study are presented as the mean ± standard deviation. All data were tested for normal distribution using the Kolmogorov–Smirnov test and homogeneity of variances with Levene's test. The data were log-transformed before analysis if they did not show a normal distribution. The t-test was used to evaluate the differences between two groups. Analysis of variance was used to compare the differences in characteristics among three different groups. The odds ratio (OR) was calculated to compare the possibility of having MetS in different age groups using a multivariable logistic regression model. In addition, Cox regression analysis was performed to determine the hazard ratio in different age groups during the follow-up period. Finally, to determine which hematological parameters were the most highly correlated with MetS, receiver-operating characteristic (ROC) curves (MedCalc Software, Broekstraat, Mariakerke, Belgium) were generated with gender specification. P (two-sided) <0.05 was considered statistically significant. All statistical analyses were performed using SPSS 18.0 software (SPSS Inc., Chicago, IL, USA).

RESULTS

The demographic characteristics and hematogram of the three age groups are shown in Table 1. Except for WC, FPG, and WBC in males and DBP, FPG, HDL-C, and TG in females, other metabolic characteristics, and hematological components were statistically significantly different among these three groups in both genders. A higher age of the participants was correlated with higher SBP and WBC. The opposite trend was observed for WC, DBP, TG, PLT, and Hb levels.

Comparisons of metabolic characteristics in participants with and without MetS among the three age groups are listed in Table 2. Except for SBP in males and SBP, DBP, and FPG in females in the oldest old group, the remaining MetS components between participants with and without MetS among the three groups were significantly different because of arbitrary grouping. WBC and Hb levels were significantly higher in participants with MetS in the young-old (65–74 years) and old-old (75–84 years) groups of both sexes (all $P < 0.001$) and PLT was significantly higher in the young-old (65–74 years) group of females ($P < 0.001$) with MetS than in participants without MetS. In contrast, there was no difference in hematological parameters between participants with and without MetS in the oldest-old (85–94 years) group.

A multivariable logistic regression model was used to determine the effect of hematological parameters on the risk of MetS after adjusting for confounding factors [Table 3]. For young-old (65–74 years) males, the hematological parameters significantly associated with the risk of MetS included WBC (OR: 1.422, 95% confidence interval [CI]: 1.336–1.514) and Hb level (OR: 1.348, 95% CI: 1.271–1.430) ($P < 0.001$). For the old-old (75–84 years) group of males, the hematological parameters significantly associated with the risk of MetS included WBC (OR: 1.191, 95% CI: 1.125–1.261) and Hb level (OR: 1.203, 95% CI: 1.122–1.290) ($P < 0.001$). For the young-old (65–74 years) group of females, a positive association was observed between MetS incidence and WBC (OR: 1.526, 95% CI: 1.437–1.620), Hb level (OR: 1.237, 95% CI: 1.168–1.310), and PLT (OR: 1.101, 95% CI: 1.038–1.168) ($P < 0.001$). For the old-old (75–84 years) group of females, the ORs for MetS development were WBC (OR: 1.466, 95% CI: 1.286–1.671) and Hb level (OR 1.418, 95% CI: 1.248–1.610) ($P < 0.001$).

Table 1: Demographic data of different elderly groups

	Young-old	Old-old	Oldest-old	P
Male				
n	7648	1963	121	
Age (years)	68.7±2.8	77.8±2.5	87.0±2.2	<0.001
WC (cm)	85.1±9.1	84.9±9.6	84.6±10.1	0.492
BMI (kg/m^2)	23.8±3.1	23.2±3.2	22.8±3.2	<0.001
SBP (mmHg)	135.6±20.3	139.3±20.2	139.5±22.4	<0.001
DBP (mmHg)	77.3±11.7	75.2±11.9	73.4±12.9	<0.001
FPG (mg/dL)	109.8±32.5	110.4±32.1	105.5±17.9	0.238
TC (mg/dL)	199.8±36.4	194.3±35.4	190.8±35.0	<0.001
HDL-C (mg/dL)	49.3±13.9	50.4±14.7	51.7±16.0	0.003
LDL-C (mg/dL)	125.0±32.7	119.3±31.3	116.9±30.2	<0.001
TG (mg/dL)	127.7±68.1	123.1±65.3	110.9±50.6	0.001
LogTG	2.1±0.2	2.0±0.2	2.0±0.2	<0.001
WBC (×10^3/μL)	6.5±1.8	6.5±1.9	6.7±1.8	0.461
Hemoglobin (g/dL)	14.7±1.3	14.3±1.4	13.8±1.6	<0.001
Platelet (×10^3/μL)	213.1±55.7	202.9±57.0	197.6±52.5	<0.001
Female				
n	7521	1573	81	
Age (years)	68.5±2.7	77.8±2.6	86.8±2.0	<0.001
WC (cm)	80.1±8.9	82.1±9.6	83.5±9.1	<0.001
BMI (kg/m^2)	24.5±3.6	24.0±3.7	23.5±4.0	<0.001
SBP (mmHg)	139.9±20.8	145.9±21.2	149.5±19.4	<0.001
DBP (mmHg)	76.8±11.8	76.2±12.3	76.8±11.5	0.230
FPG (mg/dL)	110.0±33.5	110.1±29.6	109.4±26.7	0.976
TC (mg/dL)	214.3±38.5	210.5±36.9	212.7±42.4	0.002
HDL-C (mg/dL)	57.0±15.1	57.0±15.8	56.8±16.6	0.976
LDL-C (mg/dL)	129.6±34.5	125.8±32.5	127.3±37.6	<0.001
TG (mg/dL)	138.2±69.2	139.5±68.5	143.0±65.9	0.668
LogTG	2.1±0.2	2.1±0.2	2.1±0.2	0.381
WBC (×10^3/μL)	6.2±1.7	6.3±1.8	6.7±2.0	0.002
Hemoglobin (g/dL)	13.3±1.1	13.0±1.3	12.9±1.3	<0.001
Platelet (×10^3/μL)	231.2±56.5	226.2±59.4	213.1±59.4	<0.001

Data are shown as mean±SD. WC=Waist circumference; BMI=Body mass index; SBP=Systolic blood pressure; DBP=Diastolic blood pressure; FPG=Fasting plasma glucose; TC=Total cholesterol; HDL-C=High-density lipoprotein cholesterol; LDL-C=Low-density lipoprotein cholesterol; TG=Triglyceride; LogTG=Log transformed triglyceride; WBC=White blood cell count; SD=Standard deviation

There were no significant hematological parameters associated with MetS in the oldest-old (85–94 years) group in this study. However, only WBC (HR: 1.380, 95% CI: 1.193–1.597; $P < 0.001$) and Hb level (HR: 1.257, 95% CI: 1.093–1.445; $P < 0.001$) in the young-old (65–74 years) group of males and Hb level (HR: 1.727, 95% CI: 1.054–

Table 2: Demographic data of the baseline study participants with and without metabolic syndrome

	Young-old			Old-old			Oldest-old		
	MetS (−)	MetS (+)	*P*	MetS (−)	MetS (+)	*P*	MetS (−)	MetS (+)	*P*
Male									
n	5049	2599		1273	690		83	38	
Age (years)	68.7±2.8	68.7±2.8	0.436	77.9±2.5	77.8±2.5	0.591	87.0±2.3	87.1±2.0	0.858
WC (cm)	81.8±7.9	91.6±7.7	<0.001	81.3±8.2	91.6±8.1	<0.001	81.1±9.2	92.2±7.6	<0.001
SBP (mmHg)	131.4±20.0	143.6±18.3	<0.001	135.8±20.5	145.8±18.0	<0.001	137.3±20.9	144.2±25.1	0.120
DBP (mmHg)	75.4±11.5	81.0±11.2	<0.001	73.7±11.6	77.8±12.0	<0.001	71.4±11.2	77.7±15.2	0.027
FPG (mg/dL)	104.3±28.2	120.5±37.3	<0.001	104.3±23.5	121.8±41.4	<0.001	101.3±14.3	114.6±21.4	<0.001
HDL-C (mg/dL)	53.2±13.8	41.7±10.7	<0.001	54.9±14.6	42.0±10.4	<0.001	56.9±15.9	40.3±8.9	<0.001
TG (mg/dL)	102.6±46.3	176.4±76.7	<0.001	96.8±41.5	171.7±73.1	<0.001	91.2±33.6	153.8±55.0	<0.001
WBC (×103/μL)	6.3±1.7	6.8±1.8	<0.001	6.2±1.8	6.9±2.0	<0.001	6.6±2.0	6.9±1.5	0.393
Hemoglobin (g/dL)	14.6±1.3	15.0±1.3	<0.001	14.1±1.4	14.5±1.5	<0.001	13.6±1.6	14.1±1.5	0.105
Platelet (×103/μL)	212.5±55.8	214.3±55.5	0.168	201.4±58.7	205.7±53.7	0.111	198.0±53.1	196.9±51.7	0.914
Female									
n	4004	3517		718	855		30	51	
Age (years)	68.3±2.7	68.7±2.8	<0.001	77.7±2.6	77.9±2.6	0.215	87.3±2.5	86.5±1.5	0.125
WC (cm)	76.2±7.7	84.5±8.1	<0.001	77.3±8.5	86.2±8.5	<0.001	77.4±9.1	87.0±7.1	<0.001
SBP (mmHg)	134.4±20.6	146.2±19.1	<0.001	140.7±21.9	150.2±19.5	<0.001	149.3±20.9	149.6±18.7	0.948
DBP (mmHg)	74.2±11.7	79.7±11.2	<0.001	74.0±12.1	78.1±12.1	<0.001	76.3±11.1	77.0±11.9	0.782
FPG (mg/dL)	101.4±23.4	119.8±39.9	<0.001	102.0±21.3	116.9±33.6	<0.001	102.1±17.2	113.7±30.3	0.060
HDL-C (mg/dL)	63.6±14.3	49.6±12.3	<0.001	65.0±15.4	50.2±12.8	<0.001	66.1±16.7	51.4±14.1	<0.001
TG (mg/dL)	106.3±44.9	174.6±73.9	<0.001	103.1±40.5	170.1±72.1	<0.001	104.8±37.2	165.5±69.0	<0.001
WBC (×103/μL)	5.9±1.6	6.6±1.8	<0.001	5.9±1.7	6.6±1.9	<0.001	6.3±2.0	6.9±2.0	0.203
Hemoglobin (g/dL)	13.2±1.1	13.4±1.2	<0.001	12.8±1.2	13.2±1.3	<0.001	12.6±1.3	13.0±1.2	0.107
Platelet (×103/μL)	226.3±55.3	236.8±57.4	<0.001	223.0±58.9	228.9±59.6	0.050	202.8±53.0	219.2±62.5	0.233

Data are shown as mean±SD. WC=Waist circumference; SBP=Systolic blood pressure; DBP=Diastolic blood pressure; FPG=Fasting plasma glucose; HDL-C=High-density lipoprotein cholesterol; TG=Triglyceride; WBC=White blood cell count

Table 3: Multivariable logistic regression model of hematogram for the risk of metabolic syndrome

	Young old			Old-old			Oldest-old		
	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*
Male									
WBC	1.422	1.336–1.514	<0.001	1.191	1.125–1.261	<0.001	1.470	0.898–2.407	0.126
Hb	1.348	1.271–1.430	<0.001	1.203	1.122–1.290	<0.001	1.321	0.817–2.134	0.256
PLT	0.968	0.911–1.030	0.306	0.999	0.997–1.001	0.467	0.740	0.453–1.208	0.229
Female									
WBC	1.526	1.437–1.620	<0.000	1.466	1.286–1.671	<0.001	1.309	0.713–2.402	0.384
Hb	1.237	1.168–1.310	<0.000	1.418	1.248–1.610	<0.001	1.477	0.836–2.608	0.179
PLT	1.101	1.038–1.168	<0.001	1.092	0.959–1.243	0.186	1.143	0.624–2.091	0.665

CI=Confidence interval; WBC=White blood cell count; Hb=Hemoglobin; PLT=Platelet; OR=Odds ratio

2.831, $P = 0.03$) in the old-old (75–84 years) group of females were associated with an increased risk for MetS development during follow-up Table 4.

Figure 1 shows the ROC curve of the hematogram for predicting MetS development among different age groups. In the young-old (65–74 years) group of males, WBC and

Hematological parameters (WBC, Hb level and PLT) for predicting further MetS development can be used for the early detection of MetS in aged individuals with high risk, especially WBC

Table 4: Multivariable Cox regression model of hematogram for the future metabolic syndrome

	Young-old			Old-old			Oldest-old		
	HR	95% CI	P	HR	95% CI	P	HR	95% CI	P
Male									
WBC	1.380	1.193–1.597	<0.001	1.103	0.760–1.600	0.607	2.874	0.707–11.678	0.140
Hb	1.257	1.093–1.445	<0.001	1.199	0.816–1.760	0.356	9.518	1.012–89.488	0.049
PLT	0.923	0.797–1.068	0.282	1.171	0.810–1.692	0.401	0.787	0.124–5.004	0.800
Female									
WBC	1.159	0.990–1.357	0.066	1.445	0.824–2.535	0.199	Not enough event for analysis		-
Hb	1.134	0.976–1.317	0.100	1.727	1.054–2.831	0.030	Not enough event for analysis		-
PLT	1.048	0.897–1.224	0.557	1.133	0.637–2.015	0.671	Not enough event for analysis		-

CI = Confidence interval; WBC = White blood cell count; Hb = Hemoglobin; PLT = Platelet; HR = Hazard ratio

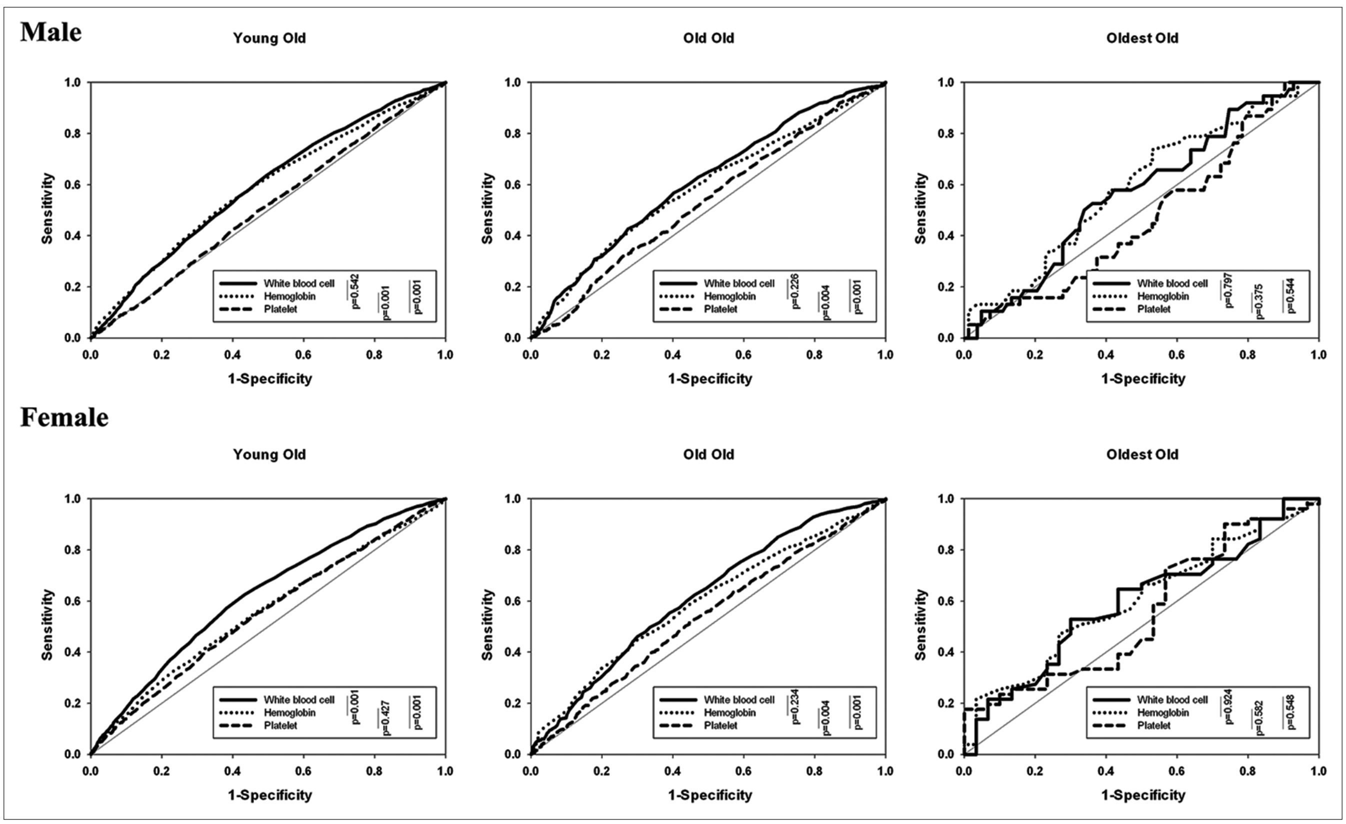

Figure 1: Receiver operating characteristic curve of hematogram in different age groups

Hb level were better predictors than PLT (WBC vs. PLT, P = 0.001, Hb vs. PLT, P = 0.004) to predict future MetS development. However, in the young-old (65–74 years) group of females, WBC was the best predictor for future MetS development (WBC vs. Hb, P = 0.001, WBC vs. PLT, P = 001). In the old-old (75–84 years) group of both sexes, WBC and Hb level were better predictors than PLT (WBC vs. PLT, P = 0.001, Hb vs. PLT, P = 0.004) for MetS development. In the oldest-old (85–94 years) group of both sexes, there was no single parameter that outweighed another for estimating future MetS development.

DISCUSSION

This is the first study to examine the ability of these three main hematological parameters to estimate future MetS development in the very aged population. We found gender and age differences in the ability to predict further

MetS development, in which WBC and Hb level in the young-old (65–74 years) population of males and Hb level in females in the old-old (75–84 years) population were independent factors. The results agree with the results of ROC analysis, which demonstrated that WBC and Hb level were better surrogate markers compared to PLT for predicting future MetS development in both genders in the aged population. However, this close association was not observed in the very aged population.

MetS is a group of metabolic abnormalities associated with insulin resistance (IR) and chronic inflammatory status and correlated with several biomarkers, such as WBC, high-sensitivity C-reactive protein, or the neutrophil to lymphocyte ratio, has been explored in different populations in previous studies.[10-12,23-25] MetS components are related to chronic inflammatory processes; therefore, ours and most previous studies confirmed the positive correlation between not only MetS components but also MetS itself and WBC.[10-12] However, some previous studies did not observe this positive association.[24,25] The possible mechanisms explaining the close association between WBC and MetS incidence include IR and adiposity, which are core defects observed in MetS. WBC is closely associated with IR and was associated with the risk of MetS even after adjusting for homeostatic model assessment-IR in apparently healthy adults in Korea.[12] Similarly, Hanley *et al*. found that WBC is an independent factor for predicting IR in nondiabetic participants.[26] A study of Japanese participants showed that WBC was a nonsignificant predictor of MetS, likely because of the low adiposity (mean BMI of 22.7 in men and 22.5 in women) of the study participants compared to in other studies.[24] Our participants in the oldest-old (85–94 years) group had less adiposity than the other two aged groups, which explains the discrepancy among the three groups. Age is another possible factor explaining the discrepancy. In a study of a Chinese adult population, WBC was positively associated with MetS, but this correlation disappeared when participant age was > 50 years.[10] The results of these studies are partially concordant with our results, in which WBC was strongly associated with MetS in the young-old (65–74 years) and old-old (75–84 years) groups with greater adiposity, but not in the oldest-old (85–94 years) group.

Studies exploring the association between MetS and Hb level have been limited. A study by Laudisio *et al*. found that participants with higher Hb levels had a higher incidence of MetS in participants aged older than 65 years.[13] Furthermore, MetS was associated with a lower probability of Hb level over the 6-year follow-up period in the oldest age group, suggesting that the association between Hb level and MetS diminished with increasing age.[13] These results are consistent with those of our study and most previous reports involved young and middle-aged populations.[23,27,28] The exact mechanism of this association remains unclear. However, previous studies showed that higher Hb level was associated with lower adiponectin[29] and higher IL-6 levels,[30] which may partly explain the increasing MetS development in participants of high Hb levels.

The relationship between PLT and MetS has been extensively explored, but the results have not been consistent. Most studies confirmed the positive correlation between PLT and MetS independently in different age and ethnic populations.[14,16,31-34] Few studies have focused on this positive association among older populations.[14,34] Our previous study showed that PLT is an independent factor for predicting future MetS development in both cross-sectional and longitudinal studies.[14] These results were not consistent with those of the current study, which may be explained by the study population and methods used. The present study focused on the association among subgroups in the older population without comparing the results with a younger population. We found a positive relationship between MetS and PLT only in the young-old (65–74 years) group of females in the cross-sectional study, but not in the longitudinal follow-up. Age may affect the relationship between PLT and MetS, whose association became insignificant when the participants were older in a previous study.[10] In a study by Balduini and Noris, age- and sex-related PLT variation was observed, and they found that PLT decreases with age and in male participants.[35] Another explanation may be related to successful aging. Participants experiencing successful aging demonstrated a high level of functioning across age-related processes and may also have genetic protection from chronic diseases.[36]

In this study, we also examined the ability of these three hematological parameters to predict future MetS development among the aged population. In the current study, all three hematological parameters were found to be correlated with MetS components in the cross-sectional study. Generally, WBC was the best parameter for predicting MetS development in the elderly population, followed by Hb and PLT, and finally using the ROC curve comparison. These results are similar in part to those of previous studies.[23] Lohsoonthorn *et al*. investigated the associations between hematological parameters and MetS risk among middle-aged professional and office workers in a Thailand population.[23] They found that elevated WBC was the most useful parameter for predicting MetS in both genders compared to other parameters. However, Hb and PLT can also be used to predict MetS development only in the female population. The possible mechanism for this relationship is attributed to the strong association between WBC and IR and represents a marker of inflammation status. Chen *et al*. demonstrated that WBC, but not PLT or Hb, was an independent risk factor for IR in middle-aged and elderly population in Taiwan.[37] However, these results should be interpreted with caution because the studies were conducted using different analysis methods.

In the present study, we explored the association between hematological makers and MetS development in a specific population. Thus, the very aged population can be examined using a simple test. There were several limitations to this study. All participants were healthy and collected from a screening center in Taiwan. The participants received regular health examinations, which may not represent the general population. Consequently, this population may have a lower risk of chronic inflammation disease than the general population. Moreover, the number of participants in the oldest-old (85–94 years) group was too small to represent the oldest-old (85–94 years) population and for analysis. Finally, the demographic information such as daily alcohol intake and dietary components was not determined in the current study, which may have influenced our results.

CONCLUSIONS

We found that elevated WBC, Hb level, and PLT were strongly associated with the risk of MetS development in the older population, and WBC was the most sensitive test. Hematological parameters for predicting further MetS development can be used for the early detection of MetS in aged individuals with high risk.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Third Report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III) final report. Circulation 2002;106:3143-421.
2. Grundy SM, Brewer HB Jr., Cleeman JI, Smith SC Jr., Lenfant C; American Heart Association; National Heart, Lung, *et al.* Definition of metabolic syndrome: Report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. Circulation 2004;109:433-8.
3. Nutrition and Health Survey in Taiwan 2005-2008. Institutes NHR. Nutrition and Health Survey in Taiwan; 2010. Available from: http://www.nahsit.nhri.org.tw/node/21. [Last updated on 2009 Dec 09; Last cited on 2016 Jul 26].
4. Percent Distribution of Population by Three-Stage Age Group and Dependency Ratio for Counties and Citiesr. Department of Household Registration. Statistics End of Year; 2015. Available from: http://www.ris.gov.tw/en/web/ris3-english/end-of-year. [Last updated on 2016 Oct 6; Last cited on 2016 Jul 26].
5. Shoelson SE, Lee J, Goldfine AB. Inflammation and insulin resistance. J Clin Invest 2006;116:1793-801.
6. Johnson RJ, Nakagawa T, Sanchez-Lozada LG, Shafiu M, Sundaram S, Le M, *et al.* Sugar, uric acid, and the etiology of diabetes and obesity. Diabetes 2013;62:3307-15.
7. Whitehead JP, Richards AA, Hickman IJ, Macdonald GA, Prins JB. Adiponectin – a key adipokine in the metabolic syndrome. Diabetes Obes Metab 2006;8:264-80.
8. Lohsoonthorn V, Dhanamun B, Williams MA. Prevalence of metabolic syndrome and its relationship to white blood cell count in a population of Thai men and women receiving routine health examinations. Am J Hypertens 2006;19:339-45.
9. Lee YJ, Shin YH, Kim JK, Shim JY, Kang DR, Lee HR. Metabolic syndrome and its association with white blood cell count in children and adolescents in Korea: The 2005 Korean National Health and Nutrition Examination Survey. Nutr Metab Cardiovasc Dis 2010;20:165-72.
10. Tao LX, Li X, Zhu HP, Huo D, Zhou T, Pan L, *et al.* Association of hematological parameters with metabolic syndrome in Beijing adult population: A longitudinal study. Endocrine 2014;46:485-95.
11. Oda E. High-sensitivity C-reactive protein and white blood cell count equally predict development of the metabolic syndrome in a Japanese health screening population. Acta Diabetol 2013;50:633-8.
12. Jung CH, Lee WY, Kim BY, Park SE, Rhee EJ, Park CY, *et al.* The risk of metabolic syndrome according to the white blood cell count in apparently healthy Korean adults. Yonsei Med J 2013;54:615-20.
13. Laudisio A, Bandinelli S, Gemma A, Ferrucci L, Antonelli Incalzi R. Metabolic syndrome and hemoglobin levels in elderly adults: The Invecchiare in Chianti Study. J Am Geriatr Soc 2013;61:963-8.
14. Chen YL, Hung YJ, He CT, Lee CH, Hsiao FC, Pei D,

et al. Platelet count can predict metabolic syndrome in older women. Platelets 2015;26:31-7.
15. Chang YL, Pei C, Pei D, Tang SH, Hsu CH, Chen YL, *et al*. Association between platelet count and components of metabolic syndrome in geriatric Taiwanese males. Int J Gerontol 2012;6:215-9.
16. Chen YL, Hsu CH, Hseih CH, Wang K, Wu CZ, Wang CY, *et al*. Association between platelet count and components of metabolic syndrome in geriatric Taiwanese women. Int J Gerontol 2012;6:201-5.
17. Liu H, Hsu CH, Lin JD, Hsieh CH, Lian WC, Wu CZ, *et al.* Predicting metabolic syndrome by using hematogram models in elderly women. Platelets 2014;25:97-101.
18. Kawamoto R, Tabara Y, Kohara K, Miki T, Kusunoki T, Abe M, *et al.* Hematological parameters are associated with metabolic syndrome in Japanese community-dwelling persons. Endocrine 2013;43:334-41.
19. Fu YH, Hsu CH, Lin JD, Hsieh CH, Wu CZ, Chao TT, *et al.* Using hematogram model to predict future metabolic syndrome in elderly: a 4-year longitudinal study. Aging Male 2015;18:38-43.
20. Li PF, Chen JS, Chang JB, Chang HW, Wu CZ, Chuang TJ, *et al.* Association of complete blood cell counts with metabolic syndrome in an elderly population. BMC Geriatr 2016;16:10.
21. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, *et al.* Harmonizing the metabolic syndrome: A joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation 2009;120:1640-5.
22. Metabolic Syndrome Criteria in Taiwan Adults. Health Promotion Administration MoHaW, Republic of China (Taiwan). Available from: http://www.hpa.gov.tw/Bhpnet/Web/HealthTopic/TopicArticle.aspx?No=200712250123&parentid=200712250023. [Last updated on 2015 Jan 30; Last cited on 2016 Jul 26].
23. Lohsoonthorn V, Jiamjarasrungsi W, Williams MA. Association of hematological parameters with clustered components of metabolic syndrome among professional and office workers in Bangkok, Thailand. Diabetes Metab Syndr 2007;1:143-9.
24. Oda E, Kawai R. Comparison between high-sensitivity C-reactive protein (hs-CRP) and white blood cell count (WBC) as an inflammatory component of metabolic syndrome in Japanese. Intern Med 2010;49:117-24.
25. Shimakawa T, Bild DE. Relationship between hemoglobin and cardiovascular risk factors in young adults. J Clin Epidemiol 1993;46:1257-66.
26. Hanley AJ, Retnakaran R, Qi Y, Gerstein HC, Perkins B, Raboud J, *et al.* Association of hematological parameters with insulin resistance and beta-cell dysfunction in nondiabetic subjects. J Clin Endocrinol Metab 2009;94:3824-32.
27. Wang YY, Lin SY, Liu PH, Cheung BM, Lai WA. Association between hematological parameters and metabolic syndrome components in a Chinese population. J Diabetes Complications 2004;18:322-7.
28. Wu S, Lin H, Zhang C, Zhang Q, Zhang D, Zhang Y, *et al.* Association between erythrocyte parameters and metabolic syndrome in urban Han Chinese: a longitudinal cohort study. BMC Public Health 2013;13:989.
29. Kawamoto R, Tabara Y, Kohara K, Miki T, Kusunoki T, Takayama S, *et al.* Hemoglobin is associated with serum high molecular weight adiponectin in Japanese community-dwelling persons. J Atheroscler Thromb 2011;18:182-9.
30. Fornal M, Wizner B, Cwynar M, Królczyk J, Kwater A, Korbut RA, *et al.* Association of red blood cell distribution width, inflammation markers and morphological as well as rheological erythrocyte parameters with target organ damage in hypertension. Clin Hemorheol Microcirc 2014;56:325-35.
31. Furman-Niedziejko A, Rostoff P, Rychlak R, Golinska-Grzybala K, Wilczynska-Golonka M, Golonka M, *et al.* Relationship between abdominal obesity, platelet blood count and mean platelet volume in patients with metabolic syndrome. Folia Med Cracov 2014;54:55-64.
32. Aypak C, Türedi O, Bircan MA, Yüce A. Could mean platelet volume among complete blood count parameters be a surrogate marker of metabolic syndrome in pre-pubertal children? Platelets 2014;25:393-8.
33. Lin JD, Chiou WK, Chang HY, Liu FH, Weng HF, Liu TH. Association of hematological factors with components of the metabolic syndrome in older and younger adults. Aging Clin Exp Res 2006;18:477-84.
34. Park BJ, Shim JY, Lee HR, Jung DH, Lee JH, Lee YJ. The relationship of platelet count, mean platelet volume with metabolic syndrome according to the criteria of the American Association of Clinical Endocrinologists: A focus on gender differences. Platelets 2012;23:45-50.
35. Balduini CL, Noris P. Platelet count and aging. Haematologica 2014;99:953-5.
36. Rowe JW, Kahn RL. Human aging: Usual and successful. Science 1987;237:143-9.
37. Chen LK, Lin MH, Chen ZJ, Hwang SJ, Chiou ST. Association of insulin resistance and hematologic parameters: Study of a middle-aged and elderly Chinese population in Taiwan. J Chin Med Assoc 2006;69:248-53.