Observational Study

Medicine

OPEN

Association of hemoglobin levels with metabolic syndrome and its components in older korean males

A nationwide population-based cross-sectional study

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Abstract

Metabolic syndrome (MetS) is a cluster of metabolic abnormalities associated with an increased risk of cardiovascular disease, type 2 diabetes mellitus, and mortality. Hemoglobin levels have been suggested to be associated with metabolic disorders and cardiometabolic risk factors; however, evidence regarding their relationship with MetS remains inconsistent, particularly in older populations. This study aimed to investigate the association between hemoglobin levels, MetS, and its components in older Korean males. This study analyzed data from the sixth Korea National Health and Nutrition Examination Survey (2013–2015). A total of 1680 men aged ≥ 60 years with normal hemoglobin levels (13–17 g/dL) were included, after excluding participants with cancer, chronic kidney disease, insufficient fasting time, or missing data. Participants were categorized into tertiles according to their hemoglobin levels. MetS was defined according to the modified National Cholesterol Education Program Adult Treatment Panel III criteria with Korean-specific waist circumference cutoffs, as the presence of at least 3 of the following components: abdominal obesity, elevated blood pressure, high fasting plasma glucose, high triglyceride levels, and low high-density lipoprotein cholesterol. Weighted logistic regression analyses were performed to evaluate the associations between hemoglobin tertiles and MetS and its components. The prevalence of MetS increased across hemoglobin tertiles (33.8%, 38.3%, and 48.8%, respectively). Participants in the highest tertile had significantly higher odds of having MetS (adjusted odds ratio [OR], 1.78; 95% confidence interval [CI], 1.28–2.47). Higher hemoglobin levels were also associated with abdominal obesity (OR, 2.03; 95% CI, 1.39–2.97), high fasting plasma glucose (OR, 1.71; 95% CI, 1.22–2.41), and high triglyceride levels (OR, 2.30; 95% CI, 1.64–3.22), but were not significantly associated with elevated blood pressure or low high-density lipoprotein cholesterol. Higher hemoglobin levels were significantly associated with an increased prevalence of MetS and several of its components in older Korean males. These findings suggest that hemoglobin levels may serve as a simple and accessible marker for identifying older adults at increased metabolic risk.

Abbreviations: CI = confidence interval, FPG = fasting plasma glucose, HDLC = high-density lipoprotein cholesterol, KNHANES = Korea National Health and Nutrition Examination Survey, MetS = metabolic syndrome, OR = odds ratio, TG = triglycerides.

Keywords: abdominal obesity, hemoglobin, KNHANES, metabolic syndrome

1. Introduction

Metabolic syndrome (MetS) is characterized by a cluster of metabolic abnormalities, including abdominal obesity, hypertension, hyperglycemia, hypertriglyceridemia, and low high-density lipoprotein cholesterol (HDLC).[1] It is associated with an increased risk of cardiovascular disease, type 2 diabetes mellitus, and all-cause mortality.[2] The prevalence of MetS has increased worldwide over recent decades, particularly among older adults, posing a substantial public health burden.[3] In the United States, the prevalence of MetS has been reported to be approximately 39.8% in adults and exceeds 56% among individuals aged ≥ 60 years.[4] In Korea, the prevalence stands at approximately 23% among adults and exceeds 45% among older populations.[5] This trend likely reflects not only population aging and increased life expectancy but also a true increase in metabolic risk factors associated with lifestyle changes.[6]

Hemoglobin levels reflect the oxygen-carrying capacity of the blood and may serve as an indicator of overall physiological status.[7]

The author has no funding and conflicts of interest to disclose.

The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party.

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How to cite this article: Park J-M. Association of hemoglobin levels with metabolic syndrome and its components in older korean males: A nationwide population-based cross-sectional study. Medicine 2026;105:24(e49342).

Received: 16 March 2026 / Received in final form: 24 May 2026 / Accepted: 31 May 2026

http://dx.doi.org/10.1097/MD.0000000000049342

Recent studies have reported that higher hemoglobin levels are associated with metabolic disorders, including insulin resistance, obesity, and cardiovascular risk factors.[8,9] Elevated hemoglobin concentrations have also been associated with components of MetS, including increased triglycerides (TG), impaired glucose metabolism, and abdominal obesity.[8,10] These elevated levels may reflect increased blood viscosity, chronic hypoxia, or metabolic dysregulation, which may subsequently contribute to MetS development.[11,12] Given that hemoglobin measurement is routinely performed in clinical practice, identifying its association with MetS may provide a simple and accessible approach for early risk stratification and identification of individuals at increased metabolic risk.

Previous studies investigating the association between hemoglobin levels and MetS have reported inconsistent findings. For example, some cohort studies have demonstrated that higher hemoglobin concentrations are associated with an increased incidence of MetS.[9,13] In addition, large-scale population-based analyses using data from the Taiwan Biobank and United Kingdom Biobank have reported a positive or U-shaped association between hemoglobin levels and MetS.[8] However, studies conducted in specific populations, such as elderly adults in Italy and occupational cohorts in Ethiopia, have demonstrated variations in the magnitude and patterns of these associations according to sex and population characteristics, suggesting potential population-specific effects.[14,15] These discrepancies may be attributed to differences in study design, population characteristics, and underlying comorbidities. Furthermore, relatively few studies have focused on older populations, who are particularly vulnerable to metabolic disorders,[6] and population-based studies investigating this association in older Korean males remain limited. Because hemoglobin levels differ substantially between males and females, and hormonal factors such as menopause may influence metabolic risk,[16,17] restricting the analysis to males may reduce heterogeneity and allow a clearer evaluation of this association. Moreover, metabolic risk increases with aging, making older adults an important population for investigation. Therefore, this study aimed to investigate the association between hemoglobin levels and MetS and its individual components in a nationally representative sample of older Korean males.

2. Methods

2.1. Study population

Data from the sixth Korea National Health and Nutrition Examination Survey (KNHANES VI, 2013–2015) were used. The KNHANES is a nationwide, population-based survey designed to assess the health and nutritional status of the Korean population using complex, multistage probability sampling. Males aged ≥ 60 years were initially considered for the analysis. Participants were excluded if they had fasted for < 8 hours before blood sampling or had missing data for hemoglobin levels or MetS components. Because certain conditions may influence hemoglobin levels, participants with a history of cancer or chronic kidney disease were also excluded. In addition, individuals with hemoglobin levels outside the normal reference range (13–17 g/dL) were excluded to minimize the influence of anemia or polycythemia. After applying these exclusion criteria, a total of 1680 men aged ≥ 60 years were included in the final analysis.

The KNHANES protocol was approved by the Institutional Review Board of the Korea Centers for Disease Control and Prevention (IRB Nos. 2013-07CON-03-4C, 2013-12EXP-03-5C, and 2015-01-02-6C). All participants provided written informed consent.

2.2. Measurements

Anthropometric measurements were obtained by trained personnel following standardized protocols. Body mass index was calculated as weight divided by height squared (kg/m^2). Waist circumference was measured at the midpoint between the lower margin of the rib cage and the iliac crest. Blood pressure was measured using a standard sphygmomanometer after participants had rested for at least 5 minutes. Blood samples were collected after an overnight fast and analyzed in a central, certified laboratory. Fasting plasma glucose (FPG), TG, and HDLC levels were measured using a Hitachi Automatic Analyzer 7600 (Hitachi). Hemoglobin levels and leukocyte counts were measured using an automated hematology analyzer (XE-2100D, Sysmex).

2.3. MetS definition

MetS was defined according to the modified National Cholesterol Education Program Adult Treatment Panel III criteria with Korean-specific waist circumference cutoffs.[18,19] Participants were considered to have MetS if they met at least 3 of the following 5 criteria: abdominal obesity (waist circumference ≥ 90 cm); elevated blood pressure (systolic blood pressure ≥ 130 mm Hg, diastolic blood pressure ≥ 85 mm Hg, or the use of antihypertensive medication); high FPG (≥ 100 mg/dL or the use of antidiabetic medication); high TG levels (≥ 150 mg/dL); or low HDLC levels (< 40 mg/dL).

2.4. Statistical analysis

All statistical analyses were conducted using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp.). All analyses incorporated sampling weights, strata, and primary sampling units to account for the complex survey design of the KNHANES.

Participants were categorized into tertiles according to their hemoglobin levels: T1 (13.0–14.3 g/dL), T2 (14.4–15.2 g/dL), and T3 (15.3–17.0 g/dL). Continuous variables were presented as means with standard errors, and categorical variables were expressed as percentages with standard errors. Differences across hemoglobin tertiles were assessed using weighted 1-way analysis of variance for continuous variables and weighted chi-square tests for categorical variables.

Multivariate logistic regression analyses were performed to evaluate the association between hemoglobin tertiles and MetS and its individual components. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated after adjusting for age, smoking status, alcohol consumption, regular exercise, residential area, household income, and education level. A 2-sided P value < .05 was considered statistically significant.

3. Results

Table 1 shows participant characteristics according to hemoglobin tertiles. Higher hemoglobin tertiles were associated with less favorable metabolic profiles, including higher body mass index, waist circumference, systolic blood pressure, diastolic blood pressure, TG, and leukocyte counts.

Table 2 shows the prevalence of MetS and its components according to hemoglobin tertiles. The prevalence of MetS increased progressively across hemoglobin tertiles (33.8%, 38.3%, and 48.8%, respectively). Similar increasing trends were observed for several MetS components, particularly abdominal obesity, high FPG, and high TG.

Table 3 presents the multivariate-adjusted ORs and 95% CIs for MetS and its components according to hemoglobin tertiles. Compared with participants in the lowest hemoglobin tertile, those in the highest tertile had significantly higher odds of having MetS, abdominal obesity, high FPG, and high TG. The adjusted ORs (95% CIs) in the highest hemoglobin tertile were 1.78 (1.28–2.47) for MetS, 2.03 (1.39–2.97)

Table 1

Participant characteristics according to hemoglobin level tertiles.

	All	T1 (13.0–14.3 g/dL)	T2 (14.4–15.2 g/dL)	T3 (15.3–17.0 g/dL)	*P* value
Unweighted *N*	1680	530	570	580	
Age (yrs)	67.8 (0.2)	69.1 (0.3)	67.4 (0.3)	67.0 (0.3)	< .001
BMI (kg/m^2)	23.9 (0.1)	23.2 (0.1)	23.8 (0.1)	24.6 (0.1)	< .001
Waist circumference (cm)	85.8 (0.2)	84.2 (0.4)	85.7 (0.3)	87.6 (0.4)	< .001
SBP (mm Hg)	125.3 (0.5)	123.4 (0.9)	125.5 (0.8)	126.9 (0.8)	.013
DBP (mm Hg)	74.3 (0.3)	71.3 (0.5)	74.5 (0.5)	76.9 (0.5)	< .001
FPG (mg/dL)	108.2 (0.8)	105.3 (1.2)	107.8 (1.1)	111.3 (1.3)	.004
Total cholesterol (mg/dL)	183.6 (1.0)	176.4 (1.6)	183.1 (1.7)	190.8 (1.6)	< .001
TG (mg/dL)	150.5 (3.3)	127.1 (4.4)	152.0 (7.3)	171.0 (4.9)	< .001
HDLC (mg/dL)	46.6 (0.3)	47.2 (0.6)	46.4 (0.5)	46.4 (0.5)	.511
Leukocyte count (cells/μL)	6550 (53)	6330 (107)	6530 (88)	6780 (83)	.003
Platelet count (10^3 cells/L)	234.1 (2.0)	234.9 (3.3)	239.2 (3.7)	228.4 (2.6)	.042
Current smoker (%)	27.0 (1.3)	25.3 (2.4)	27.8 (2.1)	27.6 (2.0)	.661
Alcohol drinker (%)	36.4 (1.4)	27.8 (2.3)	35.2 (2.3)	45.3 (2.5)	< .001
Regular exerciser (%)	18.3 (1.3)	18.3 (2.2)	17.5 (2.1)	19.1 (2.3)	.867
Residence in rural area (%)	23.8 (2.2)	23.4 (2.9)	26.1 (2.8)	21.9 (3.0)	.403
Household income (US $/month)	2701 (83)	2433 (115)	2846 (130)	2809 (144)	.033
Education					.778
≤ Elementary school	36.7 (1.6)	39.4 (2.8)	34.8 (2.4)	36.2 (2.6)	
Middle school	17.9 (1.2)	18.4 (2.1)	18.1 (1.9)	17.3 (1.9)	
High school	27.9 (1.3)	26.5 (2.4)	27.8 (2.1)	29.4 (2.3)	
≥ University	17.4 (1.3)	15.7 (2.0)	19.3 (2.0)	17.1 (2.1)	

Data are presented as weighted percentages (SE) or weighted means (SE).

1 US $ = 1000 Korean won.

BMI = body mass index, DBP = diastolic blood pressure, FPG = fasting plasma glucose, HDLC = high-density lipoprotein cholesterol, N = number of participants, SBP = systolic blood pressure, SE = standard error, TG = triglycerides, US = United States.

P values were calculated using the weighted chi-squared test and 1-way analysis of variance for categorical and continuous variables, respectively.

Table 2

Prevalence of MetS and its components according to hemoglobin level tertiles.

	T1 (13.0–14.3 g/dL)	T2 (14.4–15.2 g/dL)	T3 (15.3–17.0 g/dL)	*P* value
MetS (%)	33.8 (2.4)	38.3 (2.3)	48.8 (2.3)	< .001
Abdominal obesity (%)	25.0 (2.3)	25.9 (2.1)	38.7 (2.2)	< .001
Elevated BP (%)	59.3 (2.5)	59.4 (2.2)	62.6 (2.5)	.547
High FPG (%)	47.3 (2.5)	54.8 (2.3)	63.3 (2.4)	< .001
High TG (%)	37.2 (2.4)	42.7 (2.4)	52.1 (2.1)	< .001
Low HDLC (%)	28.1 (2.3)	31.3 (2.1)	29.0 (2.2)	.590

Data are presented as weighted percentages (SE).

BP = blood pressure, FPG = fasting plasma glucose, HDLC = high-density lipoprotein cholesterol, MetS = metabolic syndrome, SE = standard error, TG = triglycerides.

P values were obtained from the weighted chi-squared test.

Table 3

Multivariate-adjusted ORs and 95% CIs for MetS and its components according to hemoglobin level tertiles.

	T1 (13.0–14.3 g/dL)	T2 (14.4–15.2 g/dL)	T3 (15.3–17.0 g/dL)
MetS	1	1.16 (0.82–1.63)	1.78 (1.28–2.47)
Abdominal obesity	1	1.01 (0.68–1.51)	2.03 (1.39–2.97)
Elevated BP	1	1.05 (0.77–1.44)	1.13 (0.81–1.57)
High FPG	1	1.25 (0.91–1.73)	1.71 (1.22–2.41)
High TG	1	1.37 (0.97–1.95)	2.30 (1.64–3.22)
Low HDLC	1	0.97 (0.68–1.37)	0.87 (0.60–1.27)

ORs and 95% CIs were estimated using multiple logistic regression models after adjusting for age, smoking status, alcohol consumption, regular exercise, residential area, household income, and education level.

BP = blood pressure, CI = confidence interval, FPG = fasting plasma glucose, HDLC = high-density lipoprotein cholesterol, MetS = metabolic syndrome, OR = odds ratio, TG = triglycerides.

for abdominal obesity, 1.71 (1.22–2.41) for high FPG, and 2.30 (1.64–3.22) for high TG, after adjusting for the aforementioned confounding factors. Elevated BP and low HDLC were not significantly associated with hemoglobin tertiles.

4. Discussion

Higher hemoglobin levels were significantly associated with an increased prevalence of MetS and several of its components in this nationwide population-based study of older Korean males.

Participants in the highest hemoglobin tertile had significantly higher odds of having MetS, abdominal obesity, high FPG, and high TG compared with those in the lowest tertile. However, elevated blood pressure and low HDLC were not significantly associated with hemoglobin levels. Previous studies examining MetS in older adults have focused on lifestyle or behavioral factors rather than hematologic markers.[20] In contrast, relatively little attention has been given to the potential role of hemoglobin levels in metabolic abnormalities.

The present findings are consistent with previous studies reporting a positive association between hemoglobin levels and metabolic abnormalities. He et al reported that higher hemoglobin concentrations were associated with an increased incidence of MetS in a prospective study of Chinese adults, and Hashimoto et al similarly demonstrated a positive association in a large population-based cohort in Japan.[9,13] Large-scale analyses using data from the Taiwan Biobank and United Kingdom Biobank also reported positive or U-shaped associations between hemoglobin levels and MetS across diverse populations.[8]

However, some studies have reported variations in the magnitude and patterns of these associations. Laudisio et al examined the association between hemoglobin levels and MetS in the InCHIANTI Study, a community-based cohort of 1036 adults aged ≥ 65 years in Tuscany, Italy, and found that MetS was significantly associated with higher hemoglobin levels in women but not in men, suggesting potential sex-specific effects.[14] Nebeck et al investigated hematological parameters and MetS in an occupational cohort of 1868 working adults in Addis Ababa, Ethiopia, and reported that hemoglobin was positively associated with MetS in women, whereas the association in men was less consistent across hemoglobin quartiles.[15] These discrepancies may reflect differences in study design, sex distribution, age composition, and population-specific metabolic profiles. The present study restricted the analysis to older Korean males to minimize hormonal heterogeneity and focused on a nationally representative older population, which may partly explain the more consistent positive associations observed across hemoglobin tertiles.

Several mechanisms may explain the relationship between hemoglobin levels and MetS. Higher hemoglobin levels may reflect increased blood viscosity, which can impair microcirculatory blood flow and tissue perfusion.[12,21] Reduced tissue perfusion may limit insulin and glucose delivery to peripheral tissues, thereby impairing insulin-mediated glucose uptake and contributing to insulin resistance.[22,23] Furthermore, impaired microvascular circulation and reduced oxygen delivery may promote tissue hypoxia and endothelial dysfunction, both of which are closely associated with metabolic dysregulation.[12,21,22]

Inflammation may also contribute to this relationship. Chronic low-grade inflammation is a well-established feature of MetS and has been associated with alterations in erythropoiesis, oxidative stress, and insulin resistance.[24] The elevated leukocyte counts observed across hemoglobin tertiles in the present study may support the potential contribution of underlying inflammatory processes. In addition, insulin resistance may increase hepatic very-low-density lipoprotein production, thereby contributing to elevated TG levels.[25,26] However, because of the cross-sectional design of this study, it remains unclear whether elevated hemoglobin levels directly contribute to metabolic dysfunction or simply reflect underlying metabolic and inflammatory states.

The observed association between hemoglobin levels and abdominal obesity may also be related to underlying metabolic dysfunction. Visceral adiposity is strongly associated with insulin resistance, chronic inflammation, and altered lipid metabolism.[27,28] Several mechanisms may link these metabolic alterations to erythropoiesis and hemoglobin regulation. Insulin and hyperinsulinemia have been suggested to stimulate erythroid progenitor activity and erythropoiesis, indicating that insulin resistance may contribute to increased red blood cell production and higher hemoglobin levels.[29] Moreover, obesity-related inflammatory pathways and erythropoietic responses may further influence erythropoiesis in individuals with metabolic dysfunction.[30] Furthermore, alterations in iron metabolism associated with obesity and chronic inflammation, including increased hepcidin production, may affect iron availability for erythropoiesis and hemoglobin synthesis.[29] In this context, hemoglobin levels may reflect underlying metabolic disturbances rather than acting as a direct causal factor.

Hemoglobin levels were not significantly associated with elevated blood pressure or low HDLC in this study. Although previous studies have reported associations between hemoglobin levels and blood pressure, the results remain inconsistent.[31–33] The lack of a significant association with blood pressure in the present study may be partly explained by the fact that blood pressure regulation involves complex neurohormonal, vascular, and renal mechanisms that are less directly linked to the metabolic pathways associated with hemoglobin regulation.[34] In contrast, the significant associations observed with abdominal obesity, hyperglycemia, and hypertriglyceridemia may reflect closer mechanistic relationships with insulin resistance, visceral adiposity, and metabolic dysregulation. Similarly, HDLC levels are predominantly regulated by genetic, dietary, and reverse cholesterol transport mechanisms[35] that may operate more independently of the inflammatory and insulin resistance-related pathways linking hemoglobin to other MetS components. Therefore, while multiple factors influence all MetS components, the biological pathways connecting hemoglobin to abdominal obesity, hyperglycemia, and hypertriglyceridemia may be more mechanistically proximate than those linking hemoglobin to blood pressure or HDLC.

Because hemoglobin measurement is routinely performed in clinical practice, hemoglobin levels may serve as a simple and easily accessible marker reflecting underlying metabolic risk in older adults. Thus, measuring hemoglobin levels may provide additional information for identifying individuals at higher risk of metabolic abnormalities.

This study had some limitations. Because of its cross-sectional design, causal relationships between hemoglobin levels and MetS could not be established, and reverse causality could not be excluded. Additionally, residual confounding may have remained despite adjustment for multiple covariates. Furthermore, because this study included only older Korean males, the findings may not be generalizable to other ethnic populations. In addition, because this study included only individuals with hemoglobin levels within the normal reference range, the findings may not be applicable to individuals with anemia or polycythemia.

Despite these limitations, this study has several strengths. Nationally representative data from the KNHANES were used, thereby enhancing the generalizability of the findings to the Korean population. Additionally, the relatively large sample size strengthened the reliability and generalizability of the findings. A wide range of confounders closely linked with MetS, including lifestyle behaviors and socioeconomic status, was also adjusted for in the multivariate analysis.

In conclusion, higher hemoglobin levels were significantly associated with a higher prevalence of MetS and several of its components in older Korean males. These findings suggest that hemoglobin levels may serve as a marker of metabolic health in older adults. Further longitudinal studies are needed to clarify the causal relationship between hemoglobin levels and MetS.

Author contributions

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