Occupational Differences in C-Reactive Protein Among Working-Age Adults in South Korea

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Objective: To examine the association between occupational class and high-sensitivity C-reactive protein (hsCRP) in Korean workers. **Methods:** We used a nationally representative sample of Koreans ($n = 2591$) aged 19 to 65 years from the 2015 Korea National Health and Nutrition Examination Survey. The concentration of hsCRP (mg/L) was assessed by a high sensitivity immunoturbidimetric assay. Current occupation was categorized as: white-collar (managers/professionals), pink-collar (clerks/service/sales), blue-collar (craft/equipment/machine-assembling, agricultural/forestry/fishery, and elementary-level labor), or unemployed. Cross-sectional linear regression models adjusted for sociodemographic/work-related/health conditions and behaviors. **Results:** Compared with blue-collar workers, white-collar workers showed significantly higher levels of hsCRP ($\beta = 0.16$, 95% CI: 0.02, 0.30) after adjusting for all covariates, whereby the pattern was more pronounced among professionals. However, the association was not significant for unemployed and pink-collar workers. **Conclusions:** Findings suggest that Korean white-collar workers, particularly professionals, have elevated levels of inflammation.

Keywords: cardiovascular disease, C-reactive protein, inflammation, occupational health, social gradient, socioeconomic status

Learning Objectives

- Discuss previous findings on socioeconomic gradients in health, including differences in reports from developed Western versus East Asian countries.
- Summarize the new findings on the association between occupational class and high-sensitivity C-reactive protein (hsCRP) among workers in South Korea.
- Discuss the findings in the context of prior studies of occupational class and health outcomes, including the possible effects of cultural and risk factor differences between Western and East Asian countries.

Socioeconomic gradients in health are well documented in developed Western countries, whereby higher mortality and morbidity have been reported among lower versus higher social classes.[1–6] For instance, in the British Whitehall Study cohorts, researchers identified an inverse stepwise relationship between civil service employment grade and cardiovascular disease (CVD) incidence and mortality.[7] Subsequent studies reported similar occupational gradients across a broad range of CVD risk factors including metabolic, psychological, and behavioral profiles.[2–4,7–10] However, evidence of such monotonic socioeconomic gradient in CVD is not universal, even in developed countries. In particular, contradictory or inconsistent findings have been reported in two industrialized East Asian countries, Japan and South Korea.

In Japan, previous studies found that male managers and professionals had higher all-cause mortality rate compared with lower occupational grades during the period 2000 to 2005, as well as a substantially increased suicide mortality rate in both men and women over the period 1975 to 2005.[11–13] This pattern was consistently observed in psychosocial and behavioral factors with higher job-related stress and more unhealthy behaviors found among managers and professionals than the other working classes among Japanese.[13,14] In South Korea, studies showed mixed findings. While the risks of all-cause mortality and CVD were found to be generally higher among lower (manual vs non-manual) occupational classes,[15,16] the opposite pattern was observed for cardiometabolic dysfunctions such as metabolic syndrome and obesity, particularly among men.[17–19]

Given these complex and inconsistent findings, investigating the occupational inequalities of CVD risk at biological level may provide a valuable window to understand how occupational status "gets under the skin" among the populations. Recent studies documented that the conventional social gradients were consistently observed in the distribution of immune markers and inflammatory process among Western populations. For instance, lower versus higher occupational class has been associated with elevated concentrations of inflammatory markers including high sensitivity C-reactive protein (hsCRP) and fibrinogen,[20–25] well-documented risk markers of cardiovascular disease and mortality.[26] A similar pattern was found for other measures of socioeconomic status such as education and income in Western countries.[20–25,27] However, little work has been done among Koreans. In the present study, therefore, we sought to examine the evidence on the association between occupational class and CVD risk at the bioimnunological level among working-age Korean adults by focusing on hsCRP levels.

PARTICIPANTS AND METHODS

Samples

Data were drawn from the Korean National Health and Nutrition Examination Survey in 2015 (KNHANES VI-2).[28]

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Clinical significance: Findings in Wester populations showed elevated risks of cardiovascular disease among lower versus higher occupational class. However, in working-age Koreans, white collar-workers, particularly professionals, (vs blue-collar) showed higher levels of C-reactive protein. This suggests higher risks of cardiovascular disease among white-collar workers, warranting further investigation and targeted prevention strategies.

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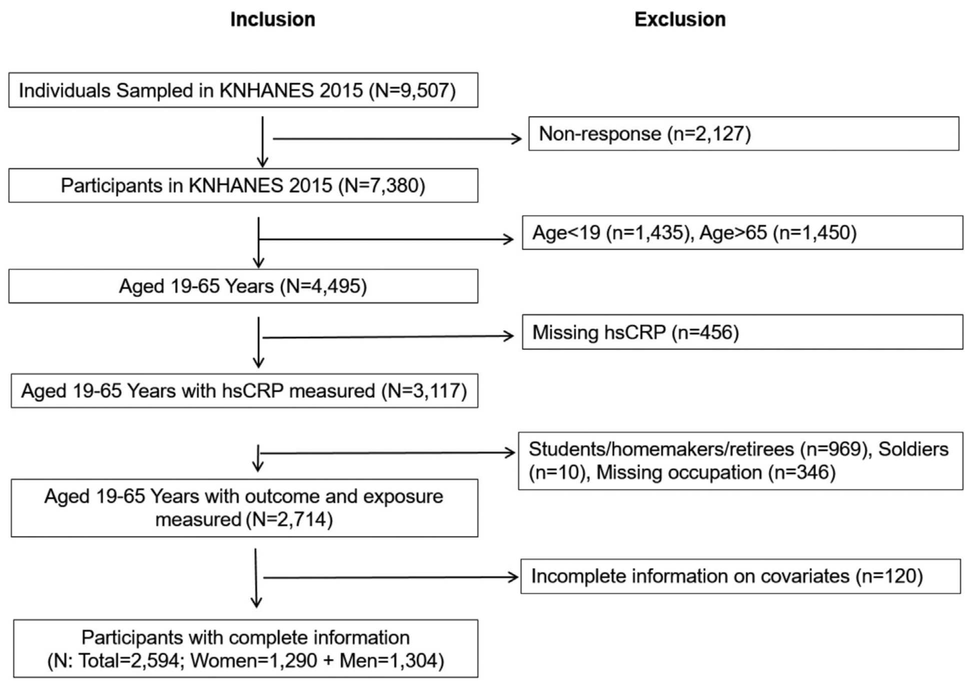

FIGURE 1. Flow chart of the sample selection processes from the Korea National Health and Nutrition Examination Survey (KNHANES) in 2015.

Detailed information on KNHANES can be found elsewhere.[28] Briefly, the Korean Centers for Disease Control and Prevention (KCDC) has conducted the KNHANES since 1998, measuring population health profiles of noninstitutionalized Koreans (aged 1 year or older) through health examinations, nutrition surveys, and health interviews. The survey employed a stratified multistage cluster probability sampling design to draw a nationally representative sample of Koreans. As shown in Fig. 1, in KNHANES VI-2, of the initially targeted individuals ($n = 9507$), approximately 80% ($n = 7380$) responded the survey. Of these, we excluded participants aged younger than 19 years ($n = 1435$) or older than 65 years ($n = 1450$), those with a missing CRP level ($n = 456$), those who reported their occupation as soldier ($n = 10$), students/homemakers/retirees ($n = 969$), or did not report their current occupation ($n = 346$), and those with missing information on any other variables used in this analysis ($n = 120$), resulting in a total analytic sample of 2594 (1290 women and 1304 men). Our study received an exemption from an IRB review by the Office of Human Research Administration at the Harvard T.H. Chan School of Public Health due to the de-identified publicly available nature of the data used in this study.

Measurement of hsCRP

Blood samples were obtained from the participants who underwent overnight fasting for at least 8 hours before the blood draw at a mobile examination center, which then were centrifuged, refrigerated, and transferred to the central laboratory in Seoul, South Korea. Biochemical information was assessed at the laboratory within 24 hours from the time of sample collection. Our outcome of interest, high-sensitivity C-reactive protein (hsCRP, mg/L), was measured using a high-sensitivity immunoturbidimetry method (Cobas, Roche, Germany).[29] Due to the right-skewed distribution of hsCRP values in our sample, we used a natural-logarithm transformed value of hsCRP for our analysis.

Occupational Classification

Participants reported their current occupation based on the 10 major groups of the Korean Standard Classification of Occupations (KSCO), which was developed according to the International Standard Classification of Occupations (ISCO).[30] Based on prior literature,[30] occupational groups were classified into four occupational classes: (a) white-collar workers, i.e., managers and professionals; (b) pink-collar workers, that is, clerks, service, and sales workers; and (c) blue-collar workers, that is, technicians, craft workers, and device/machine operators/assemblers, skilled agricultural/fishery workers, and elementary-level laborers; and (d) unemployed, that is, those who lost or were seeking jobs, except for homemakers/students/others.

Covariates

Trained medical staff at a mobile examination center assessed participants' blood pressure (three times for systolic and diastolic blood pressure, respectively, with a standard mercury sphygmomanometer in a sitting position after a 5-minute' rest) and anthropometric information including waist circumference (with a measuring tap to the nearest 1 mm), weight (with an electronic scale to the nearest 100 g), and height (with a portable stadiometer to the nearest 1 mm).[28] Based on the revised criteria for Asian-Pacific Populations by the World Health Organization, body mass index (BMI, kg/m^2) was classified as underweight (less than 18.5), normal weight (more than or equal to 18.5 and less than 23.0), overweight (more than or equal to 23.0 and less than 25.0), and obesity (more than or equal to 25.0).

Other biomarkers such as high-density lipoprotein cholesterol (HDL-C, mg/dL), triglyceride (TG, mg/dL), and fasting glucose (mg/dL) were assessed with an automatic hematology analyzer (Hitachi 7600–210, Japan) based on the aforementioned blood collection procedure.

Metabolic syndrome was identified as the presence of 3+ markers of cardiovascular risk including elevated waist circumference for Asian-Pacific populations (more than or equal to 80 cm for women, more than or equal to 90 cm for men), elevated blood pressure (more than or equal to 135/85 mmHg or antihypertensive medication use), elevated fasting plasma glucose (more than or equal to 100 mg/L or anti-hyperglycemic medication use), elevated triglyceride (more than or equal to 150 mg/dL), and low high-density lipoprotein cholesterol (less than 50 mg/dL for women, less than 40 mg/dL for men), based on the Joint Scientific Statement by the American Heart Association, National Heart, Lung, and Blood Institute, and International Diabetes Federation.[31]

Sociodemographic characteristics included age (grouped into 19 to 29, 30 to 39, 40 to 49, 50 to 59, 60 to 65 years), sex, education (grouped by highest educational degree achieved including college graduate or above, high school graduate, middle school graduate, or less), household income (quartiles of the equivalized household income), residential area (urban, rural), and marital status (never married, married, widowed/separated/divorced). Work-related factors included weekly working hours, categorized into three groups (more than or equal to 0 and less than 40; more than or equal to 40 and less than 49; more than or equal to 49 h/wk) based on prior literature,[32] precarious employment (yes vs none). Severe chronic condition was defined as having one or more of a self-reported history of cancer, stroke, and coronary heart disease.

Behavioral factors included smoking (never, former, current smokers over the past month), high-risk drinking (defined as two or more weekly occasions of 5+ drinks for women and 7+ drinks for men), and moderate-to-vigorous physical activity (150+ vs 0 to 149 minutes per week). The Korean version of the Global Physical Activity Questionnaire was used to assess the weekly amount of physical activity, the weighted sum of moderate (with a weight of 1) and vigorous (with a weight of 2) levels of physical activity every week, and a cut-off of 150 min/wk was used to define sufficient amount of regular exercise based on the guideline from the World Health Organization.[33] Psychological status included perceived stress level (high/very high vs little/a little).

Statistical Analysis

To understand the characteristics of our sample, we analyzed the distribution of dependent and independent variables by using survey weighted mean and standard deviation for continuous variables and frequency and percentage for binary/categorical variables. To determine the association between occupational class and hsCRP, we ran four linear regression models in sequence, as follows: (a) Model 1 with sociodemographic variables (age, sex, education, region, household income, marital status), (b) Model 2 with work-related characteristics (weekly working hours, shiftwork) and history of severe chronic condition added to Model 1, (c) Model 3 with behavioral and psychological factors (smoking, drinking, physical activity, and perceived stress) added to Model 2, and (d) Model 4 with presence of metabolic syndrome and BMI class added to Model 3.

Based on previous research showing differential association of occupational class with mortality and cardiometabolic risk across sexes in South Korea,[19,34] we further examined whether the association differed between women and men. However, based on the non-significant interaction between occupational class and sex, we decided not to perform stratified analysis by sex. As a post-hoc analysis, to understand the specific contribution of each individual working group particularly among the white-collar occupations (ie, managers and professionals) to the overall association, we ran the same models with each specific working group, instead of the overall white-collar class. For all analyses, we employed a complex-survey analysis approach (eg, SVY command) by using Stata/MP 15.0 (Stata Corp LLC, College Station, TX) to adjust for the design effects induced by the complex survey design. Statistical significance was set as 0.05 (two-sided).

RESULTS

Table 1 shows the characteristics of the study sample. The mean (standard deviation) of hsCRP was 1.11 mg/L (1.95) among all participants, 1.20 (1.95) among men, and 0.99 (1.90) among women. The proportion of occupational class was 24.4% white-collar (23.4% of men and 25.8% of women), 37.1% pink-collar (32.2% of men and 43.7% of women); 30.3% blue-collar (37.8% of men and 20.1% of women), and 8.2% unemployed (6.6% men and 10.4% women).

Table 2 shows the results from our survey-adjusted multivariable regression models to examine the association between occupational class and hsCRP levels (log-transformed, mg/L). Compared with blue-collar workers, white-collar workers showed significantly higher levels of log-transformed hsCRP ($\beta = 0.15$, 95% CI: 0.00, 0.29), after adjusting for sociodemographic variables in Model 1. The association remained statistically significant after further adjusting for work-related factors and medical history ($\beta = 0.16$, 95% CI: 0.01, 0.30) in Model 2, health-related behaviors (ie, smoking, high-risk drinking, and physical activity) and perceived stress ($\beta = 0.17$, 95% CI: 0.02, 0.32) in Model 3, and metabolic conditions such as BMI class and metabolic syndrome ($\beta = 0.16$, 95% CI: 0.02, 0.30) in Model 4.

However, we failed to find significant difference in log-transformed hsCRP levels for other working classes such as pink-collar workers ($\beta = 0.02$, 95% CI: −0.09, 0.13) and unemployed ($\beta = 0.11$, 95% CI: −0.07, 0.30), compared with blue-collar workers, after adjusting for sociodemographic factors in Model 1. These patterns were consistent across all different models.

Table 3 and Fig. 2 present findings of our ad-hoc analysis decomposing the contribution from each white-collar occupation such as managers and professionals to the observed association of white-collar (vs blue-collar) class and hsCRP. The survey-adjusted mean (standard deviation) of hsCRP was 0.86 mg/L (0.90) among managers ($n = 45$), 1.17 mg/L (2.04) among professionals ($n = 551$), 1.02 mg/L (1.74) among clerks ($n = 440$), 1.02 mg/L (2.02) among service workers ($n = 272$), 0.90 mg/L (1.33) among sales workers ($n = 264$), 1.19 mg/L (2.09) among blue-collar workers ($n = 816$), and 1.21 mg/L (2.20) among unemployed ($n = 206$). Multivariable adjusted model showed that, compared with blue-collar workers, professionals, in particular, showed a significantly elevated level of hsCRP ($\beta = 0.17$, 95% CI: 0.02, 0.33), after adjusting for sociodemographic factors. This relationship was robust after further adjusting for work-related factors ($\beta = 0.18$, 95% CI: 0.03, 0.34), health-related behaviors ($\beta = 0.20$, 95% CI: 0.05, 0.35), and metabolic conditions ($\beta = 0.19$, 95% CI: 0.04, 0.33), in sequence. However, the same association was not observed among managers. Compared with blue-collar class, the occupation of managers did not show a significantly different level of hsCRP ($\beta = 0.01$, 95% CI: −0.26, 0.27), after adjusting for sociodemographic factors, which remained consistent after further adjusting for work-related factors, health-related behaviors, and metabolic conditions. These indicate that professionals, but not managers, drive the observed elevated levels of hsCRP among white-collar workers compared with blue-collar workers.

DISCUSSION

Consistent with the well-established socioeconomic gradients for a range of health outcomes including mortality, morbidity, and health-related behaviors, studies in Western populations have found similar patterns for immune functions and inflammatory markers.[20–25] However, evidence for a corresponding social class gradient in inflammatory markers has been lacking in East Asian populations. The present study found that, compared with blue-collar workers, white-collar workers exhibited higher levels of hsCRP in working-aged Koreans. Moreover, the relationship was primarily driven by professionals, but not managers, among the white-collar group. Although our findings are based on a single inflammatory marker and further investigation with other pro-inflammatory markers related with cardiovascular disease risk, including interleukin-6 (IL-6) and tumor necrosis factor alpha receptor 2 (TNFR2) are needed, our results may suggest that Korean

TABLE 1. Characteristics of the Study Sample

	All	White-Collar	Pink-Collar	Blue-Collar	Unemployed
	$N=2594$	$N=596$ (24.4%)	$N=976$ (37.1%)	$N=816$ (30.3%)	$N=206$ (8.2%)
Dependent Variable	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
CRP, mg/L	1.11 (1.95)	1.15 (1.99)	0.99 (1.72)	1.19 (2.01)	1.21 (2.20)
Independent Variables	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**
Age, y					
19–29	419 (20.9)	117 (25.0)	172 (22.3)	53 (9.0)	77 (45.7)
30–39	454 (21.5)	154 (27.0)	180 (23.2)	92 (16.6)	28 (15.4)
40–49	675 (26.8)	190 (29.8)	264 (26.7)	186 (27.8)	35 (14.7)
50–59	731 (23.6)	102 (15.1)	281 (23.4)	309 (32.6)	39 (16.8)
60–65	315 (7.3)	33 (3.2)	79 (4.4)	176 (14.0)	27 (7.5)
Gender					
Female	1,290 (42.6)	306 (45.0)	565 (50.2)	294 (28.3)	125 (42.6)
Male	1,304 (57.4)	290 (55.0)	411 (49.8)	522 (71.7)	81 (57.4)
Education					
≤ Middle school	523 (15.4)	5 (0.6)	135 (9.6)	350 (35.4)	33 (12.3)
High school	960 (37.7)	106 (18.7)	412 (41.3)	362 (48.2)	80 (39.4)
≥ College	1111 (46.9)	485 (80.7)	429 (4.9)	104 (16.3)	93 (48.3)
Household income					
1st (lowest) quartile	200 (7.4)	13 (1.8)	58 (5.6)	97 (12.0)	32 (14.9)
2nd quartile	564 (20.5)	69 (12.3)	178 (17.2)	258 (29.7)	59 (25.6)
3rd quartile	850 (34.3)	190 (33.6)	341 (36.0)	253 (33.3)	66 (32.0)
4th (highest) quartile	980 (37.9)	324 (52.3)	399 (41.2)	208 (25.0)	49 (27.6)
Residential area					
Urban	2157 (84.9)	542 (91.1)	845 (88.3)	590 (75.2)	180 (87.0)
Rural	437 (15.1)	54 (8.9)	131 (11.7)	226 (24.8)	26 (13.1)
Marital status					
Never married	569 (28.0)	150 (30.8)	221 (28.8)	94 (16.0)	104 (60.3)
Married	1820 (65.7)	427 (66.7)	666 (63.9)	641 (75.8)	86 (33.4)
Separated/divorced/widowed	205 (6.3)	19 (2.5)	89 (7.3)	81 (8.2)	16 (6.4)
Weekly working hours					
0–39 h	938 (34.0)	214 (33.6)	314 (30.7)	287 (31.6)	123 (58.9)
40–48 h	882 (35.2)	241 (40.4)	360 (39.5)	236 (29.1)	45 (22.7)
49+ h	774 (30.9)	141 (26.1)	302 (29.9)	293 (39.4)	38 (18.4)
Precarious employment (yes)	934 (35.8)	186 (31.6)	345 (35.1)	403 (49.7)	0 (0.0)
Metabolic syndrome (yes)	703 (24.7)	125 (19.1)	255 (24.2)	279 (31.0)	47 (20.5)
BMI class					
Underweight (BMI <18.5 kg/m^2)	87 (4.1)	25 (4.2)	32 (4.1)	14 (2.3)	16 (10.2)
Normal weight (BMI: 18.5–23.0)	982 (37.7)	244 (40.5)	380 (38.4)	269 (33.0)	89 (43.0)
Overweight (BMI: 23.0–25.0)	621 (23.6)	141 (23.8)	234 (24.6)	217 (25.9)	29 (10.3)
Obese (BMI ≥25.0)	904 (34.6)	186 (31.5)	330 (32.9)	316 (38.9)	72 (36.6)
History of cancer/stroke/coronary heart disease (yes)	104 (3.1)	15 (2.1)	33 (2.6)	43 (4.3)	13 (4.3)
Smoking status					
Current smokers	566 (25.3)	100 (19.2)	185 (22.8)	234 (33.4)	47 (25.2)
Former smokers	518 (20.6)	108 (18.8)	165 (17.7)	220 (28.2)	25 (10.9)
Never smokers	1510 (54.1)	388 (61.9)	626 (59.5)	362 (38.4)	134 (64.0)
High-risk drinking (yes)	364 (15.9)	61 (11.1)	146 (17.4)	138 (19.6)	19 (9.2)
Physical activity (+150 min/wk)	1328 (54.1)	328 (57.0)	516 (55.9)	366 (48.4)	118 (58.1)
Perceived high-level stress (yes)	797 (32.3)	198 (32.7)	321 (35.0)	216 (28.4)	62 (33.7)

N represents raw frequency and % represents survey weighted column frequency.

professionals may be at elevated risk of future cardiovascular disease compared with other working classes. To our knowledge, this is the first study to document such an association in South Korea.

Our findings therefore contradict previous studies from Western countries, showing inverse occupational class gradients in chronic inflammation[20–25] with some exceptions of null association.[35] For instance, research from the Whitehall II study revealed that individuals with a higher (vs lower) employment grade tended to have lower concentrations of hsCRP, independent of age, sex, BMI, smoking, and alcohol drinking.[21] Previous studies pointed to the role of psychosocial work environment and health-related behaviors to explain occupational class inequalities in inflammation.[20] Workers in lower employment grade were found to have worse psychosocial work environment in European countries.[2,36] Elevated work-related stress was also known to be associated with increased risk of chronic systemic inflammation and cardiovascular disease.[37–39] For instance, a French population-based study found that work stress, indicated by a combination of perceived high-efforts and low-rewards at work, was associated with unfavorable

TABLE 2. Association Between Occupational Class and High-Sensitivity C-Reactive Protein (Log-Transformed, mg/L) Among All Participants ($n = 2{,}594$)

	Beta (95% CI)			
	Model 1[a]	Model 2[a]	Model 3[a]	Model 4[a]
White-collar workers	0.15* (0.00, 0.29)	0.16* (0.01, 0.30)	0.17* (0.02, 0.32)	0.16* (0.02, 0.30)
Pink-collar workers	0.02 (−0.09, 0.13)	0.03 (−0.08, 0.15)	0.04 (−0.07, 0.16)	0.02 (−0.09, 0.13)
Blue-collar workers	Ref	Ref	Ref	Ref
Unemployed	0.11 (−0.07, 0.30)	0.15 (−0.04, 0.35)	0.16 (−0.03, 0.36)	0.14 (−0.04, 0.31)
Weekly working hours:				
<40 vs 40–48 h/wk		0.00 (−0.10, 0.11)	0.00 (−0.10, 0.11)	−0.01 (−0.10, 0.09)
>48 vs 40–48 h/wk		0.01 (−0.09, 0.11)	−0.01 (−0.11, 0.10)	−0.01 (−0.11, 0.09)
Precarious work		0.06 (−0.03, 0.16)	0.07 (−0.03, 0.15)	0.05 (−0.04, 0.14)
Severe chronic condition		0.06 (−0.18, 0.30)	0.07 (−0.18, 0.31)	0.08 (−0.17, 0.34)
Current smokers (vs never smokers)			0.09 (−0.03, 0.21)	0.05 (−0.07, 0.18)
Former smokers			0.17** (0.05, 0.30)	0.15** (0.04, 0.27)
Physical activity (≥150 vs <150 min/wk)			0.00 (−0.12, 0.12)	−0.07 (−0.18, 0.04)
High-risk drinking			−0.09* (−0.17, −0.01)	−0.10** (−0.18, −0.02)
Perceived stress (high vs little)			0.04 (−0.05, 0.13)	0.01 (−0.08, 0.09)
Metabolic syndrome				0.29*** (0.17, 0.42)
Underweight (vs normal weight)				−0.25* (−0.45, −0.05)
Overweight				0.29*** (0.17, 0.40)
Obesity				0.48*** (0.36, 0.60)

[a]All models adjusted for age, gender, education, household income, residential area, and marital status.
***P-values <0.001.
**P-values <0.01.
*P-values <0.05.

TABLE 3. Association Between Occupational Class and High-Sensitivity C-Reactive Protein (Log-Transformed, mg/L) Among All Participants ($n = 2{,}594$)

		Beta (95% CI)			
Occupational Class (N, %)[a]	**Mean (SD) of hsCRP[b], mg/L**	**Model 1[c]**	**Model 2[d]**	**Model 3[e]**	**Model 4[f]**
Managers (N = 45, 1.7%)	0.86 (0.90)	0.01 (−0.26, 0.27)	0.02 (−0.24, 0.28)	0.02 (−0.24, 0.27)	−0.05 (−0.30, 0.20)
Professionals (N = 551, 22.8%)	1.17 (2.04)	0.17* (0.02, 0.33)	0.18* (0.03, 0.34)	0.20* (0.05, 0.35)	0.19* (0.04, 0.33)
Clerks (N = 440, 18.0%)	1.02 (1.74)	0.07 (−0.07, 0.22)	0.09 (−0.06, 0.24)	0.10 (−0.05, 0.25)	0.06 (−0.08, 0.20)
Service workers (N = 272, 9.4%)	1.02 (2.02)	−0.03 (−0.20, 0.14)	−0.03 (−0.20, 0.14)	−0.01 (−0.19, 0.16)	−0.04 (−0.20, 0.12)
Sales workers (N = 264, 9.8%)	0.90 (1.33)	0.02 (−0.12, 0.15)	0.03 (−0.11, 0.17)	0.03 (−0.11, 0.17)	0.03 (−0.11, 0.17)
Blue−collar workers (N = 816, 30.3%)	1.19 (2.09)	Ref	Ref	Ref	Ref
Unemployed (N = 206, 8.2%)	1.21 (2.20)	0.12 (−0.06, 0.31)	0.16 (−0.03, 0.36)	0.17 (−0.02, 0.37)	0.15 (−0.03, 0.32)

[a]Raw frequency and survey-adjusted percentage were presented.
[b]Survey-adjusted means and SDs were presented.
[c]Model 1 adjusted for age, gender, education, household income, residential area, and marital status
[d]Model 2 additionally adjusted for precarious employment, weekly working hours, and severe chronic condition, based on Model 1.
[e]Model 3 additionally adjusted for smoking, high-risk drinking, physical activity, and perceived stress, based on Model 2.
[f]Model 4 additionally adjusted for metabolic syndrome and body-mass index class.
*P-values <0.05.

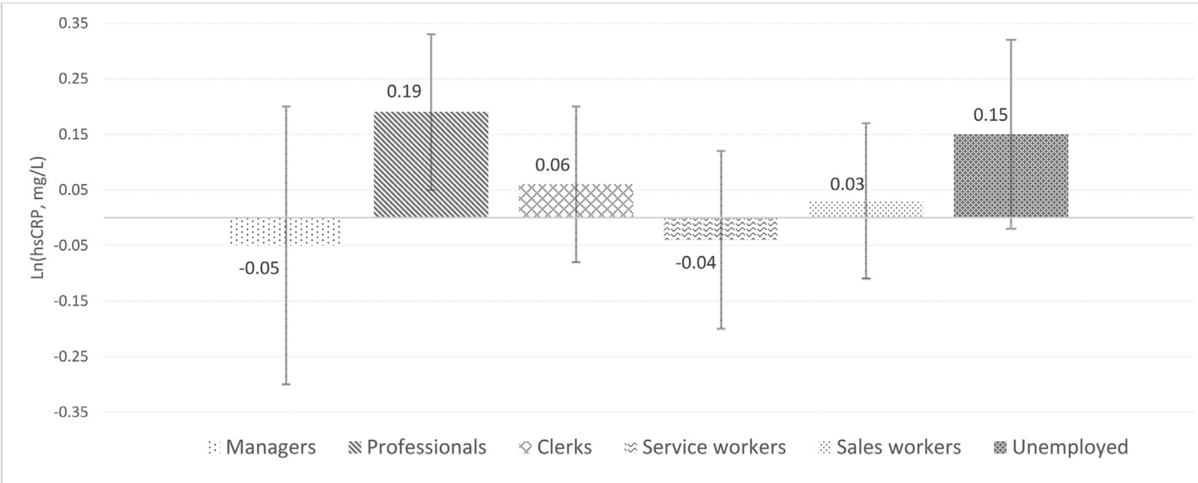

FIGURE 2. Multivariable-adjusted difference in log-transformed values of high-sensitivity C-reactive protein (mg/L) by occupational group (reference group: blue-collar workers) among Korean adults aged 19 to 65 years ($n=2594$). Note: The effects estimates were obtained by regression model that adjusted for complex survey design, as well as covariates such as age, sex, education, household income, marital status, urbanicity of residential region, precarious employment, weekly working hours, severe chronic condition, smoking, high-risk drinking, physical activity, perceived stress, metabolic syndrome, and body-mass index (BMI, kg/m^2) class. The reference group is set as blue-collar workers, including crafts, machine/device operators/assemblers, elementary-level laborers, and agricultural/forestry/fishery workers.

markers of systemic inflammation and metabolic functioning.[37] These findings from developed Western countries suggest that the disproportionate distribution of work stress may contribute to the inverse association between occupational grade and chronic inflammation.

Strikingly, in our analysis however, white-collar workers, particularly professionals, showed elevated levels of hsCRP compared with blue-collar workers, even after adjusting for an extensive range of sociodemographic, metabolic, and behavioral factors. While further prospective research is warranted, this suggests that professionals may be at an elevated risk of future CVD compared with blue-collar workers in South Korea.

More broadly, our findings are in line with the findings in the Japanese working population. For instance, Suzuki et al[12,13] found that, despite the overall decline in premature mortality and suicidal mortality among most of occupational classes during 1975 to 2005 in Japan, the rate was either stalled (for premature mortality) or even substantially increased among male managerial/administrative workers during the same period. Similarly, Wada et al[11] found that Japanese male managers/professionals had higher all-cause mortality rate compared with lower occupational grades during the period of 2000 to 2005.[40] Recently, Zaitsu et al[41,42] found the same pattern in the distribution of renal cell cancer with increased risk detected in higher occupational class (ie, managers and professionals) among men, which were partially mediated by cardiometabolic dysregulations such as obesity, hypertension, and diabetes.

To understand such counter-intuitive pattern in SES gradient among Asian populations, previous studies pointed to the interplay among economic condition, labor market environment, and traditional work-related ethics.[42] For instance, Japan experienced dramatic economic growth during 1960 to 1989, during which the country achieved the highest longevity around the world and life-long employment.[12,13] However, following the collapse of the asset bubble in the early 1990s, there was a substantial increase in precarious employment. Suzuki et al[12,13] suggested that the shift in labor market from life-long to precarious employment could result in elevated psychological distress and long working hours among male managerial and professional workers, which in turn contributed to the stalled decline in premature mortality and dramatic increase in suicidality among male managers and professionals in Japan. Similarly, Zaitsu et al[41,42] proposed that workers in higher positions may be more susceptible to elevated psychological distress since the Japanese tradition of "omotenashi," which emphases hospitality and customer satisfaction, could impose high levels of responsibility and psychological distress particularly to managers and professionals than workers in lower positions. This increased level of work-related stress could lead to increased risk of chronic diseases through both direct (eg, sustained hyper-activations in hypothalamic-pituitary-adrenal-axis and chronic inflammatory process) and indirect (eg, unhealthy coping behaviors such as smoking, heavy drinking, and physical inactivity) pathways.[41,42]

South Korea experienced similar trajectory in economic growth and labor market change as Japan. After the rapid economic growth during 1970 to 1996, Korea experienced economic crisis in 1997 to 1998, through which labor market flexibility has been substantially inflated. This resulted in increased job insecurity such as precarious employment and voluntary early retirement plans and prevalent long working hours.[43,44] Previous studies found that such work-place psychosocial adversities were associated with increased risk of cardiovascular disease[45–49] with exceptions of null association.[50] In the Korean context, precarious employment and long working hours were associated with adverse health outcomes such as hypertension,[43] suicidality,[51,52] and worse self-rated health.[44] However, in our sample, we were not able to find evidence of significant associations of work environments such as precarious employment and long working hours with levels of hsCRP. It is also possible that burn-out of professionals might explain such counter-intuitive relationship. Emerging evidence pointed to the burn-out of professionals in diverse settings such as healthcare, education, and technology in South Korea.[53,54] However, due to limited data availability, we were not able to test potential contribution of psychosocial work environment.

Our study has several limitations. First, since we used a cross-sectional design, we cannot infer causality. Second, due to limited measures in the survey, we were not able to examine the potential role of psychosocial work environment (ie, job demand-control and effort-reward imbalance) and perceived job insecurity in explaining the observed association. Also, due to the limited data availability, we were unable to examine such associations with other pro-inflammatory markers that predict cardiovascular disease risk (eg, IL-6 and TNFR2). However, our study used a nationally representative sample of the Korean working-age population, in which the findings were robust before and after the adjustments of an extensive range of sociodemographic, behavioral, and biological factors. To our knowledge, this is the first study to document the association between occupational class and inflammatory markers such as hsCRP among Koreans.

Our findings suggest that the levels of systemic inflammation may differ across occupational classes in South Korea, whereby white-collar workers, particularly professionals, have elevated levels of inflammatory markers such as hsCRP. This coincides with the prior evidence showing higher a prevalence of metabolic dysfunction among white-collar workers among Korean and an increased risk of mortality and suicidality among professionals and managers among Japanese populations. Our findings, together with these previous studies, suggest that professionals may be at elevated risk of cardiovascular disease, contradicting the conventional social gradients in health outcomes from many developed Western countries. Further investigation is warranted to verify such associations and understand the specific context and mechanisms that contribute to the counter-intuitive relationship among the populations.

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REFERENCES

1. Kawachi I, Daniels N, Robinson DE. Health disparities by race and class: why both matter. *Health affairs (Millwood)*. 2005;24:343–352.
2. Marmot M, Allen J, Bell R, et al. WHO European review of social determinants of health and the health divide. *Lancet*. 2012;380:1011–1029.
3. Chandola T, Britton A, Brunner E, et al. Work stress and coronary heart disease: what are the mechanisms? *Eur Heart J*. 2008;29:640–648.
4. Adler NE, Rehkopf DH. U.S. disparities in health: descriptions, causes, and mechanisms. *Annu Rev Public Health*. 2008;29:235–252.
5. Mackenbach JP, Stirbu I, Roskam AJ, et al. Socioeconomic inequalities in health in 22 European countries. *N Engl J Med*. 2008;358:2468–2481.
6. Pappas G, Queen S, Hadden W, Fisher G. The increasing disparity in mortality between socioeconomic groups in the United States, 1960 and 1986. *N Engl J Med*. 1993;329:103–109.
7. Marmot MG, Shipley MJ. Do socioeconomic differences in mortality persist after retirement? 25 year follow up of civil servants from the first Whitehall study. *BMJ*. 1996;313:1177–1180.
8. Stringhini S, Berkman L, Dugravot A, et al. Socioeconomic status, structural and functional measures of social support, and mortality: The British Whitehall II Cohort Study, 1985–2009. *Am J Epidemiol*. 2012;175:1275–1283.
9. Marmot MG, Shipley MJ, Hemingway H, Head J, Brunner EJ. Biological and behavioural explanations of social inequalities in coronary heart disease: the Whitehall II study. *Diabetologia*. 2008;51:1980–1988.
10. Matthews KA, Gallo LC, Taylor SE. Are psychosocial factors mediators of socioeconomic status and health connections? A progress report and blueprint for the future. *Ann N Y Acad Sci*. 2010;1186:146–173.
11. Wada K, Kondo N, Gilmour S, et al. Trends in cause specific mortality across occupations in Japanese men of working age during period of economic stagnation, 1980–2005: retrospective cohort study. *BMJ*. 2012;344:e1191.
12. Suzuki E, Kashima S, Kawachi I, Subramanian SV. Social and geographic inequalities in premature adult mortality in Japan: a multilevel observational study from 1970 to 2005. *BMJ Open*. 2012;2:e000425.
13. Suzuki E, Kashima S, Kawachi I, Subramanian S. Social and geographical inequalities in suicide in Japan from 1975 through 2005: a census-based longitudinal analysis. *PLoS One*. 2013;8:e63443.
14. Takao S, Kawakami N, Ohtsu T. Occupational class and physical activity among Japanese employees. *Soc Sci Med*. 2003;57:2281–2289.
15. Lee HE, Kim HR, Chung YK, Kang SK, Kim EA. Mortality rates by occupation in Korea: a nationwide, 13-year follow-up study. *Occup Environ Med*. 2016;73:329–335.
16. Song YM, Ferrer RL, Cho SI, Sung J, Ebrahim S, Davey Smith G. Socioeconomic status and cardiovascular disease among men: the Korean national health service prospective cohort study. *Am J Public Health*. 2006;96:152–159.
17. Ryu JY, Hong S, Kim CH, et al. Prevalence of the metabolic syndrome among Korean Workers by Occupational Group: Fifth Korean National Health and Nutrition Examination Survey (KNHANES) 2010. *Ann Occup Environ Med*. 2013;25:13.
18. Yoo S, Cho H-J, Khang Y-H. General and abdominal obesity in South Korea, 1998–2007: gender and socioeconomic differences. *Prev Med*. 2010;51:460–465.
19. Lee W, Yeom H, Yoon JH, et al. Metabolic outcomes of workers according to the International Standard Classification of Occupations in Korea. *Am J Ind Med*. 2016;59:685–694.
20. Fraga S, Marques-Vidal P, Vollenweider P, et al. Association of socioeconomic status with inflammatory markers: a two cohort comparison. *Prev Med*. 2015;71:12–19.
21. Owen N, Poulton T, Hay FC, Mohamed-Ali V, Steptoe A. Socioeconomic status, C-reactive protein, immune factors, and responses to acute mental stress. *Brain Behav Immun*. 2003;17:286–295.
22. Ramsay S, Lowe GD, Whincup PH, Rumley A, Morris RW, Wannamethee SG. Relationships of inflammatory and haemostatic markers with social class: results from a population-based study of older men. *Atherosclerosis*. 2008;197:654–661.
23. Stringhini S, Batty GD, Bovet P, et al. Association of lifecourse socioeconomic status with chronic inflammation and type 2 diabetes risk: the Whitehall II prospective cohort study. *PLoS Med*. 2013;10:e1001479.
24. Pedersen JM, Budtz-Jorgensen E, De Roos A, et al. Understanding the relation between socioeconomic position and inflammation in post-menopausal women: education, income and occupational prestige. *Eur J Public Health*. 2017;27:1074–1079.
25. Hemingway H, Shipley M, Mullen MJ, et al. Social and psychosocial influences on inflammatory markers and vascular function in civil servants (the Whitehall II study). *Am J Cardiol*. 2003;92:984–987.
26. Collaboration ERF. C-reactive protein concentration and risk of coronary heart disease, stroke, and mortality: an individual participant meta-analysis. *Lancet*. 2010;375:132–140.
27. Gimeno D, Ferrie JE, Elovainio M, et al. When do social inequalities in C-reactive protein start? A life course perspective from conception to adulthood in the Cardiovascular Risk in Young Finns Study. *Int J Epidemiol*. 2008;37:290–298.
28. Kweon S, Kim Y, Jang MJ, et al. Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). *Int J Epidemiol*. 2014;43:69–77.
29. Lee YB, Kim SY, Park YG, et al. Evaluation of socioeconomic status as a risk factor of pterygium using the Korean National Health and Nutrition Examination Survey 2010 to 2011: A STROBE-compliant article. *Medicine (Baltimore)*. 2017;96:e6343.
30. Yang S, Kim W, Choi KH, Yi YG. Influence of occupation on lumbar spine degeneration in men: the Korean National Health and Nutrition Examination Survey 2010–2013. *Int Arch Occup Environ Health*. 2016;89:1321–1328.
31. Lim S, Shin H, Song JH, et al. Increasing prevalence of metabolic syndrome in Korea: the Korean National Health and Nutrition Examination Survey for 1998–2007. *Diabetes care*. 2011;34:1323–1328.
32. Park JW, Park JS, Kim S, Park M, Choi H, Lim S. The association between long working hours and hearing impairment in noise unexposed workers: data from the 5th Korea National Health and Nutrition Examination Survey (KNHANES 2010–2012). *Ann Occup Environ Med*. 2016;28:55.
33. Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*. 2012;380:247–257.
34. Son M, Armstrong B, Choi JM, Yoon TY. Relation of occupational class and education with mortality in Korea. *J Epidemiol Community Health*. 2002;56:798–799.
35. Kivimaki M, Lawlor DA, Juonala M, et al. Lifecourse socioeconomic position, C-reactive protein, and carotid intima-media thickness in young adults: the cardiovascular risk in Young Finns Study. *Arterioscler Thromb Vasc Biol*. 2005;25:2197–2202.
36. Wahrendorf M, Dragano N, Siegrist J. Social position, work stress, and retirement intentions: a study with older employees from 11 European Countries. *Eur Soc Rev*. 2013;29:792–802.

37. Magnusson Hanson LL, Westerlund H, Goldberg M, et al. Work stress, anthropometry, lung function, blood pressure, and blood-based biomarkers: a cross-sectional study of 43,593 French men and women. *Sci Rep*. 2017;7:9282.
38. Clays E, De Bacquer D, Delanghe J, Kittel F, Van Renterghem L, De Backer G. Associations between dimensions of job stress and biomarkers of inflammation and infection. *J Occup Environ Med*. 2005;47:878–883.
39. Wirtz PH, von Kanel R. Psychological stress, inflammation, and coronary heart disease. *Curr Cardiol Rep*. 2017;19:111.
40. Tanaka H, Toyokawa S, Tamiya N, Takahashi H, Noguchi H, Kobayashi Y. Changes in mortality inequalities across occupations in Japan: a national register based study of absolute and relative measures, 1980–2010. *BMJ open*. 2017;7:e015764.
41. Zaitsu M, Kaneko R, Takeuchi T, Sato Y, Kobayashi Y, Kawachi I. Occupational inequalities in female cancer incidence in Japan: hospital-based matched case-control study with occupational class. *SSM Popul Health*. 2018;5:129–137.
42. Zaitsu M, Cuevas AG, Trudel-Fitzgerald C, Takeuchi T, Kobayashi Y, Kawachi I. Occupational class and risk of renal cell cancer. *Health Sci Rep*. 2018;1:e49.
43. Seon JJ, Lim YJ, Lee HW, et al. Cardiovascular health status between standard and nonstandard workers in Korea. *PLoS One*. 2017;12:e0178395.
44. Kim MH, Kim CY, Park JK, Kawachi I. Is precarious employment damaging to self-rated health? Results of propensity score matching methods, using longitudinal data in South Korea. *Soc Sci Med*. 2008;67:1982–1994.
45. Kivimäki M, Kawachi I. Work stress as a risk factor for cardiovascular disease. *Curr Cardiol Rep*. 2015;17:74.
46. Kivimaki M, Nyberg ST, Batty GD, et al. Job strain as a risk factor for coronary heart disease: a collaborative meta-analysis of individual participant data. *Lancet*. 2012;380:1491–1497.
47. Bannai A, Tamakoshi A. The association between long working hours and health: a systematic review of epidemiological evidence. *Scand J Work Environ Health*. 2014;40:5–18.
48. Lee S, Colditz GA, Berkman LF, Kawachi I. Prospective study of job insecurity and coronary heart disease in US women. *Ann Epidemiol*. 2004;14:24–30.
49. Non AL, Rimm EB, Kawachi I, Rewak MA, Kubzansky LD. The effects of stress at work and at home on inflammation and endothelial dysfunction. *PLoS One*. 2014;9:e94474.
50. Lee S, Colditz G, Berkman L, Kawachi I. A prospective study of job strain and coronary heart disease in US women. *Int J Epidemiol*. 2002;31:1147–1153. discussion 1154.
51. Han KM, Chang J, Won E, Lee MS, Ham BJ. Precarious employment associated with depressive symptoms and suicidal ideation in adult wage workers. *J Affect Disord*. 2017;218:201–209.
52. Min K-B, Park S-G, Hwang SH, Min J-Y. Precarious employment and the risk of suicidal ideation and suicide attempts. *Prev Med*. 2015;71:72–76.
53. Kim HS, Yeom HA. The association between spiritual well-being and burnout in intensive care unit nurses: a descriptive study. *Intensive Crit Care Nurs*. 2018;46:92–97.
54. Yoon HS, Sok SR. Experiences of violence, burnout and job satisfaction in Korean nurses in the emergency medical centre setting. *Int J Nurs Pract*. 2016;22:596–604.