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Socioeconomic Disparities in the Association Between All-Cause Mortality and Health Check-Up Participation Among Healthy Middle-Aged Workers: A Nationwide Study

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ABSTRACT



Background: This study assessed the relationship between non-participation in health check-ups and all-cause mortality and morbidity, considering socioeconomic status.

Methods: Healthy, middle-aged (35–54 years) working individuals who maintained either self-employed or employee status from 2006–2010 were recruited in this retrospective cohort study from the National Health Insurance Service in Korea. Health check-up participation was calculated as the sum of the number of health check-ups in 2007–2008 and 2009–2010. Adjusted hazard ratio (HR) and 95% confidence interval (CI) of all-cause mortality were estimated for each gender using multivariable Cox proportional hazard models, adjusting for age, income, residential area, and employment status. Interaction of non-participation in health check-ups and employment status on the risk of all-cause mortality was further analyzed.

Results: Among 4,267,243 individuals with a median 12-year follow-up (median age, 44; men, 74.43%), 89,030 (2.09%) died. The proportion (number) of deaths of individuals with no, one-time, and two-time participation in health check-ups was 3.53% (n = 47,496), 1.66% (n = 13,835), and 1.33% (n = 27,699), respectively. The association between health check-up participation and all-cause mortality showed a reverse J-shaped curve with the highest adjusted HR (95% CI) of 1.575 (1.541–1.611) and 1.718 (1.628–1.813) for men and women who did not attend any health check-ups, respectively. According to the interaction analysis, both genders showed significant additive and multiplicative interaction, with more pronounced additive interaction among women who did not attend health check-ups (relative excess risk due to interaction, 1.014 [0.871–1.158]).

Conclusion: Our study highlights the significant reverse J-shaped association between health check-up participation and all-cause mortality. A pronounced association was found among self-employed individuals, regardless of gender.

Keywords: All-Cause Mortality; Health Check-Ups; Nationwide Study; Self-Employed; Socioeconomic Status

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Disclosure

The authors have no potential conflicts of interest to disclose.

Data Availability Statement

Data and study materials are not available to other researchers.

Author Contributions

Conceptualization: Yun B, Oh J, Choi J, Rozek L, Sim J, Lee J, Yoon JH. Data curation: Yun B, Oh J. Formal analysis: Yun B, Oh J, Kim Y. Funding acquisition: Yoon JH. Investigation: Yun B, Choi J, Park H, Lee J, Yoon JH. Methodology: Yun B, Oh J, Kim Y, Yoon JH. Project administration: Yoon JH. Resources: Yun B, Yoon JH. Software: Yun B, Yoon JH. Supervision: Yoon JH. Validation: Oh J, Choi J, Rozek L, Sim J. Visualization: Yun B, Park H. Writing - original draft: Yun B. Writing - review & editing: Choi J, Rozek L, Sim J, Yoon JH.

INTRODUCTION

Periodic health check-ups have been used as a medical practice for preventing various diseases.¹⁻³ Several countries, including Great Britain, Germany, the Netherlands, Australia, Japan, and the United States, provide periodic health check-ups for preventive purposes.³⁻⁸ According to the Framework Act on Health Examination, the Republic of Korea's government also provides complementary health check-up for all employees and heads of households for the early detection, diagnosis, and treatment of diseases.⁹ Given that periodic health check-ups are a free well-known government service, examining vulnerable populations excluded from complimentary national health check-ups might be important for the social aspect of preventive health services.

Initially, periodic health check-ups in Korea focused mainly on the working population. Since 1995, the services have been expanded to the self-employed and dependents aged 40 years and older.¹⁰ In 2008, the Organization for Economic Co-operation and Development (OECD) reported that the ranking for the proportion of the self-employed population in the Republic of Korea was sixth among the OECD countries, followed by China, Turkey, Greece, Mexico, and Brazil.¹¹ However, significantly fewer self-employed individuals than standard workers attended regular health check-ups.¹² This disparity in health check-up participation might contribute to subsequent health outcomes, making further research in this area crucial.¹³ Furthermore, this discrepancy might even be more pronounced for middle-aged individuals according to their employment status due to unmet needs on healthcare services.¹⁴

Several observational studies have explored the association between participating in health check-ups and all-cause mortality or cardiovascular comorbidities in the Republic of Korea.^{15,16} However, these studies did not specifically investigate the varying proportions and extent of health effects related to health check-up participation among working populations. Therefore, there is a research gap concerning whether the association between non-participation in health check-ups and the increased risk of health outcomes might differ based on employment status and related socioeconomic characteristics.

Hence, this study aimed to assess the relationship between participation in health check-ups and all-cause mortality or comorbidities among healthy, middle-aged workers considering several socioeconomic factors in a large nationwide cohort with a long-term follow-up period.

METHODS**Data and study population**

Data from the entire population of the Republic of Korea registered in the National Health Insurance Service (NHIS) database were used. The NHIS database includes demographic and socioeconomic characteristics; records of hospitalizations, outpatients, health check-ups, and medical procedures; and prescriptions of all citizens in Korea, covering 97.2% of the entire population from 2002 to 2022.¹⁷ Moreover, in the Republic of Korea, the NHIS divides all citizens into several categories based on insurance type: heads of the household who are self-employed and their household members, employees and their household members and medical aid beneficiaries. The inclusion criteria were defined as individuals aged 35–54 years who maintained the same type of insurance, either employee or self-employed (heads of the household) for at least 5 years (2006–2010), representing the middle-aged working

population in the Republic of Korea. Unemployed and medical aid recipients were not included since this study aimed to assess the effect of non-participation in health check-ups among the working population, whose income level is recorded.

The index date was defined as January 2011. The washout period was set from January 2002 to December 2010 to exclude patients with diseases included in Charlson Comorbidity Index (CCI) disease list^{18,19} (**Supplementary Table 1**). The exclusion criteria were as follows: 1) foreigners or disabled based on the disability registration system implemented by the Korean government in 1988²⁰; 2) missing information, including region and income; and 3) history of any diseases included in CCI.

Outcomes and variables

The primary outcome was all-cause mortality. The secondary outcomes were the incidences of morbidities including all types of malignancies (except thyroid and basal cell skin cancer), cardiovascular diseases, and mental disorders. The participants were followed up until death or December 2022, whichever came first. In the analyses of secondary outcomes, participants were followed up until the incidence of the target diseases, death, or last follow-up date, which was December 2022.

According to recommendations from the Korean government, all heads of households should undergo the national health check-up every 2 years since 1995, regardless of the insurance type.²¹ During health check-ups, each participant underwent physical measurements and answered several health-related questionnaires. Health check-up participation was divided into three groups, as follows: none (0), one-time (1), and two-time (2). The response of one or more health check-up participations in 2007–2008 and in 2009–2010 were each converted into binary variables, yes (1) or no (0). Health check-up participation was estimated as the sum of health check-up participations in 2007–2008 and 2009–2010.

All covariates related to demographic (age and gender) and socioeconomic (employment status and income level traits) characteristics were defined based on the annual updated information for each individual from the NHIS. Age group was divided into the following 5-yearly categories: 35–39, 40–44, 45–49, and 50–54 years. Employment status of participants was categorized as self-employed and employee-insured, based on their insurance type. Participants were divided into quartiles based on their income level, determined according to the insurance premium paid to the NHIS. Participants' residential areas were divided into Seoul, other metropolitan cities, Gyeonggi, and other provinces. All diseases were defined according to the International Classification of Diseases, Tenth Revision codes (**Supplementary Table 1**). The diagnosis date of cardiovascular diseases and mental disorders was defined as the earliest date of any hospitalization related to the disease. For cancer, the earliest date with a "V193" code according to the government program for rare and intractable diseases was applied to extract the diagnosis date.

Statistical analyses

Baseline characteristics of all individuals according to employment status and gender were reported as frequencies (percent) and compared using the χ^2 test. The incidence rates were calculated as the number of cases per 100,000 person-years, and 95% confidence intervals (CIs) were estimated using Poisson distribution. All analyses were stratified according to gender. Adjusted hazard ratios (HRs) and 95% CIs of the outcomes by non-participation in health check-ups were estimated for both genders using multivariable Cox proportional

hazard models. Model 1 was adjusted for age. Model 2 was adjusted for age, gender, income level, residential area, and employment status.

Moreover, subgroup analysis stratified by employment status was implemented. We further analyzed the interaction between non-participation in health check-ups and employment status on the risk of all-cause mortality. The extent and significance of this interaction were measured through multiplicative and additive methods, specifically the relative excess risk due to interaction (RERI).²²⁻²⁴ Within the framework of two binary factors, denoted as A and B, and considering the presence or absence of these factors indicated by "+" and "-", respectively, the RERI can be mathematically represented using the following formula involving relative risks (RR):

$$\text{RERI} = \text{RR}_{A+B+} - \text{RR}_{A+B-} - \text{RR}_{A-B+} + 1$$

The same analyses were performed for the interaction between non-participation in health check-ups and income level and the risk of all-cause mortality. In the interaction analysis, income level was categorized as either high or low, using the median value of insurance premiums paid as the dividing threshold. All analyses were performed using R, version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria) and SAS Enterprise, version 8.2 (SAS Institute, Cary, NC, USA).

Ethics statement

This study adhered to the ethical principles of the 1975 Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of Yonsei University Hospital (IRB number: 4-2022-0813). The need for informed consent was waived owing to the retrospective nature of the study.

RESULTS

Participant baseline characteristics

Of 6,928,666 participants who were consistently self-employed (head of the household) or employed aged 35–54 years of the entire population of the Republic of Korea in 2006–2010, 4,267,243 participants were included in the analysis after applying the exclusion criteria (**Supplementary Fig. 1**). The median (interquartile range) age of all the participants was 44 (range: 39–48) years, and the proportion of men was 74.43%.

The proportion of individuals among the entire population who participated in health check-ups was as follows: 48.93% (n = 2,088,069) for two times, 19.56% (n = 834,841) for one-time, and 31.50% (n = 1,344,333) for none. Regarding employment status, the proportion of non-participation was significantly higher in the self-employed group (69.22%; n = 1,049,911) than in the employee group (10.70%; n = 294,422). For all individuals, older age was significantly associated with less non-participation for both genders and all employment categories. In the self-employed group, lower income level was significantly associated with more non-participation in health check-ups (**Tables 1 and 2**).

Incidence and risk of all-cause mortality and secondary outcomes by number of health check-ups

Over a median follow-up of 12 years, 2.09% (n = 89,030) of the individuals died: 3.53% (n = 47,496) representing non-participation, 1.66% (n = 13,835) representing one-time

Table 1. Baseline characteristics of individuals stratified by gender, employment status, and health check-up participation (men)

Variables	Self-employed (n = 1,118,235)			P value	Employee (n = 2,057,799)			P value
	None (n = 796,149)	One-time (n = 235,268)	Two-times (n = 86,818)		None (n = 228,948)	One-time (n = 368,242)	Two-times (n = 1,460,609)	
Age group, yr				< 0.001				< 0.001
35–39	156,019 (87.23)	19,336 (10.81)	3,498 (1.96)		58,321 (9.08)	114,389 (17.8)	469,934 (73.13)	
40–44	221,618 (72.98)	65,074 (21.43)	16,968 (5.59)		67,905 (11.1)	119,596 (19.55)	424,116 (69.34)	
45–49	227,830 (68.63)	75,959 (22.88)	28,177 (8.49)		57,592 (12.66)	77,795 (17.1)	319,487 (70.24)	
50–54	190,682 (62.77)	74,899 (24.66)	38,175 (12.57)		45,130 (12.94)	56,462 (16.19)	247,072 (70.86)	
Income				< 0.001				< 0.001
Low	303,977 (84.04)	46,274 (12.79)	11,434 (3.16)		57,052 (22.75)	67,012 (26.72)	126,730 (50.53)	
Low-middle	182,401 (74.17)	47,588 (19.35)	15,944 (6.48)		52,596 (9.37)	99,444 (17.72)	409,194 (72.91)	
High-middle	142,560 (64.43)	56,562 (25.56)	22,149 (10.01)		38,818 (6.28)	89,277 (14.44)	490,021 (79.28)	
High	167,211 (57.79)	84,844 (29.32)	37,291 (12.89)		80,482 (12.82)	112,509 (17.93)	434,664 (69.25)	
Residential area				< 0.001				< 0.001
Seoul	173,567 (73.93)	45,345 (19.31)	15,864 (6.76)		70,442 (16.41)	99,842 (23.26)	258,922 (60.33)	
Other metropolitan cities	192,876 (69.98)	59,533 (21.6)	23,200 (8.42)		46,264 (8.79)	79,693 (15.14)	400,379 (76.07)	
Gyeonggi	195,749 (71.55)	57,379 (20.97)	20,471 (7.48)		63,182 (11.49)	107,133 (19.49)	379,399 (69.02)	
Other provinces	233,957 (69.99)	73,011 (21.84)	27,283 (8.16)		49,060 (8.88)	81,574 (14.76)	421,909 (76.36)	

Table 2. Baseline characteristics of individuals stratified by gender, employment status, and health check-up participation (women)

Variables	Self-employed (n = 398,625)			P value	Employee (n = 692,584)			P value
	None (n = 253,762)	One-time (n = 102,432)	Two-times (n = 42,431)		None (n = 65,474)	One-time (n = 128,899)	Two-times (n = 498,211)	
Age group, yr				< 0.001				< 0.001
35–39	60,221 (85.43)	8,568 (12.16)	1,700 (2.41)		25,325 (11.4)	49,910 (22.46)	146,943 (66.14)	
40–44	71,890 (64.67)	30,391 (27.34)	8,877 (7.99)		18,337 (9.22)	39,702 (19.95)	140,939 (70.83)	
45–49	66,200 (58.29)	33,142 (29.18)	14,235 (12.53)		12,983 (8.21)	24,012 (15.19)	121,118 (76.6)	
50–54	55,451 (53.63)	30,331 (29.33)	17,619 (17.04)		8,829 (7.79)	15,275 (13.48)	89,211 (78.73)	
Income				< 0.001				< 0.001
Low	137,298 (70.35)	42,639 (21.85)	15,236 (7.81)		25,643 (9.9)	48,840 (18.85)	184,657 (71.26)	
Low-middle	48,755 (60.67)	22,018 (27.4)	9,582 (11.92)		15,867 (8.85)	32,838 (18.32)	130,558 (72.83)	
High-middle	35,342 (56.32)	18,779 (29.92)	8,633 (13.76)		11,397 (6.94)	28,293 (17.22)	124,584 (75.84)	
High	32,367 (53.64)	18,996 (31.48)	8,980 (14.88)		12,567 (13.98)	18,928 (21.05)	58,412 (64.97)	
Residential area				< 0.001				< 0.001
Seoul	62,011 (64.78)	23,803 (24.87)	9,908 (10.35)		23,343 (14)	38,433 (23.05)	104,941 (62.95)	
Other metropolitan cities	62,320 (61.84)	26,742 (26.53)	11,721 (11.63)		12,571 (7.04)	28,748 (16.11)	137,150 (76.85)	
Gyeonggi	59,964 (63.79)	24,407 (25.96)	9,637 (10.25)		17,098 (10)	33,928 (19.85)	119,871 (70.14)	
Other provinces	69,467 (64.25)	27,480 (25.42)	11,165 (10.33)		12,462 (7.06)	27,790 (15.74)	136,249 (77.19)	

Values are expressed by number (%).

participation, and 1.33% (n = 27,699) representing two-time participation. For both genders, mortality rate (per 100,000 person-years) was the highest in the self-employed, non-participation group (men: 386.66 [382.68–390.66] and women: 184.71 [179.90–189.63]) (**Fig. 1**). Regarding secondary outcomes, the non-participation group had a higher incidence of cardiovascular and mental diseases, notably in the self-employed group (**Supplementary Table 2**).

All models presented a significant relationship between less number of health check-ups and an increased risk of all-cause mortality after adjusting for age, income level, residential area, and employment status (**Table 3**). The relationship showed a reverse J-shaped association with the highest adjusted HR (95% CI) of 1.575 (1.541–1.611) and 1.718 (1.628–1.813) for men and women, respectively, in the non-participation group. Concerning secondary outcomes (**Supplementary Table 3**), the risk of cardiovascular diseases and mental diseases were significantly higher in the non-participation group than in the participation group (men: adjusted HRs [95% CIs], 1.324 [1.292–1.355] versus 1.272 [1.224–1.322] and women: 1.381

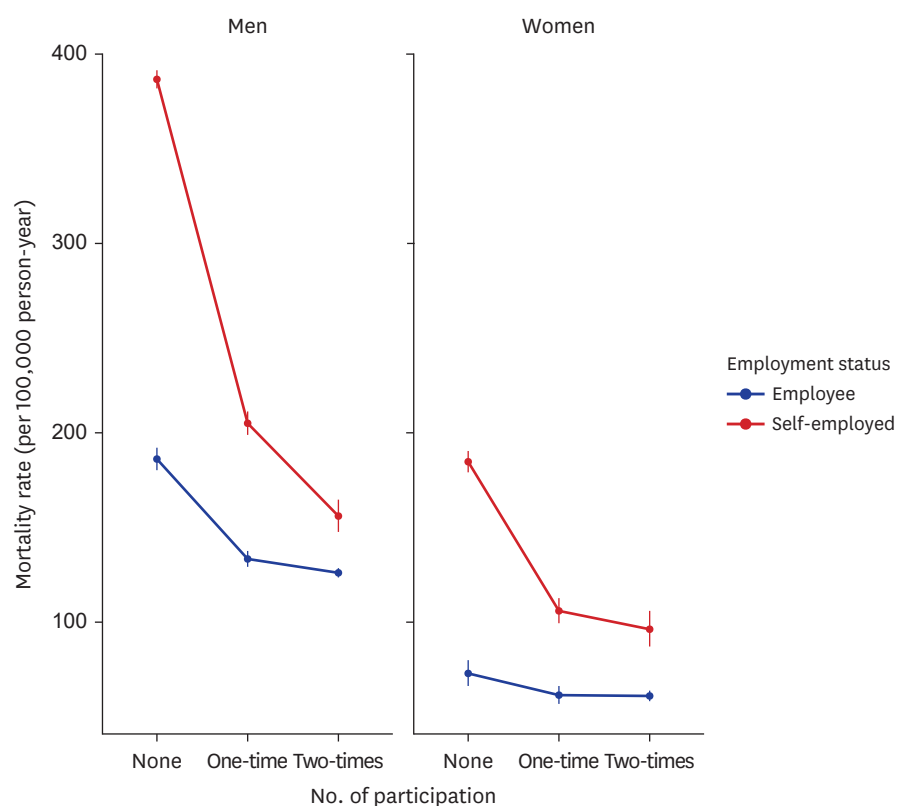


Fig. 1. Incidence rate of all-cause mortality according to health check-up participation stratified by gender.

[1.276–1.494] versus 1.414 [1.330–1.504]), while the risk of cancer was minimally increased or not significant.

Risk of all-cause mortality associated with the number of health check-ups by employment status

The results of the stratification analysis by gender and employment status are shown in Fig. 2. The relationship between the risk of all-cause mortality and number of health check-ups showed reverse J-shaped associations in all four groups: employed/self-employed men and women. The risk of all-cause mortality was the highest for the self-employed, non-participation group for both genders (men: adjusted HR [95% CI], 2.277 [2.165–2.395] and women: 2.007 [1.828–2.205]).

Table 3. Multivariable cox proportional hazard models of all-cause mortality by participating health check-up

Variables	Participating health check-up	Adjusted HR (95% CI)		
		Crude	Model 1	Model 2
Men	Two-times	1.000 (reference)	1.000 (reference)	1.000 (reference)
	One-time	1.263 (1.235–1.291)	1.176 (1.150–1.202)	0.973 (0.951–0.997)
	None	2.681 (2.638–2.724)	2.446 (2.407–2.486)	1.575 (1.541–1.611)
Women	Two-times	1.000 (reference)	1.000 (reference)	1.000 (reference)
	One-time	1.272 (1.209–1.339)	1.265 (1.202–1.332)	1.034 (0.977–1.094)
	None	2.538 (2.440–2.640)	2.528 (2.430–2.630)	1.718 (1.628–1.813)

Model 1: adjusted for age; Model 2: adjusted for age, income level, residential area, and employment status.

HR = hazard ratio, CI = confidence interval.

Association Between All-Cause Mortality and Health Check-Up Participation

Employment status	No. of health check-ups	No. of cohort	Person-year	Rate (per 100,000 person-year)	Adjusted HR (95% CI)
Men employee	Two-times	1,460,609	17,418,512	126.06	1.000 (reference)
	One-time	368,242	4,389,787	133.38	1.037 (1.007–1.068)
	None	228,948	2,722,157	186.14	1.334 (1.293–1.377)
Men self-employed	Two-times	86,818	1,035,020	156.04	1.000 (reference)
	One-time	235,268	2,797,622	205.03	1.337 (1.265–1.413)
	None	796,149	9,383,783	386.66	2.277 (2.165–2.395)
Women employee	Two-times	498,211	5,961,396	61.03	1.000 (reference)
	One-time	128,899	1,542,367	61.46	1.106 (1.029–1.189)
	None	65,474	782,930	72.93	1.296 (1.185–1.417)
Women self-employed	Two-times	42,431	506,958	96.26	1.000 (reference)
	One-time	102,432	1,223,282	105.94	1.141 (1.028–1.267)
	None	253,762	3,018,165	184.71	2.007 (1.828–2.205)

Fig. 2. The association between non-participation in health check-ups and the risk of all-cause mortality stratified by gender and employment status. HR = hazard ratio, CI = confidence interval.

Interaction between non-participation and employment status on the risk of all-cause mortality

According to the interaction analysis (Table 4), both genders showed significant additive and multiplicative interaction, with a more pronounced additive interaction among women (RERI, 1.014 [0.871–1.158]). The risk of all-cause mortality in the self-employed, non-participation group was significantly increased by 108% and 172% for men and women, respectively, compared with that in the employees who participated in either one-time or two-time health check-ups.

In the interaction analysis based on employment status (Table 5), the self-employed group showed significant additive interaction between low-income and non-participation in health check-ups on the risk of all-cause mortality for both genders. The risk of all-cause mortality

Table 4. Interaction between non-participation in health check-ups and employment status on the risk of all-cause mortality

Health check-ups		Employment status						Adjusted HR (95% CI) for self-employed within strata of health check-up participation
		Employee			Self-employed			
		Person-year	Rate	Adjusted HR (95% CI)	Person-year	Rate	Adjusted HR (95% CI)	
Men								
Participation	21,808,298	127.53	1.000	3,832,642	191.8	1.096 (1.068–1.125)	1.096 (1.068–1.125)	
Non-participation	2,722,157	186.14	1.257 (1.219–1.295)	9,383,783	386.66	2.084 (2.050–2.119)	1.659 (1.610–1.708)	
Adjusted HR (95% CI) for non-participation in health check-ups within strata of employment status			1.257 (1.219–1.295)			1.902 (1.854–1.951)	Additive scale (RERI): 0.732 [0.683–0.780] Multiplicative Scale: 1.514 [1.456–1.574]	
Women								
Participation	7,503,763	61.12	1.000	1,730,240	103.11	1.437 (1.359–1.519)	1.437 (1.359–1.519)	
Non-participation	782,931	72.93	1.271 (1.165–1.387)	3,018,165	184.71	2.723 (2.617–2.833)	2.142 (1.964–2.335)	
Adjusted HR (95% CI) for non-participation in health check-ups within strata of employment status			1.271 (1.165–1.387)			1.895 (1.795–2.000)	Additive scale (RERI): 1.014 [0.871–1.158] Multiplicative Scale: 1.490 [1.345–1.651]	

All models were adjusted for age, income level, and residential area. Rates are expressed per 100,000 person-years. HR = hazard ratio, CI = confidence interval, RERI = relative excess risk due to interaction.

Table 5. Interaction between non-participation in health check-ups and income level on the risk of all-cause mortality stratified by employment status and gender

Health check-ups	Income level						Adjusted HR (95% CI) for low-income within strata of health check-up participation
	High			Low			
	Person-year	Rate	Adjusted HR (95% CI)	Person-year	Rate	Adjusted HR (95% CI)	
(A) Men, employee							
Participation	12,352,336	104.22	1.000	9,455,962	157.99	1.715 (1.675–1.756)	1.715 (1.675–1.756)
Non-participation	1,347,623	149.82	1.346 (1.284–1.410)	1,374,534	221.75	2.250 (2.163–2.341)	1.672 (1.581–1.769)
Adjusted HR (95% CI) for non-participation in health check-ups within strata of income level			1.346 (1.284–1.410)			1.312 (1.262–1.364)	Additive scale (RERI): 0.190 [0.086–0.294] Multiplicative Scale: 0.975 [0.917–1.036]
(B) Men, self-employed							
Participation	2,726,716	141.71	1.000	1,105,926	315.30	2.333 (2.228–2.442)	2.333 (2.228–2.442)
Non-participation	4,469,120	228.59	1.871 (1.802–1.941)	4,914,663	530.39	4.455 (4.306–4.609)	2.382 (2.328–2.437)
Adjusted HR (95% CI) for non-participation in health check-ups within strata of income level			1.871 (1.802–1.941)			1.910 (1.843–1.979)	Additive scale (RERI): 1.252 [1.150–1.354] Multiplicative Scale: 1.021 [0.970–1.075]
(C) Women, employee							
Participation	2,460,892	54.74	1.000	5,042,871	64.23	1.126 (1.056–1.201)	1.126 (1.056–1.201)
Non-participation	262,475	64.39	1.166 (0.994–1.369)	520,455	77.24	1.480 (1.324–1.654)	1.269 (1.060–1.519)
Adjusted HR (95% CI) for non-participation in health check-ups within strata of income level			1.166 (0.994–1.369)			1.314 (1.184–1.458)	Additive scale (RERI): 0.187 [–0.048–0.422] Multiplicative Scale: 1.127 [0.931–1.363]
(D) Women, self-employed							
Participation	815,418	76.40	1.000	914,822	126.91	1.704 (1.546–1.879)	1.704 (1.546–1.879)
Non-participation	1,031,144	12.13	1.779 (1.616–1.960)	1,987,020	217.71	3.235 (2.973–3.521)	1.818 (1.707–1.936)
Adjusted HR (95% CI) for non-participation in health check-ups within strata of income level			1.779 (1.616–1.960)			1.898 (1.778–2.026)	Additive scale (RERI): 0.751 [0.580–0.922] Multiplicative Scale: 1.067 [0.958–1.198]

All models were adjusted for age and residential area. Rates are expressed per 100,000 person-years.

HR = hazard ratio, CI = confidence interval, RERI = relative excess risk due to interaction.

in the low-income, self-employed, non-participation group was significantly higher than that of the high-income, self-employed, health check-up participation group (men: adjusted HR [95% CI] 4.455 [4.306–4.609] and women: 3.235 [2.973–3.521]).

DISCUSSION

Our study highlights a significant reverse J-shaped relationship between the number of health check-ups attended and increased risk of all-cause mortality for both genders, using a large nationwide cohort. The significantly increased risk of all-cause mortality among non-participants may have resulted from the increased risk of cardiovascular and mental diseases. Moreover, subgroup analysis found a prominent association between non-participation and all-cause mortality in the self-employed group for both genders. According to the interaction analysis, both genders showed a significant additive interaction between non-participation and employment status on the risk of all-cause mortality, while the interaction between non-participation and income level was significant in the self-employed group.

To the best of our knowledge, this was the first study to examine the inverse association between participation in health check-ups and all-cause mortality in terms of socioeconomic factors including employment status and income level. Previous studies conducted in the Republic of Korea have focused on medical factors and cost-effectiveness of health check-

ups, especially for cardiovascular disease, which is similar to our findings.^{15,16} In addition to medical factors, we explored a socioeconomically vulnerable working population, namely low-income, self-employed women who do not attend health check-ups. Moreover, our study enrolled approximately 14 million participants using a nationwide database. Given that the NHIS covers 97.2% of the entire population of the Republic of Korea, this study that did not use any sampling process has representativeness.²⁵

Participants with a low socioeconomic status might struggle to access health check-ups due to informational inequality and time/economic burden.²⁶⁻²⁸ The interaction analysis results showed that this relationship was significant in the self-employed group, regardless of gender. As the RERI values were larger than zero with statistical significance, the combined effect of employment status and health check-up non-participation is greater than their individual effects. This was also consistent with the combined effect of income level and health check-up non-participation in the self-employed group. According to article 175 of the Occupational Safety and Health Act in Korea, employers or employees shall be punished by administrative fine if they fail to provide or undergo health check-ups.²⁹ Unlike employees who are constantly managed by their company, self-employed individuals are significantly less likely to participate in health check-ups.¹² Therefore, self-employed individuals with lower income might be one of the most vulnerable populations in terms of the social aspects of health check-ups. Low socioeconomic status is significantly associated with a higher risk of mortality and comorbidities than that observed with high socioeconomic status.^{30,31} Promoting health examinations for the vulnerable group could be a useful first step towards reducing health disparities.

Several previous studies have elucidated the relationship between health check-up participation and a healthy lifestyle,^{32,33} which could be interpreted with health intentions and related behaviors. Individual and societal health can be improved via health intentions and behaviors, and health behaviors could be decided through multi-level approaches, including personal, environmental, and policy levels.^{34,35} Health check-ups in the Republic of Korea might be critical for reducing the information disparity in health effects. Moreover, increased healthy behavior intentions in the participation in health check-ups group might explain the increased risk of cardiovascular and mental diseases in the non-participation in health check-ups group. This result is consistent with those of previous studies that examined the importance of healthy lifestyle in patients with the above-mentioned diseases.³⁶⁻³⁸ Our study also found significant dose-response relationship between non-participation in health check-ups and the secondary outcomes. In addition, the increased risk of cardiovascular diseases among individuals who do not undergo health check-ups also strengthen the preventive role of health check-ups.¹⁰ Unlike cardiovascular and mental diseases, the extent of the association between cancer incidence and non-participation in health check-ups was minimal or insignificant.

This study had several limitations. First, we could not examine the causal relationship between participation in health check-ups and all-cause mortality as this was an observational study. Second, owing to limited information in the NHIS database for people covered by national insurance, unmeasured confounders, including lifestyle habits, subjective health status, and chronic disease status, may still have played an important role in our findings. To overcome and minimize this limitation, we restricted our sample to healthy workers with no history of diseases included in the CCI disease list and excluded foreigners and people with disabilities. However, further studies with abundant information are needed

for further clarification. Third, employment status and income level were indirectly inferred from the insurance type and paid insurance premium. Although several previous studies have used the same definition,³⁹⁻⁴² detailed employment status regarding employees being regular or precarious could not be clarified. A prospective study with more accurate information about socioeconomic status is necessary. Finally, this study did not consider private health check-ups performed by private hospitals or check-up institutions. However, these institutions usually use the national health check-up system for reimbursement of the cost of basic measurements and blood tests; therefore, most participants who undergo private health check-ups would have been included in the participation group.

In conclusion, our study highlights the significant reverse J-shaped association between number of health check-ups and all-cause mortality. A pronounced association was found among self-employed individuals, regardless of gender, and the highest risk of all-cause mortality was reported among low-income, self-employed women compared with low-income, employed women. Health check-ups should be appropriately promoted to high-risk populations, considering their socioeconomic traits.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1

ICD-10 code used for defining disease or procedure in the study

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Supplementary Table 2

The number (incidence rate) of mortality and secondary outcomes according to sex, employment status, and the number of health check-up participation

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Supplementary Table 3

Multivariable cox proportional hazard models of the secondary outcomes by participating health check-up

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Supplementary Fig. 1

Schematic flow chart of participant selection process

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