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Original article

Physical activity domains and suicidal ideation: Findings from a nationally representative Korean survey

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ABSTRACT

Background: Suicide is a major public health issue, and Korea has the highest suicide rate among OECD countries. Suicidal ideation is a precursor to suicide. Although physical activity benefits mental health, evidence for its link with suicidality is inconsistent, particularly regarding domain-specific effects. We examined domain-specific physical activity in relation to suicidal ideation in a nationally representative sample of Korean adults.
Methods: We analyzed data from 31,723 adults aged ≥19 years in the Korea National Health and Nutrition Examination Survey (2015–2023). Suicidal ideation was self-reported, and physical activity was measured with the WHO Global Physical Activity Questionnaire. The Metabolic equivalent (MET)-minutes/week for work, leisure, and transportation time were calculated separately. Multiple logistic regression with survey weights was used, with subgroup analyses by sex, age, and occupation. Exploratory mediation analysis was conducted to examine depression as a mediator in association between domain-specific physical activity and suicidal ideation.
Results: 4.8% of participants reported suicidal ideation. In men, high work activity remained significantly increased odds for suicide ideation, particularly among those aged 19–39 years (OR=2.21, 95% CI: 1.17–4.15) and in pink-collar workers (service and sales workers) (OR=3.36, 95% CI: 1.45–9.09), while high leisure activity was protective in those ≥60 years (OR=0.18, 95% CI: 0.07–0.48). No significant associations between physical activity and suicidal ideation were observed in women.
Conclusions: Domain-specific physical activity was differentially associated with suicidal ideation. Work-related activity increased risk in certain male subgroups, whereas leisure-time activity was protective in older men, underscoring the need to consider activity context in suicide prevention.

1. Introduction

Suicide is a leading cause of death worldwide, and Korea reports the highest suicide rate among OECD countries (Society at a Glance 2024, OECD). Suicidal ideation is a critical precursor to suicide attempts and deaths, and identifying and preventing suicidal ideation at an early stage is a crucial public health priority. Understanding the risk factors of suicidal ideation therefore provides the foundation for developing effective suicide prevention strategies.

Physical activity is well known to confer benefits for mental health, including reductions in depression, anxiety, and stress (Hachenberger et al., 2023; Herring et al., 2010; Pearce et al., 2022), and recent studies using objectively measured activity have demonstrated a causal protective effect against depression (Choi et al., 2019). However, evidence regarding the relationship between physical activity and suicidality remains inconsistent. While some studies have reported physical activity as a protective factor against suicidal ideation and suicide attempts (Huo et al., 2024; Laflamme et al., 2022), others have found no significant associations (Fabiano et al., 2023). A recent systematic review further suggested that among individuals with mental or other medical disorders, physical activity was associated with suicide attempts but not with suicidal ideation or suicide death (Fabiano et al., 2023), highlighting persistent uncertainty in this field.

In the context of suicidality, most prior studies have focused on the total volume of physical activity, with limited attention to differences across activity domains. Physical activity can be broadly classified into

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leisure-time, occupational, and transportation-related domains, each of which has distinct contextual characteristics and health implications (Bull et al., 2020). Several studies have reported protective associations of leisure-time activity with depression or suicidal ideation (Mikkelsen et al., 2010; Zhang et al., 2025), whereas occupational activity has been linked to null or even adverse mental health outcomes (Mizrahi et al., 2023; Park et al., 2025), and findings for transportation-related activity have been mixed (Zhang et al., 2025). These observations underscore the need to examine physical activity by domain to clarify their differential associations with suicidal ideation.

Among these domains, evidence regarding work-related physical activity and suicidal ideation remains particularly limited. Occupational physical activity varies substantially by job type, with blue-collar workers often engaging in physically demanding tasks and white-collar workers typically performing sedentary work (Sung et al., 2021). Such differences, together with occupational stress, job insecurity, and workplace social environments, may influence suicide risk through diverse psychosocial pathways (Niedhammer et al., 2020).

Patterns of physical activity also differ across sociodemographic characteristics such as sex and age. Men and women tend to engage in different types and intensities of physical activity, partly reflecting gendered occupational roles and social expectations (Kjellsson, 2021). In addition, overall physical activity levels and intensity generally decline with age (Martin et al., 2014). These variations suggest that the mental health implications of domain-specific physical activity may not be uniform across population subgroups, yet such heterogeneity has been insufficiently explored in relation to suicidal ideation.

Against this background, the present study aimed to investigate the associations between domain-specific physical activity (work, leisure, and transportation) and suicidal ideation in a nationally representative sample of Korean adults. We further explored whether these associations differed by sex, age, and occupational group to identify population-specific patterns and potentially vulnerable subgroups. Supplementary analyses examined suicidal planning and attempts, and, for associations observed with suicidal ideation, we assessed the potential mediating role of depression to gain insight into underlying psychological pathways.

2. Materials and methods

2.1. Data source and study participants

This study was based on data from the Korea National Health and Nutrition Examination Survey (KNHANES), an annual, nationally representative cross-sectional survey conducted by the Korea Disease Control and Prevention Agency (KDCA) to assess health behaviors, chronic disease prevalence, nutritional status, and health service utilization among the Korean population. KNHANES employs a stratified multistage probability sampling design, with enumeration districts and households serving as the primary and secondary sampling units, respectively. Within each selected enumeration district, a fixed number of households was systematically sampled, and all household members aged ≥1 year were eligible for face-to-face interviews (Kweon et al., 2014).

KNHANES consists of four components: a household screening survey, health interview survey, health examination survey, and nutrition survey. Trained interviewers conducted face-to-face structured interviews in selected households, and for some modules, a self-administered questionnaire was used. The survey covered a broad range of topics, including health behaviors, mental health, dietary intake, quality of life, and chronic disease prevalence. In addition, physical measurements and blood tests were conducted using mobile examination centers.

For this study, we restricted the analytic sample to adults aged ≥19 years with complete information on suicidal ideation, domain-specific physical activity (work, leisure, and transportation; MET-minutes), and prespecified covariates. Among 43,901 eligible participants from KNHANES 2015, 2017, 2019, 2021, 2022, and 2023, we excluded those with missing data on suicidal ideation ($n = 6878$), physical activity ($n = 4285$), or covariates ($n = 1015$), resulting in a final sample of 31,723 participants for the primary analysis (Fig. 1).

For a predefined subgroup analysis, we further restricted the sample to survey years with available information on physician-diagnosed depression (2015, 2017, 2019, and 2021), which also allowed more comprehensive ascertainment of comorbidities, including cancer. After applying the same inclusion criteria, 21,725 participants were included in this subgroup analysis (Fig. 1).

2.2. Measures

2.2.1. Suicidal behaviors and physical activity

Suicide ideation was assessed using a self-reported response to the question, “Have you seriously thought about committing suicide in the past year?” For supplementary analyses, suicidal planning and suicide attempts were assessed using the questions, “Have you made any specific plans to commit suicide in the past year?” and “Have you ever attempted suicide in the past year?”, respectively. Participants were categorized into binary groups (yes/no) for each outcome.

Physical activity was assessed using the Global Physical Activity Questionnaire (GPAQ) developed by the World Health Organization (WHO). MET-minutes per week were calculated by assigning 8.0 METs to vigorous-intensity activities and 4.0 METs to moderate-intensity activities, in accordance with WHO guidelines (WHO, 2012). Based on the total MET values, total physical activity levels were classified into three categories: low, moderate, and high, following the WHO recommendations.

To further examine the domain specific physical activity, MET values

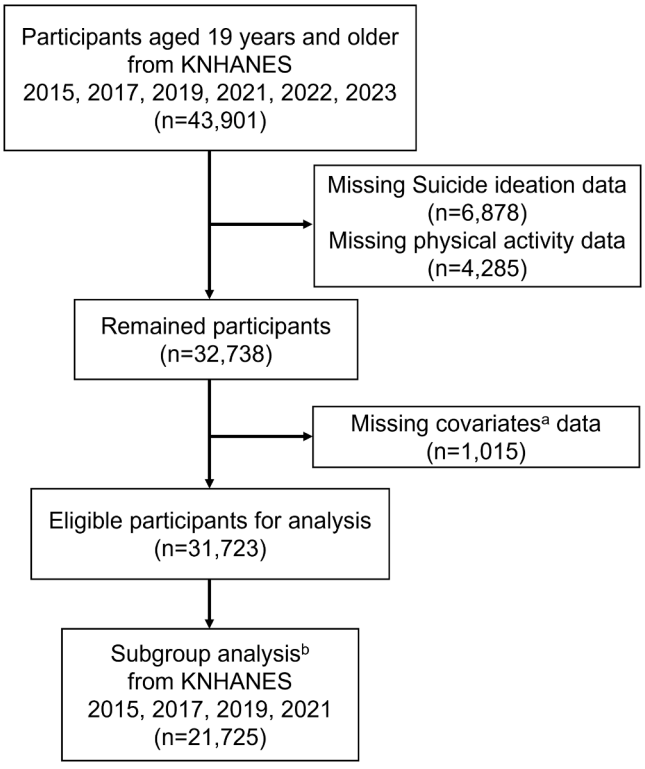

Fig. 1. Inclusion and exclusion flowchart of the study population
Covariates[a]: age, sex, income, marital status, occupation, education, BMI, comorbidity, smoking, drink
Subgroup analysis[b]: Using survey years with detailed medical history information, models were additionally adjusted for an extended set of comorbidities and depression diagnosis.

were separately calculated for activity domains. Physical activity data from the GPAQ were classified into three domains: work-related, leisure-time, and transportation activity. Work-related activity included physical tasks performed as part of paid or unpaid work, such as farming, construction, or household labor. Leisure-time activity encompassed sports, exercise, and other recreational physical activities performed during free time. Transportation activity referred to walking or cycling to get to and from places (WHO, 2012). Each domain-specific physical activity variable was analyzed as a binary variable. Given the skewed distribution of domain-specific MET values with a substantial proportion of zeros, participants reporting zero METs were separated, and the remaining non-zero values were divided into tertiles (low, moderate, high) within each domain. For the analysis, the zero, low, and moderate categories were combined and compared with the high activity group. The tertile thresholds were as follows: 0–1440 and ≥1512 MET-min/week for work-related activity, 0–1080 and ≥1088 MET-min/week for leisure-time activity, and 0–800 and ≥812 MET-min/week for transportation activity.

2.2.2. Covariates

In this study, a range of sociodemographic and health-related variables that could potentially confound the relationship between suicide ideation and physical activity were included as covariates. A directed acyclic graph (DAG) was constructed to identify plausible confounding pathways between domain-specific physical activity and suicidal ideation. Based on this framework, covariates were selected a priori, including sex, age, household income, marital status, occupation, educational attainment, smoking status, alcohol use, body mass index (BMI), comorbidity, and physician-diagnosed depression (Supplementary Figure 1).

Age was categorized into three groups to reflect the life stages of adults aged 19 years or older: 19–39 years (young adults), 40–59 years (middle-aged adults), and 60 years or older (older adults). Household income was based on self-reported monthly income collected through interviews, and participants were classified into quartiles according to the income distribution of each survey year. Marital status was dichotomized into married and non-married groups. Occupation was classified into four groups according to job characteristics and economic activity. Managers, professionals and related occupations, and office workers were categorized as white collar; service and sales workers as pink collar; skilled agricultural and fishery workers, craft and related trades workers, plant and machine operators and assemblers, and elementary occupations as blue collar; and housewives, students, and others not currently engaged in economic activity as unemployed or economically inactive (Sung et al., 2021). The classification of occupational groups is presented in Supplementary Table 1. Educational attainment was categorized into three groups: middle school graduation or less (≤11years), high school graduation (12–13 years), and college graduation or higher (≥14years).

Smoking status was based on self-reported current cigarette smoking and categorized into never smokers, former smokers, and current smokers. Participants who reported smoking every day or occasionally at the time of the survey were classified as current smokers, those who reported having smoked in the past but not currently were classified as former smokers, and those who reported never having smoked were classified as never smokers. Alcohol use was also assessed by self-report regarding alcohol consumption in the past year, and participants were classified as non-drinkers (no alcohol in the past year), occasional drinkers (less than once to four times per month), and frequent drinkers (two to four times per week or more) (Lee et al., 2023). Body mass index (BMI) was measured during health examinations using mobile examination vehicles and categorized into three groups: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), and overweight or obese (≥25 kg/m^2) (WHO, 2000).

Finally, comorbidity was assessed by summing the number of chronic conditions diagnosed among participants. In the main analysis using six years (2015–2023), comorbidity status was defined based on six conditions that were consistently available across all years: hypertension, dyslipidemia, diabetes, asthma, renal disease, and atopic dermatitis. Based on the total number of comorbidities, participants were classified into three groups: none (0), one (1), and two or more (≥2). For the subgroup analysis including only the survey years with detailed medical history information (2015, 2017, 2019, and 2021), a broader set of comorbidities was available and incorporated into the analysis. These included hypertension, dyslipidemia, stroke, myocardial infarction, angina, asthma, diabetes, gastric cancer, liver cancer, colon cancer, breast cancer, cervical cancer, lung cancer, thyroid cancer, other cancers, renal disease, liver cirrhosis and depression. Additionally, depression diagnosis was included as an additional covariate and modeled as a binary variable.

2.3. Statistical analysis

All analyses accounted for the complex sampling design of the KNHANES, and appropriate sample weights were applied to ensure national representativeness. First, we compared sociodemographic characteristics and physical activity levels—including WHO-based physical activity levels and domain-specific MET values for work, leisure, and transportation—between individuals with and without suicidal ideation. As all variables were categorical, chi-square tests were used to assess group differences.

Multiple logistic regression models were used to examine associations between suicidal ideation and physical activity. Using the low activity group as the reference, we estimated odds ratios (ORs) and 95 % confidence intervals (CIs) for moderate and high physical activity levels. We also evaluated the associations between suicidal ideation and domain-specific physical activity (work, leisure, and transportation MET). Covariates included in the models were sex, age group, household income quartile, marital status, occupational category, education level, smoking status, alcohol use, BMI, and comorbidity. These covariates were adjusted for in the main analysis using data from all six survey years (2015–2023). In the subgroup analysis limited to the four survey years with available information on physician-diagnosed depression (2015, 2017, 2019, and 2021), depression was additionally included as an adjustment variable.

Stratified analyses were conducted by sex, and sex-stratified models were further stratified by age group and occupational category to examine whether associations between domain-specific physical activity and suicidal ideation differed across subgroups.

In addition, exploratory mediation analyses were conducted to examine whether depression mediated the associations of significant physical activity variables (modeled as continuous variables) with suicidal ideation. Associations with suicidal planning and attempts were also examined.

Statistical significance was determined using two-sided tests with a significance threshold of $p < 0.05$. To account for multiple comparisons, Bonferroni correction was applied by multiplying the p-values by 4 accounting for the four physical activity domains (total, work-related, leisure-time, and transportation).

We calculated E-values for the observed odds ratio and the limit of the 95 % confidence interval closest to the null to assess the minimum strength of association that an unmeasured confounder would need to have with both exposure and outcome to fully explain away the observed association.

In addition, we conducted a quantitative bias analysis using a rule-out (deterministic) approach to evaluate the potential impact of unmeasured confounding. We examined a range of plausible scenarios by varying the prevalence of the confounder in the exposed group [$\Pr(U|E=1)$] from 20 % to 40 %, while fixing the prevalence in the unexposed group [$\Pr(U|E=0)$] at 10 %, and by varying the association between the confounder and suicidal ideation [OR(U,Y)] from 1.5 to 3.0. Bias-adjusted odds ratios were calculated under each scenario to assess

how strongly an unmeasured confounder would need to be associated with both exposure and outcome to attenuate the observed associations. All analyses were performed using R software (version 4.3.3).

3. Results

3.1. Baseline characteristics of the study population

Table 1 presents the sociodemographic and health-related characteristics of the study population according to the presence of suicide ideation. Individuals who reported suicide ideation were more likely to be female (62.0 % vs. 56.0 %, $p < 0.001$) and aged 60 years or older (44.4 % vs. 37.4 %, $p < 0.001$), compared to those without such experience.

Household income was significantly associated with suicide ideation ($p < 0.001$). The proportion of participants in the lowest income quartile was markedly higher among those with suicide ideation (36.7 %) than among those without (18.0 %). Similarly, the proportion of unmarried individuals was significantly greater in the suicide ideation group (22.2 % vs. 18.0 %, $p < 0.001$).

Occupational status also differed significantly between the two groups ($p < 0.001$). The proportion of white-collar workers was lower in the suicide ideation group (14.0 % vs. 25.7 %), while those categorized as unemployed or economically inactive were more prevalent in the suicide ideation group (53.5 % vs. 38.3 %). Educational attainment was also associated with suicide ideation; participants with middle school education or less accounted for a greater proportion of those with suicide ideation (44.0 % vs. 28.0 %, $p < 0.001$).

Health behavior variables showed differed significantly by suicide ideation status. Current smoking was more common among those with suicide ideation (25.9 % vs. 16.0 %, $p < 0.001$), and patterns of alcohol consumption also differed significantly ($p < 0.001$). In terms of body mass index (BMI), the proportion of individuals classified as overweight or obese (BMI ≥ 25) was higher in the suicide ideation group (38.9 % vs. 35.0 %, $p = 0.001$).

Multimorbidity was more frequently observed among those with suicide ideation. The proportion of participants with two or more comorbid conditions (e.g., hypertension, dyslipidemia, diabetes, asthma, renal disease, atopic dermatitis) was significantly higher in the suicide ideation group (29.7 % vs. 22.0 %, $p < 0.001$).

Significant group differences were also observed in physical activity levels. According to the WHO classification, individuals with suicide ideation were more likely to belong to the low physical activity group (68.4 % vs. 61.7 %, $p < 0.001$), with lower proportions in the moderate and high physical activity groups. Regarding type-specific physical activity, participants with suicide ideation were less likely to engage in high-level leisure-time physical activity (6.2 % vs. 10.1 %, $p < 0.001$). Although the proportion of individuals with high work-related METs was higher in the suicide ideation group (3.9 % vs. 3.0 %, $p = 0.041$), no statistically significant difference was observed in the levels of transport-related physical activity between the groups ($p = 0.421$).

3.2. Associations between domain-specific physical activity and suicide ideation

The associations between physical activity level and suicide ideation were examined (Fig. 2). Compared to the low physical activity group (Level 1), the moderate physical activity group (Level 2) showed lower odds of suicide ideation (OR = 0.86, 95 % CI: 0.74–1.00); however, this association was not statistically significant ($p = 0.056$, adjusted $p = 0.224$). The high physical activity group (Level 3) exhibited a slightly elevated odds of suicide ideation (OR = 1.17, 95 % CI: 0.93–1.47, $p = 0.187$), which also remained non-significant after correction (adjusted $p = 0.748$).

Analysis by domain-specific types of physical activity revealed that individuals with high work-related MET levels had a significantly higher

Table 1
Baseline characteristics by presence of suicide ideation.

		No suicide ideation		Suicide ideation		
		$N = 30,202$		$N = 1521$		
		N(%)		N(%)		p-value
Sex						**<0.001*****
	Men	13,299	(44.0)	578	(38.0)	
	Women	16,903	(56.0)	943	(62.0)	
Age, years						**<0.001*****
	19–39	7706	(25.5)	386	(25.4)	
	40–59	11,214	(37.1)	459	(30.2)	
	≥60	11,282	(37.4)	676	(44.4)	
Income						**<0.001*****
	Low	5441	(18.0)	558	(36.7)	
	Lower-middle	7340	(24.3)	382	(25.1)	
	Upper-middle	8305	(27.5)	306	(20.1)	
	High	9116	(30.2)	275	(18.1)	
Marital status						**<0.001*****
	Married	24,780	(82.0)	1183	(77.8)	
	Unmarried	5422	(18.0)	338	(22.2)	
Occupation						**<0.001*****
	White collar[a]	7749	(25.7)	213	(14.0)	
	Pink collar[a]	3792	(12.6)	173	(11.4)	
	Blue collar[a]	7106	(23.5)	321	(21.1)	
	Unemployed or Economic inactive[a]	11,555	(38.3)	814	(53.5)	
Education						**<0.001*****
	Middle school or less	8451	(28.0)	669	(44.0)	
	High school graduate	9993	(33.1)	509	(33.5)	
	College graduate or higher	11,758	(38.9)	343	(22.6)	
Smoking status						**<0.001*****
	Never smoker	18,415	(61.0)	802	(52.7)	
	Former smoker	6945	(23.0)	325	(21.4)	
	Current smoker	4842	(16.0)	394	(25.9)	
Alcohol use						**<0.001*****
	Non-drinker	8667	(28.7)	510	(33.5)	
	Occasional	15,443	(51.1)	660	(43.4)	
	Frequent	6092	(20.2)	351	(23.1)	
BMI (Kg/m2)						**0.001****
	<18.5	1242	(4.1)	77	(5.1)	
	18.5–25	18,404	(60.9)	852	(56.0)	
	>25	10,556	(35.0)	592	(38.9)	
Comorbidity						**<0.001*****
	0	14,831	(49.1)	600	(39.4)	
	1	8734	(28.9)	469	(30.8)	
	≥2	6637	(22.0)	452	(29.7)	
PA level						**<0.001*****
	Level 1 (low)	18,620	(61.7)	1040	(68.4)	
	Level 2 (moderate)	8884	(29.4)	355	(23.3)	
	Level 3 (high)	2698	(8.9)	126	(8.3)	
Work MET						**0.041***
	Low ~ Moderate	29,299	(97.0)	1461	(96.1)	
	High	903	(3.0)	60	(3.9)	
Leisure MET						**<0.001*****
	Low ~ Moderate	27,141	(89.9)	1426	(93.8)	
	High	3061	(10.1)	95	(6.2)	
Move MET						0.421
	Low ~ Moderate	24,946	(82.6)	1269	(83.4)	
	High	5256	(17.4)	252	(16.6)	

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
White collar[a]: Managers, professionals and related occupations, office workers.
Pink collar[a]: Service and sales workers.
Blue collar[a]: Skilled agricultural and fishery workers, craft and related trades workers, plant and machine operators and assemblers, elementary occupations.
Unemployed or Economic inactive[a]: Housewives, students, and others not currently engaged in economic activity.
Comorbidity: the number of diseases (Hypertension, Dyslipidemia, Diabetes, Asthma, Renal disease, Atopic dermatitis).

Work time MET: 0/low/moderate (0–1440 MET-min/week); high (1512–27,360 MET-min/week).
Leisure time MET: 0/low/moderate (0–1080 MET-min/week); high (1088–12,960 MET-min/week).
Move time MET: 0/low/moderate (0–800 MET-min/week); high (812–25,200 MET-min/week).

odds of suicide ideation compared to those with low-to-moderate work-related MET (OR = 1.50, 95 % CI: 1.08–2.09, $p = 0.016$). However, this association was no longer statistically significant after Bonferroni correction (adjusted $p = 0.064$).

No significant associations were observed between suicide ideation and either leisure-time MET (OR = 0.89, 95 % CI: 0.69–1.14, $p = 0.352$, adjusted $p = 1.000$) or transportation-related MET (OR = 1.04, 95 % CI: 0.87–1.24, $p = 0.666$, adjusted $p = 1.000$). Detailed estimates are provided in Supplementary Table 2. In additional analyses examining the associations between physical activity and suicidal planning or

Type of physical activity	N	(%)	OR (95% CIs)	p-value	Adjusted p-value
PA Level 1 : low	19660	(62.0)	1.00		
PA Level 2 : moderate	9239	(29.1)	0.86 (0.74, 1.00)	0.056	0.224
PA Level 3 : High	2824	(8.9)	1.17 (0.93, 1.47)	0.187	0.748
Low ~ Moderate Work MET	30760	(97.0)	1.00		
High Work MET	963	(3.0)	**1.50 (1.08, 2.09)**	**0.016***	0.064
Low ~ Moderate Leisure MET	28567	(90.1)	1.00		
High Leisure MET	3156	(9.9)	0.89 (0.69, 1.14)	0.352	1.000
Low ~ Moderate Move MET	26215	(82.6)	1.00		
High Move MET	5508	(17.4)	1.04 (0.87, 1.24)	0.666	1.000

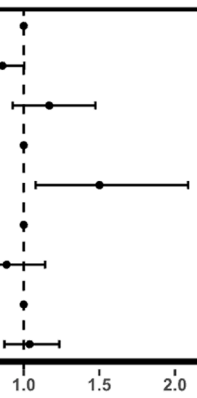

Fig. 2. Associations between total MET, work, leisure, and move-related MET and suicide ideation
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Adjusted for age, sex, income, marital status. occupation, education, BMI, comorbidity, smoking, drinkWork time MET: 0/low/moderate (0–1440 MET-min/week); high (1512–27,360 MET-min/week)Leisure time MET: 0/low/moderate (0–1080 MET-min/week); high (1088–12,960 MET-min/week)Move time MET: 0/low/moderate (0–800 MET-min/week); high (812–25,200 MET-min/week)
Adjusted p-values were calculated using the Bonferroni correction (multiplied by 4).

Sex	Type of physical activity	N	(%)	OR (95% CIs)	p-value	Adjusted p-value
Male	PA Level 1 : low	8,294	(59.8)	1.00		
	PA Level 2 : moderate	3,910	(28.2)	0.92 (0.71, 1.18)	0.497	1.000
	PA Level 3 : High	1,673	(12.1)	**1.46 (1.05, 2.01)**	**0.023***	0.092
	Low ~ Moderate Work MET	13,311	(95.9)	1.00		
	High Work MET	566	(4.1)	**1.95 (1.27, 2.99)**	**0.002****	**0.008****
	Low ~ Moderate Leisure MET	12,009	(86.5)	1.00		
	High Leisure MET	1,868	(13.5)	1.03 (0.72, 1.48)	0.869	1.000
	Low ~ Moderate Move MET	11,370	(81.9)	1.00		
	High Move MET	2,507	(18.1)	1.20 (0.93, 1.56)	0.166	0.664
Female	PA Level 1 : low	11,366	(63.7)	1.00		
	PA Level 2 : moderate	5,329	(29.9)	**0.81 (0.67, 0.99)**	**0.034***	0.136
	PA Level 3 : High	1,151	(6.4)	0.94 (0.67, 1.31)	0.714	1.000
	Low ~ Moderate Work MET	17,449	(97.8)	1.00		
	High Work MET	397	(2.2)	1.11 (0.65, 1.89)	0.712	1.000
	Low ~ Moderate Leisure MET	16,558	(92.8)	1.00		
	High Leisure MET	1,288	(7.2)	0.78 (0.55, 1.10)	0.158	0.632
	Low ~ Moderate Move MET	14,845	(83.2)	1.00		
	High Move MET	3,001	(16.8)	0.91 (0.73, 1.15)	0.441	1.000

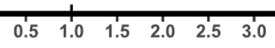

Fig. 3. Sex-stratified associations between work, leisure, and move-related MET and suicide ideation
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Adjusted for age, income, marital status. occupation, education, BMI, comorbidity, smoking, drink.
Work time MET: 0/low/moderate (0–1440 MET-min/week); high (1512–27,360 MET-min/week)
Leisure time MET: 0/low/moderate (0–1080 MET-min/week); high (1088–12,960 MET-min/week)
Move time MET: 0/low/moderate (0–800 MET-min/week); high (812–25,200 MET-min/week)
Adjusted p-values were calculated using the Bonferroni correction (multiplied by 4).

attempts, high work-related physical activity remained significantly associated with both outcomes even after Bonferroni correction. For suicidal planning, participants with high work-related METs showed higher odds of reporting suicidal plans (OR = 2.20, 95 % CI: 1.33–3.64, p = 0.002, adjusted p = 0.009) (Supplementary Table 3). Similarly, high work-related METs were associated with an increased likelihood of suicide attempts (OR = 3.06, 95 % CI: 1.52–6.14, p = 0.002, adjusted p = 0.007) (Supplementary Table 4). In contrast, high leisure-time physical activity was inversely associated with suicidal attempts (OR = 0.39, 95 % CI: 0.16–0.95, p = 0.038), but this association was no longer significant after Bonferroni adjustment (adjusted p = 0.152).

3.3. Subgroup differences by sex and age in type-specific physical activity

The sex-stratified associations between type-specific physical activity and suicide ideation were examined (Fig.3). Among males, high levels of total physical activity (Level 3) were significantly associated with increased odds of suicide ideation compared to low physical activity levels (Level 1), with an OR of 1.46 (95 % CI: 1.05–2.01, p = 0.023); however, this association was not statistically significant after Bonferroni correction (adjusted p = 0.092). In contrast, no significant association was observed for moderate physical activity levels (OR = 0.92, 95 % CI: 0.71–1.18, p = 0.497, adjusted p = 1.000).

Notably, high work-related MET levels among males were

Sex	Age, years	N(%)	Type of physical activity	OR (95% CIs)	p-value	Adjusted p-value
Male	19-39	3438(93.0)	Low ~ Moderate Work MET	1.00		
		260(7.0)	High Work MET	**2.21 (1.17, 4.15)**	**0.014***	**0.056**
		2907(78.6)	Low ~ Moderate Leisure MET	1.00		
		791(21.4)	High Leisure MET	1.41 (0.87, 2.27)	0.166	0.665
		2911(78.7)	Low ~ Moderate Move MET	1.00		
		787(21.3)	High Move MET	**1.74 (1.14, 2.65)**	**0.010***	**0.041***
	40-59	4672(95.3)	Low ~ Moderate Work MET	1.00		
		228(4.7)	High Work MET	1.53 (0.76, 3.09)	0.236	0.945
		4272(87.2)	Low ~ Moderate Leisure MET	1.00		
		628(12.8)	High Leisure MET	1.00 (0.52 , 1.92)	0.990	1.000
		4124(84.2)	Low ~ Moderate Move MET	1.00		
		776(15.8)	High Move MET	1.09 (0.67, 1.75)	0.736	1.000
	60≤	5201(98.5)	Low ~ Moderate Work MET	1.00		
		78(1.5)	High Work MET	1.75 (0.62, 4.98)	0.293	1.000
		4830(91.5)	Low ~ Moderate Leisure MET	1.00		
		449(8.5)	High Leisure MET	**0.18 (0.07, 0.48)**	**<.001*****	**0.002****
		4335(82.1)	Low ~ Moderate Move MET	1.00		
		944(17.9)	High Move MET	0.74 (0.49, 1.12)	0.157	0.627
Female	19-39	4222(96.1)	Low ~ Moderate Work MET	1.00		
		172(3.9)	High Work MET	0.76 (0.38, 1.52)	0.443	1.000
		3940(89.7)	Low ~ Moderate Leisure MET	1.00		
		454(10.3)	High Leisure MET	0.87 (0.55, 1.39)	0.563	1.000
		3547(80.7)	Low ~ Moderate Move MET	1.00		
		847(19.3)	High Move MET	0.99 (0.68, 1.43)	0.956	1.000
	40-59	6623(97.8)	Low ~ Moderate Work MET	1.00		
		150(2.2)	High Work MET	**2.12 (1.02, 4.41)**	**0.045***	0.179
		6187(91.3)	Low ~ Moderate Leisure MET	1.00		
		586(8.7)	High Leisure MET	0.64 (0.32, 1.28)	0.211	0.842
		5643(83.3)	Low ~ Moderate Move MET	1.00		
		1130(16.7)	High Move MET	0.88 (0.61, 1.29)	0.513	1.000
	60≤	6604(98.9)	Low ~ Moderate Work MET	1.00		
		75(1.1)	High Work MET	0.57 (0.19, 1.77)	0.333	1.000
		6431(96.3)	Low ~ Moderate Leisure MET	1.00		
		248(3.7)	High Leisure MET	0.67 (0.28, 1.64)	0.383	1.000
		5655(84.7)	Low ~ Moderate Move MET	1.00		
		1024(15.3)	High Move MET	0.77 (0.54, 1.09)	0.146	0.582

Fig. 4. Sex- and age-stratified associations between work, leisure, and move-related MET and suicide ideation
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Adjusted for income, marital status. occupation, education, BMI, comorbidity, smoking, drink.
Work time MET: 0/low/moderate (0–1440 MET-min/week); high (1512–27,360 MET-min/week)
Leisure time MET: 0/low/moderate (0–1080 MET-min/week); high (1088–12,960 MET-min/week)
Move time MET: 0/low/moderate (0–800 MET-min/week); high (812–25,200 MET-min/week)
Adjusted p-values were calculated using the Bonferroni correction (multiplied by 4).

significantly associated with suicide ideation (OR = 1.95, 95 % CI: 1.27–2.99, $p = 0.002$), and this association remained significant after Bonferroni correction (adjusted $p = 0.008$). No statistically significant associations were found for leisure- or move-related MET levels among males.

Among females, moderate levels of total physical activity were associated with significantly reduced odds of suicide ideation (OR = 0.81, 95 % CI: 0.67–0.99, $p = 0.034$); however, the significance did not hold after correction for multiple comparisons (adjusted $p = 0.136$). High levels of total physical activity and all domain-specific MET levels (work, leisure, move) showed no statistically significant associations with suicide ideation in females, either before or after Bonferroni correction.

Age-stratified analyses were additionally conducted for each type of physical activity (Fig.4). Among males aged 19–39 years, both high work-related and high transportation-related MET levels were significantly associated with increased odds of suicide ideation. Specifically, high work MET was associated with an OR = 2.21 (95 % CI: 1.17–4.15, $p = 0.014$), and this association remained marginally significant after Bonferroni correction (adjusted $p = 0.056$). High transportation MET with an OR = 1.74 (95 % CI: 1.14–2.65, $p = 0.010$; adjusted $p = 0.041$).

Among males aged 60 years and older, high levels of leisure MET were significantly associated with decreased odds of suicide ideation (OR = 0.18, 95 % CI: 0.07–0.48, $p < 0.001$; adjusted $p = 0.002$). No other significant associations were observed in the male 40–59 age groups.

Among females, none of the associations between domain-specific MET levels and suicide ideation remained statistically significant after multiple comparison adjustment. In the 40–59 age group, high work MET was initially associated with increased odds of suicide ideation (OR = 2.12, 95 % CI: 1.02–4.41, $p = 0.045$), but this association lost significance after Bonferroni correction (adjusted $p = 0.179$). All other associations across female age subgroups were non-significant both before and after adjustment.

In the subgroup analysis that included expanded comorbidity variables and additional adjustment for depression, the previously observed association between high work-time physical activity and suicidal ideation was no longer statistically significant. However, high leisure-time physical activity remained strongly associated with lower odds of suicidal ideation among men aged ≥60 years (OR = 0.03, 95 % CI: 0.00–0.23, $p = 0.001$; adjusted $p = 0.003$) (Supplementary Table 5).

The additional analyses examining suicidal planning and suicide attempts are presented in the Supplementary Materials (Supplementary Tables 6, 7).

3.4. Occupational variation in the association between physical activity and suicide ideation

We additionally conducted stratified analyses to examine whether the association between type-specific physical activity and suicide ideation varied by occupational group (Fig.5). Among males, those in pink-collar occupations with high work-related MET exhibited significantly increased odds of suicide ideation (OR = 3.63, 95 % CI: 1.45–9.09, $p = 0.006$; adjusted $p = 0.024$). Similarly, males in the unemployed or economic inactive group who engaged in high levels of work-related physical activity also showed increased odds of suicide

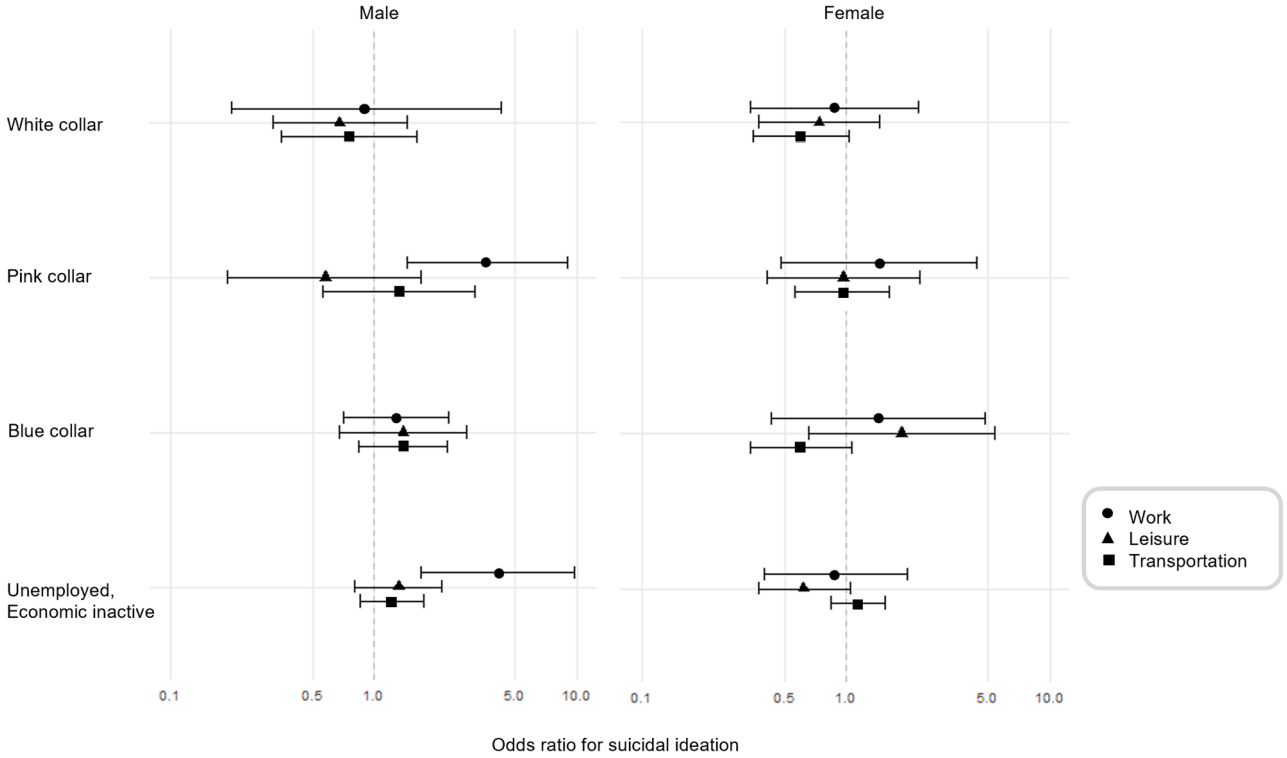

Fig. 5. Sex- and Occupation-stratified associations between work, leisure, and move-related MET and suicide ideation.
Adjusted for income, marital status. occupation, education, BMI, comorbidity, smoking, drink.
White collar: Managers, professionals and related occupations, office workers
Pink collar: Service and sales workers
Blue collar: Skilled agricultural and fishery workers, craft and related trades workers, plant and machine operators and assemblers, elementary occupations
Unemployed or Economic inactive: Housewives, students, and others not currently engaged in economic activity
Work time MET: 0/low/moderate (0–1440 MET-min/week); high (1512–27,360 MET-min/week)
Leisure time MET: 0/low/moderate (0–1080 MET-min/week); high (1088–12,960 MET-min/week)
Move time MET: 0/low/moderate (0–800 MET-min/week); high (812–25,200 MET-min/week).

ideation (OR = 4.11, 95 % CI: 1.71–9.83, $p = 0.002$; adjusted $p = 0.006$).. No other statistically significant associations were observed between type-specific physical activity and suicide ideation in other occupational groups among males. In females, no significant associations were found across any occupational group. Detailed estimates are presented in Supplementary Tables 8, 9.

The additional analyses examining suicidal planning and suicide attempts are presented in the Supplementary Materials (Supplementary Tables 10, 11, 12, 13).

3.5. Exploratory mediation analysis in the associations between significant physical activity variables and suicidal ideation

We further examined whether depression mediated the associations between domain-specific physical activity and suicidal ideation (Supplementary Table 14). In age-stratified analyses (Supplementary Table 14-A), the proportion of mediation by depression was substantial across several subgroups. Among men aged 19–39 years, the proportion mediated for work-related physical activity was 0.999 (95 % CI: 0.970–1.024, $p < 0.001$), and for transportation-related activity, 1.002 (95 % CI: 0.962–1.031, $p = 0.002$). A significant mediation effect was also observed for work-related physical activity among women aged 40–59 years (1.012, 95 % CI: 0.923–1.078, $p = 0.002$), and for leisure-time activity among men aged ≥60 years (1.105, 95 % CI: 0.278–1.783, $p = 0.034$).

In occupation-stratified analyses (Supplementary Table 14-B), the mediation effect of depression remained significant among men in pink-collar occupations (1.002, 95 % CI: 0.963–1.025, $p = 0.004$) and among unemployed or economically inactive men (0.997, 95 % CI: 0.926–1.076, $p = 0.002$).

3.6. Sensitivity analyses for unmeasured confounding

Sensitivity analyses for unmeasured confounding were conducted using E-values and quantitative bias analysis. E-values for the point estimates were generally above 1.5, with some associations exceeding 3 (Supplementary Tables 2–9).

In quantitative bias analyses, the associations remained elevated under mild-to-moderate confounding scenarios and were only attenuated under strong assumptions (Supplementary Table 15).

4. Discussion

This study examined the associations between domain-specific physical activity and suicidal ideation using nationally representative data and revealed heterogeneous patterns across activity domains and population subgroups. Overall, work-related physical activity tended to show unfavorable associations with suicidal ideation, whereas leisure-time physical activity appeared protective in specific subgroups. These patterns were particularly evident among men and varied further by age and occupational context, underscoring the importance of considering both the domain and the social context of physical activity rather than total activity volume alone.

These findings consistent with the concept of the “physical activity paradox,” originally proposed by Holtermann and colleagues, which highlights that leisure-time physical activity is generally health-promoting, whereas occupational physical activity may have adverse health consequences despite contributing substantially to overall activity levels (Holtermann et al., 2012). Leisure-time physical activity is typically voluntary, of moderate intensity, and allows for recovery, characteristics that may support psychological well-being (Karihtala et al., 2023; Zhou et al., 2023). In contrast, work-related physical activity is often prolonged, repetitive, and performed at higher intensity, with little autonomy and limited opportunities for recovery (Karihtala et al., 2023), contributing to chronic fatigue, occupational stress, and psychological burnout (Rose et al., 2017; Xu et al., 2025). From this perspective, physical activity accumulated primarily through work may have different mental health implications than activity undertaken for leisure.

Subgroup analyses suggested that depressive symptoms may be relevant to the observed associations in certain populations. Among younger men, the association between high work-related physical activity and suicidal ideation was attenuated after adjustment for depression, and exploratory mediation analyses indicated that depression may be associated with this relationship. Given the cross-sectional design, these findings should be interpreted cautiously; however, they suggest that the mental health burden associated with occupational physical activity in younger men may be partly intertwined with depressive symptoms. By contrast, among older men, the protective association of leisure-time physical activity with suicidal ideation remained evident after accounting for depression, implying that the benefits of leisure-time activity may extend beyond depressive pathways alone. Together, these findings underscore that the qualitative context in which physical activity occurs—and its psychological consequences—may be more important than the total volume of activity in shaping suicide risk.

Age- and sex-specific differences may reflect broader variations in social roles, work conditions, and the nature of physical activity. For younger men, associations with work- and transportation-related physical activity may be linked to structural factors such as economic insecurity, high job demands, and physically burdensome labor (Nam et al., 2021; Seong et al., 2021). In contrast, the protective association of leisure-time physical activity with suicidal ideation among older men may be explained by its role in maintaining social relationships, enabling autonomy, and alleviating stress, which together provide psychosocial benefits (Hou et al., 2024). The absence of consistent associations among women may partly reflect limitations in measurement, as standard physical activity instruments may inadequately capture informal or unpaid activities, including domestic and caregiving labor, which constitute a substantial component of women’s activity patterns (Jacob et al., 2020).

The findings from occupational subgroup analyses further support these interpretations. Among men in pink-collar occupations, high levels of work-related physical activity were significantly associated with suicidal ideation. Pink-collar occupations may include service and sales roles such as retail work, call-center and customer service positions, caregiving, hospitality and food service jobs, and other forms of front-line service labor. Individuals in these occupations often face a combination of emotional labor, physically demanding tasks performed for prolonged periods, inconsistent or unpredictable schedules, and limited job security (Yoo, 2023). Such working conditions can contribute to heightened psychological strain and may partly explain the observed association. A similar pattern was observed among unemployed or economically inactive men, a group may include students engaged in temporary or part-time manual work, day laborers, and individuals with intermittent or unstable employment. These circumstances may involve irregular work availability, unstable income, and increased socioeconomic vulnerability, all of which can amplify stress and negatively influence mental health (Thomson et al., 2022). Taken together, these findings highlight that not only the amount of occupational physical activity but also the broader qualitative features of work environments, job stability, and labor conditions may be closely linked to suicidal ideation.

From a public health perspective, these findings caution against a uniform approach to physical activity promotion in suicide prevention. While total physical activity is important for physical health, the mental health implications depend heavily on the domain and context in which activity occurs. Interventions should focus on reducing excessive occupational physical demands, promoting opportunities for leisure-time physical activity, and ensuring adequate recovery time. Age-specific approaches may also be necessary. Younger adults, particularly young men, may be vulnerable to the adverse effects of high occupational

physical activity, especially in unstable or labor-intensive work environments (Milner et al., 2017). Targeted support—such as improving work conditions, reducing excessive physical workload, and screening for depression—may therefore be especially important for this age group. In contrast, for older adults, encouraging accessible and enjoyable leisure-time physical activity may help maintain mental well-being, given the strong protective associations observed in this population. These findings suggest that suicide prevention strategies should consider not only the amount but also the context and domain of physical activity, particularly in identifying high-risk groups and tailoring interventions accordingly.

Particular attention is warranted for high-risk groups such as young men and workers in service occupations, who may be especially vulnerable In South Korea, while suicide rates were historically highest among older adults; however, more recent data indicate that the burden of suicide risk has been shifting toward younger age groups. Notably, emerging evidence indicates a deterioration in suicide-related indicators among young men (Kwon et al., 2009). Moreover, national survey data during the COVID-19 pandemic showed that younger men exhibited disproportionately high levels of anxiety, depression, and stress, with clinically significant anxiety most prevalent among those in their 30 s (Jung et al., 2021). These patterns suggest that young men may be emerging as a newly vulnerable high-risk group.

This study has several strengths. First, it utilized a large, nationally representative dataset of Korean adults, enhancing the generalizability of the findings. Second, to our knowledge, this is the first study to examine domain-specific physical activity—work, leisure, and transportation—in relation to suicidal ideation, addressing an important gap in the existing literature. Third, by conducting extensive stratified analyses by age, sex, and occupational group, we were able to identify heterogeneous associations across diverse population subgroups, providing a more nuanced understanding of potential effect modification. In addition, we incorporated a comprehensive set of covariates and applied rigorous statistical procedures, including adjustments for multiple comparisons, thereby strengthening the robustness and credibility of the results.

Nevertheless, several limitations must be noted. The cross-sectional design precludes causal inference, and the self-reported nature of physical activity introduces potential measurement error and recall bias. Furthermore, some associations lost statistical significance after adjustment for multiple comparisons, highlighting the need for replication in future studies. In addition, information on certain potential confounders, including family psychiatric history and non-alcohol substance use, was not available in the dataset. Although we attempted to address this issue through adjustment for proximal variables and sensitivity analyses, residual confounding cannot be excluded.

Despite these limitations, our findings demonstrate that domain-specific physical activity and sociodemographic context play important roles in shaping the relationship with suicidal ideation, underscoring the importance of incorporating qualitative aspects of physical activity into suicide prevention strategies.

Future research should therefore incorporate longitudinal designs and pay closer attention to gender- and generation-specific vulnerabilities. Such efforts will provide critical evidence for tailoring suicide prevention strategies to the unique needs of diverse population groups, including the growing cohort of young men at elevated risk. The findings highlight the need for strategies that address both excessive work-related physical activity and the lack of opportunities for restorative leisure-time activity. Approaches may include implementing structured activity breaks, improving recovery opportunities in labor-intensive occupations, and integrating physical and mental health programs within workplaces (Kitano et al., 2025). At the same time, community- and workplace-based initiatives that promote enjoyable leisure-time physical activity—such as accessible exercise programs, environmental improvements, and targeted support for populations facing participation barriers—may help strengthen protective factors for mental health. Finally, occupation- and age-specific planning, combined with equity-focused policy design, will be essential for creating balanced interventions that effectively reduce suicide risk across diverse population groups (Kohler et al., 2023).

5. Conclusion

In this nationally representative study, domain-specific physical activity showed differential associations with suicidal ideation across sex, age, and occupational subgroups, while total physical activity level was not consistently associated with suicidal ideation after multiple comparison adjustment. High work-related physical activity was associated with increased odds of suicidal ideation among younger men, particularly those in pink-collar occupations or who were unemployed or economically inactive, whereas high leisure-time physical activity was associated with lower odds of suicidal ideation among men aged 60 years and older, underscoring the importance of considering activity type and context in suicide prevention.

Ethics statement

The Korea National Health and Nutrition Examination Survey (KNHANES) was conducted with approval from the Institutional Review Board (IRB) of the Korea Disease Control and Prevention Agency (IRB Nos. 2013–12EXP-03–5C, 2018–01–03-C-A, 2018–01–03–5C-A, 2018–01–03–4C-A, and 2022–11–16-R-A). This study was approved by the IRB of the Severance Hospital, Korea (IRB No 4–2025–0820).

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CRediT authorship contribution statement

Jieun Noh: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis. **Lita Kim:** Writing – review & editing, Conceptualization. **Chaelin Hwang:** Writing – review & editing. **Eung Ju Park:** Writing – review & editing. **Ji Su Yang:** Writing – review & editing. **Sun Jae Jung:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Sun Jae Jung reports financial support was provided by National Research Foundation of Korea. Sun Jae Jung reports financial support was provided by Ministry of Health & Welfare, Republic of Korea. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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