

# Impact of Physical Activity on the Association Between Unhealthy Adolescent Behaviors and Anxiety Among Korean Adolescents: A Cross-sectional Study

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**Objectives:** Adolescents who engage in unhealthy behaviors are particularly vulnerable to anxiety. We hypothesized that participation in physical activity could influence the relationship between anxiety and unhealthy behaviors in adolescents. These behaviors include smoking, alcohol consumption, and unsafe sexual activity.

**Methods:** This study included 50 301 students from the first year of middle school to the third year of high school, all from Korea. The unhealthy adolescent behaviors examined included current alcohol consumption, current smoking, and unsafe sexual behavior. Anxiety levels were assessed using the Generalized Anxiety Disorder-7 questionnaire (GAD-7).

**Results:** The participants had a mean age of 15.19 years and an average GAD-7 score of 4.23. No significant differences were observed in GAD-7 score among exercising participants when categorized by smoking status ( $p=0.835$ ) or unsafe sexual behavior ( $p=0.489$ ). In contrast, participants in the non-exercise group who engaged in these behaviors demonstrated significantly higher GAD-7 scores ( $p<0.001$  and  $0.016$ , respectively). The only significant interaction was found between unsafe sexual behavior and exercise ( $p=0.009$ ). Based on logistic regression analysis, within the non-exercise group, significant positive associations were observed between current smoking and anxiety (odds ratio [OR], 1.36; 95% confidence interval [CI], 1.18 to 1.57), as well as between unsafe sexual behavior and anxiety (OR, 1.33; 95% CI, 1.02 to 1.73). However, within the exercise group, no significant association was found between anxiety and either smoking or unsafe sexual behavior. Furthermore, no significant interaction was observed between unhealthy behaviors and exercise.

**Conclusions:** These findings are insufficient to conclude that physical activity influences the relationship between unhealthy behaviors and anxiety.

**Key words:** Adolescent, Smoking, Underage drinking, Anxiety, Exercise

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## INTRODUCTION

Adolescent health, including physical, mental, and social well-being, is of the utmost importance [1-5]. Tobacco and alcohol use persist as the most common risky behaviors among adolescents. As of 2017, 19.6% of high school students in the United States were current smokers, and current alcohol drinkers included 18.8% of male and 26.8% of female adolescents

[6-9]. In Korea, the average age of first drinking experience has been steadily decreasing, from 13.0 years for boys and 13.7 years for girls in 2018, to 12.9 years for boys and 13.5 years for girls in 2019 [10]. Furthermore, early pregnancy and child-birth resulting from unsafe sexual behavior have been identified among the key adolescent health issues highlighted by the World Health Organization (WHO) and Sustainable Development Goal 3. In Africa, for example, despite a decline in the adolescent birth rate, the prevalence of teenage pregnancy remained high in 2020, at 25.4% [11].

Adolescents engaging in unhealthy behaviors, including smoking, alcohol consumption, and risky sexual activities, frequently exhibit low self-efficacy. This renders them more susceptible to anxiety than their counterparts who do not engage in such behaviors [12-14]. The act of smoking cigarettes may incite anxiety via the manipulation of neurotransmitter systems and the induction of epigenetic alterations [15]. Comorbidities such as alcohol abuse and anxiety disorders are common [16], and ethanol may alter neurobiological mechanisms that modulate stress and anxiety circuits [17].

Research has indicated that regular exercise can effectively reduce anxiety and its symptoms [18,19]. The positive impact of consistent exercise appears to be comparable to those of meditation or relaxation. Exercise can also enhance an individual's self-efficacy, thereby reducing anxiety. Individuals with high self-efficacy report significantly lower anxiety levels after exercising compared to those with low self-efficacy [20].

The relationship between unhealthy behaviors and anxiety, as well as between exercise and anxiety, has been well established. However, the dynamics of these relationships remain complex. Despite the rising prevalence of unhealthy behaviors among young people and the increasing recognition of the importance of physical activity, the specific impact of exercise and any potential interactions with unhealthy behaviors remain ambiguous. This study was conducted to explore the potential role of physical activity in relation to anxiety among adolescents engaging in unhealthy behaviors.

## METHODS

### Study Population

The Korea Youth Risk Behavior Survey is conducted to assess the health behaviors of Korean adolescents, plan and evaluate youth health promotion programs, and generate health indicators for international comparison [21]. Initiated in 2005, this

annual survey is performed in accordance with government-approved statistics (Statistics Korea, approval No. 11758). The target demographic for the survey includes students from the first year of middle school through the third year of high school. The survey utilizes an anonymous, self-administered online questionnaire, with students participating via computer labs within their schools.

In the present study, we employed data from the year 2022. The target population of the survey included 56 213 individuals, of whom 51 850 participated (participation rate, 92.2%). The study population was administered an extensive survey covering various areas including demographics, diet, current physical and mental health, health-related behaviors, and other pertinent factors. The survey questionnaire was composed of 114 questions in total. Out of the 51 850 participants, 1549 were excluded from the study due to incomplete data on demographics ( $n=86$ ), current physical and mental behavior ( $n=22$ ), and health-related behavior questionnaires ( $n=1379$ ). This resulted in a final study population of 50 301 adolescents. Within this group, 2789 individuals reported having engaged in sexual intercourse, forming a subset of participants for the analysis of sexual behavior.

### Unhealthy Adolescent Behaviors

The variables related to unhealthy behaviors in adolescents included experiences of smoking, alcohol consumption, and unsafe sexual practices. Adolescents who reported consuming alcohol on more than 1 day in the past 30 days were categorized as current drinkers. Similarly, those who reported using any form of tobacco product on more than 1 day in the past 30 days were categorized as current smokers. The variable for unsafe sexual behavior was determined based on contraceptive practices among the sexually active adolescents ( $n=2789$ ). Participants were divided into 2 groups: those who always or mostly used contraception, indicating safe sexual behavior, and those who occasionally or never used contraception, indicating unsafe sexual behavior.

### Anxiety

Generalized anxiety disorder (GAD) is a prevalent anxiety disorder characterized by persistent worrying, symptoms of anxiety, and tension in children and adolescents. In this study, anxiety levels were assessed using the Generalized Anxiety Disorder-7 questionnaire (GAD-7). The GAD-7 is a reliable and valid self-report screening tool for generalized anxiety symp-

toms in adolescents [22]. The GAD-7 consists of 7 questions used to evaluate the individual's experiences over the prior 2 weeks. Each question is scored on a scale of 0 to 3, with response options reflecting the frequency of the experienced symptom: "not at all," "several days," "more than 7 days," and "nearly every day." The total GAD-7 score can range from 0 to 21. Based on previous studies, a cut-off point of 10 on the GAD-7 score is interpreted as indicative of anxiety [23,24].

### Physical Activity

According to both the WHO guidelines on physical activity and the youth physical activity guidelines developed by the Ministry of Health and Welfare in Korea, the criteria for physical activity among youth include participating in more than moderate aerobic physical activity for at least 60 minutes each day and engaging in high-intensity physical activity for a minimum of 3 days per week [9,25]. The number of days in which the criteria were met for more than moderate physical activity, as indicated by an increased heart rate or breathlessness, was evaluated. A separate question was used to assess the number of days that included high-intensity physical activity.

### Other Variables of Interest

In addition to the primary variables of interest, this study incorporated several demographic and health-related behavior variables, considered other variables of interest. The demographic variables included sex (male or female), school level (middle school or high school), economic status (lower or upper-middle), and cohabitation status regarding parents (none, with 1 parent, or with both parents). Smartphone usage was quantified by the amount of time spent on the device during weekdays. The experience of violence (yes or no) was assessed based on whether medical treatment was sought due to violence-related incidents. Other health-related behavior variables included self-reported sleep quality (good or poor), and daily perceived stress levels (high or low).

### Statistical Analysis

All statistical analyses were performed using PROC procedures in SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). All tests were 2-sided, with the level of statistical significance established at  $\alpha=0.05$ . All variables, except for age and GAD-7 score, were treated as categorical variables.

To explore the impact of physical activity on the association between anxiety and risk behavior, the participants were di-

vided into exercise and non-exercise groups, based on exercise status as a potential moderating variable. This division was implemented to determine whether the calculated coefficients significantly varied between these groups, thereby validating the presence of interaction effects. In terms of demographics, we utilized an adjusted general linear model to compute the least squares means of the GAD-7 score for each group, based on unhealthy behaviors. Additionally, we conducted an adjusted logistic regression analysis to examine the relationship between the severity of anxiety and physical activity. Odds ratios (ORs) and 95% confidence intervals (CIs) were computed. The models were adjusted for sex, year in school, economic status, cohabitation status, experience of violence, smartphone usage time, sleep quality, perceived stress, and other risk behaviors (current smoking or current alcohol consumption). In these analyses, the independent variables were unhealthy behaviors, while the dependent variables were the presence or absence of anxiety or the GAD-7 score. For the interaction analysis, interaction terms—representing the relationship between individual unhealthy behaviors and physical activity—were included in each model.

### Ethics Statement

The all data was provided with personal information removed. The ethics approval for this study was waived by the Institutional Review Board under Seoul National University College of Medicine and Seoul National University Hospital (IRB No. E-2307-029-1447).

## RESULTS

### Participant Characteristics

Table 1 presents the characteristics of the study population, including the number of participants (n), percentage (%), mean GAD-7 score, standard error (SE), and corresponding *p*-values for each variable. Of the 50 301 participants, 25 312 were male and 24 989 were female. The mean age of the study population was 15.19 years (SE, 0.01), and the mean GAD-7 score was 4.23 (SE, 0.02). Higher mean GAD-7 scores were significantly associated with male sex ( $p<0.001$ ), older age ( $p<0.001$ ), high school student status ( $p<0.001$ ), lower economic class ( $p<0.001$ ), living with a single parent ( $p<0.001$ ), and having experienced violence ( $p<0.001$ ). Additional factors contributing to higher mean GAD-7 scores included poor sleep ( $p<0.001$ ), higher perceived stress ( $p<0.001$ ), current smoking ( $p<0.001$ ),

**Table 1.** Participant characteristics (n=50 301)

Characteristics	n (%)	GAD-7 score, mean ± SE	p-value	Characteristics	n (%)	GAD-7 score, mean ± SE	p-value
Year in school			<0.001	Experience of violence			<0.001
Middle school 1	9067 (18.0)	3.92 ± 0.05		No	49 237 (97.8)	4.18 ± 0.02	
Middle school 2	9166 (18.2)	4.20 ± 0.05		Yes	1064 (2.1)	6.47 ± 0.21	
Middle school 3	9212 (18.3)	4.37 ± 0.05		Poor sleep			<0.001
High school 1	8182 (16.2)	4.19 ± 0.05		No	27 416 (54.5)	3.21 ± 0.03	
High school 2	7672 (15.2)	4.14 ± 0.06		Yes	22 885 (45.5)	5.43 ± 0.04	
High school 3	7002 (13.9)	4.55 ± 0.06		Perceived stress			<0.001
Sex			<0.001	Low	29 559 (58.7)	2.36 ± 0.02	
Male	25 312 (50.3)	3.53 ± 0.03		High	20 742 (41.2)	6.89 ± 0.04	
Female	24 989 (49.6)	4.96 ± 0.03		Current smoking			<0.001
School level			<0.001	No	47 850 (94.9)	4.17 ± 0.02	
Middle school	27 445 (54.5)	4.17 ± 0.03		Yes	2451 (5.05)	5.42 ± 0.13	
High school	22 856 (45.4)	4.30 ± 0.03		Current alcohol use			<0.001
Economic status			<0.001	No	43 915 (87.1)	4.11 ± 0.02	
Upper-middle class	44 691 (88.8)	4.06 ± 0.02		Yes	6386 (12.8)	5.07 ± 0.07	
Lower class	5610 (11.1)	5.68 ± 0.08		Physical activity			<0.001
Cohabitation status			<0.001	No	47 192 (93.8)	4.25 ± 0.02	
Without parent	10 735 (21.3)	4.03 ± 0.05		Yes	3109 (6.18)	3.92 ± 0.09	
With single parent	5762 (11.4)	4.73 ± 0.07		Sexual intercourse			<0.001
With both parents	33 804 (67.2)	4.22 ± 0.03		Never	47 512 (94.4)	4.16 ± 0.02	
Smartphone usage (hr/day)			<0.001	Ever	2789 (5.54)	5.35 ± 0.12	
<5	30 185 (60.0)	3.93 ± 0.03		Unsafe sexual behavior (n=2789)			<0.001
5-10	16 733 (33.2)	4.56 ± 0.04		No	1827 (65.5)	5.17 ± 0.14	
10-15	2626 (5.2)	5.14 ± 0.11		Yes	962 (34.4)	5.70 ± 0.22	
≥15	757 (1.5)	5.81 ± 0.25					

GAD-7, Generalized Anxiety Disorder-7 questionnaire; SE, standard error.

**Table 2.** Distribution of anxiety levels based on unhealthy behavior

Anxiety level	Total participants (n=50 301)	Current smoking		Current alcohol use		Unsafe sexual behavior	
		No (n=47 850)	Yes (n=2451)	No (n=43 915)	Yes (n=6386)	No (n=1827)	Yes (n=962)
None	32 359 (64.3)	31 028 (64.8)	1331 (54.3)	28 725 (65.4)	3634 (56.9)	1023 (55.9)	522 (54.2)
Mild	11 547 (22.9)	10 928 (22.8)	619 (25.2)	9909 (22.5)	1638 (25.6)	479 (26.2)	231 (24.0)
Moderate	4080 (8.1)	3793 (7.9)	287 (11.7)	3425 (7.8)	655 (10.2)	187 (10.2)	107 (11.1)
Severe	2315 (4.6)	2101 (4.4)	214 (8.7)	1856 (4.2)	459 (7.2)	138 (7.5)	102 (10.6)
p-value	-	<0.001		<0.001		0.032	

Values are presented as number (%).

current alcohol consumption ( $p < 0.001$ ), a lack of regular exercise ( $p < 0.001$ ), and having engaged in sexual intercourse ( $p < 0.001$ ), particularly when unsafe sexual behavior was involved ( $p < 0.001$ ).

### Distribution of Anxiety

Table 2 displays the distribution of anxiety levels (ranging from none to severe) among the participants, categorized by

their engagement in unhealthy behaviors. Significantly higher levels of anxiety were observed among smokers compared to non-smokers ( $p < 0.001$ ) and among drinkers compared to non-drinkers ( $p < 0.001$ ). Furthermore, a significant difference in anxiety levels was also noted between participants who practiced safe sexual behaviors and those who did not ( $p = 0.032$ ). These findings suggest that individuals who engage in smoking, alcohol consumption, or unsafe sexual behaviors tend to

**Table 3.** Prevalence of anxiety by unhealthy behavior

Variables	Total participants	<i>p</i> -value	Interaction term ( <i>p</i> -value) <sup>1</sup>	Exercise group	<i>p</i> -value	Non-exercise group	<i>p</i> -value
Current smoking		<0.001	0.403		0.006		<0.001
Subject (n)	50 301			3109		47 192	
No							
No anxiety	41 956 (87.6)			2551 (87.9)		39 405 (87.6)	
Anxiety	5894 (12.3)			349 (12.0)		5545 (12.3)	
Yes							
No anxiety	1950 (79.5)			172 (82.2)		1778 (79.3)	
Anxiety	501 (20.4)			37 (17.7)		464 (20.6)	
Current alcohol use		<0.001	0.126		<0.001		<0.001
Subject (n)	50 301			3109		47 192	
No							
No anxiety	38 634 (87.9)			2324 (88.8)		36 310 (87.9)	
Anxiety	5281 (12.0)			292 (11.1)		4989 (12.0)	
Yes							
No anxiety	5272 (82.5)			399 (80.9)		4873 (82.6)	
Anxiety	1114 (17.4)			94 (19.0)		1020 (17.3)	
Unsafe sexual behavior		0.019	0.331		0.319		0.029
Subject (n)	2789			266		2523	
No							
No anxiety	1502 (82.2)			143 (87.1)		1359 (81.7)	
Anxiety	325 (17.7)			21 (12.8)		304 (18.2)	
Yes							
No anxiety	753 (78.2)			81 (79.4)		672 (78.1)	
Anxiety	209 (21.7)			21 (20.5)		188 (21.8)	

Values are presented as number (%).

<sup>1</sup>Interaction between each unhealthy behavior and exercise (that is, smoking and exercise, alcohol drinking and exercise, and unsafe sexual behavior and exercise).

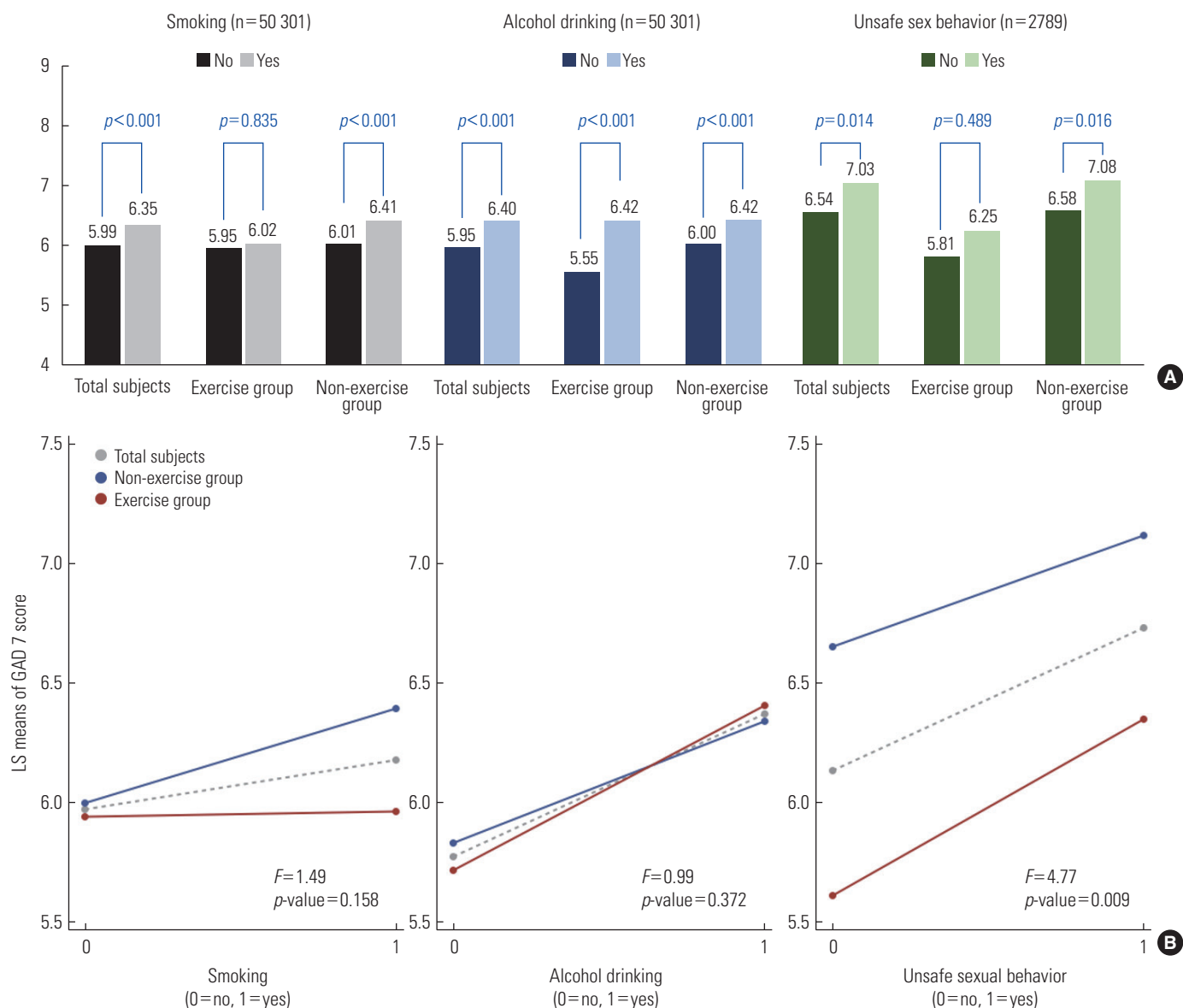
experience a greater degree of anxiety.

Table 3 presents the number of participants with or without anxiety, categorized by their engagement in unhealthy behavior. Of 50 301 participants, 3109 individuals adhered to the guidelines for physical activity, constituting the exercise group, while the remaining 47 192 participants did not engage in regular physical activity, forming the non-exercise group. Within the exercise group, the prevalence of anxiety was significantly lower in non-smokers and non-drinkers compared to smokers ( $p=0.006$ ) and drinkers ( $p<0.001$ ). However, no statistically significant difference in the prevalence of anxiety was observed between individuals who engaged in unsafe sexual behaviors and those who did not ( $p=0.319$ ). In the non-exercise group, non-smokers, non-drinkers, and those not engaging in unsafe sexual behavior also had a significantly lower prevalence of anxiety compared to smokers ( $p<0.001$ ), drinkers ( $p<0.001$ ), and those who engaged in such behavior ( $p=0.029$ ). Upon introducing interaction terms between risky behaviors (smoking,

alcohol consumption, and unsafe sexual behavior) and exercise, none of these interaction terms were found to be statistically significant ( $p=0.373$ ,  $0.208$ , and  $0.734$ , respectively).

### Anxiety Scores by Unhealthy Behavior and Physical Activity

Figure 1 shows the least squares means of participants' GAD-7 scores, categorized by unhealthy behaviors and physical activity. Across all participants, current smokers exhibited a higher mean GAD-7 score than non-smokers (6.35 vs. 5.99, respectively;  $p<0.001$ ). Similarly, current drinkers displayed a higher mean GAD-7 score than non-drinkers (6.40 vs. 5.95, respectively;  $p<0.001$ ). Adolescents who engaged in unsafe sexual behaviors had a mean GAD-7 score of 7.03, whereas those who practiced safe sexual behaviors had a lower mean score, at 6.54 ( $p=0.014$ ). Upon stratification by physical activity engagement, the non-exercise group exhibited significant differences in GAD-7 scores in relation to current smoking,



**Figure 1.** Anxiety scores by unhealthy adolescent behavior and physical activity. (A) Regression model 1 was adjusted for sex, year in school, economic status, cohabitation status, experience of violence, smartphone usage time, sleep quality, perceived stress, and other risk behaviors (current smoking or current alcohol use). (B) Regression model 2 was adjusted for model 1+the interaction term between each unhealthy behavior and exercise (that is, smoking and exercise, alcohol drinking and exercise, and unsafe sexual behavior and exercise). LS, least squares; GAD-7, Generalized Anxiety Disorder-7 questionnaire.

current alcohol consumption, and unsafe sexual behaviors ( $p < 0.001$ ,  $< 0.001$ , and  $0.016$ , respectively). However, within the exercise group, the differences in GAD-7 scores for current smoking or unsafe sexual behavior were not significant ( $p = 0.835$  and  $0.489$ , respectively). The interaction effects between smoking and exercise, and between drinking and exercise, were not significant in the analysis ( $p = 0.158$  and  $0.372$ , respectively). However, the interaction effect between unsafe sexual behavior and exercise was significant ( $F = 4.77$ ,  $p = 0.009$ ).

### Anxiety by Unhealthy Behavior and Physical Activity

Table 4 presents the results of a logistic regression analysis examining the relationship between anxiety and unhealthy behaviors in adolescents, segmented by physical activity. The reference group was defined as including participants who did not engage in each unhealthy behavior. Across all participants, the adjusted model revealed a significant positive relationship between current smoking and anxiety (OR, 1.34; 95%

**Table 4.** Odds ratios of anxiety by unhealthy behavior and physical activity<sup>1</sup>

Variables	Total participants	Interaction term ( <i>p</i> -value) <sup>2</sup>	Exercise group	Non-exercise group
Current smoking				
Subject (n)	50 301		3109	47 192
No	1.00 (reference)		1.00 (reference)	1.00 (reference)
Yes	1.34 (1.16, 1.54)*	0.373	1.18 (0.70, 2.00)	1.36 (1.18, 1.57)*
Current alcohol use				
Subject (n)	50 301		3109	47 192
No	1.00 (reference)		1.00 (reference)	1.00 (reference)
Yes	1.18 (1.08, 1.3)*	0.208	1.96 (1.37, 2.81)*	1.14 (1.03, 1.26)*
Unsafe sexual behavior				
Subject (n)	2789		266	2523
No	1.00 (reference)		1.00 (reference)	1.00 (reference)
Yes	1.33 (1.04, 1.71)*	0.734	1.38 (0.58, 3.32)	1.33 (1.02, 1.73)*

Values are presented as odds ratio (95% confidence interval).

<sup>1</sup>The regression model was adjusted for sex, year in school, economic status, cohabitation status, experience of violence, smartphone usage, sleep quality, perceived stress, and other risk behaviors (current smoking or current alcohol use).

<sup>2</sup>Interaction between each unhealthy behavior and exercise (that is, smoking and exercise, alcohol drinking and exercise, and unsafe sexual behavior and exercise).

\**p*<0.05.

CI, 1.16 to 1.54). Similarly, significant positive relationships were found between unsafe sexual behavior and anxiety (OR, 1.33; 95% CI, 1.04 to 1.71). Within the non-exercise group, the positive relationships remained significant, both between anxiety and current smoking (OR, 1.36; 95% CI, 1.18 to 1.57) and between anxiety and unsafe sex (OR, 1.33; 95% CI, 1.02 to 1.73). However, among participants who exercised, no significant associations were found between anxiety and current smoking, or between anxiety and unsafe sexual behavior. Regarding alcohol consumption, significant positive relationships were found between current drinking and anxiety, irrespective of exercise status. However, the interaction effects between each unhealthy behavior and exercise were not significant (smoking, *p*=0.373; alcohol consumption, *p*=0.208; unsafe sexual behavior, *p*=0.734).

## DISCUSSION

### Summary

In this study, we examined the impact of exercise on the relationship between unhealthy behaviors during adolescence and anxiety among students in Korea. We found that individuals who engaged in smoking, alcohol consumption, or unsafe sexual behavior tended to experience more severe anxiety. When we stratified the data based on physical activity, we found no significant differences in GAD-7 score within the exercise group between current smokers and non-smokers, or

between those who did and did not engage in unsafe sexual behavior. However, within the non-exercise group, anxiety scores were significantly lower among those who did not engage in unhealthy behaviors than those who did, with the exception of alcohol consumption. In the regression model, only the interaction between unsafe sex behavior and exercise was significant, while the other interaction terms with smoking or alcohol were not. In the logistic regression analysis, within the non-exercise group, anxiety was significantly positively associated with both smoking and unsafe sexual behavior. However, this relationship was not evident within the exercise group. Alcohol consumption did not demonstrate a similar trend in relation to anxiety within either the exercise or non-exercise groups. In terms of interaction, none of the interactions between unhealthy behaviors and exercise were significant in the adjusted logistic regression model.

### Adolescent Unhealthy Behaviors and Anxiety

Numerous studies have substantiated the reciprocal relationships between unhealthy behaviors in adolescents and anxiety disorders. Adolescents who currently smoke or drink are susceptible to anxiety, and those with anxiety are inclined to smoke and consume alcohol. A longitudinal investigation revealed that smoking more than 20 cigarettes per day during adolescence was associated with GAD in early adulthood (OR, 5.53; 95% CI, 1.84 to 16.66) [26]. The quantity and frequency of cigarette smoking were also associated with GAD (OR, 1.36; 95%

CI, 1.07 to 1.71). This result could be explained by the potential roles of neurotransmitter systems, inflammation, oxidative and nitrosative stress, mitochondrial dysfunction, and epigenetic effects in the pathogenesis of anxiety [15]. Psychological factors have also been linked to unsafe sexual behavior among adolescents. According to a study in Slovakia, students in early adolescence who exhibited anxiety or depression were particularly likely to engage in unsafe sex (OR, 1.07; 95% CI, 1.02 to 1.12) [27].

Regarding alcohol use, heavy drinking early in adolescence has been shown to be associated with an increased risk of anxiety due to heightened vulnerability in the developing brain [13]. In a cross-sectional study of Norwegian secondary school students [28], more severe anxiety symptoms were associated with alcohol use among girls. However, a 2019 longitudinal study in Pittsburgh did not consistently find an association between the severity of anxiety and alcohol use [29]. In the present study, the pattern observed among alcohol drinkers did not align with that of smokers or individuals who engaged in unsafe sexual behavior. This discrepancy may be due to a strong reciprocal relationship between alcohol consumption and anxiety, a relationship that cannot be overcome simply with regular exercise. Moreover, the odds ratio for anxiety and alcohol use was higher in the exercise group than in the non-exercise group, a finding that calls for further research.

## Exercise

It has been relatively well established that physical exercise can reduce anxiety in both adults and adolescents [18,19,30]. In the general population, an inverse correlation has frequently been observed between physical activity and the incidence or symptoms of anxiety disorders [31]. A large population-based study in the Netherlands revealed that individuals who exercised were, on average, less anxious (standard difference, -0.18) than non-exercisers, provided they exercised for at least 60 minutes per week with a metabolic equivalent of task score of 4 or higher [32]. A 6-month randomized exercise intervention applied among Swedish girls also revealed that the group who exercised displayed significant differences in Social Physique Anxiety Scale scores compared to non-exercisers ( $p < 0.05$ ). Although most randomized controlled trials have suggested benefits of exercise for reducing anxiety, methodological limitations remain [33].

The absence of the relationship in the exercise group in this study could be attributed to the same pathology by which exercise mitigates anxiety. Although the exact mechanism be-

hind exercise's prevention of anxiety is not fully understood, several potential mechanisms have been suggested [28]. Regular aerobic exercise is associated with reduced activity in the sympathetic nervous system and the hypothalamic-pituitary-adrenal axis. Furthermore, exercise influences the release of corticotrophin-releasing factor and adrenocorticotrophic hormone [34]. From a physiological perspective, enhancing self-efficacy through managing the stress of exercise and diverting attention away from stressors may also contribute to decreased anxiety in adolescents [28,35]. This is particularly relevant as adolescent smoking and sexual behaviors have been specifically associated with lower self-efficacy or self-esteem [36].

However, this information does not necessarily suggest that exercise yields positive effects on unhealthy behaviors. For instance, among 8 randomized controlled trials on smoking, only 2 identified a positive effect of exercise on abstinence from smoking [37]. Furthermore, another meta-analysis concluded that exercise did not result in decreased alcohol consumption, while it was not feasible to investigate the moderating effects of smoking [38].

Likewise, based on the findings of the present study, physical activity cannot be said to significantly influence the relationship between unhealthy behaviors and anxiety. The interaction term did not yield statistically significant results, indicating that exercise does not function as an interacting or moderating variable in this relationship. However, it is still possible that exercise may affect the relationship between unhealthy behaviors and anxiety in other ways or from different perspectives. This is because the estimated coefficients varied significantly between groups when verifying the interaction effect in the divided samples.

## Strengths and Limitations

To our knowledge, this is the first study to evaluate the impact of physical activity on the relationship between unhealthy behaviors in adolescents and anxiety, utilizing a large student dataset. Nonetheless, this study had limitations. First, due to its cross-sectional design, causality could not be definitively established. Additionally, a confounding effect may have been present. We employed an adjusted model with multiple covariates, but we cannot rule out the possibility of a residual confounding effect from unmeasured or external factors, such as the consumption of coffee or other substances potentially increasing anxiety in adolescents. Moreover, the data for smoking, alcohol use, unsafe sexual behavior, GAD-7 score, and ex-



ercise were self-reported, which could have led to inaccuracies or bias, particularly given the public-school setting of the survey. The results may vary depending on the definitions or measurement methods used for exercise and such behaviors. Additionally, variations in sample size across variables could have impacted the CIs and significance levels of these analyses. For instance, the limited number of individuals engaging in unsafe sexual behavior may have influenced the results. The effect size can also impact statistical outcomes; that is, if the actual size of the interaction effect between unhealthy behavior and exercise was small, detection would be difficult. Due to data limitations, we were unable to directly estimate the inherent interaction effects when examining differences between groups with regard to interaction effects [39].

In this study, we were unable to find evidence suggesting that exercise influences the relationship between adolescent unhealthy behaviors and anxiety. Contrary to popular belief, our findings indicate that physical activity may not serve as a cost-effective intervention for adolescent anxiety arising from unhealthy behaviors. We recommend further research, considering the potential for minor interaction effects, measurement methods, external factors, and the presence or absence of other confounding variables.

## CONFLICT OF INTEREST

The authors have no conflicts of interest associated with the material presented in this paper.

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## AUTHOR CONTRIBUTIONS

Conceptualization: Lee HJ, Min KB. Data curation: Lee HJ, Choi JP, Oh K. Formal analysis: Lee HJ. Funding acquisition: Min JY, Min KB. Methodology: Lee HJ, Min JY, Min KB. Writing –

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