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Association Between Depressed Mood Changes and Physical Activity Among Adolescents Post COVID-19 Pandemic

Jina Jang[1], Bong-Jo Kim[1,2], Cheol-Soon Lee[2,3], Boseok Cha[1,2], So-Jin Lee[1,2], Dongyun Lee[2,3], Young-Ji Lee[3], Eunji Lim[3], Nuree Kang[4], and Jae-Won Choi[1]

[1]Department of Psychiatry, Gyeongsang National University Hospital, Jinju, Korea
[2]Department of Psychiatry, Gyeongsang National University College of Medicine, Jinju, Korea
[3]Department of Psychiatry, Gyeongsang National University Changwon Hospital, Changwon, Korea
[4]Department of Psychiatry, Seoul National University Hospital, Seoul, Korea

Objectives: Following the coronavirus disease 2019 (COVID-19) pandemic, adolescents have experienced decreased physical activity and a decline in mental health. This study analyzed the association between changes in depressed mood after the COVID-19 pandemic and physical activity among adolescents.

Methods: The analysis was based on the results of the 17th Youth Health Behavior Online Survey conducted in 2021, which included 54848 middle and high school students in South Korea. Information on physical activity included low-intensity physical activity lasting >60 min/day, high-intensity physical activity, and strength training exercises. A logistic regression analysis was performed to evaluate the association between physical activity and changes in depression after the COVID-19 pandemic.

Results: After adjusting for sociodemographic characteristics and previous depression, adolescents who performed strength training exercises more than once per week had a 0.95-fold lower risk (odds ratio [OR]=0.948, 95% confidence interval [CI]=0.905–0.994, p=0.027) of increasing depression after the COVID-19 pandemic, while the risk of decreasing depression increased by 1.22-fold (OR=1.215, 95% CI=1.131–1.305, p<0.001). The results were not significant for low-intensity physical activity for >60 min/day and high-intensity physical activity.

Conclusion: Strength-training exercises are significantly associated with the prevention of depression among adolescents following the COVID-19 pandemic.

Keywords: Physical activity; Depression; COVID-19; Adolescents.

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Address for correspondence: Jae-Won Choi, Department of Psychiatry, Gyeongsang National University Hospital, 79 Gangnam-ro, Jinju 52727, Korea
Tel: +82-55-750-9788, Fax: +82-55-759-0003, E-mail: lingker77@naver.com

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic led to emergency measures such as social distancing and school closures. This affected the daily life and lifestyle of adolescents, leading to inadequate diets, decreased physical activity, increased obesity [1], and increased Internet use, watching videos, or playing games on computers and smartphones [2]. Owing to the suspension of in-person classes, the transition to remote learning significantly changed students' learning environments and daily lives [3]. For example, suspending in-person classes at school may reduce students' motivation to study [4]. Remote learning at home can lead to a lack of adequate guidance from teachers, poor academic concentration, increased learning burden, increased psychological stress associated with assignments, and increased demands for self-care [5]. In addition, because of social distancing and self-isolation, adolescents may have experienced a lack of social connectivity and isolation due to limited contact with friends and a reduced range of social activities [1,6]. The increased learning burden and reduced number of close friendships can cause depression and anxiety in adolescents. Moreover, restrictions on access to mental health services due to social distancing can also contribute to worsening depression and anxiety [7-9].

Factors that can positively affect adolescents' mental health, such as physical activity that provides various benefits for their physical, mental, and social development, must be identified and developed [10-12]. Physical activity promotes physical development in this population by strengthening muscles,

improving cardiorespiratory endurance and flexibility, and increasing vitality by improving energy consumption and sleep quality [10]. Exercise reduces inflammation and stimulates the secretion of neurotransmitters such as serotonin and endorphins. This results in a positive mood and happiness, promoting mental stability and positive thinking, successively relieving stress, and reducing feelings of depression and anxiety [11]. Physical activity improves self-esteem, increases self-efficacy, and helps adolescents develop self-regulation and independence by setting goals and challenging themselves through exercise [13]. Physical activity also provides an opportunity to form and maintain social relationships; through athletic teams and club activities, youths can build close relationships with their peers and feel the joy of being together [12]. These social connections can help young people develop social support and friendships, prevent feelings of isolation, and promote social adjustment [14].

Therefore, adequate physical activity must be maintained during adolescence. However, when adolescents do not attend school due to weekends or vacations, their physical activity levels decrease, and they spend more time watching smartphones and TV and develop irregular sleep patterns [1]. During the COVID-19 pandemic, adolescents' physical activity decreased owing to school closures, and >50% of the adolescents were not physically active or walked for <1 h per day [15]. The World Health Organization guidelines recommend that children and adolescents aged 5–17 years should engage in moderate-to high-intensity aerobic physical activities for at least 60 min per day every day each week, and also include high-intensity aerobic physical activity to strengthen muscles and bones at least three days a week [16]. Maintaining an adequate level of physical activity has positive effects on mental health. One study suggested that increased physical activity during the COVID-19 pandemic was associated with a reduction in mood disorders [17]. Other studies have reported a positive association between muscle strengthening and mental health [18-20]. Therefore, the decrease in physical activity of adolescents due to the COVID-19 pandemic has presumably contributed to the deterioration of mental health, including depressed mood.

The hypotheses of this study are as follows: First, since the COVID-19 pandemic, South Korean adolescents' physical activity has decreased, and their mental health has deteriorated. Second, physically active adolescents were less likely to experience worsening depression during the COVID-19 pandemic. This study aimed to examine the association between depressed mood and physical activity in adolescents after the COVID-19 pandemic and analyze factors that can protect adolescents from worsening depressed mood in situations of high psychological stress, such as the COVID-19 pandemic.

METHODS

Study subjects

This study was based on the results of the 17th Youth Health Behavior Online Survey conducted in 2021 [21]. Since its launch in 2005 to understand adolescents' health behaviors in South Korea, the survey has been conducted jointly by the Korea Disease Control and Prevention Agency and the Ministry of Education every year. The target population was defined as students enrolled in middle and high schools nationwide as of April 2021. The survey was conducted with students from their first year of middle school to their third year of high school. The survey was conducted anonymously online in the school computer labs using a self-report method. The sampling process was divided into population stratification, allocation of sampling, and sampling. In the population stratification phase, the population was divided into 117 tiers, using 39 regional groups and school levels (middle school, general high school, and specialized high school) as stratification variables to minimize sampling errors. In the sample allocation phase, the sample was allocated to 400 middle and 400 high schools, and each of the five middle and high schools was first allocated to 17 cities and provinces. Stratified cluster random sampling was used; the primary and secondary extraction units were the school and the class, respectively. All students in the selected sample classes were surveyed, except for those who were excluded from the sample due to long absences that prevented their independent participation in the survey and others who were unable to decode text. Students with literacy problems were also excluded from the sample. A total of 54848 students from 800 schools participated in the survey. This study was approved by the Institutional Review Board of the Gyeongsang National University Hospital (IRB number: GNUH 2023-06-017).

Survey questions

Sociodemographic information

Sociodemographic data included sex, age, school level, academic achievement, and economic status. Academic achievement and economic status were divided into five categories: upper, upper-middle, middle, lower-middle, and lower.

Physical activity

Physical activity-related variables included physical activity for at least 60 min per day, high-intensity physical activity, and muscle-strengthening exercises. For physical activity of at least 60 min per day, the survey asked, "In the last 7 days,

how many days have you performed physical activities (of any kind) with a higher-than-normal heart rate or were out-of-breath for a total of more than 60 min per day?" The subjects could choose among eight answers: "none in the last 7 days," "1 day a week," "2 days a week," "3 days a week," "4 days a week," "5 days a week," "6 days a week," and "7 days a week." For high-intensity physical activity, the survey asked, "In the last 7 days, how many days have you performed >20 min of high-intensity physical activity that makes you feel out of breath or sweating?" The respondents were asked to choose one of six answers: "none in the last 7 days," "1 day a week," "2 days a week," "3 days a week," "4 days a week," and "5 or more days a week." Regarding muscle-strengthening exercises, the survey asked, "In the last 7 days, how many days have you done exercises that build muscle strength (muscle-strengthening exercise) such as push-ups, sit-ups, lifting weights, dumbbells, iron bars, and parallel bars?" They were asked to choose one of six answers: "none in the last 7 days," "1 day a week," "2 days a week," "3 days a week," "4 days a week," and "5 or more days a week."

Emotional state

The question on changes in depressed mood due to the COVID-19 pandemic asked about changes in depressed mood compared to before the COVID-19 pandemic based on responses using one of five answers: "very increased," "increased," "did not change," "decreased," and "decreased very much." Depressed mood was measured by asking, "In the last 12 months, have you ever felt so sad or hopeless that you stopped your daily activities for 2 weeks?" The respondents were asked to choose one of two answers: "none in the last 12 months" or "yes in the last 12 months."

Statistical analysis

Considering the sampling design of the raw data of the Youth Health Behavior Survey, the samples were extracted using a complex design method. Stratified variables, cluster variables, and weights were used as complex sample design elements for analysis, according to the guidelines for data analysis of the complex sample design of the Korea Disease Control and Prevention Agency. In this analysis, the relationship between physical activity types, including physical activity of ≥60 min, high-intensity physical activity, or muscle-strengthening exercises, and changes in depressed mood after the COVID-19 pandemic were assessed using the chi-square test. Logistic regression analysis was performed to identify the association between physical activity and changes in depressed mood after the COVID-19 pandemic. For this, depressed mood changes after the COVID-19 pandemic was set as the dependent variable and coded as "increased," "no change," or "decreased." The number of days of physical activity lasting >60 min, high-intensity physical activity, and muscle-strengthening exercises were set as the independent variables. The coding for these variables was changed to "yes in the last 7 days" and "no in the last 7 days." In addition, age, sex, academic achievement, economic status, and pre-existing depressed mood were used as covariates to adjust the analysis. IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA) was used to perform the statistical analyses. A $p \leq 0.05$ was considered statistically significant.

RESULTS

Subjects characteristics

The survey was conducted in a total of 800 schools (400 middle schools and 400 high schools); however, due to the overburden of the teachers in charge of the survey support and the inability to use the computer lab, the present study analyzed data from 796 schools (399 middle schools and 397 high schools) involving 54848 students. The survey participation rate was 92.8% based on the number of students. The number of targeted participants was the number of students in the roll books on the survey day.

Among the participants, 51.7% were male, and 48.3% were female. The rate of depressed mood changes after the COVID-19 pandemic among female students was higher than that among male students (39.3% vs. 60.7%, $p<0.001$). Male students were more likely to have a decreased depressed mood after the COVID-19 pandemic than those female students (66.9% vs. 33.3%, $p<0.001$). Students in the upper level of academic achievement were less likely to have a reduced depressed mood after the COVID-19 pandemic than those in the lower level (8.2% vs. 12.6%, $p<0.001$). Students in the upper level of economic status were less likely to have an increased depressed mood after the COVID-19 pandemic than those in the lower middle (30.9% vs. 47.0%, $p<0.001$) and lower levels (30.9% vs. 45.5%, $p<0.001$) (Table 1). Students who had experienced depressive feelings in the past 12 months reported a significantly higher rate of depression after the COVID-19 pandemic than those who had no history of depression (61.4% vs. 6.7%, $p<0.001$). The reduction rate of depressed mood after the COVID-19 pandemic was significantly higher among students with increased physical activity than those with decreased physical activity (20.2% vs. 8.0%, $p<0.001$) (Table 1).

Change in depressed mood after the COVID-19 pandemic according to the number of days of physical activity

Fig. 1 shows the changes in depressed mood after the CO-

Table 1. Descriptive characteristics of the study population according to changes in depressed mood after the COVID-19 pandemic

Variables	Value (n=54848)	Changes in depressed mood after the COVID-19 pandemic			p		
		Increased (a)	No change (b)	Decreased (c)	a-b	b-c	a-c
Age (yr)	15.23±0.03	15.33±0.03	15.24±0.03	14.77±0.04	<0.001	<0.001	<0.001
Male	28393 (51.7)	7679 (39.3)	16962 (57.5)	3752 (66.9)	<0.001	<0.001	<0.001
School grade					<0.001	<0.001	<0.001
Middle school student	30006 (51.0)	10221 (35.0)	16169 (53.3)	3616 (11.7)			
High school student	24829 (49.0)	9509 (38.8)	13393 (53.6)	1927 (7.7)			
Academic achievement					<0.001	<0.001	<0.001
Upper	7082 (12.7)	2655 (38.2)	3831 (53.5)	596 (8.2)			
Upper middle	13441 (24.5)	5097 (38.8)	7218 (53.1)	1126 (8.1)			
Middle	16899 (31.0)	5697 (34.8)	9459 (55.5)	1743 (9.7)			
Lower middle	12001 (22.0)	4381 (37.3)	6254 (51.8)	1366 (10.9)			
Lower	5412 (9.9)	1900 (36.1)	2800 (51.3)	712 (12.6)			
Economic status					<0.001	<0.001	<0.001
Upper	5940 (10.9)	1789 (30.9)	3293 (55.3)	858 (13.8)			
Upper middle	15622 (29.3)	5637 (37.0)	8366 (53.0)	1618 (9.9)			
Middle	27071 (49.0)	9463 (36.0)	15147 (55.4)	2461 (8.7)			
Lower middle	5090 (9.0)	2336 (47.0)	2300 (44.6)	454 (8.4)			
Lower	1112 (1.9)	505 (45.5)	456 (41.4)	151 (13.1)			
Depressed mood in the past 12 months					<0.001	<0.001	<0.001
Yes	14687 (26.8)	8924 (61.4)	4736 (31.9)	1027 (6.7)			
No	40148 (73.2)	10806 (27.9)	24826 (61.3)	4516 (10.7)			
Physical activity for at least 60 min per day					0.001	0.030	<0.001
Yes	36588 (66.0)	12967 (36.2)	19793 (53.8)	3828 (10.0)			
No	18247 (34.0)	6763 (38.2)	9769 (52.7)	1715 (9.0)			
High-intensity physical activity					<0.001	<0.001	<0.001
Yes	37055 (66.3)	12802 (35.4)	20141 (54.0)	4112 (10.6)			
No	17780 (33.7)	6928 (39.9)	9421 (52.3)	1431 (7.8)			
Muscle-strength training exercise					<0.001	<0.001	<0.001
Yes	26471 (47.4)	8612 (33.3)	14624 (54.9)	3235 (11.8)			
No	28364 (52.6)	11118 (40.1)	14938 (52.1)	2308 (7.8)			
Changes in physical activity after the COVID-19 pandemic					<0.001	<0.001	<0.001
Increased	11094 (19.4)	3507 (32.5)	5249 (47.3)	2338 (20.2)			
No change	17740 (31.5)	3978 (22.8)	12711 (71.5)	1051 (5.7)			
Decreased	26001 (49.1)	12245 (47.7)	11602 (44.3)	2154 (8.0)			

Values are presented as mean±standard deviation or number (%). COVID-19, coronavirus disease 2019

VID-19 pandemic according to the number of days of physical activity, high-intensity physical activity, and muscle-strengthening exercises. Fig. 1A shows the relationships between the number of days of physical activity lasting at least 60 min in the last 7 days and the change in depressed mood after the COVID-19 pandemic. As the number of days of physical activity increased, more participants showed decreased depressed mood, and vice versa. Fig. 1B shows the relationship between the number of days of high-intensity physical activity in the last 7 days and the changes in depressed mood after the COVID-19 pandemic. As the number of days of high-intensity physical activity increased, the number of participants with increased depressed mood decreased, and the number of participants with decreased depressed mood increased. Fig. 1C shows the relationship between the number of days of muscle-strengthening exercise in the last 7 days and the change in depressed mood after the COVID-19 pandemic. As the number of days of muscle-strengthening exercises increased, the rate of increased depressed mood decreased, and the rate of decreased depressed mood increased.

Logistic regression analysis of the association between physical activity and changes in depressed mood after the COVID-19 pandemic

Students who engaged in physical activity for at least 60 min a day at least once per week had a 0.93-fold (odds ratio [OR]=0.928, 95% confidence interval [CI]=0.888−0.969, p=0.001) risk of increased depressed mood and a 0.92-fold (OR=0.923, 95% CI=0.859−0.992, p=0.030) decreased risk of depressed mood after the COVID-19 pandemic in Model 1. However, in Model 2, after adjusting for sex, age, academic achievement, and economic status, the risk of depressed mood increased by 1.088-fold (OR=1.088, 95% CI=1.040−1.137, p<0.001), while the decreased risk of depressed mood was not significant. The results of Model 3, which was additionally corrected for depressed mood over the past 12 months, were not significant for either increased or decreased depressed mood (Table 2).

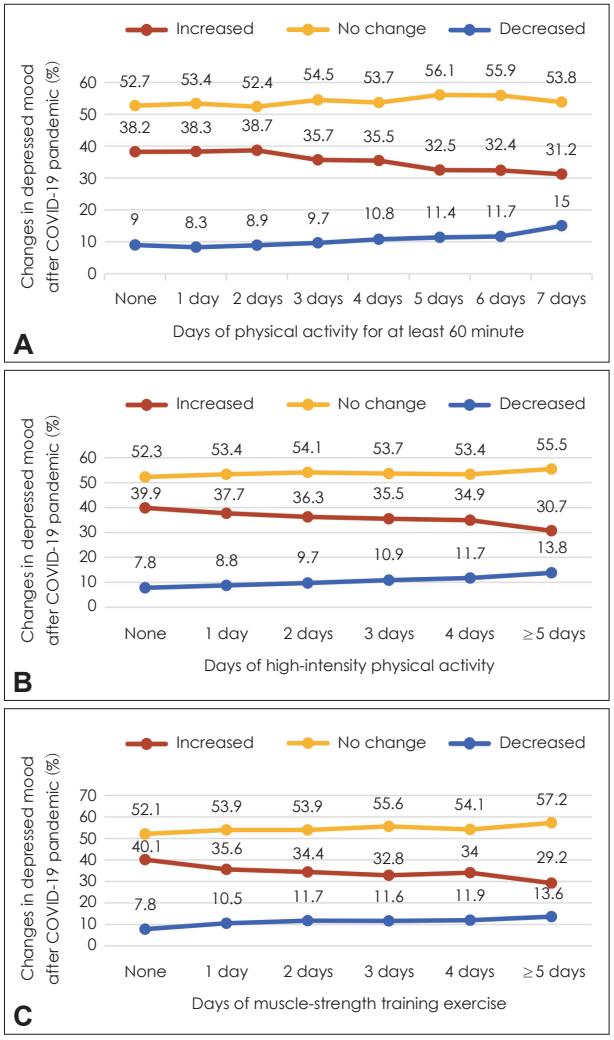

Fig. 1. Changes in depressed mood after the COVID-19 pandemic according to the number of physical activity days. A: Changes according to the number of physical activity days (for at least 60 min). B: Changes according to the number of high-intensity physical activity days. C: Changes according to the number of strength-training exercise days. COVID-19, coronavirus disease 2019.

Students who engaged in high-intensity physical activity at least once per week showed a 0.86-fold lower risk of increased depressed mood after the COVID-19 pandemic (OR=0.857, 95% CI=0.820−0.896, p<0.001) and a 0.76-fold (OR=0.764, 95% CI=0.711−0.822, p<0.001) reduced risk of a decreased depressed mood in Model 1. In Model 2, participants who engaged in high-intensity physical activity at least once per week had a 1.06-fold increased risk of increased depressed mood (OR=1.058, 95% CI=1.013−1.106, p=0.012) and reduced depressed mood (OR=1.120, 95% CI=1.040−1.206, p=0.003). In Model 3, the effect of high-intensity physical activity on the reduction in depressed mood was similar to that in Model 2; however, the effect on the increase in depressed mood was not significant (Table 2).

Students who performed muscle-strengthening exercises at least once per week showed a 0.79-fold reduced risk of increased depressed mood after the COVID-19 pandemic (OR=0.787, 95% CI=0.755−0.821, p<0.001) and a 1.43-fold (OR=1.433, 95% CI=1.338−1.534, p<0.001) reduced depressed mood risk in Model 1. In Model 2, the risk of increased depressed mood among participants who performed muscle-strengthening exercises at least once per week was not significant (p=0.615), while the possibility of reducing depressed mood increased (OR=1.224, 95% CI=1.140−1.314, p<0.001). In Model 3, muscle-strengthening exercises performed at least once per week were associated with a 0.95-fold reduced risk of increased depressed mood (OR=0.948, 95% CI=0.905−0.994, p=0.027), while the probability of decreased depressed mood was increased by 1.22-fold (OR=1.215, 95% CI=1.131−1.305, p<0.001) (Table 2). Subgroup analysis by sex (male or female) and grade (middle or high school) showed a 1.257-fold increased possibility of decreased depressed mood after the COVID-19 pandemic (OR=1.257, 95% CI=1.149−1.376, p<0.001) among male students who performed muscle-strengthening exercises at least once per week, and a 1.177-fold increased probability among female students who performed muscle-strengthening exercises at least once per week (OR=1.177, 95% CI=1.042−1.329, p=0.030). The possibility of a decreased depressed mood after the COVID-19 pandemic was 1.224-fold higher (OR=1.224, 95% CI=1.112−1.348, p<0.001) among middle school students and 1.236-fold higher (OR=1.236, 95% CI=1.100−1.390, p=0.001) among high school students, similar to the results of the primary analysis (Supplementary Table 1 in the online-only Data Supplement).

DISCUSSION

This study analyzed the relationship between adolescents'

Table 2. Association between the implementation of physical activity and changes in depressed mood after the COVID-19 pandemic

Variables	Changes in depressed mood after the COVID-19 pandemic				
	Increased OR (95% CI)	p	No change	Decreased OR (95% CI)	p
Model 1					
Physical activity for at least 60 min	0.928 (0.888 to 0.969)	0.001	Ref.	0.923 (0.859 to 0.992)	0.030
High-intensity physical activity	0.857 (0.820 to 0.896)	<0.001	Ref.	0.764 (0.711 to 0.822)	<0.001
Muscle-strength training exercise	0.787 (0.755 to 0.821)	<0.001	Ref.	1.433 (1.338 to 1.534)	<0.001
Model 2					
Physical activity for at least 60 min	1.088 (1.040 to 1.137)	<0.001	Ref.	0.987 (0.916 to 1.064)	0.738
High-intensity physical activity	1.058 (1.013 to 1.106)	0.012	Ref.	1.120 (1.040 to 1.206)	0.003
Muscle-strength training exercise	1.011 (0.968 to 1.057)	0.615	Ref.	1.224 (1.140 to 1.314)	<0.001
Model 3					
Physical activity for at least 60 min	1.031 (0.983 to 1.081)	0.209	Ref.	0.981 (0.910 to 1.058)	0.618
High-intensity physical activity	1.001 (0.955 to 1.049)	0.970	Ref.	1.113 (1.034 to 1.198)	0.004
Muscle-strength training exercise	0.948 (0.905 to 0.994)	0.027	Ref.	1.215 (1.131 to 1.305)	<0.001

Model 1 was not adjusted. Model 2 was adjusted for age, sex, academic achievement, and economic status. Model 3 was adjusted for age, sex, academic achievement, economic status, and depressed mood in the past 12 months. CI, confidence interval; COVID-19, coronavirus disease 2019; OR, odds ratio

physical activity and changes in depressed mood after the COVID-19 pandemic using data from the 17th Youth Health Behavior Survey. Since the onset of the COVID-19 pandemic, physical activity among Korean adolescents has decreased, and the number of adolescents who feel that their depressed mood has worsened has increased. The association between physical activity and changes in depressed mood identified in this study suggests that improving health through physical activity may be a protective factor against depressed mood. Physical activity is an essential factor that can positively affect adolescents' mental health [17], and has been recommended to improve adolescents' mental health in situations of great psychological stress, such as COVID-19 [22]. However, in this study, adolescents' physical activity decreased significantly after the COVID-19 pandemic, and the rate of decrease (49.1%) was 2.5 times higher than that of increase (19.4%). However, approximately 4-fold more adolescents (36.9%) reported a worsening depressed mood than adolescents who reported decreased depressed mood (9.7%). Therefore, decreased physical activity may be associated with worsening depressed mood in adolescents.

In this study, the associations between changes in depressed mood and physical activity of ≥60 min or high-intensity physical activity were not significant; however, the rate of increased depressed mood after the COVID-19 pandemic in relation to muscle-strengthening exercises decreased after adjusting for pre-existing depression. In a previous study comparing the effects of aerobic and muscle-strengthening exercises on depression in adults, both aerobic and muscle-strengthening exercises, regardless of sex, significantly reduced feelings of depression [23]. A study targeting showed that both aerobic and anaerobic exercises had significant effects on reducing depression and that anaerobic exercise had a more significant effect on strengthening self-concept compared to aerobic exercise [24]. Previous studies on the effects of aerobic and muscle-strengthening exercises in adolescents who were overweight or obese have suggested that muscle-strengthening exercises alone or a combination of both exercises may have a positive psychological effect [25]. The results of the present study showed that aerobic exercise was not significantly related to changes in depression in adolescents; however, muscle-strengthening exercises showed a significant association.

Muscle strength is an essential health indicator, as it is associated with lower mortality rates in the adult population, regardless of age [26]. One meta-analysis observed a significant correlation between muscle strength and reduced depressive symptoms [27], while two extensive studies reported the positive effects of muscle-strengthening exercise on depression in adults [28,29]. Both studies, which suggested depressive symptom improvement by muscle-strengthening exercises, were performed in adult cohorts in different countries. In recent years, the discovery of muscle secretomes has drawn attention to the effects of the muscular systems on health maintenance. In response to muscle contraction, myokines such as serum interleukin-6 (IL-6), irisin, brain-derived neurotrophic factor, kynurenine, and cathepsin B can cross the blood-brain barrier and deliver the positive effects of physical activity to the brain [30]. Myokines exert beneficial effects in neurodegenerative diseases through various regulatory mechanisms, including cell survival, neurogenesis, neuroinflammation, protein stability, oxidative stress, and protein modification. Moreover, myokines are effective in depression treatment and prevention [31,32]. Among myo-

kines, IL-6 is associated with depressive symptoms and reduced physical activity in older adults, while irisin levels are inversely correlated with depression and can predict reduced quality of life [30]. Depending on the exercise type and method, the types of myokines released differ; particularly, muscle-strengthening exercises strongly stimulate myokine release [33]. Few studies have assessed the association between muscle-strengthening exercises and depression in large adolescent cohorts. The present study provides evidence for this association.

This study had several limitations. First, owing to the cross-sectional design, the interpretation of the causal relationship between physical activity and depressed mood was limited. As a pre-existing depressed mood may have affected the implementation of muscle-strengthening exercises, additional regression analysis was performed to determine the association between muscle-strengthening exercises and pre-existing depression, which revealed no significant association. Therefore, pre-existing depression did not significantly affect muscle-strengthening exercises, and an inverse causal relationship can be ruled out. Second, the level of physical activity was examined based only on the number of days of physical activity performed, and the analysis used variables converted to assess only whether physical activity was performed. The level of physical activity varies among individuals, and detailed information on the duration and intensity of physical activity per day was lacking. Third, depression was self-reported by asking questions about subjective depressed moods. As the questions asked about pre-existing depression in "the past 12 months," recall bias cannot be ruled out. Future studies should use a standardized tool such as the Beck Depression Inventory, which is used to assess depression symptoms, to allow for more objective investigations. However, in this study, we evaluated the changes in depressed mood after COVID-19 by asking the adolescents about their perceived changes. Thus, the possibility of information bias was lower and more reliable. Despite these limitations, to our knowledge, this study is the first to demonstrate the association between changes in depressed mood and physical activity in adolescents after the COVID-19 pandemic. Another strength of this study is the use of data collected from a large population sample with high response rates. In addition, this study assessed the changes in adolescents' mental health during the COVID-19 pandemic and found that approximately four times as many adolescents (36.9%) reported worsening depression as those who reported a decrease in depression (9.7%). The results of this study confirmed that physical activity, particularly muscle-strengthening exercises, was an effective way to prevent the worsening of depression.

CONCLUSION

This study examined the association between changes in depressed mood and physical activity among adolescents following the COVID-19 pandemic. Light physical activity of >60 min and high-intensity physical activity per day showed no significant associations after adjusting for sex, age, academic achievement, economic status, and pre-existing depressed mood. Conversely, muscle-strengthening exercises had a significant effect in preventing the worsening of depressed mood and reducing depression. These results could inform the development and implementation of adolescent physical activity programs to prevent and manage depressed moods.

Supplementary Materials

The online-only Data Supplement is available with this article at https://doi.org/10.5765/jkacap.230043.

Availability of Data and Material

The datasets generated or analyzed during the current study are available in the Korea Disease Control and Prevention Agency repository (http://www.kdca.go.kr/yhs/).

Conflicts of Interest

Jae-Won Choi, a contributing editor of the *Journal of the Korean Academy of Child and Adolescent Psychiatry*, was not involved in the editorial evaluation or decision to publish this article. All remaining authors have declared no conflicts of interest.

Author Contributions

Conceptualization: Jae-Won Choi. Data curation: Jina Jang. Investigation: Eunji Lim, Nuree Kang. Methodology: Jina Jang, Dongyun Lee, Jae-Won Choi. Project administration: Bong-Jo Kim, Cheol-Soon Lee. Supervision: Boseok Cha, So-Jin Lee. Validation: Young-Ji Lee. Writing—original draft: Jina Jang, Jae-Won Choi. Writing—review & editing: Bong-Jo Kim, Cheol-Soon Lee, Boseok Cha, So-Jin Lee, Dongyun Lee, Young-Ji Lee, Eunji Lim, Nuree Kang.

ORCID iDs

Jina Jang	https://orcid.org/0009-0004-5075-6102
Bong-Jo Kim	https://orcid.org/0000-0003-2419-7306
Cheol-Soon Lee	https://orcid.org/0000-0003-1479-6962
Boseok Cha	https://orcid.org/0000-0002-3309-8863
So-Jin Lee	https://orcid.org/0000-0003-2904-9206
Dongyun Lee	https://orcid.org/0000-0002-3977-3663
Young-Ji Lee	https://orcid.org/0000-0003-0201-2518
Eunji Lim	https://orcid.org/0000-0003-3967-8524
Nuree Kang	https://orcid.org/0000-0001-7630-4033
Jae-Won Choi	https://orcid.org/0000-0002-4516-1954

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