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Analyzing longitudinal changes in physical activity, self-esteem, and depression among male adolescents: evidence from the 2018–2022 Korean children and youth panel survey

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Abstract

Background: This study investigated longitudinal changes in physical activity, self-esteem, and depression among Korean male adolescents to explore implications for long-term adolescent health and well-being. **Methods**: Data were drawn from the Korean Children and Youth Panel Surveys from 2018 to 2022. **Results**: The results revealed that all three indicators—physical activity, self-esteem, and depression symptoms—worsened over time. However, no significant differences were observed in physical activity between 2020 and 2021, in self-esteem between 2021 and 2022, or in depression between 2020 and 2021 or 2021 and 2022. Quadratic trajectories best fit the data across all variables, indicating nonlinear developmental patterns. Male adolescents with higher initial scores showed steeper early declines, whereas those with slower initial decreases exhibited steeper declines later. **Conclusions**: These findings suggest that Korean male adolescents experience progressive deterioration in physical, psychological, and emotional health as they grow older. Promoting long-term adolescent health and well-being requires continuous monitoring and targeted strategies that promote physical activity, strengthen self-esteem, and support mental well-being throughout adolescence.

Keywords

Adolescent boys; Depression; Latent growth modeling; Physical activity; Self-esteem

1. Introduction

According to the World Health Organization (WHO), physical activity is defined as any physical movement produced by skeletal muscles that requires energy expenditure, and includes exercises performed to improve or maintain physical fitness and sports performed within set rules [1]. WHO recommends an average of at least 60 minutes of moderate- to high-intensity physical activities per day for children and adolescents under 18 years old [2]. Importantly, adolescence is a period of heightened susceptibility to mental health issues, with the potential onset of depressive symptoms and low self-esteem that can continue into adulthood. Engaging in regular physical activity is proposed as a feasible approach to support psychological well-being, correlating with fewer depressive symptoms and improved mood in adolescents [3–5]. Consequently, insufficient physical activity poses a dual risk, impacting both physical health and mental health protection and promotion in this age group.

Although there is clear evidence that a higher level of physical activity among adolescents is associated with significant health benefits [6, 7], 80% of adolescents worldwide do not get enough physical activity [8]. Such activity is particularly ben-

eficial for creating health-promoting habits that can prevent, affect, and manage chronic diseases [9]. Specifically, studies have shown that there is a significant association between physical activity and hypertension, cancer, and cardiovascular health [10–12]. In children and adolescents, physical activity has been found to positively influence their cardiovascular and metabolic health [13]. In studies of the young, their participation in physical activities has been proven to be positively associated with body composition, cardiac metabolism, and bone health [14–16]; along with having a positive impact on signs of depression, negative moods, and mental health [3–5]. These effects have all been confirmed among children and adolescents [17, 18].

Consistent with this evidence, physical activity is associated with better psychological and mental health in adolescents, including lower depressive symptoms and anxiety and higher self-esteem [17, 19]. As such, it is closely associated with not only adolescent physical health, but also their psychological, emotional, and mental health. Nevertheless, the insufficient physical activity among most adolescents poses a potential risk and concern for their long-term health and well-being, as the sedentary habits will have lasting effects. Therefore, to assess and implement appropriate measures for the management of

adolescent well-being, we need to ensure that we understand the current status of their physical and mental health by systematically collecting and analyzing trends over time.

Self-esteem is a subjective perspective of one's worth [20], namely, how positively one views oneself as important and worthy [21]. In a study of Korean adults [22], self-esteem differed based on demographic, socioeconomic, psychological, physical, and relational factors. As noted, self-esteem is a critical factor in adolescence that can affect adulthood [23] and is reported to be a predictor of health, criminal behavior, and economic status [24]. However, as with adults, self-esteem in adolescence is influenced by other factors. One recent study on adolescents in Nordic countries reported that self-esteem was associated with psychological factors, such as loneliness and mental well-being [25]. Relational factors, such as parenting styles and social media use, have also been noted to be associated with self-esteem [26, 27]. From a socioeconomic perspective, self-esteem has been shown to play a moderating role in the relationship between social class and subjective well-being [28]. From a demographic standpoint, consistent differences in self-esteem between the sexes have been observed, with male adolescents generally reporting higher levels of self-esteem than their female counterparts—showing a more pronounced decline in self-esteem during adolescence [29, 30]. These consistently reported sex variations suggests that pooled analyses may mask subgroup-specific developmental patterns. Therefore, we focused on male adolescents to describe male-specific trajectories during early to middle adolescence. Nevertheless, including female adolescents in sex-comparative analyses remains a crucial domain for future research. Given these differences, examining developmental patterns specifically among male adolescents remains important, as their trajectories may differ in meaningful ways. Adolescent self-esteem, influenced by multiple surrounding factors, can influence various situations in adulthood. Consequently, tracking self-esteem during adolescent development is essential for tailoring interventions that promote a favorable future and long-term well-being in adulthood.

Depression, a common mental health disorder, characteristically first appears in mid to late adolescence [31]. The prevalence of depression is closely associated with age, as it tends to increase gradually throughout childhood and adolescence [31]. In terms of its risk, depression is associated with suicide; and depression in adolescence is considered a predictor of depression in adulthood [32]. Although depression is classified as a common disorder, because of its association with suicide, it should be dealt with strictly as it is directly linked to life. Therefore, early recognition of depression in adolescents is vital [33].

According to a study in the US [34], the prevalence of depression among adolescents increased by 7.7% between 2009 and 2019. Notably, the difference in prevalence between boys and girls increased from 6.4% to 14.8% during this period, suggesting a more significant rise in depression prevalence among girls. These findings highlight the urgency of further research focusing on girls' depressive trajectories. Simultaneously, sex-specific trends further emphasize the need to characterize within-group longitudinal patterns among boys, because pooled analyses may obscure subgroup-specific de-

velopmental changes; therefore, the present study focused on male adolescents to address this gap. Such sex-specific trends underscore the importance of examining depressive trajectories within specific subgroups, including male adolescents, whose patterns may differ in meaningful ways. Accordingly, the present study examined male adolescents as a distinct subgroup to characterize within-group longitudinal change, rather than treating sex only as a covariate. Although it is difficult to identify the cause of depression in adolescents, environmental and genetic factors are known to be influential [31]. Specifically, adolescent depression has been shown to be closely associated with socioenvironmental factors, such as interpersonal and family relationships [35–37]; such relationships include not only offline but also online activities, such as the use of social media [38]. In addition, genetic factors, such as body dissatisfaction, have also been reported as contributors [39]. As it appears most commonly during adolescence and causes negative changes, we need to ensure establishment of an environment for early intervention by accurately identifying the changing patterns of depression among adolescents.

To that end, our study investigates the longitudinal changes in physical activity, self-esteem, and depression among Korean male adolescents to identify suitable interventions that can lead to healthy habits over time. Adolescence is a period of physical, psychological, and emotional growth and change that has long-term effects on adult quality of life. Although various factors influence adolescent health, we focused on physical activity, self-esteem, and depression as representative indicators. Despite the conceptual connections between physical activity, self-esteem, and depressive symptoms, this study explores the domain-specific longitudinal trajectories of each indicator among Korean male adolescents. These variables have primarily been examined in cross-sectional studies, while longitudinal studies have largely focused on adults or on the COVID-19 pandemic. This is essential, as the dynamics and strength of associations among these variables—physical activity, self-esteem, and depressive symptoms—may vary significantly across developmental stages. However, evidence on how these relationships evolve over time remains limited, underscoring the novelty and priority of the present longitudinal analysis. To fill this gap in the literature, we analyzed five-year longitudinal data to examine changes in physical activity, self-esteem, and depression among Korean male adolescents over time. By doing so, our findings can enhance our understanding of the developmental patterns of Korean boys and provide foundational data for designing appropriate interventions to address adolescent health issues. Our hypotheses were as follows.

H1. Korean male adolescents will show significant annual differences in physical activity, self-esteem, and depression.

H2. Korean male adolescents will exhibit systematic longitudinal trends and individual variability in the trajectories of physical activity, self-esteem, and depression.

2. Materials and methods

2.1 Subjects

Our study used raw data from the yearly Korean Children and Youth Panel Survey (KCYPS) conducted by the Korea National Youth Policy Institute [40]. This study employed a longitudinal panel design using data from the KCYPS, a large-scale national survey conducted by the Korea National Youth Policy Institute. The KCYPS adopts a stratified multistage cluster sampling design to collect annual data on children and adolescents in Korea, with the aim of tracking developmental, behavioral, and psychosocial changes over time. The sample population comprised a cohort of initially fourth-grade students, with the analysis period covering five years, 2018 to 2022. The surveys were conducted between August and November of each year, with an investigator visiting each household to conduct the survey in-person. However, in 2020, the survey combined both in-person and online methods because of the COVID-19 pandemic. In 2018 (in fourth-grade), the first year of the survey, the original panel comprised 2607 children (boys = 1313, girls = 1294) selected by stratified multistage cluster sampling. Because the KCYPS uses a complex sampling design, the present study describes patterns observed in this national panel cohort; population-level generalizations should be interpreted cautiously. In each subsequent year, missing values occurred because of the inability to track the student; therefore, the number of children who participated in the survey was 2437 (boys = 1221, girls = 1216) in 2019 (fifth grade), 2411 (boys = 1211, girls = 1200) in 2020, 2275 (boys = 1145, girls = 1130) in 2021, and 2311 (boys = 1155, girls = 1156) in 2022. Across waves, participation varied due to attrition and intermittent item nonresponse; therefore, retention-related bias is possible, and the findings should be interpreted with caution. For the present study, inclusion criteria were participation in the KCYPS panel and availability of data for at least one survey wave during the observation period. Female adolescents were excluded from the analytic sample to enable a focused examination of male-specific developmental trajectories in physical activity, self-esteem, and depression. For the current analysis, only male adolescents were included, and girls were excluded from the analytic sample to examine male-specific developmental trajectories. Sex-comparative analyses might be informative, but they were beyond the scope of this study, which sought to describe focused male-specific longitudinal patterns. While this approach enabled a focused analysis of male-specific developmental trajectories, it limits the generalizability of findings to the full adolescent population.

2.2 Survey instruments

2.2.1 Physical activity

We measured physical activity with three self-reported items from the KCYPS, originally developed by the Korea Ministry of Gender Equality and Family and adapted by the Korea National Youth Policy Institute [41, 42]: (a) How many hours of exercise and physical activity did you take part in on weekdays during the past semester? (excluding school class time); (b) How many hours of exercise and physical activity did you take part in on weekends during the past semester? and (c) How many hours of vigorous exercise, sufficient to induce perspiration, did you engage in during the past week? The amount of exercise and physical activity during weekdays and weekends was rated on a seven-point Likert scale (1: none; 2: 0–30 min; 3: 30 min–1 h; 4: 1–2 h; 5: 2–3 h; 6: 3–4 h; and 7: ≥4 h). The amount of exercise in the past week was rated on a five-point Likert scale (1: none; 2: 1 h; 3: 2 h; 4: 3 h; and 5: ≥4 h). The scale for item (c) was converted to a seven-point scale for consistency with the scale for items (a) and (b). Specifically, we recoded the 5-point categories to the closest corresponding hour-based categories on the 7-point scale as follows: 1 (none) → 1, 2 (1 h) → 3 (30 min–1 h), 3 (2 h) → 4 (1–2 h), 4 (3 h) → 5 (2–3 h), and 5 (≥4 h) → 7 (≥4 h). The original response categories' ordinal meaning was preserved by this recoding, which ensured a consistent response format across the three physical-activity items. Cronbach's α for each year was acceptable: 2018 = 0.711, 2019 = 0.717, 2020 = 0.758, 2021 = 0.716, and 2022 = 0.731.

2.2.2 Self-esteem

We measured self-esteem using the 10-item Rosenberg Self-Esteem Scale, adapted for use in Korea [21]: (a) I am satisfied with myself; (b) At times, I think I am no good at all; (c) I feel that I have a number of good qualities; (d) I feel that I'm a person of worth; (e) I feel I do not have much to be proud of; (f) I feel useless at times; (g) I am able to do things as well as most other people; (h) I wish I could have more respect for myself; (i) I am inclined to think that I am a failure; and (j) I take a positive attitude toward myself. Each item was rated on a four-point Likert scale (from 1 = Strongly disagree to 4 = Strongly agree). For statistical analysis, items (b), (e), (f), and (i) were reverse-scored, with higher scores indicating higher self-esteem. Cronbach's α for each year was acceptable: 2018 = 0.824, 2019 = 0.836, 2020 = 0.818, 2021 = 0.827, and 2022 = 0.808.

2.2.3 Depression

Depressive symptoms were assessed utilizing a 10-item self-report scale developed by Kim and implemented in the KCYPS [43]: (a) I don't have much energy; (b) I feel unhappy, sad, or depressed; (c) I worry a lot; (d) I have thoughts of wanting to die; (e) I cry a lot; (f) When something goes wrong, I often blame myself; (g) I am lonely; (h) Nothing is interesting or fun to me; (i) I don't think the future is bright; and (j) I find everything to be difficult. Each item was rated on a four-point scale (from 1 = Strongly disagree to 4 = Strongly agree). All items were reverse-scored for statistical analysis, with higher scores indicating lower depression. Accordingly, higher scores indicate fewer depressive symptoms (*i.e.*, better mental health), and a decline in depression scores with time reflects worsening depressive symptoms. Cronbach's α for each year was good: 2018 = 0.892, 2019 = 0.905, 2020 = 0.925, 2021 = 0.903, and 2022 = 0.894.

2.3 Data analysis

For data analysis, we investigated longitudinal changes in physical activity, self-esteem, and depression among Korean male adolescents using the following procedures. First, we ran

repeated-measures analyses of variance to assess annual differences in each factor. Since the repeated-measures analysis of variance (ANOVA) requires complete observations across all five waves, this procedure was conducted using complete cases for each variable. Second, we applied unconditional latent growth modeling to identify the trajectory of each factor over time. In latent growth modeling, missing data were addressed using the maximum-likelihood estimation framework in Amos, allowing participants with partially observed data to contribute to parameter estimation. For each variable, we compared linear and quadratic models and, based on the model comparison results, tested the means, variances, and covariances of the selected model to examine changes over time. Model fit was evaluated using standard goodness-of-fit (GoF) indices, including the Turker-Lewis index (TLI), comparative fit index (CFI), and root mean square error of approximation (RMSEA). We also tested the significance of standardized and unstandardized coefficients to confirm the longitudinal trends of each variable. All analyses were performed using SPSS and Amos 24.0 (IBM Corp., Armonk, NY, USA), with significance set at $p < 0.05$. Since the KCYPS was designed using stratification and multistage clustering, we conducted individual-level analyses without applying sampling weights or adjusting standard errors for clustering; therefore, estimates should be interpreted as pertaining to the analytic sample rather than as fully design-based population estimates.

3. Results

3.1 Changes in physical activity, self-esteem, and depression by year

As noted, we performed repeated-measures analysis of variance to assess annual differences in physical activity, self-esteem, and depression among Korean male adolescents (Table 1). Because repeated-measures ANOVA requires complete observations across waves, this analysis was based on participants with non-missing values at all five time points for the corresponding variable. Fig. 1 displays the mean values for each factor by year. For all three variables, the sphericity assumption was violated (physical activity: Mauchly's W = 0.91, $\chi^2(9) = 193.02$, $p < 0.001$, Greenhouse-Geisser epsilon (ε_GG) = 0.95; self-esteem: Mauchly's W = 0.87, $\chi^2(9) = 292.98$, $p < 0.001$, $\varepsilon\_GG = 0.93$; depression: Mauchly's W = 0.93, $\chi^2(9) = 193.02$, $p < 0.001$, $\varepsilon\_GG = 0.97$). Accordingly, we applied the Huynh-Feldt correction. The results indicated significant differences across years in physical activity ($F = 252.64$, $p < 0.001$), self-esteem ($F = 271.15$, $p < 0.001$), and depression scores ($F = 84.32$, $p < 0.001$). Physical

activity scores showed a gradual decline over time, although no significant difference was observed between 2020 and 2021. Similarly, self-esteem scores decreased across years, with no significant variance between 2021 and 2022. Furthermore, depression scores also gradually declined, indicating worsening depressive symptoms. However, *post-hoc* analyses revealed no significant differences in depression scores between 2020 and 2021 or between 2021 and 2022. Overall, these findings demonstrate significant longitudinal changes in all three variables across early to middle adolescence, thereby supporting Hypothesis 1.

3.2 Trajectory of physical activity, self-esteem, and depression by year

As described earlier, we compared linear and quadratic latent growth models to identify the best-fitting trajectory for physical activity, self-esteem, and depression (Table 2). Model fit was evaluated using standard global fit indices (TLI >0.90, CFI >0.90, RMSEA <0.08). For physical activity, both the linear and quadratic models satisfied the cut-off criteria, although the quadratic model demonstrated relatively better fit. For self-esteem, the linear model did not meet the cut-off values for TLI and RMSEA, and for depression, the linear model failed to meet all fit criteria. In contrast, the quadratic models for both self-esteem and depression satisfied all fit indices. Overall, the quadratic models exhibited superior fit across all three variables, indicating that nonlinear trajectories better captured the developmental patterns of physical activity, self-esteem, and depression among male adolescents.

Table 3 presents the means, variances, and covariances of the latent growth parameters for physical activity, self-esteem, and depression, and Fig. 2 illustrates the observed scores along with the estimated linear and quadratic trajectories. For all three variables, the means of the intercept, linear slope, and quadratic slope were statistically significant ($p < 0.001$). The linear slope was negative, whereas the quadratic slope was positive, indicating that although physical activity, self-esteem, and depression decreased over time, the rate of decline gradually slowed. Since depression scores were reverse-scored (higher scores indicate fewer depressive symptoms), a decline over time indicates worsening depressive symptoms. Accordingly, in the interpretation of the growth parameters, decreases in depression scores are described as increases in depressive symptoms to prevent misinterpretation. The variances of the intercept, linear slope, and quadratic slope were also significant for all three variables ($p < 0.001$), suggesting substantial individual differences in both initial levels and rates of change. Regarding covariances, the intercept–linear

T A B L E 1. Differences in physical activity, self-esteem, and depression by year.

	2018 (a) (n = 1313)	2019 (b) (n = 1221)	2020 (c) (n = 1211)	2021 (d) (n = 1145)	2022 (e) (n = 1155)	F	*post-hoc*
Physical activity	4.22 ± 1.35	3.97 ± 1.36	3.41 ± 1.44	3.39 ± 1.30	3.27 ± 1.32	252.636***	a > b > c, d > e
Self-esteem	3.32 ± 0.46	3.15 ± 0.45	3.10 ± 0.45	3.02 ± 0.45	2.97 ± 0.43	271.150***	a > b > c > d, e
Depression	3.51 ± 0.50	3.40 ± 0.51	3.28 ± 0.61	3.30 ± 0.52	3.28 ± 0.52	84.320***	a > b > c, d, e

***p < 0.001, assessed through repeated-measures analysis of variance.; a = 2018, b = 2019, c = 2020, d = 2021, e = 2022.
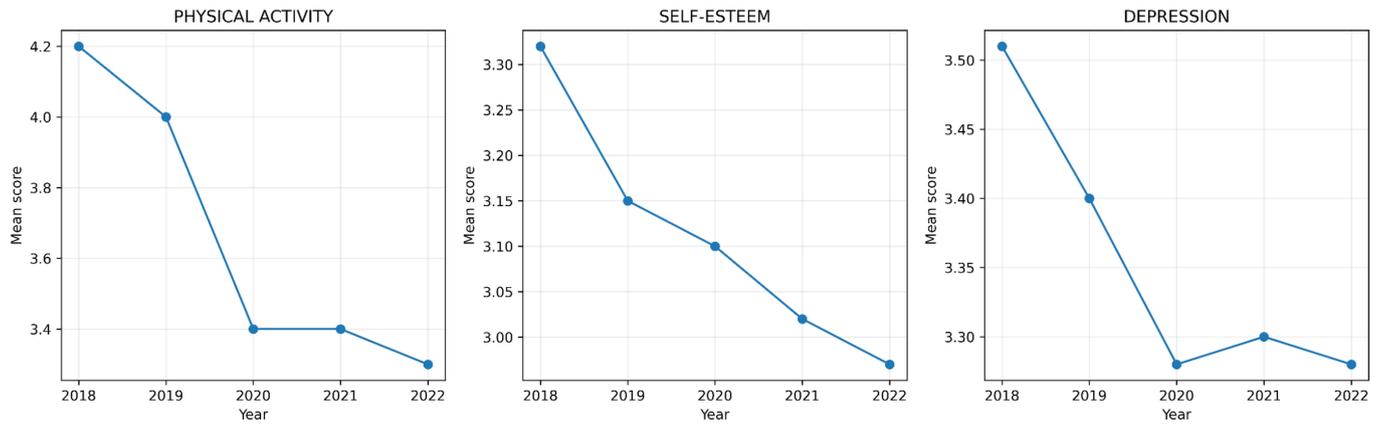
F I G U R E 1. Changes in physical activity, self-esteem, and depression among Korean male adolescents.

T A B L E 2. Comparison of fit of linear and quadratic models.

	χ^2	df	p	Turker-Lewis index	Comparative fit index	Root mean square error of approximation
Physical activity						
Linear model	15.863	10	<0.001***	0.904	0.936	0.076
Quadratic model	78.784	6	<0.001***	0.922	0.969	0.068
Self-esteem						
Linear model	209.780	10	<0.001***	0.871	0.914	0.088
Quadratic model	15.829	6	0.015*	0.989	0.996	0.025
Depression						
Linear model	218.083	10	<0.001***	0.807	0.872	0.089
Quadratic model	65.509	6	<0.001***	0.908	0.963	0.062

*$p < 0.05$, ***$p < 0.001$, assessed through structural equation analysis.*

T A B L E 3. Mean, variance, and covariance of prediction models.

	Mean	Variance	Covariance		
			Intercept-slope	Slope-quad	Intercept-quad
Physical activity					
Intercept	3.830***	1.223***			
Slope	−0.390***	0.371***	−0.386***	−0.061***	0.049***
Quad	0.040***	0.011***			
Self-esteem					
Intercept	3.291***	0.102***			
Slope	−0.149***	0.056***	−0.026***	−0.011***	0.030
Quad	0.017***	0.003***			
Depression					
Intercept	3.466***	0.140***			
Slope	−0.141***	0.081***	−0.040***	−0.017***	0.004
Quad	0.022***	0.004***			

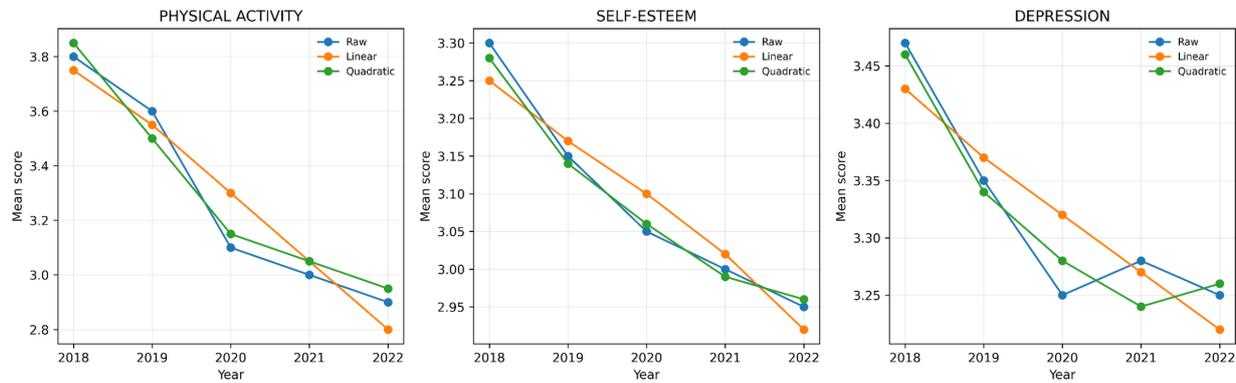*****$p < 0.001$, assessed through structural equation analysis.*

F I G U R E 2. Trajectory of changes in physical activity, self-esteem, and depression according to raw scores, linear model, and quadratic model.

slope, linear slope–quadratic slope, and intercept–quadratic slope covariances were all statistically significant for physical activity ($p < 0.001$). This indicates that students with higher initial levels experienced faster initial declines, but their rate of decline slowed more noticeably over time; conversely, students who initially declined more slowly tended to show steeper decreases later in adolescence. For self-esteem and depression, the intercept–quadratic slope covariance was not statistically significant ($p > 0.05$), indicating that initial levels were not directly associated with the curvature of change. However, the intercept–linear slope and linear slope–quadratic slope covariances were significant, suggesting that students with higher initial self-esteem or lower initial depression tended to experience steeper declines, and those experiencing slower early declines showed steeper decreases later. Consequently, H2 was supported.

4. Discussion

In this study, we examined longitudinal changes in physical activity, self-esteem, and depression among Korean male adolescents from 2018 to 2022. Specifically, we analyzed annual differences in each variable and identified the longitudinal trajectories of change using latent growth modeling. By examining nonlinear patterns and individual variability in these trajectories, our study provides a detailed understanding of how key physical and psychological indicators evolve during early to middle adolescence. These findings should be interpreted with caution, due to the coinciding study period with the COVID-19 pandemic, which substantially altered adolescents' daily routines, school environments, and opportunities for physical activity. Consequently, pandemic restrictions may have affected changes in physical activity, self-esteem, and depressive symptoms observed during this period.

These Korean male adolescents showed decreasing participation in physical activity over time. This pattern is consistent with findings from studies in the United States, which reported rapid declines in physical activity among individuals aged 10–24 years [44]. A study conducted across multiple European countries similarly showed gradual decreases in physical activity from ages 4–5 through 14–15 years [45]. In our results, the sharpest decline occurred in 2020, which aligns with the onset of the COVID-19 pandemic. Importantly,

this study is observational and the 2020 wave included a hybrid in-person and online data-collection mode, the temporal coincidence with the COVID-19 outbreak should be interpreted cautiously. We do not attribute the 2020 change to the pandemic without careful consideration. Several studies have reported substantial reductions in adolescents' physical activity levels during the pandemic [46–48]. Neville *et al.* [49] found that participation in physical activity among children and adolescents decreased by approximately 20% before and after the COVID-19 outbreak. Studies in Korea also observed continued decreases in physical activity, with limited differences between 2020 and 2021 but more notable declines between 2021 and 2022, even after social activity restrictions began to relax. The latent growth modeling results further indicated that physical activity showed a nonlinear decline, with the rate of decrease gradually slowing over time. This indicates that while physical activity persists diminishing during early to middle adolescence, the rate of decline becomes less pronounced as adolescents age. From a mechanistic perspective, during early to middle adolescence, the decline in physical activity may reflect reduced discretionary time and fewer opportunities for organized or informal activity as academic demands increase [50, 51]. In the Korean context, increased time spent on schoolwork and private education, along with limited access to convenient community sport spaces for some students, may further constrain routine physical activity; these interpretations remain speculative and warrant direct measurement in future studies [52, 53].

We also found that self-esteem among Korean male adolescents decreased over time. This trend is consistent with findings from a study on French middle school students, which reported a 21% decline in self-esteem over a 10-year period [54]. Unlike physical activity, we did not observe a rapid change in self-esteem during the COVID-19 pandemic. The largest decrease occurred between 2018 and 2019, and no significant difference was found between 2021 and 2022, suggesting that the declining trend had largely stabilized by 2021. A study of Japanese children and adolescents similarly reported no pandemic-related decrease in self-esteem [55], partially aligning with our findings. The latent growth modeling results indicated that self-esteem followed a nonlinear decline, with the rate of decrease gradually diminishing over time. Although the overall trend showed a decrease, its intensity weakened as

adolescents grew older.

Depression symptoms among Korean male adolescents tended to worsen over time. This pattern aligns with global trends, as one study reported that the worldwide prevalence of adolescent depression rose from 24% between 2001 and 2010 to 37% between 2011 and 2020, with particularly sharp increases among Asian adolescents [56]. Similarly, a study of American adolescents reported a 7.7% rise in depressive symptoms between 2009 and 2019 [34]. Conversely, our study findings report that depression scores decreased between 2018 and 2020, indicating worsening depressive symptoms, and no rapid changes were observed during the COVID-19 pandemic. The decrease stagnated after 2020, with no significant changes through 2022. A multinational study involving adolescents in the United States, the Netherlands, and Peru found significant increases in depressive symptoms during the six months before and after the onset of COVID-19 [57]. In our data, however, similar increases occurred both before and after the pandemic period, making it unclear whether COVID-19 had a unique impact. The latent growth modeling results indicated that depression scores showed a nonlinear decline (reverse-scored), indicating symptom worsening, with the rate of decline slowing over time. Although depressive symptoms worsened overall during early to middle adolescence, the pattern of change became more gradual with age.

4.1 Practical implications

Our findings provide an important basis for understanding changes in the physical, psychological, and mental health of Korean male adolescents over time, a group for whom developmental health patterns have been less frequently examined independently. The indicators for physical activity, self-esteem, and depression all worsened as students advanced to higher grades. In other words, male adolescents gradually engaged in less physical activity, their self-evaluations of personal worth weakened, and their depressive symptoms intensified during early to middle adolescence. These patterns suggest that Korean male adolescents experience increasing physical, psychological, and emotional challenges as they grow older, highlighting the need for targeted strategies to support healthy development and promote long-term well-being.

The latent growth modeling results further demonstrated nonlinear trajectories across all three variables, with the rate of decline gradually slowing over time. This indicates that although these health indicators worsen during adolescence, the pace of change becomes less steep as students mature. Since each trajectory was modeled independently, this study does not examine predictive or directional relationships among changes in physical activity, self-esteem, and depressive symptoms. Collectively, these findings underscore the importance of early and continuous monitoring, as well as the implementation of interventions that foster physical activity, strengthen self-esteem, and support mental health throughout adolescence.

4.2 Limitations

Several limitations of our study warrant mention. First, the data were measured using self-reported questionnaires, which may introduce reporting bias. Although physical activity was assessed using multiple items, measurement accuracy may still be limited. For self-esteem and depression, respondents may also have under-reported negative thoughts or emotions due to social desirability.

Second, because our study used longitudinal data, the observation period was restricted to grades 4 through 8. Including developmental periods before fourth grade and after eighth grade would enable a more comprehensive understanding of changes across the entirety of adolescence.

Third, although the original panel included 2607 fourth-grade students, our analysis was limited to the 1313 boys in this cohort, which may not represent all Korean adolescents. Caution is advised in generalizing results due to potential retention-related bias from attrition and intermittent missingness across waves, as participants who remained in the panel could differ systematically from those lost to follow-up. The study highlights the necessity for future research to formally assess attrition bias and replicate findings and use robust methods for missing data. Furthermore, while the KCYPS utilized a complex sampling design, sampling weights or clustering adjustments were not applied in this analysis, which may lead to underestimated standard errors. Consequently, careful interpretation regarding the generalizability of the findings to the broader population is required.

Fourth, we focused on physical activity, self-esteem, and depression as the primary indicators of adolescent physical and psychological health. In addition, we modeled physical activity, self-esteem, and depression separately to describe domain-specific developmental trajectories. Future studies should apply parallel-process and conditional growth models to examine how changes across domains co-develop and to identify predictors of coupled change. Additional variables—such as stress, social support, sleep quality, or academic pressures—may provide a more multidimensional understanding in future studies.

Fifth, because our analysis included only male adolescents, we were unable to examine how other background characteristics might account for individual differences in developmental trajectories. Future studies should incorporate a wider range of predictors to better capture the variability in adolescents' physical and psychological development.

Despite these limitations, our study contributes to the literature by analyzing a large-scale national panel cohort using longitudinal modeling techniques. These strengths enhance the applicability and robustness of the findings.

5. Conclusions

We analyzed the longitudinal changes in physical activity, self-esteem, and depression among Korean male adolescents from 2018 to 2022. The findings showed that physical activity gradually declined, self-esteem weakened, and depressive symptoms worsened as students advanced to higher grades, as reflected by decreasing depression scores over time. These nonlinear developmental patterns suggest that Korean male adolescents face growing physical, psychological, and emotional challenges during early to middle adolescence. Accordingly, interventions that promote regular physical activity, enhance self-esteem, and support mental health are needed

to foster long-term well-being. Future studies should extend the analysis to include female adolescents and a broader set of background variables to fully understand developmental differences across populations.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

WYS and MHB—conceptualization; data curation; writing–review and editing; supervision; project administration. XYZ and JSL—methodology; formal analysis; writing–original draft preparation; visualization. All authors have read and agreed to the published version of the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The survey collection process was approved by the Korea Youth Policy Research Institute Ethics Review Committee (approval numbers: 402002, 201906-HR-Unique-014-01, 202007-HR-Unique-016, 202106-HR-Unique-011, and 202206-HR-Unique-026-11) and conducted according to the principles outlined in the Declaration of Helsinki. All participants were informed about the study procedure and its purpose, and they voluntarily signed an informed consent form.

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CONFLICT OF INTEREST

The authors declare no conflict of interest. Wi-Young So is serving as one of the Editorial Board members of this journal. We declare that Wi-Young So had no involvement in the peer review of this article and has no access to information regarding its peer review. Full responsibility for the editorial process for this article was delegated to CFY.

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