Research article

Comparison of national trends in physical activity among adolescents before and during the COVID-19 pandemic: A nationally representative serial study in South Korea

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ABSTRACT

Background: The COVID-19 pandemic has dramatically altered daily routines and lifestyle behaviors worldwide, potentially significantly impacting physical activity levels, especially among adolescents. Understanding these changes is crucial for developing targeted interventions to promote health and well-being in this vulnerable population. This paper will explore longitudinal trends of physical activities (PA) in Korean adolescents, focusing on changes between the pre and late-COVID-19 pandemic periods.

Methods: The data used were from the Korea Youth Risk Behavior Web-Based Survey for consecutive years from 2009 to 2022. In this study, we have separated data into the pre-COVID-19 pandemic (2009–2019) and the pandemic. Following the World Health Organization (WHO)'s guideline, we analyzed adolescent self-reported moderate-to-vigorous physical activity (MVPA)

Results: A total of 890,941 adolescents, people aged between 12 and 18 years old. The 14-year trends in MVPA showed an upward trend both before the pandemic (β, 0.005; 95 % confidence interval [CI], 0.004–0.005) and during the pandemic (β, 0.004; 0.002–0.006). Furthermore, the

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prevalence of MVPA recovered/increased in 2022 (5.61 % in 2020, 5.22 % in 2021, and 6.34 % in 2022). Similar to the MVPA patterns, the mean metabolic equivalent task (MET) score increased during before the pandemic (β, 15.392; 12.523–18.261) and during the pandemic (β, 49.518; 41.948–57.088). However, unlike MVPA patterns, the MET slope changed positively (β_{diff}, 34.126; 26.031–42.221).

Conclusion: Present findings suggest that Korean adolescents achieving the recommended PA levels by the WHO remained steady despite the pandemic. This stability in PA levels during a significant disruption (i.e. the COVID-19 pandemic) is noteworthy and warrants further investigation into the factors that may have contributed to this resilience, including potential influences from various societal and environmental elements.

1. Introduction

Physical activity (PA) plays a crucial role in adolescent development, a significant period in human growth. The World Health Organization (WHO) recognizes the importance of PA and has released guidelines to emphasize its requirements and benefits. These guidelines recommend that children and adolescents aged 5–17 years engage in an average of 60 min per day of moderate-to-vigorous physical activity (MVPA) [1]. This recommendation is based on extensive research demonstrating the positive impacts of adequate PA during adolescence. Regular PA fosters overall health and contributes to lifelong well-being by promoting muscle and bone development. By meeting these recommended PA levels, adolescents can maximize their potential for healthy growth and set a foundation for long-term health benefits [1–3].

The COVID-19 pandemic has disrupted daily routines worldwide, potentially affecting adolescent PA levels. While lockdowns and social distancing measures may have reduced opportunities for structured exercise, increased health awareness during this period might have motivated some to maintain or increase their PA levels. Understanding these dynamics is crucial for developing targeted interventions to promote healthy behaviors during and after such pandemics. Thus, it is imperative to investigate adolescents' health behavior trends from 2009 to 2022. The present paper builds on data from a 14-year survey of 890,941 students; this is the first study to include 2022 data on the MVPA attainment of adolescents.

The impact of the COVID-19 pandemic on PA varies based on adolescents' age, sex, grade, body mass index (BMI), region of residence, smoking, alcohol consumption, economic level, and school performance [4–8]. However, limited recent research exists on whether these variables influence PA trends, especially during the late COVID-19 pandemic [9]. Therefore, this study aimed to report the longitudinal trend in PA among Korean adolescents using data from the Korean Youth Risk Behavior Web-Based Survey (KYRBS) between 2009 and 2022. This study will also determine changes in PA between the pre-COVID-19 pandemic and the COVID-19 pandemic. It is anticipated that findings from this study will inform the development of public health guidelines, particularly those of school health systems post-COVID-19[10], thereby providing valuable scientific findings to aid in promoting adolescent health in South Korea.
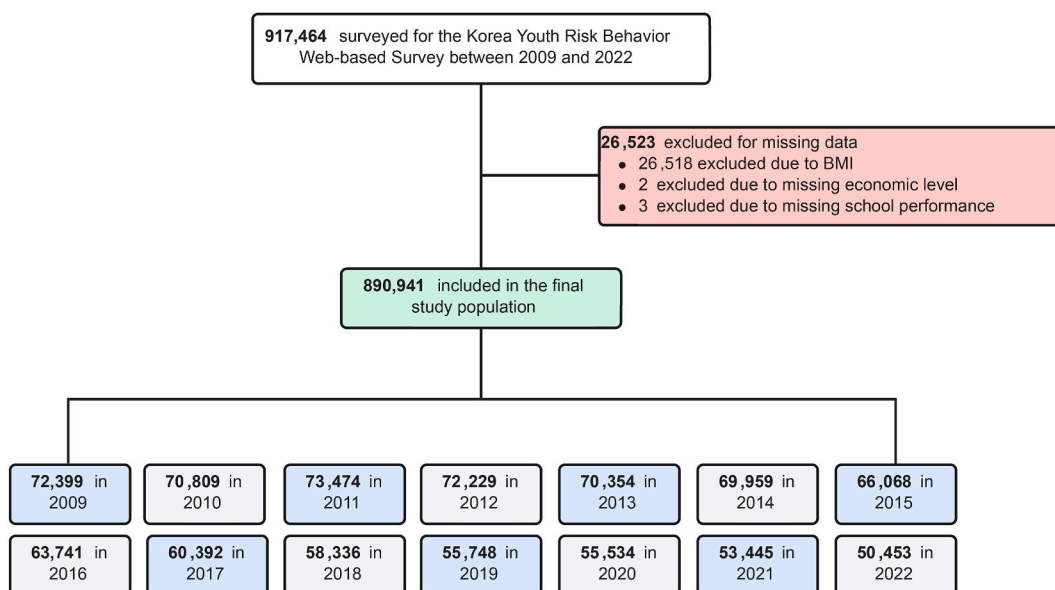

Fig. 1. Flowchart of the population used in the study among Korean adolescents in 2009–2022.

2. Methods and materials

2.1. Data and study population

This study was based on the raw data from 2009 to 2022 gathered by KYRBS, a study that utilized survey-based questionnaires among students in South Korea. Initiated by the Korea Disease Control and Prevention Agency (KDCA), a large-scale and population-based survey was administered to advance understanding of the health risk behaviors of Korean adolescents [11,12]. Over the period, the average response rate of the survey was 95.02 %. Using 39 regions and school classes as stratification variables, we divided the population into 117 strata to minimize sampling error during the population stratification phase [13].

In this study, 917,464 students who completed the survey were selected as subsets in grades 7 to 12 (aged 12 to 18). Due to the dearth of necessary variables, 26,523 cases were excluded. Thus, the final sample for data analysis was 890,941 (Fig. 1). KYRBS data were anonymous, and the study protocol was approved by the Institutional Review Board of Kyung Hee University (KHSIRB-23-384). All the participants (or their parents or legal guardians in the case of children under 16) provided written informed consent. This study was conducted in accordance with the principles of the Declaration of Helsinki.

2.2. Survey period

KYRBS commenced in 2005, however, variables related to physical activity were collected from 2009 onwards. Therefore, the 2005 to 2008 datasets were excluded from the present analysis. Following the methodological approach used in the Korea National Health and Nutrition Examination Survey, to stabilize the prevalence, the survey period was separated into seven time frames: 2009–2010, 2011–2013, 2014–2016, 2017–2019, 2020, 2021, and 2022. Since the first case of COVID-19 was reported in January 2020, we considered 2020 to be the year of the start of the COVID-19 pandemic (early COVID-19 pandemic) [14]. Before the COVID-19 pandemic, we divided years into 2–3 consecutive year intervals to stabilize the estimates [14]. However, during the COVID-19 pandemic, we separated each year to analyze change among the individual years.

2.3. Outcome

The primary outcomes of this study were the prevalence of MVPA among Korean adolescents and the mean metabolic equivalent task (MET) score. The survey obtained information about the frequency (day/week) and duration (times/week) of the students' performing moderate PA and vigorous PA in the preceding seven days. For an enhanced comparison between the data, we also converted the amount of PA into MET-minutes score [7].

To convert PA data into MET minutes per week, the MET minutes for moderate-intensity activities need to be calculated first. To calculate this the number of minutes spent in moderate-intensity activities each day needs to be determined and this is then multiplied by 4.0. Next, this result is multiplied by the number of days the activity was performed in a week. Similarly, to calculate MET minutes per week for vigorous-intensity activities, the same process is repeated but the number of minutes spent in vigorous activities is multiplied by 8.0 and not 4.0. Finally, to obtain the total PA MET minutes per week, the MET minutes from both moderate and vigorous activities are summed [15].

2.4. Covariates

Included covariates for this study were age, sex, grade, BMI (underweight, normal, overweight, and obese), region of residence (rural and urban area) [16], smoking (non-smoker and smoker), alcohol consumption (non-drinker, drinker under three days/week, and drinker over three days/week), economic level (high, middle high, middle, middle low, and low), and school performance (high, middle high, middle, middle low, and low). BMI was calculated with body height, weight, sex, and age in the 2017 Korean National Growth Charts for children and adolescents, which provides age- and sex-specific BMI percentiles for those aged 3–18 years, defining obesity as a BMI at or above the 95th percentile for age and sex [17].

2.5. Statistical analyses

We applied a weighted complex sampling analysis to calculate the estimates of Korean adolescent's achievement on required PA by the WHO guideline [15,18]. In order to appraise the trend of MVPA prevalence, particularly during the COVID-19 pandemic, from 2009 to 2022, we have employed weighted linear regression modes. Differences of β (β_{diff}) and 95 % confidence interval (CI) were calculated to analyze the trend changes between 2009-2019 and 2020–2022 (before and during the COVID-19 pandemic) [18]. Additionally, we utilized weighted logistic regression models to derive the weighted odds ratios (ORs) and 95 % CI, to provide a more comprehensive understanding of the practical significance of our findings. Given our large sample size, which increases the likelihood of obtaining statistically significant results, effect size measures offer valuable insight into the magnitude of observed changes. Additionally, in order to validate the primary findings of the study, we performed a stratification analysis by age, sex, grade, BMI, region of residence, smoking, alcohol consumption, economic level, school performance, and education level of parents by using all weighted linear and logistic regression models.

All statistical analyses were performed using the SAS software (version 9.4; SAS Institute, Cary, NC, USA) [19]. We used a two-sided test and considered p-values <0.05 statistically significant [20].

Table 1

Demographic crude characteristics of Korean adolescents (total n = 890,941).

	Total	Pre-pandemic				Early-pandemic	Mid-pandemic	Late-pandemic
		2009 to 2010	2011 to 2013	2014 to 2016	2017 to 2019	2020	2021	2022
Total, N	890,941	143,208	216,057	199,768	174,476	53,534	53,445	50,453
Age, years, mean (SE)	15.01	15.06	14.96	14.96	14.99	15.09	15.09	15.10
	(0.002)	(0.005)	(0.004)	(0.004)	(0.004)	(0.008)	(0.008)	(0.008)
Sex, n (%)								
Boy	457,791	75,242	109,559	102,447	89,334	27,687	27,773	25,749
	(51.38)	(52.54)	(50.71)	(51.28)	(51.20)	(51.72)	(51.97)	(51.04)
Girl	433,150	67,966	106,498	97,321	85,142	25,847	25,672	24,704
	(48.62)	(47.46)	(49.29)	(48.72)	(48.80)	(48.28)	(48.03)	(48.96)
Grade, n (%)								
7th-9th grade (middle school)	456,039	73,570	109,373	99,970	88,205	28,292	29,319	27,310
	(51.19)	(51.37)	(50.62)	(50.04)	(50.55)	(52.85)	(54.86)	(54.13)
10th-12th grade (high school)	434,902	69,638	106,684	99,798	86,271	25,242	24,126	23,143
	(48.81)	(48.63)	(49.38)	(49.96)	(49.45)	(47.15)	(45.14)	(45.87)
BMI, kg/m^2, mean (SE)	20.94	20.46	20.61	20.88	21.28	21.53	21.62	21.38
	(0.004)	(0.008)	(0.006)	(0.007)	(0.008)	(0.016)	(0.017)	(0.017)
BMI, n (%)								
Underweight	70,684	13,187	17,579	15,250	11,969	4029 (7.53)	4314 (8.07)	4356 (8.63)
	(7.93)	(9.21)	(8.14)	(7.63)	(6.86)			
Normal	668,552	112,197	168,422	151,789	127,398	37,295	36,431	35,020
	(75.04)	(78.35)	(77.95)	(75.98)	(73.02)	(69.67)	(68.17)	(69.41)
Overweight	75,680	10,084	16,642	16,987	16,319	5531 (10.33)	5372	4745 (9.40)
	(8.49)	(7.04)	(7.70)	(8.50)	(9.35)		(10.05)	
Obese	76,025	7740 (5.40)	13,414	15,742	18,790	6679 (12.48)	7328	6332
	(8.53)		(6.21)	(7.88)	(10.77)		(13.71)	(12.55)
Region of residence, n (%)								
Rural	86,041	18,871	26,181	15,769	13,364	4192 (7.83)	3988 (7.46)	3676 (7.29)
	(9.66)	(13.18)	(12.12)	(7.89)	(7.66)			
Urban	804,900	124,337	189,876	183,999	161,112	49,342	49,457	46,777
	(90.34)	(86.82)	(87.88)	(92.11)	(92.34)	(92.17)	(92.54)	(92.71)
Smoking, n (%)								
Non-smoker	829,447	128,828	196,824	187,802	165,582	51,223	51,044	48,144
	(93.10)	(89.96)	(91.10)	(94.01)	(94.90)	(95.68)	(95.51)	(95.42)
Smoker	61,494	14,380	19,233	11,966	8894 (5.10)	2311 (4.32)	2401 (4.49)	2309 (4.58)
	(6.90)	(10.04)	(8.90)	(5.99)				
Alcohol consumption, n (%)								
Non-drinker	746,095	113,111	175,863	169,149	148,158	47,885	47,872	44,057
	(83.74)	(78.98)	(81.40)	(84.67)	(84.92)	(89.45)	(89.57)	(87.32)
Drinker under 3 days/week	127,824	26,042	35,184	27,337	23,503	5008 (9.35)	4970 (9.30)	5780
	(14.35)	(18.18)	(16.28)	(13.68)	(13.47)			(11.46)
Drinker over 3 days/week	17,022	4055 (2.83)	5010 (2.32)	3282 (1.64)	2815 (1.61)	641 (1.20)	603 (1.13)	616 (1.22)
	(1.91)							
Economic level, n (%)								
High	75,748	8476 (5.92)	14,016	17,194	18,710	5862 (10.95)	5743	5747
	(8.50)		(6.49)	(8.61)	(10.72)		(10.75)	(11.39)
Middle high	233,289	31,353	51,575	53,524	50,854	15,033	15,352	15,598
	(26.18)	(21.89)	(23.87)	(26.79)	(29.15)	(28.08)	(28.72)	(30.92)
Middle	424,248	67,866	102,832	95,884	81,915	25,738	26,438	23,575
	(47.62)	(47.39)	(47.59)	(48.00)	(46.95)	(48.08)	(49.47)	(46.73)
Middle low	125,302	26,650	37,338	26,948	19,125	5724 (10.69)	4890 (9.15)	4627 (9.17)
	(14.06)	(18.61)	(17.28)	(13.49)	(10.96)			
Low	32,354	8863 (6.19)	10,296	6218 (3.11)	3872 (2.22)	1177 (2.20)	1022 (1.91)	906 (1.80)
	(3.63)		(4.77)					
School performance, N (%)								
High	108,165	16,120	23,400	25,149	23,302	6572 (12.28)	6883	6739
	(12.14)	(11.26)	(10.83)	(12.59)	(13.36)		(12.88)	(13.36)
Middle high	220,860	34,404	51,899	50,505	44,743	13,195	13,227	12,887
	(24.79)	(24.02)	(24.02)	(25.28)	(25.64)	(24.65)	(24.75)	(25.54)
Middle	253,690	38,733	59,038	56,556	51,432	16,241	16,530	15,160
	(28.47)	(27.05)	(27.33)	(28.31)	(29.48)	(30.34)	(30.93)	(30.05)
Middle low	211,605	36,514	54,754	46,915	38,458	12,287	11,662	11,015
	(23.75)	(25.50)	(25.34)	(23.48)	(22.04)	(22.95)	(21.82)	(21.83)
Low	96,621	17,437	26,966	20,643	16,541	5239 (9.79)	5143 (9.62)	4652 (9.22)
	(10.84)	(12.18)	(12.48)	(10.33)	(9.48)			

BMI, Body mass index; SE, Standard error.

3. Results

3.1. Characteristics of the participants

From 2009 to 2022, 890,941 students who responded to this survey were eligible for this study. In 2009–2010, there were 143,208 adolescents, followed by 216,057 in 2011–2013, 199,768 in 2014–2016, 174,476 in 2017–2019, 53,445 in 2020 (early pandemic), 53,445 in 2021 (mid-pandemic), and 50,453 in 2022 (late pandemic). The group's weighted average age was 15.01 years, and more boys (51.38 %) than girls (48.62 %) participated in the survey (Fig. 1, Tables 1 and 2). In addition, we investigated demographics yearly in Tables S1 and S2.

The estimated prevalence of alterations in the recommended level of MVPA from 2009 to 2022 is displayed in Table 3 and Fig. 2. Evidence shows that male students were likelier than female students to engage in MVPA. Compared to the pre-COVID-19 pandemic era, there was no difference in MVPA (β_{diff}, −0.001; 95 % CI, −0.003 to 0.001). The weighted prevalence of recommended levels of MVPA remained at 5.61 % in 2020 (early pandemic) and at 5.22 % in 2021 (mid-pandemic) but increased to 6.34 % in 2022 (late pandemic). The likelihood of performing the recommended amount of MVPA remained steady after COVID-19 compared to the period from 2017 to 2019 (OR, 1.028; 95 % CI, 0.987 to 1.071). Most subgroups' trend was similar to overall MVPA, but some showed differences. The characteristics of sex (boy), grade (7th-9th grade), BMI (underweight, normal, and obese), economic level, school performance (middle high, middle, and middle-low), and education level of parents (high school, and college or more) showed a similar trend. However, the characteristics of sex (girl) (β_{diff}, −0.002; 95 % CI, −0.004 to −0.001), grade (10th-12th grade) (β_{diff}, −0.004; 95 % CI, −0.007 to −0.002), region of residence: rural (β_{diff}, −0.004; 95 % CI, −0.005 to −0.003), urban (β_{diff}, −0.001; 95 % CI, −0.002 to −0.001), BMI (overweight) (β_{diff}, −0.006; 95 % CI, −0.011 to −0.001), school performance (high [β_{diff}, −0.006; 95 % CI, −0.011 to −0.001]and low [β_{diff}, −0.006; 95 % CI, −0.012 to 0.000]), and education level of parents (middle school or less) (β_{diff}, −0.010; 95 % CI, −0.012 to −0.008) showed a different trend, i.e., decrease in MVPA. The percentage of male students who achieved recommended levels of MVPA was always more significant than that of female students.

The calculated mean MET score for each period is shown in Table 4. While the overall MVPA trends did not change, the MET score trend increased during the COVID-19 pandemic. The mean difference in MET score between pre-COVID-19 and during COVID-19 was 34.13 MET-min/week (95 % CI, 26.03 to 42.22). The MET score of the male group was always higher than that of the female group. To elucidate the prevalence results more comprehensively, the data were presented on an annual basis in Tables S3 and S4.

4. Discussion

4.1. Key findings

Our data shows an overall increase in the number of adolescents achieving the recommended MVPA and mean MET score both pre- and during the COVID-19 pandemic; MVPA prevalence and mean MET score have independently increased across the years despite the COVID-19 pandemic. However, unlike the overall trend, during the one-year duration of the COVID-19 pandemic, a minor reduction in MVPA percentage and mean MET score was observed. We discovered through a nationally representative study that the 14-year trends in the percentage of adolescents who reported meeting the recommended quantity of MVPA for adolescents increased; the slope did not change during the pandemic. Despite the reduction that was present in the one-year duration of the COVID-19 pandemic, MVPA and MET mean scores both have shown recovery/increase in 2022 (late COVID-19 pandemic).

During the COVID-19 pandemic, the achievement rates of the suggested criterion for MVPA among Korean adolescents were only 5.61 % in 2020, 5.22 % in 2021, and 6.34 % in 2022. While MVPA percentage and MET mean score values have continued to increase despite the pandemic, as mentioned above, they were still low; society requires policy action by policymakers to increase participation in PA.

4.2. Comparison with previous studies

Existing studies on adolescents' PA have shown decreases in PA throughout the duration of the COVID-19 pandemic period (Canada; N = 1,472,[21] USA; N = 11,875,[22] Australia; N = 1,292,[23] Bosnia Herzegovina; N = 661 [24]). However, some other existing studies have noted that some categories of adolescents have experienced an increase in PA, even during the COVID-19 lockdown periods (Ireland; N = 1214 [25]). These variations in results among studies may be caused by factors such as relatively small sample sizes, short data collection periods, and non-representative samples, which can ultimately cause bias in findings.

However, our study differs substantially from those existing studies in several respects. Unlike the studies above, the sample data leveraged had a large sample size of 890,941 which have been collected for over 14 years; this is the first study to examine PA levels of Korean adolescents, up to 2022 (late-COVID-9 pandemic). This comprehensive and long-term analysis provides a better understanding of the pattern of adolescents' PA between pre- and during-COVID-19 pandemic.

4.3. Possible mechanism

The prevalence of achieving the WHO MVPA guidelines decreased slightly at the start of the COVID-19 pandemic [22]. This could be attributed to the nationwide lockdown policy in South Korea, which led adolescents to remain indoors, consequently engaging in lower levels of PA [26]. However, interestingly, the overall trend of the MVPA achievement percentage has shown no perceptible

Table 2
Baseline weighted characteristics of Korean adolescents.

	Total	Pre-pandemic				Early-pandemic	Mid-pandemic	Late-pandemic
		2009 to 2010	2011 to 2013	2014 to 2016	2017 to 2019	2020	2021	2022
Age, years, weighted mean (95 % CI)	15.11 (15.10–15.13)	15.09 (15.06–15.13)	15.01 (14.99–15.03)	15.06 (15.04–15.08)	15.12 (15.09–15.15)	15.18 (15.14–15.23)	15.22 (15.18–15.27)	15.20 (15.15–15.25)
Sex, weighted % (95 % CI)								
Boy	52.19 (51.49–52.89)	52.82 (50.83–54.82)	52.47 (51.04–53.89)	52.15 (50.70–53.60)	52.03 (50.61–53.44)	51.93 (49.67–54.20)	51.83 (49.65–54.01)	51.68 (49.52–53.85)
Girl	47.81 (47.11–48.51)	47.18 (45.18–49.17)	47.53 (46.11–48.96)	47.85 (46.40–49.30)	47.97 (46.56–49.39)	48.07 (45.80–50.33)	48.17 (45.99–50.35)	48.32 (46.15–50.48)
Grade, weighted % (95 % CI)								
7th-9th grade (middle school)	49.39 (48.95–49.83)	50.49 (49.33–51.66)	49.23 (48.44–50.03)	47.07 (46.28–47.87)	46.68 (45.83–47.52)	49.77 (48.28–51.25)	51.13 (49.69–52.57)	51.77 (50.21–53.33)
10th-12th grade (high school)	50.61 (50.17–51.05)	49.51 (48.34–50.67)	50.77 (49.97–51.56)	52.93 (52.13–53.72)	53.32 (52.48–54.17)	50.23 (48.75–51.72)	48.87 (47.43–50.31)	48.23 (46.67–49.79)
BMI, kg/m², weighted mean	21.04 (21.02–21.05)	20.46 (20.42–20.49)	20.61 (20.59–20.63)	20.90 (20.88–20.93)	21.30 (21.27–21.33)	21.50 (21.44–21.56)	21.61 (21.55–21.67)	21.36 (21.29–21.42)
BMI, weighted % (95 % CI)								
Underweight	8.23 (8.15–8.30)	9.33 (9.14–9.52)	8.31 (8.17–8.45)	7.72 (7.58–7.85)	6.97 (6.83–7.10)	7.73 (7.47–7.98)	8.32 (8.06–8.59)	8.89 (8.63–9.14)
Normal	74.01 (73.87–74.14)	78.44 (78.14–78.73)	78.00 (77.78–78.22)	76.09 (75.85–76.32)	73.09 (72.83–73.35)	69.99 (69.50–70.48)	68.28 (67.77–68.79)	69.79 (69.28–70.30)
Overweight	8.62 (8.54–8.69)	7.01 (6.84–7.17)	7.56 (7.43–7.68)	8.40 (8.27–8.53)	9.33 (9.19–9.47)	10.17 (9.90–10.44)	9.91 (9.64–10.18)	9.20 (8.93–9.48)
Obese	9.15 (9.05–9.24)	5.23 (5.06–5.40)	6.13 (6.01–6.26)	7.80 (7.64–7.95)	10.62 (10.42–10.81)	12.12 (11.74–12.49)	13.49 (13.08–13.89)	12.12 (11.72–12.51)
Region of residence, weighted % (95 % CI)								
Rural	5.92 (5.67–6.16)	5.87 (5.36–6.39)	6.38 (5.86–6.91)	6.17 (5.62–6.72)	5.89 (5.31–6.48)	5.83 (5.04–6.62)	5.51 (4.72–6.30)	5.53 (4.61–6.44)
Urban	94.08 (93.84–94.33)	94.13 (93.61–94.64)	93.62 (93.09–94.14)	93.83 (93.28–94.38)	94.11 (93.52–94.69)	94.17 (93.38–94.96)	94.49 (93.70–95.28)	94.47 (93.56–95.39)
Smoking, weighted % (95 % CI)								
Non-smoker	93.34 (93.22–93.46)	90.05 (89.65–90.46)	90.99 (90.71–91.28)	93.74 (93.50–93.99)	94.60 (94.39–94.80)	95.72 (95.42–96.02)	95.40 (95.12–95.68)	95.26 (94.96–95.57)
Smoker	6.66 (6.54–6.78)	9.95 (9.54–10.35)	9.01 (8.72–9.30)	6.26 (6.01–6.50)	5.40 (5.20–5.61)	4.28 (3.98–4.58)	4.60 (4.32–4.88)	4.74 (4.43–5.04)
Alcohol consumption, weighted % (95 % CI)								
Non-drinker	84.47 (84.31–84.62)	79.17 (78.73–79.62)	81.48 (81.15–81.82)	84.13 (83.82–84.44)	84.34 (84.04–84.63)	89.51 (89.10–89.91)	89.45 (89.02–89.87)	87.17 (86.68–87.66)
Drinker under 3 days/week	13.72 (13.59–13.86)	18.02 (17.64–18.40)	16.23 (15.94–16.52)	14.18 (13.91–14.46)	13.99 (13.72–14.26)	9.32 (8.96–9.67)	9.41 (9.03–9.79)	11.60 (11.15–12.05)
Drinker Over 3 days/week	1.81 (1.77–1.85)	2.81 (2.67–2.94)	2.29 (2.20–2.37)	1.69 (1.62–1.76)	1.67 (1.60–1.75)	1.18 (1.06–1.29)	1.14 (1.04–1.25)	1.23 (1.12–1.34)
Economic level, weighted % (95 % CI)								
High	9.11 (8.99–9.23)	6.24 (6.00–6.48)	6.77 (6.59–6.94)	8.66 (8.46–8.86)	10.84 (10.61–11.06)	11.19 (10.73–11.66)	10.77 (10.38–11.15)	11.72 (11.26–12.18)
Middle high	27.24 (27.07–27.41)	22.85 (22.42–23.28)	24.47 (24.17–24.78)	27.01 (26.70–27.32)	29.52 (29.20–29.84)	28.86 (28.31–29.42)	29.52 (28.90–30.14)	31.67 (31.09–32.25)
Middle	47.37 (47.19–47.55)	47.15 (46.74–47.55)	47.26 (46.98–47.55)	47.78 (47.47–48.10)	46.69 (46.35–47.02)	47.58 (46.92–48.23)	49.07 (48.42–49.72)	46.16 (45.47–46.85)
Middle low	12.99 (12.87–13.10)	17.94 (17.61–18.28)	16.87 (16.62–17.13)	13.44 (13.22–13.65)	10.77 (10.57–10.97)	10.29 (9.96–10.61)	8.84 (8.53–9.16)	8.71 (8.39–9.03)
Low	3.29 (3.24–3.34)	5.82 (5.64–6.00)	4.62 (4.51–4.73)	3.11 (3.02–3.21)	2.19 (2.11–2.27)	2.08 (1.95–2.21)	1.80 (1.69–1.92)	1.74 (1.62–1.86)
School performance, weighted % (95 % CI)								

Table 2 (*continued*)

	Total	Pre-pandemic				Early-pandemic	Mid-pandemic	Late-pandemic
		2009 to 2010	2011 to 2013	2014 to 2016	2017 to 2019	2020	2021	2022
High	12.17 (12.06–12.28)	11.31 (11.04–11.57)	10.83 (10.65–11.02)	12.43 (12.23–12.63)	13.20 (12.99–13.42)	12.23 (11.83–12.64)	12.63 (12.28–12.98)	13.43 (13.01–13.86)
Middle high	24.82 (24.70–24.94)	24.14 (23.86–24.42)	24.14 (23.94–24.35)	25.23 (25.02–25.43)	25.54 (25.31–25.76)	24.88 (24.45–25.31)	24.68 (24.24–25.13)	25.56 (25.13–26.00)
Middle	28.92 (28.81–29.04)	27.09 (26.79–27.39)	27.43 (27.22–27.64)	28.40 (28.18–28.62)	29.60 (29.36–29.83)	30.26 (29.84–30.67)	31.12 (30.70–31.54)	30.21 (29.77–30.65)
Middle low	23.52 (23.40–23.65)	25.56 (25.25–25.87)	25.31 (25.10–25.53)	23.58 (23.36–23.79)	22.06 (21.83–22.29)	22.87 (22.41–23.33)	21.94 (21.54–22.34)	21.66 (21.21–22.11)
Low	10.56 (10.48–10.65)	11.90 (11.69–12.11)	12.28 (12.11–12.45)	10.37 (10.21–10.53)	9.60 (9.44–9.76)	9.76 (9.45–10.07)	9.63 (9.32–9.94)	9.13 (8.83–9.44)

BMI, body mass index; CI, confidence interval; SE, Standard error.

Table 3

Moderate-to-vigorous physical activity recommended achievement prevalence and trend % (95 % CI).

	Prevalence, weighted % (95 % CI)							PA trend, β (95 % CI)		PA trend difference, β difference (95 % CI)[a]	PA odds, OR (95 % CI)[b]
	Before pandemic				During pandemic						
	2009–2010	2011–2013	2014–2016	2017–2019	2020	2021	2022	Before pandemic	During pandemic		
Overall	4.00 (3.84–4.15)	4.39 (4.27–4.52)	5.29 (5.14–5.44)	5.57 (5.41–5.73)	5.61 (5.34–5.88)	5.22 (4.97–5.46)	6.34 (6.07–6.61)	**0.005 (0.004 to 0.005)**	**0.004 (0.002 to 0.006)**	−0.001 (−0.003 to 0.001)	1.028 (0.987 to 1.071)
Sex											
Boy	6.26 (6.03–6.48)	6.87 (6.68–7.05)	8.07 (7.85–8.28)	8.53 (8.30–8.76)	8.44 (8.04–8.84)	7.98 (7.59–8.36)	9.65 (9.22–10.08)	**0.006 (0.005 to 0.007)**	**0.006 (0.003 to 0.009)**	0.000 (−0.003 to 0.003)	1.019 (0.977 to 1.063)
Girl	1.46 (1.34–1.59)	1.66 (1.57–1.75)	2.26 (2.13–2.39)	2.36 (2.23–2.49)	2.55 (2.34–2.77)	2.25 (2.06–2.44)	2.79 (2.57–3.02)	**0.003 (0.003 to 0.003)**	0.001 (0.000 to 0.003)	**−0.002 (-0.004 to -0.001)**	1.074 (0.996 to 1.158)
Grade											
7th-9th grade	4.49 (4.27–4.72)	5.26 (5.08–5.45)	6.37 (6.16–6.58)	6.66 (6.44–6.88)	6.54 (6.18–6.90)	6.13 (5.80–6.47)	7.79 (7.41–8.17)	**0.006 (0.005 to 0.007)**	**0.006 (0.004 to 0.009)**	0.000 (−0.003 to 0.003)	1.026 (0.977 to 1.077)
10th-12th grade	3.49 (3.27–3.71)	3.54 (3.38–3.71)	4.32 (4.12–4.53)	4.62 (4.40–4.84)	4.69 (4.30–5.09)	4.26 (3.90–4.62)	4.78 (4.41–5.14)	**0.004 (0.004 to 0.004)**	0.000 (−0.002 to 0.003)	**−0.004 (-0.007 to -0.002)**	0.990 (0.923 to 1.062)
Region of residence											
Rural	4.11 (3.64–4.59)	4.45 (4.07–4.83)	6.08 (5.15–7.01)	6.22 (5.39–7.04)	5.55 (4.44–6.66)	5.32 (4.38–6.25)	5.76 (4.82–6.70)	**0.005 (0.005 to 0.005)**	**0.001 (0.000 to 0.002)**	**−0.004 (-0.005 to -0.003)**	0.885 (0.744 to 1.052)
Urban	3.99 (3.83–4.15)	4.39 (4.26–4.52)	5.24 (5.09–5.38)	5.53 (5.37–5.69)	5.61 (5.34–5.89)	5.21 (4.96–5.47)	6.37 (6.09–6.65)	**0.005 (0.004 to 0.005)**	**0.004 (0.004 to 0.004)**	**−0.001 (-0.002 to -0.001)**	1.038 (0.995 to 1.083)
Body mass index[c]											
Underweight	3.07 (2.75–3.39)	3.75 (3.46–4.05)	4.42 (4.07–4.78)	4.23 (3.83–4.62)	3.08 (2.51–3.64)	3.15 (2.64–3.67)	4.04 (3.47–4.61)	0.001 (0.000 to 0.002)	**0.005 (0.001 to 0.009)**	0.004 (0.000 to 0.008)	**0.808 (0.705 to 0.926)**
Normal	4.14 (3.96–4.32)	4.51 (4.37–4.64)	5.48 (5.31–5.64)	5.84 (5.65–6.02)	5.84 (5.52–6.16)	5.52 (5.22–5.83)	6.72 (6.39–7.06)	**0.005 (0.004 to 0.006)**	**0.004 (0.002 to 0.007)**	−0.001 (−0.004 to 0.002)	1.035 (0.988 to 1.084)
Overweight	3.74 (3.28–4.20)	3.98 (3.65–4.31)	4.67 (4.34–5.00)	5.27 (4.90–5.63)	6.29 (5.58–7.00)	5.58 (4.95–6.21)	6.35 (5.62–7.08)	**0.006 (0.005 to 0.008)**	0.000 (−0.005 to 0.005)	**−0.006 (-0.011 to -0.001)**	**1.162 (1.050 to 1.286)**
Obese	3.84 (3.35–4.33)	4.30 (3.93–4.68)	4.95 (4.58–5.32)	4.90 (4.57–5.22)	5.34 (4.77–5.91)	4.67 (4.19–5.16)	5.78 (5.19–6.37)	**0.004 (0.002 to 0.005)**	0.002 (−0.002 to 0.006)	−0.002 (−0.006 to 0.002)	1.074 (0.977 to 1.180)
Economic level											
High	7.92 (7.22–8.63)	8.21 (7.73–8.70)	9.13 (8.68–9.59)	8.87 (8.43–9.31)	9.10 (8.34–9.86)	8.32 (7.58–9.06)	9.20 (8.43–9.97)	**0.003 (0.002 to 0.004)**	0.001 (−0.005 to 0.006)	−0.002 (−0.008 to 0.004)	1.002 (0.928 to 1.082)
Middle high	4.12 (3.83–4.41)	4.59 (4.38–4.79)	5.53 (5.31–5.75)	5.61 (5.38–5.84)	5.49 (5.10–5.89)	5.15 (4.74–5.56)	6.72 (6.28–7.17)	**0.004 (0.003 to 0.005)**	**0.006 (0.003 to 0.009)**	0.002 (−0.001 to 0.005)	1.038 (0.975 to 1.104)

Table 3 (*continued*)

| | Prevalence, weighted % (95 % CI) | | | | | | | PA trend, β (95 % CI) | | PA trend difference, β difference (95 % CI)[a] | PA odds, OR (95 % CI)[b] |
| | Before pandemic | | | | During pandemic | | | | | | |
	2009–2010	2011–2013	2014–2016	2017–2019	2020	2021	2022	Before pandemic	During pandemic		
Middle	3.35 (3.17–3.53)	3.83 (3.69–3.97)	4.56 (4.39–4.74)	4.77 (4.59–4.95)	4.91 (4.60–5.22)	4.50 (4.22–4.79)	5.30 (4.96–5.65)	**0.004 (0.003 to 0.005)**	0.002 (0.000 to 0.004)	−0.002 (−0.004 to 0.000)	1.028 (0.973 to 1.087)
Middle low	3.57 (3.28–3.87)	3.85 (3.62–4.08)	4.72 (4.45–5.00)	5.35 (5.01–5.69)	4.79 (4.19–5.39)	5.08 (4.44–5.72)	6.02 (5.31–6.73)	**0.004 (0.003 to 0.006)**	**0.006 (0.001 to 0.011)**	0.002 (−0.003 to 0.007)	0.983 (0.889 to 1.086)
Low	5.86 (5.23–6.50)	5.49 (5.00–5.97)	6.04 (5.45–6.62)	6.97 (6.15–7.79)	8.62 (6.85–10.39)	7.91 (6.30–9.52)	9.06 (7.14–10.98)	**0.005 (0.004 to 0.007)**	0.002 (−0.007 to 0.011)	−0.003 (−0.012 to 0.006)	**1.244 (1.036 to 1.493)**
School performance											
High	4.81 (4.41–5.21)	5.14 (4.83–5.45)	6.39 (6.04–6.73)	6.72 (6.38–7.05)	6.58 (5.95–7.21)	5.81 (5.22–6.40)	6.33 (5.73–6.94)	**0.005 (0.004 to 0.007)**	−0.001 (−0.006 to 0.003)	**−0.006 (-0.011 to -0.001)**	0.925 (0.853 to 1.002)
Middle high	3.39 (3.15–3.63)	4.02 (3.83–4.22)	4.47 (4.26–4.67)	4.63 (4.40–4.86)	4.62 (4.20–5.05)	4.61 (4.22–5.01)	5.76 (5.32–6.19)	**0.003 (0.002 to 0.004)**	**0.006 (0.003 to 0.009)**	0.003 (0.000 to 0.006)	**1.085 (1.009 to 1.167)**
Middle	3.65 (3.41–3.89)	3.78 (3.61–3.96)	4.82 (4.60–5.03)	4.94 (4.73–5.15)	5.06 (4.70–5.43)	4.54 (4.16–4.92)	5.70 (5.27–6.12)	**0.004 (0.003 to 0.005)**	**0.003 (0.000 to 0.006)**	−0.001 (−0.004 to 0.002)	1.032 (0.967 to 1.101)
Middle low	3.72 (3.47–3.97)	4.30 (4.11–4.48)	5.28 (5.05–5.50)	5.82 (5.56–6.09)	5.58 (5.14–6.02)	5.50 (5.09–5.92)	6.86 (6.32–7.39)	**0.005 (0.004 to 0.006)**	**0.006 (0.003 to 0.010)**	0.001 (−0.003 to 0.005)	1.026 (0.958 to 1.098)
Low	5.84 (5.40–6.27)	6.01 (5.68–6.33)	7.28 (6.90–7.67)	7.86 (7.42–8.30)	8.69 (7.87–9.50)	7.52 (6.71–8.33)	8.86 (8.07–9.64)	**0.007 (0.006 to 0.009)**	0.001 (−0.005 to 0.006)	**−0.006 (-0.012 to 0.000)**	1.067 (0.979 to 1.163)
Education level of parents											
Middle school or less	4.03 (3.36–4.70)	3.80 (3.24–4.37)	4.74 (3.88–5.60)	6.21 (4.90–7.51)	4.97 (2.75–7.18)	6.73 (3.52–9.94)	3.65 (1.46–5.83)	**0.004 (0.002 to 0.006)**	**−0.006 (-0.007 to -0.006)**	**−0.010 (-0.012 to -0.008)**	0.805 (0.555 to 1.168)
High school	3.61 (3.40–3.82)	3.97 (3.80–4.14)	4.89 (4.67–5.11)	5.28 (5.01–5.54)	5.40 (4.88–5.92)	5.24 (4.68–5.81)	6.27 (5.67–6.88)	**0.005 (0.004 to 0.006)**	**0.004 (0.000 to 0.008)**	−0.001 (−0.005 to 0.003)	1.068 (0.985 to 1.158)
College or more	4.19 (3.99–4.40)	4.64 (4.49–4.80)	5.41 (5.24–5.58)	5.51 (5.32–5.69)	5.42 (5.11–5.74)	4.89 (4.60–5.18)	6.18 (5.84–6.52)	**0.004 (0.003 to 0.004)**	**0.004 (0.002 to 0.006)**	0.000 (−0.002 to 0.002)	1.001 (0.953 to 1.052)

BMI, body mass index; CI, confidence interval; OR, odds ratio.

Numbers in bold indicate a significant difference (p < 0.05).

[a] Estimated β was calculated using weighted linear regression and difference of β (βdiff) was conducted to analyze the trend changes between before (reference) and during the COVID-19 pandemic.

[b] Estimated OR was derived using weighted logistic regression, and OR was conducted to analyze the prevalence changes between 2017 and 2019 (reference) and 2020–2022 (during the pandemic).

[c] According to Asia-Pacific guidelines, BMI is divided into 4 groups: underweight ($<18.5 \text{ kg/m}^2$), normal ($18.5–22.9 \text{ kg/m}^2$), overweight ($23.0–24.9 \text{ kg/m}^2$), and obese (25.0 kg/m^2).
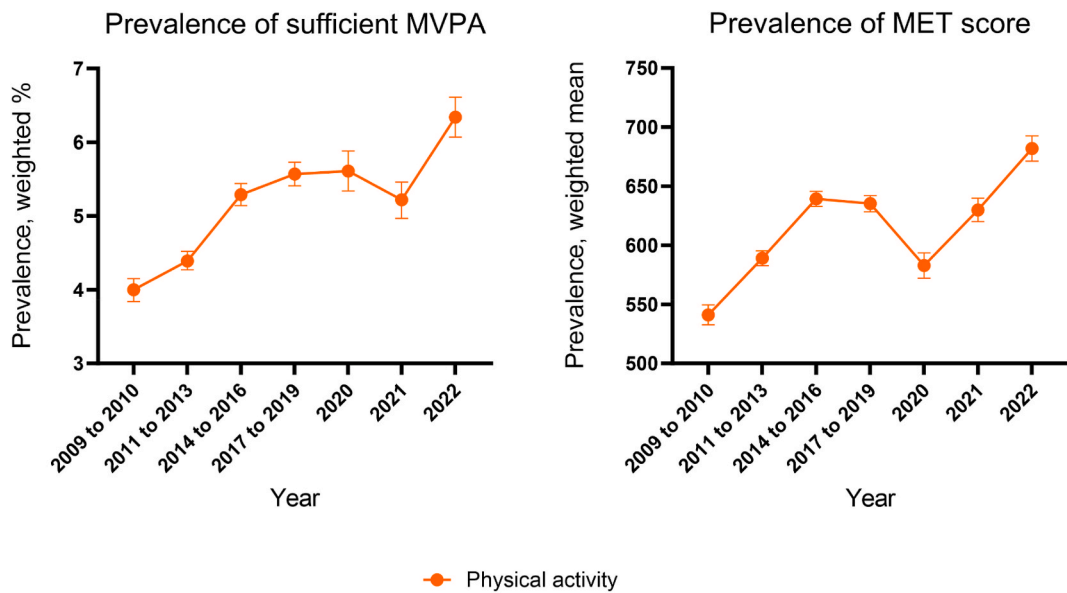
Fig. 2. Trends and prevalence of physical activities in Korean adolescents in 2009–2022. Error bar indicates 95 % CI. MVPA, moderate-to-vigorous physical activity; MET, metabolic equivalent task.

change in the slope. This may be due to adolescents being more comfortable with internet access; despite the lockdowns, adolescents were still accessing and following exercise-related content online. Thus, overall exercise has remained steadily increasing regardless of the lockdowns. This adaptation to online fitness resources demonstrates the resilience and adaptability of adolescents in maintaining physical activity levels despite challenging circumstances. Furthermore, as social distancing was eased in 2021 (mid-COVID-19 pandemic), adolescents had a greater opportunity to go out and do more aerobic activities during their leisure time [27]. Factors such as sex, age, residence, and alcohol consumption significantly influence MVPA and MET. For instance, female students showed a negative trend in MVPA. This might be due to differences in sports participation and physical activity preferences. Age is also a critical factor, with younger adolescents showing higher MVPA levels than older ones, potentially owing to increased academic pressures as they age and thus time spent is MVPA may be replaced with time spent studying in older adolescents. These demographic and lifestyle factors highlight the complex interplay of variables that influence physical activity patterns among adolescents, underscoring the need for tailored interventions that consider these diverse influences [28].

4.4. Policy implication

Adolescents, during the COVID-19 pandemic, had a greater opportunity to go out and do more aerobic activities during their leisure time [29]. Indeed, the decline in PA during the initial year of the pandemic was brief and increased as the pandemic progressed presenting an opportunity for the government [30]. This should be utilized to further underscore the significance of PA in schools while diversifying the emphasis beyond outdoor sports [31]. In the event of another pandemic or similar situation in which adolescents are forced to remain indoors for extended periods of time, the Korean government may wish to create guidelines for schools to use during their physical education periods in which they teach PA that can be performed indoors [32,33]. This would create a robust contingency plan in the event that adolescents must remain indoors for extended periods of time [32].

4.5. Limitations and strengths

Some limitations to this study should be considered. Primarily, the data originates from the survey held by KYRBS, and its generalizability is limited to Korean adolescents. Secondly, the survey methodology was based on self-reporting, which may have introduced recall and social desirability bias into the findings. Furthermore, some degree of bias might exist as 26,523 cases were excluded from the study. Additionally, the uneven distribution of the data of the study across the pre- and late-COVID-19 periods may affect the comparability of trends. Future research should aim for more balanced data collection across time periods to ensure more robust comparisons and trend analyses.

Despite these limitations, this study is of substantial importance. It is a nationwide, population-based study that describes the long-term trend of physical activity among Korean adolescents using 14 consecutive years of KYRBS data, encompassing the prevalence of physical activity before and during the COVID-19 pandemic.

Table 4
Weighted Mean MET score and trend % (95 % CI).

	MET score, weighted mean (95 % CI)							MET score trend, β (95 % CI)		MET score trend difference, β difference (95 % CI)[a]
	Before pandemic				During pandemic			Before pandemic	During pandemic	
	2009–2010	2011–2013	2014–2016	2017–2019	2020	2021	2022			
Overall	541.12 (532.64–549.59)	588.99 (582.78–595.21)	639.28 (632.86–645.69)	635.19 (628.42–641.96)	582.81 (572.07–593.55)	629.88 (619.93–639.83)	681.86 (671.20–692.52)	**15.392 (12.523 to 18.261)**	**49.518 (41.948 to 57.088)**	**34.126 (26.031 to 42.221)**
Sex										
Boy	708.27 (700.94–715.60)	754.29 (748.69–759.89)	803.46 (797.56–809.35)	814.83 (808.57–821.09)	744.76 (733.32–756.19)	790.18 (780.06–800.30)	852.23 (841.19–863.28)	**15.994 (13.037 to 18.951)**	**53.707 (45.525 to 61.890)**	**37.713 (29.013 to 46.413)**
Girl	353.95 (348.12–359.78)	406.55 (401.74–411.36)	460.36 (454.69–466.03)	440.38 (434.91–445.85)	407.83 (398.94–416.73)	457.42 (448.52–466.33)	499.61 (488.76–510.46)	**16.421 (14.994 to 17.847)**	**45.897 (38.731 to 53.062)**	**29.476 (22.170 to 36.782)**
Grade										
7th-9th grade	619.34 (608.65–630.02)	661.42 (653.66–669.19)	713.04 (705.87–720.22)	712.13 (704.24–720.02)	643.21 (630.97–655.45)	707.19 (695.83–718.55)	780.32 (768.52–792.12)	**12.286 (8.760 to 15.811)**	**68.574 (60.070 to 77.078)**	**56.288 (47.082 to 65.494)**
10th-12th grade	461.33 (448.11–474.56)	518.75 (509.24–528.26)	573.66 (563.61–583.72)	567.84 (557.32–578.37)	522.98 (505.55–540.40)	548.99 (532.95–565.03)	576.18 (559.42–592.94)	**19.845 (19.607 to 20.084)**	**26.598 (14.494 to 38.702)**	6.753 (−5.353 to 18.859)
Region of residence										
Rural	547.86 (527.44–568.28)	595.74 (578.07–613.40)	672.01 (642.94–701.09)	652.03 (622.19–681.88)	616.27 (571.71–660.82)	666.41 (630.56–702.27)	690.36 (646.06–734.66)	**22.024 (22.024 to 22.024)**	**37.202 (33.736 to 40.668)**	**15.178 (11.712 to 18.644)**
Urban	540.70 (531.79–549.61)	588.53 (582.01–595.06)	637.12 (630.58–643.67)	634.14 (627.19–641.08)	580.74 (569.64–591.84)	627.75 (617.46–638.04)	681.36 (670.45–692.28)	**14.986 (14.445 to 15.528)**	**50.304 (50.304 to 50.304)**	**35.318 (34.777 to 35.860)**
Body mass index[b]										
Underweight	472.31 (459.57–485.05)	530.62 (521.06–540.19)	568.82 (558.49–579.16)	539.58 (527.90–551.26)	419.25 (400.93–437.57)	478.70 (461.38–496.02)	537.73 (520.05–555.41)	−4.378 (−9.094 to 0.338)	**59.237 (46.480 to 71.994)**	**63.615 (50.014 to 77.216)**
Normal	543.52 (534.57–552.47)	591.37 (584.80–597.93)	642.10 (635.29–648.90)	639.23 (631.90–646.56)	584.03 (572.12–595.94)	635.19 (624.17–646.20)	688.32 (676.34–700.31)	**16.146 (13.037 to 19.256)**	**52.142 (43.691 to 60.593)**	**35.996 (26.991 to 45.001)**
Overweight	571.23 (556.64–585.83)	605.88 (594.94–616.82)	651.58 (640.71–662.44)	650.47 (639.49–661.46)	650.08 (630.19–669.96)	687.65 (669.31–705.98)	728.43 (707.53–749.33)	**20.287 (15.122 to 25.451)**	**39.146 (24.707 to 53.584)**	18.859 (3.525 to 34.193)
Obese	587.49 (570.93–604.04)	617.10 (605.46–628.74)	668.26 (657.27–679.25)	656.68 (646.44–666.92)	623.62 (606.80–640.44)	653.89 (638.24–669.53)	714.99 (697.14–732.84)	**9.120 (4.120 to 14.120)**	**45.638 (33.350 to 57.926)**	**36.518 (23.252 to 49.784)**
Economic level										
High	722.15 (704.06–740.24)	744.12 (731.69–756.56)	757.00 (745.47–768.52)	755.69 (744.59–766.80)	704.94 (683.85–726.04)	750.45 (730.43–770.47)	804.75 (783.87–825.63)	−2.867 (-4.387 to -1.347)	**49.922 (35.057 to 64.788)**	**52.789 (37.846 to 67.732)**
Middle high	589.70 (578.26–601.13)	634.32 (626.33–642.30)	670.68 (662.78–678.58)	658.15 (649.53–666.78)	607.76 (594.32–621.20)	654.03 (641.20–666.86)	714.36 (701.07–727.65)	**7.042 (3.351 to 10.734)**	**53.386 (43.927 to 62.846)**	**46.344 (36.190 to 56.498)**

Table 4 (*continued*)

	MET score, weighted mean (95 % CI)							MET score trend, β (95 % CI)		MET score trend difference, β difference (95 % CI)[a]
	Before pandemic				During pandemic					
	2009–2010	2011–2013	2014–2016	2017–2019	2020	2021	2022	Before pandemic	During pandemic	
Middle	506.58 (497.58–515.58)	559.99 (553.25–566.73)	611.96 (604.84–619.08)	601.06 (593.70–608.42)	545.22 (532.96–557.47)	592.13 (580.66–603.61)	637.61 (625.41–649.81)	**14.434 (11.233 to 17.636)**	**46.204 (37.554 to 54.855)**	**31.770 (22.546 to 40.994)**
Middle low	508.32 (496.94–519.70)	547.43 (539.05–555.81)	603.71 (594.02–613.40)	599.29 (588.21–610.37)	548.30 (529.08–567.52)	607.52 (586.59–628.45)	629.84 (609.71–649.97)	**18.489 (14.025 to 22.953)**	**41.316 (27.373 to 55.259)**	**22.827 (8.187 to 37.467)**
Low	537.13 (520.85–553.41)	570.12 (556.41–583.83)	612.05 (595.25–628.86)	633.47 (610.86–656.08)	609.92 (569.28–650.56)	651.57 (610.12–693.02)	696.79 (648.54–745.03)	**24.780 (20.057 to 29.504)**	**43.375 (22.014 to 64.736)**	18.595 (−3.282 to 40.472)
School performance										
High	598.07 (584.44–611.70)	653.70 (643.40–664.00)	702.31 (692.59–712.04)	714.06 (704.03–724.09)	647.59 (628.50–666.67)	691.29 (673.67–708.92)	752.85 (735.11–770.59)	**18.450 (13.678 to 23.222)**	**52.742 (39.693 to 65.791)**	**34.292 (20.398 to 48.186)**
Middle high	538.98 (528.51–549.46)	595.86 (587.92–603.80)	645.05 (637.19–652.90)	629.46 (621.03–637.89)	574.66 (560.92–588.41)	625.16 (611.93–638.40)	691.84 (677.43–706.26)	**13.140 (9.524 to 16.756)**	**58.601 (48.631 to 68.570)**	**45.461 (34.856 to 56.066)**
Middle	530.35 (520.10–540.60)	572.89 (565.36–580.42)	624.80 (617.07–632.53)	614.21 (606.11–622.31)	561.93 (549.13–574.73)	617.66 (605.01–630.32)	658.27 (644.65–671.88)	**12.190 (8.728 to 15.652)**	**48.193 (38.841 to 57.546)**	**36.003 (26.030 to 45.976)**
Middle low	530.35 (520.59–540.11)	575.48 (568.34–582.63)	621.03 (613.36–628.71)	620.11 (611.11–629.12)	569.19 (554.39–583.98)	614.49 (600.25–628.72)	657.10 (641.76–672.44)	**14.971 (11.295 to 18.646)**	**43.973 (33.315 to 54.630)**	**29.002 (17.729 to 40.275)**
Low	538.97 (525.86–552.07)	582.25 (573.06–591.44)	630.79 (620.09–641.49)	641.29 (629.67–652.92)	619.05 (597.32–640.78)	635.96 (615.25–656.67)	686.31 (663.55–709.06)	**24.200 (19.144 to 29.257)**	**33.389 (17.611 to 49.166)**	9.189 (−7.379 to 25.757)
Education level of parents										
Middle school or less	498.82 (479.25–518.39)	520.38 (503.10–537.67)	590.58 (567.12–614.03)	597.59 (563.48–631.70)	499.20 (436.51–561.89)	628.73 (562.27–695.19)	556.28 (491.59–620.97)	**21.202 (14.565 to 27.840)**	**28.980 (27.915 to 30.046)**	**7.778 (1.056 to 14.500)**
High school	513.32 (503.49–523.14)	558.73 (551.40–566.06)	617.92 (609.61–626.23)	613.96 (603.96–623.97)	571.20 (553.76–588.64)	611.45 (592.95–629.95)	649.63 (630.57–668.69)	**25.087 (21.176 to 28.999)**	**39.243 (26.316 to 52.171)**	**14.156 (0.650 to 27.662)**
College or more	559.75 (549.73–569.77)	610.98 (603.73–618.22)	652.26 (644.98–659.55)	642.66 (634.93–650.40)	583.11 (571.11–595.11)	629.22 (617.79–640.64)	690.91 (678.37–703.45)	**10.476 (7.194 to 13.759)**	**53.998 (45.310 to 62.687)**	**43.522 (34.234 to 52.810)**

BMI, body mass index; CI, confidence interval.

Numbers in bold indicate a significant difference (p < 0.05).

[a] Estimated β was calculated using weighted linear regression and difference of β (βdiff) was conducted to analyze the trend changes between before (reference) and during the COVID-19 pandemic.

[b] According to Asia-Pacific guidelines, BMI is divided into 4 groups: underweight (<18.5 kg/m^2), normal (18.5–22.9 kg/m^2), overweight (23.0–24.9 kg/m^2), and obese (25.0 kg/m^2).

5. Conclusion

In summary, our study described the longitudinal trend of PA among adolescents in South Korea from 2009 to 2022 by using KYRBS data. The trend of the Korean adolescents' MVPA achievement and mean MET score was steady. The overall number of Korean adolescents who achieved WHO MVPA recommendations increased over the years, despite the emergence of the COVID-19 pandemic. To ascertain the apparent prevalence of changes in adolescents' PA, continuing monitoring of PA prevalence and its trend will be needed even after the COVID-19 pandemic. Further research will allow society to empower public health for adolescents, with an emphasis on enhancing PA for adolescents, particularly as we enter the post-COVID-19 pandemic period.

CRediT authorship contribution statement

Jun Hyuk Lee: Writing – review & editing, Writing – original draft. **Yejun Son:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jaeyu Park:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hayeon Lee:** Writing – review & editing. **Yujin Choi:** Writing – review & editing. **Myeongcheol Lee:** Writing – review & editing. **Sunyoung Kim:** Writing – review & editing. **Jiseung Kang:** Writing – review & editing. **Jiyeon Oh:** Writing – review & editing. **Hyeon Jin Kim:** Writing – review & editing. **Sang Youl Rhee:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Lee Smith:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Dong Keon Yon:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Data sharing statement

Data are available on reasonable request. Study protocol, statistical code: available from DKY (email: yonkkang@gmail.com). Data set: available from the KDCA through a data use agreement.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at doi:mmcdoino

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