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Short communication

Moderate-to-vigorous intensity physical activity among U.S. adolescents before and during the COVID-19 pandemic: Findings from the Adolescent Brain Cognitive Development Study

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ABSTRACT

Only 16.1% percent of U.S. adolescents meet the recommendation of at least 60 minutes of moderate-to-vigorous intensity physical activity (MVPA) per day. Studies report declined levels of adolescent MVPA in early stages of the pandemic, but gaps remain in understanding changes beyond the initial three months of the pandemic. This study aims to describe and compare self-reported adolescent MVPA levels at multiple timepoints before and during the COVID-19 pandemic among 11,865 9-11-year-old U.S. adolescents from the Adolescent Brain Cognitive Development (ABCD) Study, including pre-pandemic (September 2016-October 2018), early (May, June, and August 2020), and later (October and December 2020, March 2021) stages of the pandemic. Poisson regression models with robust error variance were used to estimate crude and adjusted prevalence ratios (APRs) of the proportion of adolescents meeting national MVPA guidelines during early and later stages of the pandemic compared to pre-pandemic. The proportion of adolescents meeting MVPA guidelines decreased from pre (16.4%), early (11.0%), and later (4.7%) COVID-19 pandemic timepoints. Adolescent MVPA guideline adherence at early- and later-pandemic stages was 24% lower (APR 0.76, 95% CI 0.62, 0.93) and 68% lower (APR 0.32, 95% CI 0.24, 0.43) than pre-pandemic adherence, respectively. Weekly MVPA duration decreased throughout May 2020 to March 2021 ($\chi^2 = 488.9$, $p < 0.0001$). Study findings build upon existing evidence that the low achievement of national MVPA guidelines before the pandemic became even lower during the pandemic, demonstrating the need to support and improve access to adolescent MVPA opportunities during COVID-19 pandemic recovery efforts and in future pandemics.

1. Introduction

Engaging in regular moderate-to-vigorous intensity physical activity (MVPA) during adolescence yields lifelong health benefits, including musculoskeletal, cardiovascular, cognitive, and mental health (2018 Physical Activity Guidelines Advisory Committee, 2018; Dimitri et al., 2020; Whooten et al., 2019). However, the proportion of U.S. adolescents meeting the Department of Health and Human Services *Physical Activity Guidelines for Americans* recommendation of at least 60 min of

MVPA per day decreased from 16.1% to 8.9% with the onset of the COVID-19 pandemic (Nagata et al., 2022; U.S. Department of Health and Human Services, 2018). Beginning in March 2020, the COVID-19 pandemic and subsequent school closures, stay-at-home orders, physical distancing guidelines, and other government-mandated safety measures led to substantial changes to adolescents' daily routines. Previous international and U.S. studies comparing pre- to early- (i.e., first few months) pandemic MVPA levels among children detected significant decreases in activity (Dunton et al., 2020; Yang et al., 2022; Moore et al.,

Abbreviations and Acronyms: ABCD, Adolescent Brain Cognitive Development Study; HHS, U.S. Department of Health and Human Services; MVPA, moderate-to-vigorous intensity physical activity; RRR, Rapid Response Research; IPAQ-SF, International Physical Activity Questionnaire - Short Form.

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2020; Dallolio et al., 2022; Neville et al., 2022) including device-based measures (Nagata et al., 2023; Salway et al., 2022; Tanaka et al., 2023). Further, U.S. studies have found greater pre- to early- pandemic MVPA decline among middle and high schoolers, compared to younger children (Dunton et al., 2020; Tulchin-Francis et al., 2021). Given these initial findings, continued assessment of adolescent MVPA at additional COVID-19 timepoints is critical in building evidence for prioritizing adolescent MVPA interventions during the COVID-19 recovery phase and in future pandemics.

This study aims to 1) compare the prevalence of adolescents meeting national MVPA guidelines at pre-, early, and later stages of the COVID-19 pandemic and 2) evaluate changes in MVPA frequency and duration throughout the first year of the COVID-19 pandemic in a large, national sample of U.S. adolescents. The first year of the COVID-19 pandemic was characterized by great uncertainty and relatively strict public health guidance that limited adolescents' opportunities to preserve current MVPA levels or engage in MVPA altogether. We hypothesized that the proportion of adolescents meeting MVPA guidelines decreased from pre- to early pandemic stages and further declined from early to later pandemic stages, in addition to a gradual decrease in weekly MVPA levels from May 2020 to March 2021.

2. Methods

2.1. Data collection

This was a secondary data analysis of the Adolescent Brain Cognitive Development (ABCD) Study. The ABCD Study is a longitudinal study of 11,875 U.S. adolescents (9–10 years old at baseline) who receive annual, comprehensive health assessments over 10 years. Starting in May 2020, the ABCD Study began administering supplemental online questionnaires to gather insight on how the COVID-19 pandemic has impacted participants' overall health and well-being. The ABCD Study was approved by the centralized institutional review board of the University of California, San Diego, and written assent and consent were obtained from participants and their participating parent/guardian, respectively (Adolescent Brain Cognitive Development Study, 2021). For the present study, data from baseline (collected 2016–2018) and COVID-19 Rapid Response Research (RRR) Surveys 1 through 6 (collected May, June, August, October, and December 2020, and March 2021) were analyzed. Data collected May–August 2020 were considered early pandemic and October 2020–March 2021 were considered later pandemic. Pandemic response rates ranged from 32% to 47% (Fig. 1).

2.2. Moderate-to-vigorous intensity physical activity measures

Adolescent-reported MVPA data were obtained from the COVID-19 RRR Surveys at six timepoints between May 2020 and March 2021 through online questionnaires. Surveys contained questions from the Youth Risk Behavior Survey and the International Physical Activity Questionnaire - Short Form (IPAQ-SF) to obtain measures of weekly frequency (days per week) and duration (hours and minutes) on a typical day of MVPA (Appendix A). Previous research has found test–retest reliability for the IPAQ-SF is acceptable (75% of correlation coefficients above 0.65) and criterion validity with accelerometers is fair (Spearman correlation coefficients 0.30) (Barch et al., 2018; Craig et al., 2017; Craig et al., 2003; Lee et al., 2011). Weekly MVPA levels were computed as a product of frequency and duration, expressed as hours per week (Nagata et al., 2022). To assess meeting MVPA guidelines during COVID-19, a binary measure was created to indicate whether guidelines were met (reporting both a daily duration greater than or equal to 60 min and a weekly frequency of 7 days) or unmet (reporting a daily duration less than 60 min and/or a weekly frequency less than 7 days). Pre-pandemic guidelines data were obtained through baseline self-report of engaging in at least 60 min of MVPA for seven days per week.

2.3. Sociodemographic characteristics

Parent-reported sociodemographic data were obtained from the main ABCD Study at baseline. Characteristics included child age (continuous), biological sex (female or male), race/ethnicity (White, Latinx/Hispanic, Black, Asian, Native American, other), annual combined household income (low versus high income with a cutoff of \$75,000 per year, approximating the median U.S. household income), and highest level of parent education (high school education or less and college education or more) (Barch et al., 2018).

2.4. Statistical analyses

Descriptive statistics were generated for baseline sociodemographic characteristics. To assess the association between meeting MVPA guidelines at early (May 2020) and later (March 2021) pandemic stages compared to pre-pandemic (2016–2018) (Aim 1), we calculated unadjusted and sociodemographic-adjusted prevalence ratios using modified Poisson regression models with sandwich error estimation to yield robust error variance. This estimation approach was used to relax

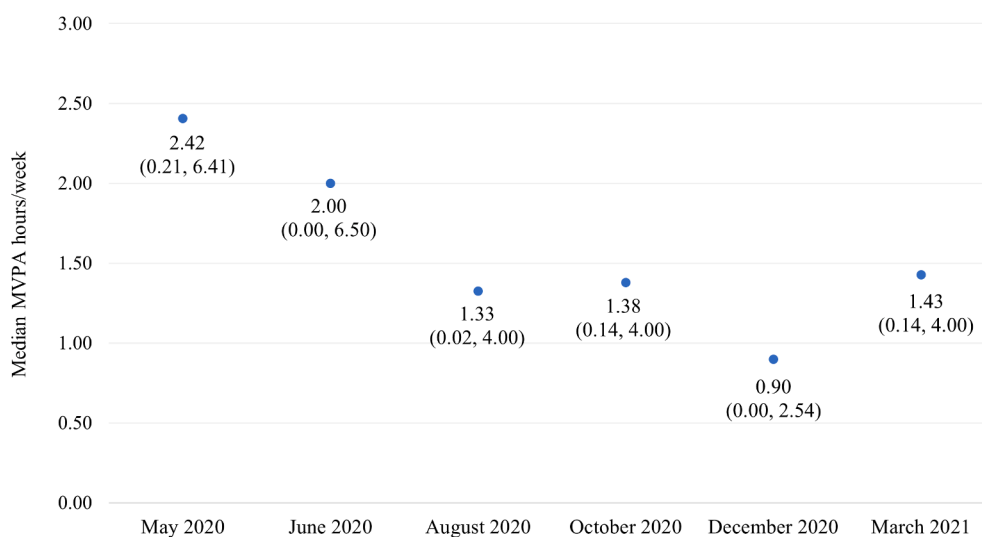


Fig. 1. Summary of adolescent-reported moderate-to-vigorous intensity physical activity (MVPA) during the COVID-19 pandemic, US Adolescent Brain Cognitive Development Study (2020–2021).

Poisson distribution assumptions for obtaining standard error and confidence interval estimates and to indicate repeated measurements of adolescent MVPA at early vs. pre-pandemic and later vs. pre-pandemic timepoints (Zou, 2004). We used generalized estimating equations assuming an exchangeable working correlation structure to account for clustering of repeated MVPA measurements within study participants (Yelland et al., 2011). Further, to examine differences in MVPA levels throughout the first year of the pandemic (Aim 2), we conducted a Friedman test for weekly MVPA duration in May, June, August, October, and December 2020, and March 2021. Analyses utilize all available data for longitudinal comparisons at early vs. pre-pandemic and later vs. pre-pandemic (Aim 1) and within single timepoints (Aim 2).

3. Results

In this sample, the median baseline age was 9.9 years, 48% were female, and 48% represented racial/ethnic minority populations (Appendix B).

Compared to the pre-pandemic period, the proportion of adolescents meeting MVPA guidelines was lower at each stage of the COVID-19 pandemic (pre: 16.4%, early: 11.0%, later: 4.7%) (Table 1). Crude prevalence ratios (CPRs) confirmed that MVPA guideline adherence at early- and later-pandemic stages was 32% lower (CPR 0.68, 95% CI 0.62, 0.75) and 71% lower (CPR 0.29, 95% CI 0.25, 0.34) than pre-pandemic adherence, respectively. Adjusting for covariates, the prevalence of MVPA guideline adherence in the early and later pandemic was 24% lower (APR 0.76, 95% CI 0.62, 0.93) and 68% lower (APR 0.32, 95% CI 0.24, 0.43) than pre-pandemic levels.

Weekly MVPA duration decreased in the first year of the pandemic from a median of 2.42 (IQR 0.21, 6.41) hours per week in May 2020 compared to 1.43 (IQR 0.14, 4.00) median hours per week in March 2021 ($\chi^2 = 488.9$, $p < 0.0001$) (Fig. 1), with a nadir in December 2020.

4. Discussion

4.1. Adolescent MVPA before and during the COVID-19 pandemic

The purpose of this study was to compare adolescent MVPA guideline adherence before and during the COVID-19 pandemic and to evaluate MVPA frequency and duration throughout the first year of the COVID-19 pandemic. Study findings aligned with our proposed hypotheses and prior literature. The proportion of adolescents meeting MVPA guidelines was lower in March 2021 (i.e., later stages) compared to before the pandemic. Similar comparisons of pre-vs-early pandemic MVPA guideline adherence were observed among Italian and Chinese adolescents (Dallolio et al., 2022; Yang et al., 2022). This finding is also consistent with U.S. and Canadian studies reporting lower adolescent MVPA levels compared to before the COVID-19 pandemic (Moore et al., 2020; Tulchin-Francis et al., 2021). The findings are not surprising since our period of study coincided with business and school closures in the

early pandemic. At this time when little was known about COVID-19 transmission, vaccination, and its potential effects among children, effective strategies to ensure adolescents' safe engagement in MVPA may have still been in development. Within households, pandemic-related stressors such as financial strain, housing insecurity, mental health challenges, and COVID-19 related illness and death may have disrupted adolescents' opportunities and motivation to maintain or initiate physical activity remotely.

Regarding our second hypothesis, weekly MVPA levels declined throughout the first year of the pandemic. However, in the latter half of 2020 through March 2021, fluctuations in weekly MVPA levels did not follow a gradual decline as hypothesized. The initial drop in adolescent MVPA detected between May-August 2020 aligns with when most schools had already shifted to remote learning, and summer extracurricular activities were cancelled or modified to meet COVID-19 safety protocols. In the following months, varied state-level pandemic response shaped opportunities for adolescents to engage in MVPA, which may contextualize why weekly MVPA levels did not consistently decline into early 2021. Our study suggests an overall downward trend in adolescent MVPA may persist, and evaluation of MVPA at additional timepoints beyond March 2021 is warranted to draw conclusions on longer-term changes in MVPA levels during the pandemic.

4.2. Strengths and limitations

A key strength of this study was its ability to assess MVPA before and during the pandemic in a large, national sample of U.S. adolescents using baseline and supplemental ABCD Study data. This also allowed for assessment of weekly MVPA duration at six timepoints throughout the first year of the pandemic, which not only provided valuable insight on immediate MVPA decreases when the pandemic was initially declared, but also on fluctuations in MVPA levels as public health guidelines adapted to changing pandemic circumstances.

This study is not without limitations. Data were self-reported and prone to social desirability response bias, potentially biasing our estimates of MVPA occurrence and association. We also did not have data to control for seasonality and were unable to rule out if detected changes in MVPA were merely due to seasonal variation; however, the incrementally lower median levels from May through August 2020 support the influence of the COVID-19 pandemic (Carson & Spence, 2010). Further, only 32%-47% of the overall ABCD Study sample responded to the six COVID-19 RRR Surveys, with response rates highest among White and high socioeconomic status participants (Appendix C). Given prior research that adolescents from racially and ethnically minoritized populations and of low socioeconomic background tend to report lower MVPA (Armstrong et al., 2018), it is possible that adolescent MVPA levels during COVID-19 may be lower than our current estimates.

Table 1

Percentage of US adolescents meeting moderate-to-vigorous intensity physical activity (MVPA) guidelines before and during the COVID-19 pandemic, Adolescent Brain Cognitive Development Study (2016–2021).

		n (%)		Crude PR ^a (95% CI)	Adjusted PR ^{a,b} (95% CI)
Met MVPA Guidelines	Before COVID-19, pre-pandemic (2016–2018)	1949	(16.4) ^c	1.00 (reference)	1.00 (reference)
	During COVID-19, early (May 2020) ^d	577	(11.0)	0.68 (0.62, 0.75)	0.76 (0.62, 0.93)
	During COVID-19, later (March 2021) ^e	205	(4.7)	0.29 (0.25, 0.34)	0.32 (0.24, 0.43)

^a Prevalence ratio estimated using Poisson regression with robust error variance.

^b Adjusted for continuous age, sex, race/ethnicity, annual household income.

^c Proportion corresponds to those that met MVPA guidelines at baseline among 11,865 eligible study population.

^d This analysis includes all participants with available data at baseline and May 2020 (N = 5,260).

^e This analysis includes all participants with available data at baseline and March 2021 (N = 4,360).

Abbreviations: PR, prevalence ratio; MVPA, moderate-to-vigorous intensity physical activity.

4.3. Study implications and recommendations

The complex factors that contribute to decreases in adolescent MVPA during the COVID-19 pandemic call for solutions that target multiple settings and levels of influence. Since schools are a primary setting for adolescent MVPA, solutions must also be flexible in the case of future intermittent or extended pandemic-related school closures. For example, schools could collaborate with community organizations to deliver physical activity programming via live video conferencing which can be streamed in classrooms or at home. Following evidence that classroom-based physical activity interventions combined with parent/caregiver support are associated with higher MVPA, additionally incorporating family-based goal setting, monitoring, and feedback components (e.g., newsletters or text notifications) may improve adolescent MVPA uptake and adherence (Forseth et al., 2021; Moore et al., 2020; Neil-Sztramko et al., 2021). If the capacity for virtual programming is limited, local authorities could prioritize reserving outdoor recreation spaces and equipment for adolescents to safely engage in outdoor MVPA during school breaks and after school hours (Guerrero et al., 2020).

While our findings are foundational in understanding how the pandemic has affected MVPA in U.S. adolescents, research that employs a more comprehensive socioecological model approach is needed to inform future directions for public health research, policy, and practice.

5. Conclusion

In summary, MVPA guideline adherence and weekly MVPA levels decreased during the COVID-19 pandemic among U.S. adolescents, whose MVPA levels were already low before the pandemic. Findings are consistent with prior studies, and further underscore the importance of additional research and immediate MVPA interventions that can improve access to adolescent MVPA opportunities during post-pandemic recovery and in future pandemics.

6. Ethics approval

The University of California, San Diego provided centralized institutional review board (IRB) approval and each participating site received local IRB approval.

7. Consent, data, materials and/or code availability

Written informed consent and assent were obtained from the parent/guardian and adolescent, respectively, to participate in the ABCD Study. Data used in the preparation of this article were obtained from the ABCD Study (<https://abcdstudy.org>), held in the NIMH Data Archive (NDA). Investigators can apply for data access through the NDA (<https://nda.nih.gov/>).

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ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in the analysis or writing of this report.

CRedit authorship contribution statement

Catherine A. Cortez: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Iris Yuefan Shao:** Methodology, Formal analysis, Writing – review & editing. **Marissa J. Seamans:** Conceptualization, Writing – original draft, Writing – review & editing. **Erin E. Dooley:** Conceptualization, Writing – original draft, Writing – review & editing. **Kelley Pettee Gabriel:** Conceptualization, Writing – original draft, Writing – review & editing. **Jason M. Nagata:** Conceptualization, Methodology, Investigation, Supervision, Writing – original draft, Writing – review & editing.

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.

Data availability

Data were obtained from the ABCD Study (<https://abcdstudy.org>), held in the NIMH Data Archive (NDA). Investigators can apply for data access through the NDA (<https://nda.nih.gov/>).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2023.102344>.

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