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Moderate-to-vigorous intensity physical activity among adolescents in the USA during the COVID-19 pandemic

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ABSTRACT

This study aimed to evaluate adolescents' moderate-to-vigorous intensity physical activity (MVPA) during the COVID-19 pandemic with regards to sociodemographic characteristics and determine mental health and resiliency factors associated with MVPA among a diverse national sample of adolescents ages 10–14 years. Data were collected during the pandemic in May 2020 from the Adolescent Brain Cognitive Development Study (ABCD, N = 5,153), a national prospective cohort study in the U.S. MVPA was quantified as the product of reported duration and frequency (hours per week), which was further summarized as the proportion meeting age-appropriate 2018 Physical Activity Guidelines for Americans. A similar estimate was generated using MVPA data collected prior to the pandemic. Mental health and resiliency measures were collected during the pandemic. Regression models examined associations between mental health or resiliency measures and MVPA during the pandemic. Median MVPA was 2 h per week (IQR 0, 6). Overall, the percentage of the cohort meeting MVPA guidelines decreased from 16.1% (pre-pandemic) to 8.9% (during the pandemic). Racial/ethnic minority adolescents and adolescents from lower socioeconomic backgrounds were significantly less likely to meet MVPA guidelines during the pandemic. Poorer mental health, COVID-related worry, and stress were associated with lower MVPA, while more social support and coping behaviors were associated with higher MVPA during the pandemic. In this large, national sample of adolescents, the proportion of those meeting MVPA Guidelines was lower during the COVID-19 pandemic, with significant disparities by race/ethnicity and socioeconomic status. Interventions to promote social support and coping behaviors may improve MVPA levels among adolescents during the pandemic.

1. Introduction

Despite the numerous psychological and physical benefits of habitual physical activity (U.S. Department of Health and Human Services, 2018), less than one-quarter of U.S. adolescents meet the Department of Health and Human Services (HHS) *Physical Activity Guidelines for Americans* (Katzmarzyk et al., 2018). Current HHS guidelines recommend children ages 6–17 years to achieve at least 60 min of moderate-to-vigorous intensity physical activity (MVPA) per day (henceforth: MVPA Guidelines) (U.S. Department of Health and Human Services, 2018). Federal (March 13, 2020) and U.S. State Public Health and Medical Emergency declarations in response to the COVID-19 pandemic (Gostin and Wiley, 2020) resulted in disruptions to children and adolescents' daily activities. Such measures, including stay-at-home orders, school and business closures, limited social activities and organized sport participation, and travel restrictions, may impede physical activity among this age group (Marques et al., 2016; Ridgers et al., 2012). Additonally, disruption of daily routines due to major life events, such as

Abbreviations: 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.

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the COVID-19 pandemic, can be associated with increased stress and lead to interruptions of, or permanent changes to, habitual behaviors, such as physical activity (Allender et al., 2008; Allender et al., 2006). Further, sudden exercise withdrawal can have a negative impact on mental health (Weinstein et al., 2017).

With school, sports, and recreation/gym facility closures due to COVID-19, declines in children's physical activity have been reported (Dunton et al., 2020; Moore et al., 2020). This reduction in activity may be even more pronounced for adolescents. Prior research exploring the relationship between age and physical activity in Canada and the U.S. found adolescents' physical activity patterns to be more impacted by COVID-19 compared to physical activity of younger children (Mitra et al., 2020; Tulchin-Francis et al., 2021). One reason for this was that younger children increased outdoor independent play, while high school-aged adolescents did not (Tulchin-Francis et al., 2021). Adolescents, particularly boys, may be less likely to participate in physical activity outside of team and peer settings (Saunders et al., 2018; Tulchin-Francis et al., 2021). In one study, about half (52%) of U.S. adolescents reported no longer being physically active after California's stay-at-home orders (Chaffee et al., 2021). Prior to the pandemic, disparities in physical activity levels existed by age, gender, race/ethnicity, and socioeconomic status (Armstrong et al., 2018), factors whose effects may be amplified due to COVID-19. Although home-based and/or technology-assisted (e.g., Zoom platform) programs can promote maintenance of physical activity during COVID-19 (Bentlage et al., 2020), socioeconomic status and race/ethnicity disparities in access to home-based physical activity promotion (Tandon et al., 2012) and the internet (Greenberg-Worisek et al., 2019) exist. While prior studies have reported declines in physical activity levels due to the COVID-19 pandemic (Dunton et al., 2020; Mitra et al., 2020; Moore et al., 2020; Tulchin-Francis et al., 2021; Verlenden et al., 2021), it is unclear if this observation is experienced similarly across important sociodemographic characteristics including gender, race/ethnicity, and socioeconomic status. Moreover, given the largely non-modifiable nature of sociodemographic characteristics, further studies are needed to determine if there are intrinsic characteristics, such as mental health and resiliency factors, associated with the disruption or maintenance of physical activity behaviors–despite the stressors and disruptions to daily routines imposed by the pandemic. Therefore, utilizing a large, demographically diverse, national sample of U.S. adolescents (ages 10–14 years) from the Adolescent Brain Cognitive Development (ABCD) Study, we tested the overarching hypothesis that reported physical activity levels were lower during the pandemic compared with pre-pandemic measures with differences that vary by participant characteristics. The study objectives were to examine: 1) MVPA (hours per week; $h \cdot wk^{-1}$) during the pandemic; 2) the proportion meeting MVPA Guidelines before and during the pandemic overall and by sociodemographic factors, including race/ethnicity; and 3) the adjusted associations of mental health and resiliency factors with MVPA during the pandemic.

2. Methods

2.1. Study population

We analyzed data from the ABCD Study, a national prospective cohort study of brain development and health among 11,875 adolescents. Analyses include data from baseline (2016–2018) and the COVID Rapid Response Research (RRR) Survey 1 (May 2020). Although the COVID data were collected relatively early on in the pandemic, findings still have relevance given the ongoing nature of the pandemic, the potential long-term impacts of pandemic-related MVPA and mental health changes in adolescents, and for future pandemics. Participants were excluded if they had missing data for physical activity, mental health and resiliency factors, and sociodemographic characteristics or completed the COVID RRR surveys out of order. The exclusion criteria resulted in an analytic sample of 5,153 participants who had complete data for baseline and the COVID RRR Survey 1 (response percentage 43.4%). Centralized institutional review board approval was obtained from the University of California, San Diego. Written informed consent and assent were obtained from a parent/guardian and the child, respectively, to participate in the ABCD study.

2.2. Measures

Sociodemographic characteristics were based on parent report and included adolescent characteristics such as age (continuous), gender (male or female), and race/ethnicity (White, Latinx/Hispanic, Black, Asian, Native American, other). Baseline parent and household characteristics included household income (less than $75,000 and $75,000 and greater, as this approximated the median household income in the U.S.), and highest parent education (high school or less versus college education or more) (Barch et al., 2018).

Mental health and resiliency scores were determined using the following COVID RRR Survey items: adolescent-reported mental health, COVID-19-related worry, perceived stress (Cohen et al., 1983), social support, and coping behaviors. See the Supplemental Appendix for a full list of questions comprising these measures.

Adolescent-reported MVPA was ascertained using questionnaires adapted from the Youth Risk Behavior Survey (Barch et al., 2018; Centers for Disease Control and Prevention, 2013) and the International Physical Activity Questionnaire Short Form (ABCD Study, 2020; Lee et al., 2011) at the ABCD Study baseline and COVID RRR May 2020 assessments, respectively, with slight discrepancies in question structure by assessment period. Physical activity in ABCD is traditionally ascertained by the reported frequency (days during the last 7 days) of spending at least 60 min per day physically active (Barch et al., 2018), while in the COVID RRR, it is by reports of the daily duration (hours and minute) and frequency (days per week) spent in MVPA. For the latter measure, continuous MVPA estimates were computed as the product of reported duration and frequency and expressed as $h \cdot wk^{-1}$. Physical activity data collected from both versions of the physical activity survey were harmonized by computing a categorical score reflecting MVPA Guidelines [pre-COVID: reported frequency of 7 days spent active for at least 60 min; COVID: reported both daily duration of $\geq$ 60 min and frequency of 7 days].

2.3. Statistical analysis

Data analysis was performed in July 2021 using Stata 15.1 and RStudio v 1.3.1093. Descriptive statistics included measures of central tendency and variability for continuous variables and frequency and proportions for categorical variables. For continuous variables, the assumption of normality was tested; the distribution of MVPA ($h \cdot wk^{-1}$) was positively-skewed. Differences in MVPA ($h \cdot wk^{-1}$) by sociodemographic characteristics were evaluated using Wilcoxon Rank Sum (for sociodemographic factors with only two categories) or Kruskal-Wallis tests (for sociodemographic factors with more than two categories). McNemar's tests were used to compare the proportions of adolescents meeting MVPA guidelines before and during COVID-19. Multiple linear regression analyses were conducted to estimate the association between mental health and resiliency factors and MVPA ($h \cdot wk^{-1}$) during the pandemic. Each independent variable (i.e., mental health, COVID-19-related worry, perceived stress, social support, and coping behaviors) was examined in separate models, adjusting for gender, race/ethnicity, parent education, income level, and study site. Adjusting for the same set of covariates, we also conducted multiple logistic regression analyses to estimate the odds of meeting MVPA guidelines during the COVID-19 pandemic by mental health and resiliency factors. In sensitivity analyses, we tested if gender or race modified the effect of mental health or resiliency factors on MVPA. Data were weighted using propensity weights from the ABCD Study to approximate the American Community Survey by the U.S. Census (Heeringa and Berglund, 2020). A two-sided

alpha = 0.05 was considered statistically significant.

3. Results

Among the analytic sample of 5,153 participants, adolescents were 12.5 ± 0.9 years old on average, 50.6% were female, and 39.5% represented racial/ethnic minority populations (Table 1). Approximately 34% of adolescents were from households below the median income of $75,000 and most had a parent with a college education or higher (89%).

3.1. Differences in MVPA during the COVID-19 pandemic by sociodemographic factors

Adolescents reported a median of 2.01 (IQR: 0.0, 6.0) h•wk^{-1} of MVPA during the pandemic (Table 2). Statistically significant differences in MVPA (h•wk^{-1}) were noted by race/ethnicity ($p < 0.001$), parent education ($p = 0.003$), and household income ($p < 0.001$). By race/ethnicity, median MVPA (h•wk^{-1}) during the pandemic was highest among adolescents identifying with another race/ethnicity (median: 3.0; IQR: 0.0, 7.5 h•wk^{-1}) followed by White adolescents (median: 2.7; IQR: 0.5 to 6.7 h•wk^{-1}), Asian adolescents (median: 2.3; IQR: 0.7 to 5.3 h•wk^{-1}), Black adolescents (median: 1.5; IQR: 0.0 to 5.8 h•wk^{-1}), Latino/Hispanic adolescents (median: 1.5; IQR: 0.0 to 5.0 h•wk^{-1}), and Native American adolescents (median: 1.5; IQR: 0.0 to 4.0 h•wk^{-1}). By parent education, median MVPA (h•wk^{-1}) during the pandemic was higher in adolescents with a parent obtaining at least a college education (median: 2.3; IQR: 0.2 to 6.0) than those with a parent with less education (median: 2.0; IQR: 0.0, 6.0) and in adolescents residing in a higher income household (median: 3.0; IQR: 0.7 to 7.0) compared to a lower income household (median: 2.0; IQR: 0.0, 5.0). Median MVPA (h•wk^{-1}) did not differ by gender.

3.2. Differences in meeting MVPA Guidelines before and during the COVID-19 pandemic; overall and by sociodemographic factors

Table 3 displays the proportion of adolescents who reported sufficient physical activity to meet MVPA Guidelines before (2016–2018) and during (May 2020) the COVID-19 pandemic. Prior to the pandemic, 16.1% of the analytic sample met MVPA Guidelines; a proportion that was significantly lower (8.9%) during the pandemic ($p < 0.001$). This finding was largely consistent within categories of sociodemographic characteristics including gender, highest parent education, and household income (all $p < 0.001$). By race/ethnicity, the proportion of adolescents meeting MVPA Guidelines was significantly lower during the pandemic compared to pre-pandemic in White, Latino/

Table 1
Sociodemographic characteristics of 5,153 participants in the Adolescent Brain Cognitive Development (ABCD) Study, baseline.

Sociodemographic characteristics	%
Adolescent characteristics	
Gender (%)	
Female	50.6%
Male	49.5%
Race/ethnicity (%)	
White	60.5%
Latino / Hispanic	15.0%
Black	13.2%
Asian	7.7%
Native American	2.8%
Other	1.0%
Parent characteristics	
Education (%)	
College education or more	89.4%
High school education or less	10.6%
Household income (%)	
Less than $25,000	8.8%
$25,000 through $49,999	11.6%
$50,000 through $74,999	13.6%
$75,000 through $99,999	18.4%
$100,000 through $199,999	34.7%
$200,000 and greater	12.9%

Propensity weights from the Adolescent Brain Cognitive Development Study were applied based on the American Community Survey from the US Census. Percent totals may sum to greater than 100% due to rounding.

Table 2
Summary of adolescent-reported moderate-to-vigorous intensity physical activity (MVPA) during the COVID-19 pandemic by sociodemographic characteristics in the Adolescent Brain Cognitive Development (ABCD) Study, May 2020 (n = 5,153).

	Hours of MVPA/week during COVID-19 (May 2020)		
Sociodemographic characteristics	Mean (SD)	Median (IQR)	p
Total	5.86 (12.03)	2.01 (0.00–6.00)	
Gender			0.11[a]
Female	5.68 (12.51)	2.00 (0.00–6.00)	
Male	6.04 (11.51)	2.33 (0.00–6.65)	
Race/ethnicity			<0.001[b]
White	6.34 (12.85)	2.68 (0.50–6.68)	
Latino/Hispanic	5.18 (11.56)	1.50 (0.00–5.00)	
Black	5.16 (9.64)	1.50 (0.00–5.84)	
Asian	5.02 (9.47)	2.31 (0.66–5.32)	
Native American	5.22 (13.36)	1.50 (0.00–4.00)	
Other	4.29 (5.49)	3.00 (0.00–7.50)	
Highest parent education			0.003[a]
College education or more	5.97 (12.25)	2.31 (0.17–6.00)	
High school education or less	4.87 (9.93)	2.00 (0.00–6.00)	
Household income			<0.001[a]
$75,000 and greater	6.35 (12.38)	3.00 (0.66–7.00)	
Less than $75,000	4.89 (11.25)	2.00 (0.00–5.01)	

Propensity weights from the Adolescent Brain Cognitive Development Study were applied based on the American Community Survey from the US Census.
[a]Wilcoxon Rank Sum test.
[b]Kruskal-Wallis test.

Table 3
Percentage of adolescents who met moderate-to-vigorous intensity physical activity (MVPA) before and during the COVID-19 pandemic by sociodemographic characteristics in the Adolescent Brain Cognitive Development (ABCD) Study, May 2020 (n = 5,153).

	Pre COVID-19 (2016–2018)	During COVID-19 (May 2020)	
Sociodemographic characteristics	%	%	p[a]
Total	16.1%	8.9%	<0.001
Gender			
Female	14.7%	7.6%	<0.001
Male	17.4%	10.3%	<0.001
Race/ethnicity			
White	18.4%	10.5%	<0.001
Latino/Hispanic	10.5%	6.2%	0.004
Black	14.0%	6.0%	<0.001
Asian	12.2%	9.4%	0.20
Native American	12.0%	4.9%	0.03
Other	26.0%	2.0%	<0.001
Highest parent education			
College education or more	16.7%	9.5%	<0.001
High school education or less	10.6%	4.0%	<0.001
Household income			
$75,000 and greater	16.9%	11.0%	<0.001
Less than $75,000	14.5%	5.0%	<0.001

Propensity weights from the Adolescent Brain Cognitive Development Study were applied based on the American Community Survey from the US Census.
[a]McNemar's test.

Hispanic, Black, Native American, and other race/ethnicity adolescents (all $p < 0.05$). The difference in proportion meeting MVPA Guidelines during the pandemic compared to pre-pandemic was statistically null among Asian adolescents.

3.3. Mental health and resiliency correlates of MVPA during the pandemic

After adjusting for non-modifiable sociodemographic characteristics, including gender, race/ethnicity, parent education, household income, and study site, poorer mental health was associated with lower MVPA (Table 4). Similarly, higher COVID-19-related worry and perceived stress were associated with lower MVPA. However, higher social support and coping behaviors were associated with higher MVPA during the pandemic. After adjustment for the same covariates, the odds of meeting MVPA Guidelines during the pandemic was lower among those reporting poorer mental health and higher perceived stress. The odds of meeting MVPA Guidelines during the pandemic was higher in adolescents reporting higher social support and coping behaviors. In sensitivity analyses, there was no evidence that gender or race modified the effect of mental health or resiliency factors on MVPA ($p > 0.05$).

4. Discussion

In this large, national sample of U.S. adolescents surveyed early in the COVID-19 pandemic, we found that median MVPA was two hours per week, which was far less than the recommended minimum threshold of seven hours per week. The proportion of adolescents meeting the HHS MVPA Guidelines decreased from 16.1% (2016–2018) to 8.9% during the pandemic (May 2020). A lower proportion of racial/ethnic minority adolescents and those from lower socioeconomic status households met MVPA Guidelines during the pandemic compared to White adolescents and those from higher socioeconomic status households, respectively. Poorer mental health and stress were associated with lower odds of meeting MVPA Guidelines, while more social support and coping behaviors were associated with higher odds of meeting MVPA Guidelines during the pandemic.

Table 4
Mental health and resiliency factors associated with moderate-to-vigorous intensity physical activity (MVPA) during the COVID-19 pandemic in the Adolescent Brain Cognitive Development (ABCD) Study, May 2020 (n = 5,153).

	Hours of MVPA/week		Met MVPA guidelines	
Factors	B (95% CI)	p	AOR (95% CI)	p
Poorer mental health	−0.75 (−1.12, −0.38)	<0.001	0.80 (0.71, 0.90)	<0.001
COVID-19 related worry	−0.37 (−0.74, −0.01)	0.047	0.89 (0.79, 1.00)	0.06
Perceived stress	−0.61 (−1.03, −0.19)	0.005	0.73 (0.62, 0.86)	<0.001
Social support	0.81 (0.25, 1.38)	0.005	1.20 (1.02, 1.40)	0.025
Coping behaviors	0.47 (0.27, 0.66)	<0.001	1.20 (1.13, 1.27)	<0.001

The B coefficient in the cells represents abbreviated outputs from a series of linear regression models specifying hours of MVPA per week as the dependent variable and the row header (mental health, resiliency factors) as the primary explanatory variable of interest. The AOR coefficient in the cells represents abbreviated outputs from a series of logistic regression models specifying meeting MVPA guidelines as the dependent variable and the row header (mental health, resiliency factors) as the primary explanatory variable of interest. Thus, the table represents the outputs from five linear regression and five logistic regression models in total. Adjusted models represent the abbreviated output from linear and logistic regression models including covariate adjustment for gender, race/ethnicity, household income, parent education, and site. Propensity weights from the Adolescent Brain Cognitive Development Study were applied based on the American Community Survey from the US Census.
Abbreviation: B, coefficient from linear regression; CI, confidence interval; AOR, adjusted odds ratio.

Our findings demonstrate a reduction in the proportion of adolescents meeting MVPA Guidelines from pre-pandemic to during the pandemic. These findings are aligned with previous studies examining changes to adolescent physical activity that resulted from the COVID-19 pandemic (Mitra et al., 2020; Tulchin-Francis et al., 2021). Before the pandemic, there was already a low prevalence of adolescents meeting MVPA guidelines across almost all populations (Carson et al., 2015). During the COVID-19 pandemic, the prevalence of adolescents meeting MVPA guidelines declined even further. As identified by prior studies, potential reasons for this decrease in adolescent MVPA during the pandemic include a lack of peer interaction and diminished adult supervision (Eyler et al., 2021). Moreover, children receiving virtual or hybrid instruction during the pandemic were more likely to report a decrease in physical activity compared to their peers who were able to continue in-person school (Verlenden et al., 2021).

4.1. Disparities in MVPA during the COVID-19 pandemic

Our results bring light to the notably low prevalence of meeting MVPA Guidelines among American Indian/Native American, Asian, Latino/Hispanic, and Black adolescents, both pre-pandemic and during the COVID-19 pandemic. Prior research has shown marginalized racial, ethnic, and socioeconomic groups have been disproportionately affected by the COVID-19 pandemic due to higher rates of unemployment, increased likelihood of being an essential worker, food insecurity, and an inordinate burden of COVID-19 related morbidity and mortality (Kearney and Muñana, 2020; Lopez et al., 2021; Roberts et al., 2020; Rogers et al., 2020; Zoorob, 2018). The pandemic has magnified the effects of structural racism and classism. Both racism and classism are inextricably intertwined with adolescents' ability to meet physical activity recommendations, with those from marginalized populations engaging in less physical activity (Armstrong et al., 2018).

Of note, only 4.9% of American Indian/Native American adolescents met the MVPA Guidelines during the pandemic, consistent with prior research showing the majority of the Native American population of youth and adults do not receive enough physical activity to reap health benefits (Fleischhacker et al., 2016). Prior research has also demonstrated that American Indians/Native Americans experience disproportionately higher rates of adverse physical health outcomes, mental health outcomes, and socioeconomic outcomes compared to White Americans (Sarche and Spicer, 2008). There is a lack of adequate funding for healthcare and behavioral health services for this community; therefore, promoting physical activity is limited by lack of support, tools, and access (Sarche and Spicer, 2008).

A major contribution to the disparities seen in minority and low-income adolescents in our study may be attributable to the impact of systemic discrimination on neighborhood designs. Inadequate access to outdoor activities (Chang and Kim, 2017), safety concerns (Molnar et al., 2004), unhealthful neighborhood design (Ding et al., 2011), and poor neighborhood perception (Kim et al., 2010) are associated with lower physical activity. Families with lower incomes or from populations experiencing structural racism in America are more likely to be adversely affected by their built environments (Bejarano et al., 2019). During the pandemic, adolescents from neighborhoods with high density living conditions, those from lower income backgrounds, those who lived in close proximity to major streets, and those who lived in apartments were less likely to engage with outdoor activities as compared to their peers (Mitra et al., 2020), which could help explain our sociodemographic findings. Furthermore, closures of schools, parks, community centers, and gyms could have exacerbated the negative impacts of the built environment on MVPA for adolescents of color and from low-income backgrounds. Our findings parallel the work being done by Canadian researchers, highlighting socioeconomic disparities in physical activity among children and adolescents during the COVID-19

pandemic (Mitra et al., 2020), but our work is in a large, national population of adolescent in the U.S.

Another contribution to these disparities noted in our study may be the impact of school closures on minority families. Overall, 93% of U.S. children were relegated to some type of online learning with the onset of COVID-19 (McElrath, 2020). Adolescents often have built-in physical education time during the school day, but the closures of most public schools led to virtual or hybrid modes of instruction. Students with the ability to attend in-person school were more likely go to private school and identify as White compared to those students participating in virtual or hybrid schooling (Verlenden et al., 2021). Children who received virtual instruction more often identified as Hispanic, Black, or multiracial than White. Moreover, children receiving virtual education during the pandemic had a decline in physical activity and outdoor time (Verlenden et al., 2021). In sum, our findings are supported by and extend prior research exploring the factors contributing to the disparities in MVPA prior to and during the COVID-19 pandemic.

4.2. Mental health

Our results show that lower levels of coping skills, poorer mental health, greater COVID-related worry, and stress were negatively associated with MVPA among adolescents during the pandemic. Potential mechanisms explaining these associations include that adolescents experiencing depression may not have energy to engage in physical activity and those worried about COVID-19 may fear exposure to the virus in gyms or public spaces, limiting options for physical activity (Wichstrøm et al., 2013). Furthermore, there may be bidirectional relationships between depression and physical activity, as engaging in physical activity may prevent depression through the release of endorphins and other biologic mechanisms (Rodriguez-Ayllon et al., 2019). Prior research has shown that disruptions of physical routines has been one of the top predictors for depression among adolescents during the COVID-19 pandemic (Giuntella et al., 2021). Youth with increased physical activity during the COVID-19 pandemic had higher resiliency scores and less reported depression than their counterparts who either had no change or decreased physical activity levels (Anyan et al., 2020). It is notable that these are potentially modifiable factors that could be addressed through interventions. Harris suggests that community-wide interventions may lead to an increase in physical activity and mental well-being, potentially through increased levels of social support and cohesion (Harris, 2018). Interventions like engaging in physical activity as a family, utilizing mobile applications to facilitate online physical challenges among friends, and decreasing barriers to outdoor access via road closures to traffic can help adolescents cultivate increased coping skills and social support (Bates et al., 2020).

4.3. Strengths and limitations

Several important limitations should be noted. MVPA was estimated based on self-report and could be subject to reporting and social desirability bias (e.g., adolescents may over-report MVPA since they know they should be physically active). The MVPA measures pre-COVID were not identical to the measures asked during COVID; therefore, there may be limitations in the comparability of the results as reliability and validity of the questions may differ. However, we were able to harmonize the questions to quantify the prevalence of meeting MVPA guidelines. Several of the mental health and resiliency questions were specific to the pandemic context and thus were not able to be formally tested for validity or reliability given the time urgency of the COVID RRR Survey. The response percentage was relatively low (43.4%)–likely due to the pandemic's impact on participants and their families–and the sample responding to the COVID survey retained a higher proportion of female, White, Asian, and higher socioeconomic status participants, which could lead to selection bias. Although we adjusted for several potential confounders in our regression analyses, there is the possibility for unmeasured confounders. Household income was reported at baseline, prior to the pandemic, and does not reflect potential changes in household income due to job loss or other hardships during the pandemic. We were unable to conduct state- or region-level analyses due to privacy restrictions with the ABCD data use agreement, but future research could investigate subgroup analyses to investigate how timing or strictness of "stay-at-home" orders or rurality could affect changes in MVPA. Despite these limitations, strengths of the study include a large, national, adolescent study population collected during the pandemic with unique mental health and resiliency measures.

5. Conclusions and Implications

The findings from this national survey suggest only 9% of adolescents met the HHS MVPA Guidelines early in the COVID-19 pandemic, with lower rates among racial/ethnic minorities and those from lower socioeconomic backgrounds. These disparities may be related to structural factors, such as neighborhood environments and systemic racism. Health care providers could consider assessing for MVPA at well-adolescent visits and counsel on recommended levels of MVPA, particularly among adolescents from minority or lower socioeconomic backgrounds. Schools, particularly those unable to offer in-person physical education classes, could provide home-based physical education options and remote classes accessible to all students, particularly those with limited space and resources. Communities could prioritize accessibility of public recreation spaces, when safe, during the pandemic. For instance, parks could implement one-way traffic patterns to promote social distancing outside (Bates et al., 2020). Local governments could prohibit automobile traffic on streets at certain times to allow for engagement in outdoor physical activity in urban settings (Bates et al., 2020). Future research could monitor MVPA levels among adolescents through the pandemic during post-vaccination and re-opening stages as well as situations similar to the pandemic and develop multi-level interventions to promote MVPA among adolescents.

CRediT authorship contribution statement

Jason M. Nagata: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Catherine A. Cortez:** Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Erin E. Dooley:** Writing – original draft, Writing – review & editing. **Puja Iyer:** Writing – original draft, Writing – review & editing. **Kyle T. Ganson:** Conceptualization, Writing – original draft, Writing – review & editing. **Kelley Pettee Gabriel:** Conceptualization, Investigation, Methodology, 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.

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the manuscript for publication.

Additional Information

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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.2021.101685.

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