

Changes in Quality of Life, Sleep, and Physical Activity During COVID-19: A Longitudinal Study of Adolescent Athletes

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Context: The abrupt cessation of school and sport participation during the COVID-19 pandemic may have negative implications for adolescent mental health.

Objectives: To (1) compare mental, physical, and social health and behaviors during pandemic-related stay-at-home mandates with the same measures collected 1 to 2 years earlier and (2) evaluate the relationships between physical activity and sleep during the pandemic and changes in anxiety, fatigue, and peer relationships between assessment times.

Design: Cohort study.

Setting: Pediatric sports medicine center.

Patients or Other Participants: A total of 39 high school athletes (25 adolescent girls, 14 adolescent boys; age = 16.2 ± 0.9 years).

Main Outcome Measure(s): Patient-Reported Outcome Measurement System anxiety, fatigue, and peer relationships short forms and the Pittsburgh Sleep Quality Index were completed twice (initial assessment in May 2018 or 2019, follow-up assessment in May or June 2020). Frequency and duration of physical activity and frequency of interaction with other individuals (family, peers, sport coaches, etc) were self-reported at follow-up assessment for the 2 weeks before

school or sport closure and the 2 weeks before questionnaire completion.

Results: Higher levels of anxiety (5.5 ± 4.0 versus 3.6 ± 3.4 points; $P = .003$) and fatigue (5.4 ± 3.7 versus 2.3 ± 2.5 points; $P < .001$) and worse sleep quality (6.6 ± 2.9 versus 4.3 ± 2.3 points; $P < .001$) were observed during the pandemic compared with previous assessments. Reductions in physical activity were noted between assessments (exercise duration: 86.4 ± 41.0 versus 53.8 ± 30.0 minutes; $P < .001$). Sleep quality but not physical activity during the pandemic predicted changes in fatigue ($P = .03$, $\beta = 0.44$ [95% CI = 0.06, 0.83]) and peer relationships ($P = .01$, $\beta = -0.65$ [95% CI = -1.16, -0.15]) from initial to follow-up assessment.

Conclusions: Mental and physical health declined during stay-at-home mandates compared with assessments 1 to 2 years earlier. Physical activity behaviors and sources of social interaction underwent changes after school and sport cessation. Sleep quality may have provided some protection against declining adolescent mental health during the pandemic, although this relationship requires further investigation.

Key Words: pediatrics, psychological health, exercise, public health

Key Points

- Adolescent athletes reported more anxiety and fatigue and worse peer relationships during the initial months of the COVID-19 pandemic (May or June 2020) compared with assessments from previous years (May 2018 or 2019).
- Physical activity frequency and duration were reduced during pandemic-related stay-at-home mandates versus the weeks before school and sport closures.
- Sleep quality but not physical activity during stay-at-home mandates predicted changes in fatigue and peer relationships after school and sport closures, indicating a complex relationship may exist between sleep and mental health in adolescent athletes.

To reduce the spread of disease during the COVID-19 pandemic, a range of public health and governmental mandates were initiated. Public health efforts in the United States, such as widespread community shut-downs, social distancing, and stay-at-home directives, have proven beneficial in decreasing daily infection rates when adhered to appropriately.¹ Secondary and unintended

consequences, such as reductions in social interaction and increased barriers to daily physical activity, also exist for these mandates and may disproportionately affect individuals who strictly adhere to such guidance. During stay-at-home mandates, adults and children reported more sedentary time,^{2–7} less time in physical activity,^{3–5,8} and reduced intensity of physical activity^{2,3} compared

with retrospective reports of prepandemic behaviors. Increased anxiety³ and depression⁹ and worse sleep⁶ were observed during the pandemic compared with reporting of prepandemic states, and relationships may exist between physical activity levels and symptoms of anxiety, depression, and social isolation during the COVID-19 pandemic.¹⁰ However, whether physical activity or other health factors, such as sleep quality, during the pandemic mitigated pandemic-related declines in mental health remains unknown.

In much of the present research on individual physical and mental health during the COVID-19 pandemic, a cross-sectional design, relying on retrospective reporting of feelings and behaviors from weeks or months earlier, was used.^{2-9,11,12} The authors of 2 systematic reviews evaluating physical and psychological health during the pandemic identified a total of 34 observational studies,^{10,13} of which 4 were longitudinal with data collection occurring both before and during the pandemic.¹⁴⁻¹⁷ Longitudinal designs offer specific strengths over those of cross-sectional research.¹⁸ Prospective reporting of thoughts, behaviors, or feelings may reduce the risk of recall bias, providing improved internal validity over retrospective studies. This may be particularly relevant in the context of a global pandemic, for which recall bias may result in underestimation of past problems given the present difficulties, a phenomenon also observed in other research.¹⁹ Studies with improved internal validity, such as longitudinal designs, are needed to obtain a better understanding of how specific measures of mental health have changed during the pandemic versus prepandemic states. Longitudinal designs also allow for within-subject, in lieu of between-subjects, investigations into adolescent mental health. Preexisting, innate, or behavioral participant characteristics may predispose individuals to better or worse mental health, more or less physical activity, or better or worse quality of life during pandemic-related mandates. Elucidating relationships between these factors in retrospective studies may be difficult when relying on cross-comparisons of 2 independent cohorts with unknown or unequal predispositions to mental health problems, a less pertinent limitation in a longitudinal design that follows a single cohort over time.

Secondarily, much of the research conducted on mental and physical health during COVID-19 stay-at-home mandates involved adults.^{10,13} Studies of children or adolescents were less common and often involved recruiting participants from the general population,^{4,5,11} creating gaps in the literature regarding more specific populations, such as high school athletes. Although researchers recently have attempted to address this gap by evaluating adolescent athletes' mental and physical health during the pandemic,^{8,9} they similarly have relied on cross-sectional designs rather than longitudinal comparisons.

The primary purpose of this longitudinal investigation was to evaluate mental health and sleep quality among adolescent athletes during COVID-19–related stay-at-home mandates compared with measures obtained 1 to 2 years earlier. We also compared behaviors of physical activity and sources of social interaction during the 2 weeks before school and sport closure compared with a 2-week period during the COVID-19 pandemic. Secondarily, we sought to determine the roles of physical activity and sleep quality during the pandemic as predictors of change in adolescent mental health between measurement points.

METHODS

Adolescent athletes completed questionnaires at 2 time points as part of a repeated-measures, longitudinal study: in May 2018, May 2019, or both (*initial*) and May or June 2020 (*follow-up*). During the initial assessments in May 2018 and 2019, athletes from a single school district were recruited to complete study questionnaires at preparticipation physical evaluations. The school district we approached for this study consisted of 5 public high schools, serving approximately 10 000 students, in a single metropolitan area. Regarding the generalizability of this cohort, approximately 29% of students enrolled in the district received a free or reduced-price lunch.²⁰ In comparison, publicly available data from the National Center for Education Statistics indicated the percentage of students receiving a free or reduced-price lunch in 2015 to 2016 was approximately 42% ($n = 376\,162$) in the state where recruitment occurred and 52% ($n = 25\,900\,186$) nationally.²¹ The National Center for Education Statistics also identified the racial and ethnic characteristics of students as 76% White and 3% Black or African American in the school district compared with 76% White and 5% Black or African American in the state and 63% White and 15% Black or African American nationally.²²⁻²⁴ Inclusion criteria for the initial evaluation were age 13 to 18 years and full clearance to participate in sport at the time of evaluation. Participants with a preexisting neurologic or psychiatric disorder or a recent injury diagnosis with existing symptoms were excluded.

In May and June 2020, after stay-at-home public health mandates, participants from the initial sample ($N = 238$) were recruited to complete follow-up assessments via an online questionnaire. Government-mandated school closures were implemented in the state on March 23, 2020, with our follow-up questionnaire administered approximately 2 to 3 months later. A total of 39 individuals completed the follow-up questionnaire, resulting in a 16.4% response rate. All enrolled participants and their parent or legal guardian provided informed assent and consent, as appropriate, and the study was approved by the Colorado Multiple Institutional Review Board and the school district involved in the study.

Repeated Measures

Participant mental health and social well-being were measured with the Patient-Reported Outcome Measurement System (PROMIS)^{25,26} anxiety, fatigue, and peer relationship short forms. Each form consisted of 4 statements related to perceived health and well-being in the last 7 days, with 5 response options on a Likert scale ranging from 0 (*never*) to 4 (*almost always*). The responses were summed to provide a total score for each of the 3 short forms, with a possible range of 0 to 16 points. For the anxiety and fatigue forms, higher scores reflected more anxiety or fatigue. Conversely, higher scores on the peer-relationship form indicated higher-quality peer relationships. The PROMIS has been validated and determined appropriate for use with pediatric populations.²⁷⁻²⁹ The Pittsburgh Sleep Quality Inventory (PSQI)³⁰ was used to assess participant sleep. The PSQI produces a global score ranging from 0 to 21, with higher scores indicating worse sleep quality. The PSQI has been validated among pediatric patients and used in previous research among healthy adolescent athletes.^{30,31}

Cross-Sectional Measures

During follow-up assessments, participants retrospectively reported behaviors of physical activity and social interaction during the 2 weeks before school closure and the 2 weeks preceding questionnaire completion. The prompts that we developed for retrospective and prospective reporting were “in the two weeks BEFORE your school closed” and “in the LAST two weeks,” respectively. Participants used a 5-point scale to rate how often they engaged in moderate-to-vigorous physical activity, with options of *never*, *less than half the days*, *half the days*, *most days*, and *every day*. *Moderate-to-vigorous physical activity* was defined as any exercise that requires moderate or greater effort and increases the heart rate. In addition, the average duration of physical activity sessions was reported in minutes. Social interaction was evaluated as the frequency of interactions with various sources of social support, including friends, teammates, coaches, other adults, and family members. We also developed these questions, and the same 5-point scale was used to evaluate the frequency of social interaction with different sources of support.

Change Variables

For the secondary analysis, changes in self-reported anxiety, fatigue, and peer relationships between initial (prepandemic) and follow-up (pandemic) assessments were calculated. Within each participant, the outcome score (PSQI score, PROMIS score, etc) obtained at the initial assessment was subtracted from the score at the follow-up assessment. Positive values for change in anxiety and fatigue represented increased anxiety or fatigue during follow-up assessment, whereas negative scores indicated that anxiety or fatigue decreased between the initial and follow-up assessments. Conversely, positive values for the change in peer relationships suggested that peer relationships improved between times, whereas negative scores showed worsened peer relationships from initial to follow-up assessments.

Statistical Analysis

Participants completed the initial assessments in 2018, 2019, or both prepandemic times. Data from the 2019 initial assessment were included in the analysis if both assessments were completed prepandemic (Table 1). We compared anxiety, fatigue, peer relationships, sleep quality, and physical activity outcomes between the initial and follow-up assessments (May or June 2020) using paired-samples *t* tests. We also compared social interaction and physical activity frequency between times using McNemar tests.

For our secondary analysis, we constructed 3 linear regression models with the primary outcomes of changes in anxiety, fatigue, and peer relationships. Predictor variables for each model were physical activity duration and PSQI score, both self-reported at the follow-up assessment. The purpose of this analysis was to evaluate the relationship between sleep and physical activity during the pandemic and observed changes in anxiety, fatigue, and peer relationships between assessment times. The PSQI score at follow-up provided a global indicator of sleep quality. Physical activity duration was selected to accurately estimate a participant's physical activity volume during the pandemic. Pearson product moment correlations were also conducted for transparency of methods, and correlation coefficients

Table 1. Participant Characteristics (N = 39)

Variable	Value Mean \pm SD
Age at follow-up assessment, y	16.2 \pm 0.9
Time spent in organized sports during 2019–2020 school year, h/wk	12.5 \pm 4.7
Sex	No. (%)
Female	25 (64)
Male	14 (36)
Time of initial assessment	
May 2018	14 (36)
May 2019	25 (64)
Member of an organized sports team during 2019–2020 school year	37 (95)
Primarily participating in a team or individual sport	
Team	28 (78)
Individual	8 (22)
Planning to participate in an organized spring sport (January–May 2020)	33 (85)
Organized sports cancelled due to COVID-19 pandemic	36 (92)

are reported. Linear regression results are presented as the predictor variable with the *P* value and β coefficient (95% CI). All statistical tests were 2 sided, evaluated at an α level of .05, and performed using Stata (version 15; StataCorp).

RESULTS

A total of 39 participants (25 [64%] adolescent girls, 14 [36%] adolescent boys; age = 16.2 \pm 0.9 years) completed initial assessments in May 2018 (*n* = 14, 36%) or 2019 (*n* = 25, 64%) and again in May or June 2020. Ninety-five percent (*n* = 37) of the athletes reported participating in an organized sport during the 2019–2020 school year, and they averaged 12.5 \pm 4.7 h/wk of sport practice before the pandemic, with 92% (*n* = 36) indicating sport cessation due to COVID-19. Additional participant characteristics are supplied in Table 1.

Longitudinal comparisons demonstrated that, during stay-at-home mandates, participants experienced more anxiety (5.5 \pm 4.0 versus 3.6 \pm 3.4 points; t_{38} = 3.12, *P* = .003) and fatigue (5.4 \pm 3.7 versus 2.3 \pm 2.5 points; t_{38} = 5.51, *P* < .001) and worse sleep quality (6.6 \pm 2.9 versus 4.3 \pm 2.3 points; t_{37} = 4.09, *P* < .001) compared with measures obtained 1 or 2 years earlier (Figure 1). No difference was found for the quality of peer relationships between these times (12.7 \pm 2.8 versus 13.4 \pm 3.8 points; t_{38} = 0.99, *P* = .32; Figure 1C).

The frequency and duration of physical activity were lower in the 2 weeks before questionnaire completion than the 2 weeks before school closure (Table 2). Participants described a higher frequency of social interaction with teammates, non-teammate peers, coaches, and noncoach mentors (eg, teachers) in the 2 weeks before school closure compared with the 2 weeks before questionnaire completion (Table 2). The frequency of social interaction with family members, however, did not differ between times (*P* > .99). The median PSQI score at follow-up assessment was 6 points (interquartile range = 5–8 points).

Secondary analyses revealed possible relationships between sleep quality at follow-up assessment and changes in self-reported fatigue and peer relationships but not in anxiety. A

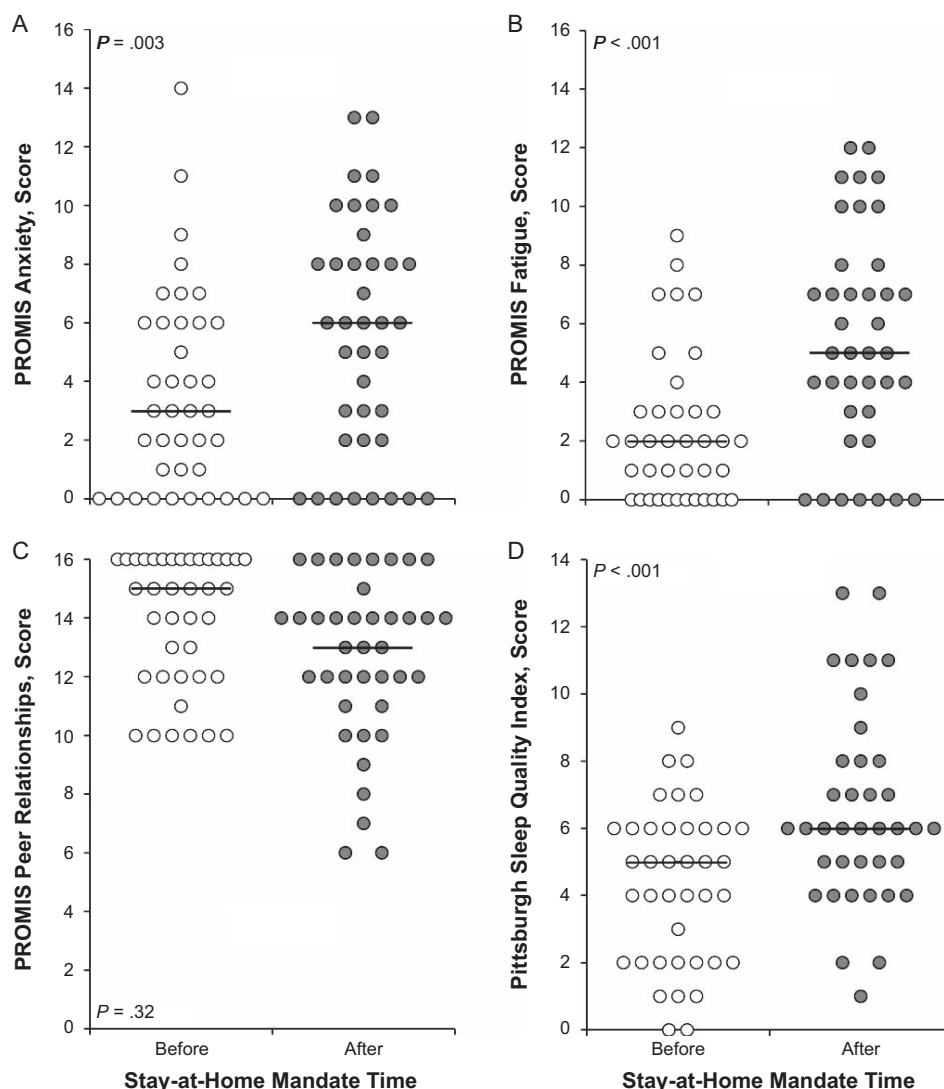


Figure 1. Individual data points describing the patient-reported outcomes before (obtained May 2018 or 2019) and after (obtained May or June 2020) the stay-at-home mandate for, A, anxiety, B, fatigue, C, peer relationships, and D, sleep quality. The black bar represents the median value. Abbreviation: PROMIS, Patient-Reported Outcome Measurement System.

regression model predicting anxiety change between times indicated that neither sleep quality nor physical activity duration at follow-up was a predictor (sleep quality: $P = .37$, $\beta = 0.20$ [95% CI = $-0.25, 0.64$]; physical activity: $P = .66$, $\beta = -0.01$ [95% CI = $-0.05, 0.03$]). Sleep quality but not physical activity duration was a predictor of change in fatigue ($P = .03$, $\beta = 0.44$ [95% CI = $0.06, 0.83$]) and change in peer relationships ($P = .01$, $\beta = -0.65$ [95% CI = $-1.16, -0.15$]) in separate regression models. Similar results were found for Pearson product moment correlations between physical activity duration and sleep quality and changes in anxiety, fatigue, and peer relationships (Figure 2).

DISCUSSION

Public health measures, community shutdowns, and stay-at-home mandates enacted in March 2020 resulted in the abrupt cessation of both school and sport for adolescent athletes across the United States. Our sample of high school athletes reported more anxiety and fatigue, worse sleep quality, and less physical activity during stay-at-home

mandates compared with behaviors before the pandemic, in line with previous cross-sectional work.^{8,9} The abrupt closure of school and organized sport in response to the COVID-19 pandemic may have affected these interdependent outcomes in numerous ways. Some mechanisms appeared to be more direct, such as reduced physical activity resulting from the temporary elimination of organized sport, whereas other mechanisms may have been more complex. For example, increased anxiety could be attributed to multiple factors, such as the extended home confinement, decreased peer engagement, reduced opportunity for stress management (eg, through sport), or reduced physical activity or sleep quality.

Although public health efforts that reduce social interaction and create barriers to physical activity are necessary to curb the spread of COVID-19, we must also consider that additional protections are needed to prevent further worsening of adolescent mental health and exercise behaviors. Researchers have suggested that social media may promote athlete connectedness,³² although the use of social media may have

Table 2. Retrospective Comparisons of Reported Physical Activity and Social Interaction Behaviors in the 2 Weeks Before School Closure Compared With the 2 Weeks Preceding Questionnaire Completion

Variable	2 wk Before School Closure	2 wk Before Questionnaire Completion	P Value
Physical activity			
Duration of exercise sessions, mean \pm SD, min	86.4 \pm 41.0	53.8 \pm 30.0	<.001
	No. (%)		
Engaged in moderate-to-vigorous physical activity most days or every day	32 (82)	10 (26)	<.001
Social interaction: Participant interacted on most days or every day with			
Friends who were not teammates	38 (97)	20 (51)	<.001
Friends who were teammates	35 (90)	13 (33)	<.001
Sports coaches	28 (72)	3 (8)	<.001
Noncoach mentors or trusted adults	33 (85)	10 (26)	<.001
Close family members	34 (87)	34 (87)	>.99

adverse effects, particularly as a potential contributor to poor health-related quality of life.³³ Engagement in daily moderate activity for acute mental health and sleep benefits³⁴ or increased access to public infrastructure, such as parks and

outdoor recreational areas,³⁵ may be more suitable options to reduce the negative effects of the pandemic on mental and physical health. However, our results suggested that improved sleep quality may be more important for mental health than

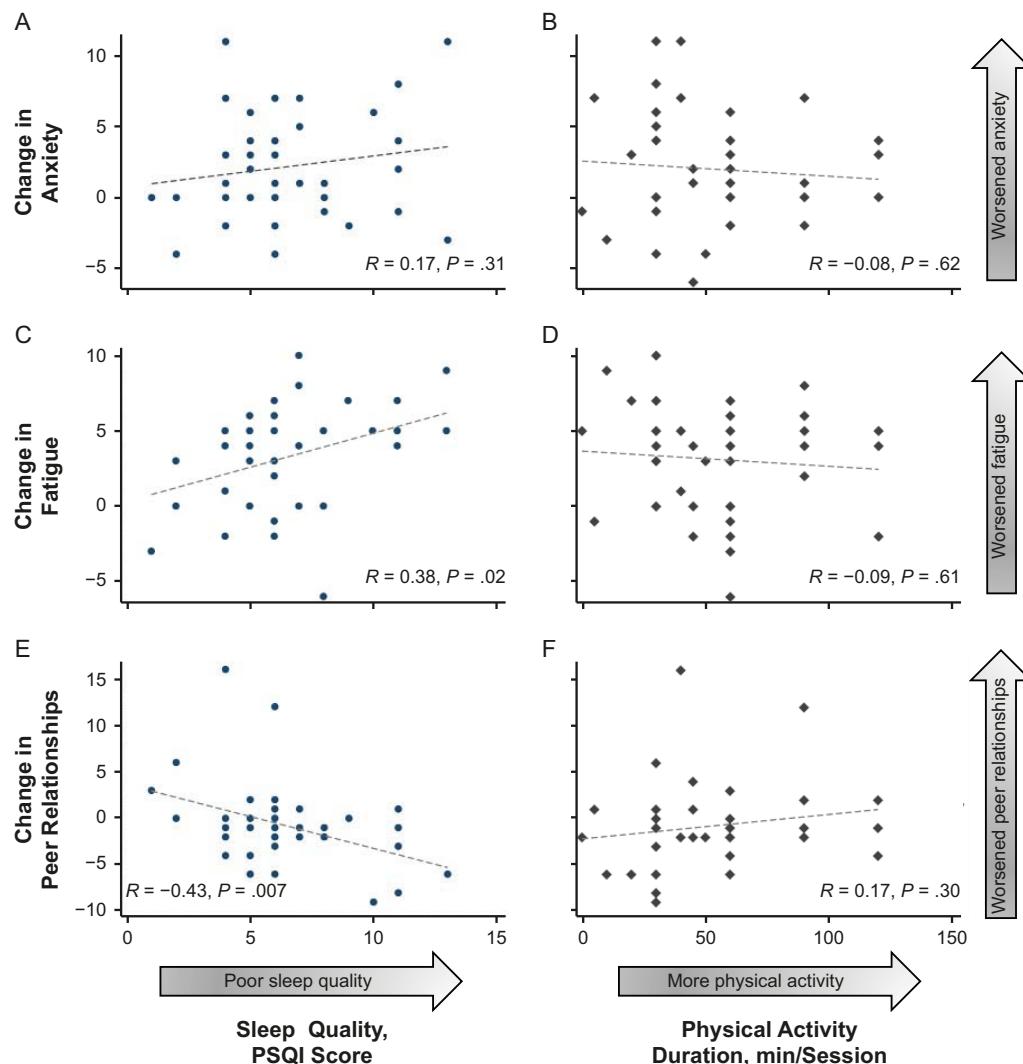


Figure 2. Scatter plot with line of best fit describing correlations of sleep quality (Pittsburgh Sleep Quality Index [PSQI] score) and physical activity duration (minutes per session) during stay-at-home mandates with the change in, A and B, anxiety, C and D, fatigue, and E and F, peer relationships between time points. Pearson product moment correlation coefficients are provided for each relationship.

increased physical activity. Similarly, recent researchers^{36,37} suggested that depression, quality of life, and physical activity levels, although improving with the return of school and sport participation, have not achieved prepandemic levels for adolescent athletes. More examination may be required to develop strategies for protecting adolescent mental health during future stay-at-home mandates or similar circumstances, such as the abrupt cessation of school or sport due to injury or retirement.

Adolescent sleep quality but not physical activity duration during follow-up assessment predicted changes in fatigue and peer relationships between times. A 1-point increase (worsening) in PSQI score at follow-up evaluation was associated with an approximately 0.4-point larger increase in fatigue and a 0.7-point larger decrease in peer relationships between times. Interpreted further, the interquartile range for PSQI at follow-up was 3 points wide. Participants with PSQI scores at the 25th percentile would be expected to report a 1.2-point greater change in fatigue and a 2.1-point greater change in peer relationships between assessments compared with participants in the 75th percentile. Regarding clinical relevance, our findings indicated that worse sleep quality during the pandemic was associated with larger increases in fatigue and larger decreases in the quality of peer relationships between assessments. Sleep and mental health often exhibit a bidirectional relationship.^{38,39} Increased fatigue and worsened peer relationships during the pandemic may have affected sleep quality and poor-quality sleep may have similarly affected fatigue and peer relationships. Previous investigators⁴⁰ demonstrated that, in healthy adolescents not meeting the recommended amount of sleep each night, replacing 15 minutes of moderate-to-vigorous physical activity with 15 minutes of sleep was associated with reduced symptoms of anxiety and depression, whereas the inverse—replacing 15 minutes of sleep with 15 minutes of moderate-to-vigorous physical activity—was associated with increased symptoms of anxiety and depression.⁴⁰ Authors³¹ have also noted an association between poor sleep quality and greater symptoms of anxiety, depression, and fatigue. Our results similarly emphasized the importance of sleep for adolescent mental health.

Participant reporting of social interaction may also be of concern. The frequencies of interactions with nearly all sources of social support measured in this study, including friends, teammates, sport coaches, and other adults, were substantially reduced during the pandemic. Although the quality of peer relationships was similar between times, adolescent athletes may have been socially isolated and might have benefited from the facilitation of social interaction. Particularly noteworthy was that only 8% ($n = 3$) of athletes reported interacting with sport coaches most days or every day during the 2 weeks preceding questionnaire completion compared with 72% ($n = 28$) in the 2 weeks before school closure. Given that the coach-athlete relationship may play an important role in student-athlete psychological well-being,⁴¹ this substantial reduction in social interaction may require additional investigation.

Our results may be important to clinicians working in secondary school settings. Even though public health efforts in the United States have effectively reduced the spread of COVID-19,¹ new variants continue to emerge, threatening school and sport participation. Practitioners should be prepared for the possibility of future school and sport shutdowns and stay-at-home mandates to curb the spread

of disease¹ and should recognize the effect of these measures on the mental and physical health of adolescent athletes. Similarly, other circumstances may cause the abrupt cessation of school and sport participation, such as injury or sport retirement, potentially resulting in reduced physical activity, poor sleep quality, or decreased interaction with sources of social support. Sudden and unforeseen closure of sport clubs for financial or other reasons may also simulate comparable circumstances. Clinicians should demonstrate caution in these situations with the understanding that adolescent mental health and physical activity may be burdened and that sleep quality could provide a possible protective effect; however, this requires generalization to circumstances not directly evaluated in this study.

Our findings should be interpreted while considering specific limitations. Primarily, only 16.4% (39/238) of eligible participants completed follow-up assessments, creating concern for nonresponse bias. To reduce the effect of potential biasing, we did not specifically cite mental health outcomes as the focus when recruiting volunteers for initial and follow-up assessments. In addition, this was a secondary analysis of data. Thus, the primary aims of this study were not known to participants at the time of enrollment, and the risk of nonresponse bias related to the willingness or unwillingness of individuals to engage in research regarding mental health may have been reduced slightly. However, we acknowledge that bias may still have been present and are unsure of how the remaining eligible athletes would have responded. Similarly, all participants were from a single school district, which may limit the generalizability of our results to student-athletes in other schools, cities, or states. Secondly, variation was present in the time interval between the initial and follow-up assessments because some athletes completed initial evaluations in 2018 and others in 2019. This may have led to variability in the number and importance of life factors occurring between initial and follow-up testing, interfering with the observed results in our longitudinal analysis.

CONCLUSIONS

Necessary public health precautions to stop or slow the spread of disease may have unintended consequences for adolescent mental health. Reductions in physical activity, worsened mental health, and changes in sources of social interaction have been observed. During the pandemic, sleep quality but not physical activity may have provided some protection against deteriorating fatigue and peer relationships, although further research is required to confirm this relationship. Practitioners who frequently interact with athletes may consider applying these findings to their specific populations when organized sport seasons are postponed or cancelled to support athlete health and safety both now and in the future.

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