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The Impact of Virtual vs. In-Person Learning on Mental Health Among High School Students
During the COVID-19 Pandemic

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Abstract

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Background: While concerns about COVID-19's impact on adolescent mental health have been raised, few have investigated how psychological outcomes compare between remote and in-person learners. This study examined levels of depression and anxiety among virtual and in-person 10th-graders, and how these outcomes varied by race, gender, and socioeconomic status.

Methods: Racially and socioeconomically diverse students (n=402) from two high schools in semi-rural Georgia completed a one-time survey in Fall 2020. Results were linked to demographic data provided by the school district. Bivariate analyses assessed for associations between demographics and mental health outcomes, and logistic regression analyses identified predictors of anxiety and depression.

Results: Average depression levels were significantly higher among virtual than in-person learners ($p < .0051$). 53% of virtual and 40% of in-person learners experienced moderate-severe depression ($p < .0469$). Overall, Multiracial, Black, and Hispanic students reported the highest rates of moderate-severe depression, and more minority learners, females, and students eligible for reduced-cost lunch experienced depressive symptoms than their counterparts. Fewer than 20% of all students experienced moderate-extreme anxiety, and there were no significant differences in anxiety levels by learning modality, race, or socioeconomic status. Female sex remained the only significant predictor of depression (OR= 2.91, 95% CI [1.67, 4.66]) and anxiety (OR= 2.92, 95% CI [1.76, 4.85]) after controlling for learning modality, race, and socioeconomic status.

Conclusion: As one of the first to assess self-reported, mental health outcomes among high school students learning virtually and in-person during COVID-19, our findings suggest levels of depression have been particularly high among female, virtual, lower-income, and minority 10th-graders. The pandemic's effects on high-school youth warrant enhanced mental health screening and tailored interventions to support the psychological well-being of our most vulnerable students both now and in the future.

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I. Introduction

In the spring of 2020, initiatives to mitigate the spread of the novel coronavirus (COVID-19) led to global containment and lockdown measures, which impacted the lives of millions in unprecedented ways¹. One of the principal precautionary measures to reduce the spread of infection was closures of schools and transitions to virtual learning environments, which created notable social and academic upheavals among students in over 90% of the world's student population². With significant and enduring changes to their home, academic, and community experiences, the psychological impacts of COVID-19 among youth have been of particular concern³⁻⁵, especially because adolescents are at higher risk of developing mental health problems relative to adults⁶.

Prior to the pandemic, psychiatric disturbances were the leading cause of disability among American adolescents, with up to 20% of those between ages 3 and 17 experiencing mood, developmental, emotional, or behavioral disorders⁷. Amidst the outbreak of COVID-19, such disturbances have worsened. US Surgeon General Vivek H. Murthy recently released an advisory warning that our youth are experiencing a “mental health crisis” that requires a coordinated and urgent response⁸. Even more, the United States Preventative Task Force just drafted a new recommendation that all youth aged eight to eighteen should be screened regularly for anxiety amidst the escalating mental health disturbances of this era⁵. Because most mental health disorders begin in childhood, psychological needs must be identified and treated as early as possible during this crucial stage of development⁷. If left untreated, poor mental health among adolescents may result in dire consequences, such as suicide, behavioral dysregulation, emotional distress, and poor mental health in adulthood. It is therefore essential to further elucidate the impact of COVID-19 on adolescent psychological health⁹ to inform ongoing strategies to address this public health problem. Prolonged closures, social isolation, economic shutdown, and heightened worries about safety and health¹⁰ have led to the short- and long-term mental health implications for school-aged students that therefore warrant more in-depth investigation^{2,9,11}.

For children and adolescents in particular, school-based learning not only offers education, but also secures access to social, psychological, and physical health resources that may help buffer stressful experiences¹². These services are of particular importance during a pandemic, as research suggests adolescents are not only more vulnerable to traumatic events than adults, but are also more prone to developing mental health concerns as a result of such stressors¹³. Research also suggests many students depend on academic environments for mental health services¹⁴, with 35% of adolescents between 2012 and 2015 receiving these services exclusively from school environments¹⁵. Consequently, after an estimated 1.5 billion school-aged students shifted to remote learning by April 2020¹⁶, child and adolescent mental health has suffered^{17,18}.

A recent meta-analysis of studies from China and Turkey found that the pooled prevalence of depression and anxiety among over 57,000 children and adolescents during the pandemic were 29% and 26%, respectively, while 48% exhibited post-traumatic stress symptoms¹⁹. A longitudinal cohort study among Chinese youth also reported the prevalence of depressive symptoms, non-suicidal self-injury, suicide ideation, and suicide attempts significantly increased when comparing pre-pandemic outcomes to those in the late spring of 2020¹⁸. Studies among European youth have also found increased mental distress^{20,21}, worsening of pre-existing mental health conditions², poorer access to mental health services², and increases in emergency room visits related to eating disorders and self-harm when comparing pre versus mid-pandemic measures²². Additional research in the United Kingdom indicated that over one third of adolescents reported higher levels of loneliness and negative well-being relative to their parents²³.

In the United States, nationwide closures of elementary and secondary schools eliminated approximately 60 million students' access to essential educational and health resources as they transitioned to virtual learning modalities²⁴. Adapting to remote learning and the lack of social and psychological support otherwise offered during traditional schooling has been one of the greatest changes for these students to endure pre versus mid-pandemic, and has been associated with poorer mental and emotional health¹². However, most of the research assessing the psychological impact of such upheaval on our youth has been based on caregivers' and/or parents' reflections, rather than students' own reports.

For instance, caregivers of public-school students reported child mental health concerns were significantly worse during the months following the start of COVID-19 stay-at-home orders compared with pre-closure, and that child mental health concerns were more likely as COVID-19 exposure and family stressors increased²⁵. Still others report worsening of their child's behavioral health²⁶, and prominent anxiety and depression²⁷, which could contribute to the observed increases in emergency department presentations for mental health-related concerns²⁸, and higher rates of suicidal ideation and attempts during the pandemic relative to the year prior²⁹. One of the few existing longitudinal studies based on adolescent self-report demonstrated significant increases in depression and anxiety among those who did not have mental health disturbances prior to the pandemic¹. Collectively, these findings suggest that virtual instruction in the context of a pandemic may negatively affect youth mental health. However, further research based on adolescent self-report alone is needed to elucidate the mental health implications of remote instruction relative to in-person learning, particularly if schools reinstate virtual learning modalities in the future.

Shifts to virtual education models have presented psychosocial stressors to youth that may not only negatively impact their psychological well-being, but may also magnify pre-existing inequities in mental health among racial and ethnic minorities and those from lower socioeconomic strata¹². Prior to the pandemic, disparities in mental health diagnosis, assessment and intervention were prominent among racial/ethnic minorities in the United States relative to their white counterparts³⁰. This has been due in large part to disproportionate exposure to violence³¹, as trauma in the home and surrounding neighborhood has been linked to post traumatic stress disorder, depression and externalizing behaviors^{32,33}. Heightened rates of food insecurity³⁴, and low socioeconomic status, which is more common among minority children, has also been associated with depression³⁵, anxiety disorders³⁶, and adjustment disorders, with youth from lower socioeconomic strata two to three times more likely to have mental health disturbances relative to their more affluent peers³⁷.

Moreover, the economic downturns of the pandemic have exacerbated economic inequity and pre-existing social inequalities³⁸, with rates of employment or wage loss highest among Hispanic

and black adults³⁹, and more than half of parents working in service industries experiencing job loss or pay cuts during the pandemic¹⁷. Economic downturns such as these have already been linked to heightened mental health disturbances among youth⁴⁰. Adolescents who are particularly susceptible to these multidimensional ramifications of COVID-19, including low socioeconomic students, Latinx and Black students⁴¹ may therefore be at heightened risk for mental health disturbances.

Furthermore, ethnic/racial minority children have poorer access to mental health resources relative to their white peers. Discrepancies in prevention, availability, and quality of mental health services prevail, as racial/ethnic minority children and adolescents are more likely to receive less and inferior health services relative to their white peers³¹. During the pandemic, threats to mental health are even more salient among children and adolescents from disadvantaged families or deprived neighborhoods^{20-22,31,42}, especially given that adolescents from low-income households and minority groups are more likely than their counterparts to depend on schools for mental health support¹⁵.

Moreover, COVID-19 disproportionately impacts individuals of lower socioeconomic status²⁵ and communities of color⁴³, who face high rates of infection and poor clinical outcomes⁴³. Increased rates of morbidity, mortality, and psychosocial challenges of this era^{31,44,45} are likely to magnify pre-existing mental health disturbances among these particularly vulnerable adolescent populations. A recent study among hourly service workers of color revealed an association between the accumulation of hardships, including job loss, income loss, and illness, and poorer parent and child mental health¹⁷. In the absence of much needed psychological support typically offered by in-person education, virtual learning may therefore contribute to worsening mental health disparities among already vulnerable students. More research is sorely needed to understand whether virtual learning has disproportionately affected mental health outcomes among minorities and communities more heavily impacted by COVID-19¹⁰ to inform public health efforts among those who are particularly at risk.

Despite the impact of COVID-19 on low-income and minority adolescents, this population is markedly underrepresented in mental health research, most notably during the pandemic.

Furthermore, few studies have investigated how measures of mental health may compare between remote and in-person learners in the same school, and how such outcomes may vary across racial groups, sex, and socioeconomic strata. A recent CDC report¹² found that parents of children receiving virtual instruction were more likely than were parents of children receiving in-person instruction to report that their children experienced decreased physical activity (63% versus 30%), time spent outside (58% versus 27%), and worsened mental or emotional health (25% versus 16%). However, this study was limited by parent self-reports and possible recall biases, as well as assessment of younger children (age 5-12), who may have greater dependence on parents at baseline. This study also found that Black, Hispanic, non-Hispanic other, and multiracial parents were more likely than white parents to report their children received remote instruction. However, differences in mental health outcomes by race and socioeconomic strata were not evaluated.

One of the few COVID-19 studies to evaluate mental health symptoms in predominantly racial and ethnic minority children found higher levels of depression, anxiety, and behavioral concerns mid-pandemic, when nearly all students were learning remotely, versus pre-pandemic⁴⁶. However, this research was again limited by caregivers' reports of symptoms in a much younger cohort of 5- to 11-year-olds, and mental health outcomes were not compared to those of white students. Investigation of the psychological wellbeing of racially and socioeconomically diverse, high-school-age students, especially those learning in virtual settings, remains limited. Further research is thus needed to assess mental health outcomes of remote versus in-person learners, and whether mental outcomes may differ by race, gender, and socioeconomic status across all students. Elucidating this impact on adolescent mental health, particularly among those most susceptible to the worst effects of the pandemic, is essential to securing their healthy development during an otherwise critical period.

Research Questions

To address some of the limitations and gaps in existing research, this study sought to examine the impact of the COVID-19 pandemic and transition to online learning on the mental health of high school students through three key research questions (RQ). RQ1) How do levels of depression and anxiety compare between those learning virtually and those who are learning in-

person within the same school district? RQ2) How do mental health outcomes compare across all students by race, biologic sex, and socioeconomic strata? RQ3) What are the significant predictors of anxiety and depression symptoms across all students, so that we may proactively recognize and support learners at risk?

These research questions were investigated among 10th-graders within two racially and economically diverse high schools in semi-rural Georgia. We hypothesized that high school students learning virtually would have a higher prevalence of anxiety and depression relative to their in-person counterparts. We also predicted that these mental health disturbances for all students would be more prevalent among racial/ethnic minority students and students of lower socioeconomic status. Finally, we hypothesized that being a racial minority, female, from a lower socioeconomic stratum and a virtual learner would be significant predictors of depression and anxiety among students. Understanding the psychological impact of in-person and virtual models is critical for providing a framework for developing interventions and designing policies to protect the mental health of the most vulnerable youth both now and in the future⁴⁷.

II. Methods

A. Study Design

To understand 10th graders' response to the COVID-19 pandemic and simultaneous transition to online learning on March 16, 2020, a cross-sectional online survey was administered through Qualtrics (Qualtrics, Provo, UT) in the Fall of 2020. The study protocol and survey received approval from the Emory University Institutional Review Board.

B. Study Sample

This study was conducted among a cohort of 10th-graders attending two racially and economically diverse public high schools in a semi-rural region of north central Georgia. All 10th-graders attending these public high schools, referred to as High School A and B, were eligible to participate (Figure 1). Parents could opt their children out of participating in the study

and all students assented before survey completion. All students who participated were also eligible to participate in a raffle to receive one of fifty \$25 Amazon gift cards irrespective of survey completion. Approximately 45% (n=507) of eligible students agreed to participate in the study. Nearly 7% of students did not report whether they were learning remotely or in-person, and were therefore excluded from analysis (n=34). Complete demographic data, including sex, race, and free or reduced lunch eligibility (FRL) were available for 85% of students who participated in the assessments. This study analyzed survey results only among these participants for whom complete demographic data were available (n=402). Among this sample, 26% were virtual students (n=105), while 74% were in-person students (n=297).

C. Data Sources

This study utilized two data sources: an online high school student COVID-19 survey administered only to 10th graders in the Fall of 2020 and demographic data provided by the school district.

Fall COVID Survey. This instrument was developed by researchers at the Rollins School of Public Health at Emory University with input from a local high school student. The survey consisted of 54, primarily multiple-choice questions assessing five key domains: 1) knowledge of and reactions to COVID-19, 2) academic success and confidence, 3) pandemic behaviors, 4) stress and mental health and 5) sleep patterns and behaviors. The survey was piloted with four local high school students who were independent from study implementation and who were asked to provide feedback. School administrators also provided feedback on the draft survey instrument. Established survey instruments were used or modified to measure the intended constructs.

The online survey was conducted in English between November 16th and December 17th, 2020, at which point students and their families had previously selected between remote learning and traditional in-person attendance. In-person learners completed the survey via Qualtrics on school laptops during an advisory period or health class. The survey was emailed to virtual students'

school email addresses by school administrators. All questions of the survey were optional and took approximately 10 minutes to complete.

School District Data. Demographic data including sex, race, ethnicity, and FRL, a surrogate for socioeconomic status as reported in prior research^{48,49}, were provided for the subset of assenting participants by the school district’s Office of Student and Data Services. The Fall COVID Survey data was linked with school-provided demographic and education data which was used for analysis.

D. Data Measures

Independent Variables

Independent variables varied for each research question. For RQ1, the independent variables were students’ self-reported learning modality, coded as “Virtual” or “In Person”. For RQ2, the independent variable was race, coded as “White”, “Black”, “Hispanic” or “Multiracial”. For RQ3, independent variables included biologic sex (male = 0; female = 1), race (Reference=”White”), learning modality (in-person=0, remote=1), and FRL coded as (no=0, yes=1).

Outcome Variables

Depressive Symptoms. Symptoms of depression were assessed using a modified Patient Health Questionnaire (PHQ-9)^{50,51}, an effective tool which has been extensively used to screen for symptoms of depression in adolescents^{52,53}. While traditionally nine items, concerns related to “self harm and feeling better off dead” were excluded from this survey at the request of the school district. Participants were asked to report the presence of the remaining eight concerns reflective of DSM-V criteria for major depressive disorder⁵⁴, such as decreased energy, poor concentration, and hopelessness, over the past two weeks on a 5-point scale, ranging from “Not at all” (1 point), “One Day” (2 points), “Several Days” (3 points), “Nearly Every Day” (4 points), to “Every Day” (5 points). Total Depression Scores were derived as the sum of all eight

questions and ranged from 8 to 40. Because of limited distribution across all groups, depression symptom severity scores were grouped, and categorized as 8-13 for “No Depression”, 14-19 for “Mild Depression” and 20-40 for “Moderate to Severe Depression.” For logistic regression analysis (RQ3), a dichotomous variable was created for the “Presence of Depressive Symptoms”, scored as “1” if students’ Depression Scores were greater than or equal to 14 on the 40-point scale (corresponding to mild, moderate, or severe depression), and “0” if scores were less than 14, corresponding to no depression.

Anxiety Symptoms. Symptoms of anxiety were analyzed using the American Psychiatric Association (APA) Severity Measure for Generalized Anxiety Disorder—Child Age 11–17 (GAD-C) questionnaire⁵⁵, a validated 10-item measure that assesses the severity of generalized anxiety disorder in children and adolescents. Participants were asked how often they experienced 10 symptoms reflecting the DSM-V criteria for generalized anxiety disorder, ranging from nervousness to sudden fright, to difficulties sleeping, over the last 7 days. The response options were “Never,” “Occasionally,” “Half the time,” “Most times,” and “All times,” scored as 1, 2, 3, 4, and 5, respectively. Raw total scores were summed across all 10 questions, with higher scores indicative of higher generalized anxiety disorder symptoms. Raw scores were then averaged across all 10 items to derive the average total score. The average total score reduces the overall score to a 5-point scale corresponding to none (1), mild (2), moderate (3), severe (4), or extreme (5) generalized anxiety disorder severity. The average total score has been found to be reliable, easy to use, and clinically useful to clinicians⁵⁵. Because of limited distribution across moderate to extreme groups, categories of summed average anxiety scores were coded as “None” ([1, 2)), “Mild” ([2,3)), and “Moderate to Extreme” ([3,5]). For logistic regression analysis (RQ3), a dichotomous variable was created for the “Presence of Anxiety Symptoms”, scored as “1” if the average of the summed GAD score was greater than or equal to 2 on the 5-point scale (corresponding to mild or moderate to extreme anxiety), and “0” if the average of the summed GAD score was less than 2.

Covariates

Demographic variables, including race, sex, FRL, and learning modality were also examined as covariates and coded as described above.

E. Statistical Analysis

Descriptive analyses were performed for the study sample of remote and in-person learners who participated in this study. Chi-squared tests were utilized to determine significant differences between remote and in-person learners. Overall prevalence for each severity level of depression and anxiety were then examined by learning modality and demographic characteristics. Chi-square tests were conducted to determine whether prevalence differed by sex, race/ethnicity, and FRL.

Total scores for depression and average summed scores for anxiety fit the normal distribution, so independent-samples *t* tests were then used to compare overall average scores between remote and in-person learners. Chi-squared testing was also utilized to examine associations between demographic variables and learning modality with the presence of any depressive symptoms (corresponding to mild, moderate, or severe depression) or anxiety symptoms (corresponding to mild or moderate to extreme anxiety).

Finally, logistic regression was used to explore predictors of depression and anxiety symptoms. The presence of depression or anxiety symptoms represented the dichotomous dependent variables, while sex, FRL, race, and learning modality were the independent variables. Crude (unadjusted) associations for each of the models were first performed, followed by adjusted models that included all covariates from the bivariate analyses. Multivariate models with the lowest AIC (best fit) were included in this report. The level of significance was set at 0.05 (two-sided), and data were analyzed using SAS version 9.4.

III. Results

The majority of the study participants were White (60%), female (53%), and in-person learners (74%), while 45% were eligible for FRL (Table 1). Approximately 44% of all participants experienced moderate to severe depression, while 32% experienced no depressive symptoms. In contrast, nearly 21% of all study participants reported moderate to extreme anxiety, while 55% did not experience anxiety symptoms.

Research Question 1: Demographics and Mental Health Outcomes of Remote vs. In-Person Learners

A significantly greater proportion of virtual learners were female (66%) relative to in-person learners (48%) ($p < .0019$), and more in-person learners were White (64%) relative to remote learners (49.5%) ($p < .0286$) (Table 2). There were no significant differences between remote and in-person learners by school attended, FRL, or English learning.

The average modified-PHQ score for depression among virtual learners was greater than the average score among in-person learners ($p < .0051$), with scores of 21.4 (range 8.0-40.0, 95% CI [19.6, 23.2]), and 18.5 (range 8.0-40.0, 95% CI [17.3, 19.6]), respectively. The mean of the average anxiety scores among virtual learners was not significantly higher than average score among in-person learners ($p = .2620$), with score of 2.1 (range 1.0-4.70, 95% CI [1.9, 2.3]), and 2.0 (range 1.0-5.0, 95% CI [1.8, 2.1]), respectively.

The prevalence of mild and moderate to severe depression was 24% and 53% respectively among remote learners, while 24% and 40% of in-person learners reported mild and moderate to severe depression (Table 3). More remote learners experienced moderate to severe depression (53%) than in-person learners (40%) ($p < .0469$), and a greater proportion of in-person learners experienced no depression relative to remote learners (36% vs. 24%, $p < .0469$). Among remote learners, the prevalence of mild anxiety and moderate to severe anxiety symptoms were 26% and 23%, respectively, while 24% and 19% of in-person learners reported mild and moderate to severe anxiety symptoms, respectively. There were no significant differences between anxiety severity prevalence across learning modalities.

Research Question 2: Mental Health Outcomes by Race, Socioeconomic Status, and Gender

Multiracial (75%), Black (47%), and Hispanic students (45%) experienced the highest rates of moderate to severe depression relative to other racial groups (Table 4). However, there were no statistically significant differences in depression severity across racial groups. Conversely, 25% of Multiracial, 21% of Hispanic, and 19% of Asian students experienced moderate to extreme anxiety. More than half of all students within each racial group, with the exception of Multiracial students, demonstrated no anxiety symptoms at all. There were no significant differences in anxiety severity across racial groups.

When assessing for the presence of *any* depressive symptoms within the previous two weeks, 68% of all survey respondents (n=343) reported experiencing mild to severe depression (Table 5). A greater proportion of female learners (78%) experienced mild to severe depressive symptoms relative to male learners (53%) ($p < .0001$), while more minority learners, including Black, Hispanic, Asian, and Multiracial students (74%) experienced depressive symptoms than White students (61%) ($p < .0139$). More students receiving free and reduced cost lunch experienced depressive symptoms (72%) relative to non-eligible students (61%) ($p < .0422$), while more remote learners (77%) experienced depressive symptoms relative to in-person learners (64%) ($p < .0229$). There were no associations between school attended and depressive symptoms.

When assessing for the presence of *any* anxiety symptoms within the previous week, 45% of all survey respondents (n=340) reported experiencing mild to extreme anxiety symptoms (Table 6). More female learners experienced anxiety symptoms (56%) than male learners (31%) ($p < .0001$). There were no significant differences in the proportion of students experiencing anxiety symptoms by schools attended, race, FRL eligibility, or learning modality.

Q3. Predictors of Depression and Anxiety Symptoms Among Learners

Unadjusted models of depression indicated that biologic sex, FRL, and learning modality were significant crude predictors of depressive symptoms (mild to severe) (Table 7). There was no significant difference in the crude odds of depressive symptoms across racial groups relative to White students. The unadjusted odds of depressive symptoms were 3.2 times greater in females than males (95% CI [1.9, 5.2]), 1.7 times greater in those eligible for FRL than those not eligible (95% CI [1.0, 2.7]), and 1.8 times greater in those learning remotely versus those learning in-person (95% CI [1.1, 3.1]). Adjusted models of depression revealed that biologic sex remained the only significant predictor of depressive symptoms when controlling for the other covariates. Females had 2.9 times higher odds of depressive symptoms than males after adjusting for race, FRL and learning modality (95% CI [1.7, 4.7]) (Table 7).

Unadjusted models of anxiety revealed that gender was the only significant crude predictor of anxiety symptoms (mild to extreme). Females were found to have 2.8 times higher odds of anxiety symptoms than males (95% CI [1.7, 4.5]) (Table 8). There was no significant difference in the odds of anxiety symptoms across racial groups, FRL, and learning modality. Adjusted models of anxiety found that biologic sex remained the only significant predictor of anxiety symptoms, with females having 2.9 times higher odds of anxiety symptoms than males after adjusting for race, FRL and learning modality (95% CI [1.8, 4.9]) (Table 8).

IV. Discussion

This cross-sectional study contributes to the limited research evaluating mental health outcomes among high school students learning remotely and in-person during the COVID-19 pandemic, particularly among an underrepresented population of racially and socioeconomically diverse students in semi-rural Georgia. Findings from our survey, which was conducted among a cohort of 10th graders in the two high schools in the same school district, suggest that virtual learners were more likely to be female and non-white, while in-person learners were more likely to be male and White. These results are consistent with prior research suggesting access to full-time, in-person learning during the pandemic has been higher among non-Hispanic White students than black and Hispanic students^{12,56}. This trend has important implications, as more limited

access to in-person learning has been associated with poorer learning, mental health, and behavioral outcomes among children¹².

In our assessment of adolescents' psychological well-being, this study suggests that more than 67% of students have experienced mild to severe depression during COVID-19, irrespective of their race, socioeconomic status, and learning modality. This prevalence of depression is notably higher than what has been reported by researcher across China and Turkey early on in the pandemic^{19,57}, with Xie et al. finding that nearly 23% of primary school children had symptoms of depression after one month of lockdown⁵⁸, and Zhang et al. discovering nearly 25% of school-aged children experienced depressive symptoms in May, 2020¹⁸. Having been evaluated more than eight months following the start of lockdown, the more than doubling of depression prevalence in our cohort may reflect a rise in mental health disturbances over the course of quarantine or the cumulative effects of pandemic-related stressors, as duration of quarantine has been associated with increased risk of negative psychological outcomes⁵⁹.

Consistent with our primary hypothesis, average levels of depression were significantly higher among virtual learners than in-person learners, and virtual learners were more likely to experience moderate to severe depression relative to their in-person counterparts. Learning modality was also a significant crude predictor of depressive symptoms, as remote learners displayed over 1.8 times higher odds of depressive symptoms than in-person learners. This trend did not remain significant after controlling for race, gender, and FRL, however. While prior studies have similarly revealed prominent levels of depression among students during the pandemic^{19-21,58,60}, none have specifically compared mental health outcomes between those learning remotely and those learning in person, which only heightens concerns for those learning away from school. Although the specific causes of poorer psychological well-being among virtual learners in this study remain unknown, loss of prosocial activities, adjustments to online schooling, increased screen time, and more frequent sedentary behaviors could play a part¹⁰. Extensive research also suggests social isolation and loneliness are associated with increased risk of depression, with duration of loneliness most strongly correlated with mental health symptoms⁶¹. It is equally plausible that heightened concerns over health and safety and increased family conflict¹⁰ are contributing, although these potential drivers require further investigation.

When evaluating for disparities in mental health outcomes, we found that Multiracial, African American, and Hispanic students experienced the highest rates of moderate to severe depression, while White students were found to have the lowest prevalence. These differences did not reach statistical significance, and race was not a significant predictor of depressive symptoms, which counter our secondary and tertiary hypotheses. However, the relatively small sample sizes of minority student cohorts across participants (i.e. n=12 Multiracial, n=17 Asian, n=30 Black) relative to the White cohort (n=178) could have contributed to our lack of significant findings.

Nonetheless, we did find a significant difference in the prevalence of experiencing *any* depressive symptoms (i.e. mild to severe) across racial groups, with Multiracial students experiencing the highest rates of any depressive symptoms, followed by Asian, Hispanic, Black and white students, respectively. These findings are consistent with prior research revealing heightened levels of depression among racial minority children during the pandemic⁴⁶. Our discovered trends build upon the current literature, which has reported more extensively on disparities in the diagnosis, treatment and access to mental health care among minority youth^{31,62} rather than on the prevalence of psychiatric disturbances alone⁶². Our findings may also reflect that minority children continue to lag behind their white counterparts in prevention, access, quality, and outcomes of mental health care³¹, areas that are perhaps even further limited during the pandemic.

This study also provides evidence that free and reduced cost lunch eligibility, an indicator of lower socioeconomic status, is a significant crude predictor of mild to severe depressive symptoms. These results are consistent with prior research, as Deighton et al. found a crude 1.20 fold increase in odds of self-reported mental health problems among those qualifying for adjusted lunch cost⁶ prior to the pandemic. Hu et al. similarly found the negative mental health impact of the pandemic has been most severe among adolescents from low-income households in the United Kingdom²¹. Our findings add to the limited body of literature evaluating the mental health of low-income students in the United States during COVID-19. In a time when the stressors of low socioeconomic status are even more prevalent⁶³, our results reveal that the

psychological risks of this era may have had an even greater impact on youth who are already disadvantaged.

Interestingly, we found that biologic sex was the only significant predictor of depression in adjusted models, with the odds of depression nearly three-fold higher in females than males after controlling for race, socioeconomic status, and learning modality. Prior evidence suggests girls experience a higher prevalence of mood disorders relative to boys with most odds ratios in the range of 1.5 to 2.5³⁰. In the context of the pandemic, others have shown that being female is a risk factor for higher rates of depressive symptoms^{60,64}, although these studies did not control for socioeconomic status and were not conducted in a racially diverse cohort. Collectively, our findings suggest particular attention must be paid to the mental health of female high school students during this pandemic and beyond.

With respect to anxiety, our results were notably different than the trends we observed for depression. Levels of anxiety were no higher among virtual learners than in-person learners, nor was there any difference in the prevalence of mild and moderate to severe anxiety when comparing remote and in-person learners. In our study population, less than a quarter of students across learning modalities experienced moderate to extreme anxiety, and more than half of students surveyed experienced no anxiety at all. Furthermore, there were no significant differences in the prevalence of mild and moderate to extreme anxiety across racial groups. These results contrast our initial hypotheses and are surprising given the marked prevalence of depression across the entire sample, as symptoms of anxiety and depression frequently co-occur in adolescence⁷⁰. However, these results mirror those of a longitudinal cohort study by Zhang et al. assessing psychological symptoms among Chinese youth before and during the pandemic¹⁸. These researchers found a 13.5-16.9% prevalence of anxiety symptoms that did not increase significantly between the two timepoints, despite marked upticks in depression symptomatology over the same period¹⁸. While the discrepancy between depression and anxiety prevalence among our cohort remains unclear, perhaps learning from a more comfortable home-based environment, diminished exposure to bullying and peer pressure, longer sleep duration⁶⁵, and avoiding the challenges associated with commuting and after school activities are less stressful for high-school aged students.

Additionally, female learners were more likely to experience mild to extreme anxiety levels relative to their male counterparts. Sex was also found to be the only significant predictor of mild to extreme anxiety, with the odds of anxiety nearly three times greater in females than males after controlling for race, FRL, and learning modality. While inconsistent with one study⁵⁸, these results mirror those of Zhou et al. whose multivariable logistic regression analyses also revealed that female gender among Chinese adolescents during COVID-19 was a risk factor for higher rates of depression and anxiety after controlling for region and grade level⁶⁰. Our findings also align with longstanding literature that suggests females have a higher prevalence of mood and anxiety disorders relative to males⁶⁶, with their odds of anxiety symptoms reported as 2 to 2.5 times greater than male counterparts³⁰. Researchers have found that high school females in particular suffer more from health and social anxiety, meta-worry, and metacognitive thoughts about the uncontrollability of worry than high school boys⁶⁷. While the exact etiologies of heightened anxiety among our cohort of females remain unknown, our results suggest that female high school students may be most at risk for developing anxiety and depression during a pandemic, and therefore deserve early, proactive psychological support.

A. Strengths and Limitations

This investigation has at least five noteworthy strengths. First, to our knowledge, this was the only study to examine the impact of learning modality on self-reported mental health outcomes among high school students during the COVID-19 pandemic. Second, this study evaluated outcomes across a racially/ethnically and socioeconomically diverse group of adolescents, who are often excluded from mental health research, as most have investigated mental health disparities among adults. Third, our study's participants were from a semi-rural area in the Southeast United States, which is often understudied and underrepresented in the psychiatric literature. Fourth, mental health outcomes were assessed using standardized, validated assessments of depression and anxiety that have been widely used clinically and throughout the literature^{52,53,55}, which offers greater credence to our findings. Finally, symptoms were evaluated based on students' personal reports, thus eliminating potential biases from parent-only reports, which most pre-existing literature has relied on.

Despite these strengths, our investigation also has several limitations. First, the cross-sectional design of this study restricts the causal inferences that can be concluded from our results. Our findings may only depict the state of high school students' mental health at one point during the pandemic, and it remains to be determined how these outcomes may change over time. Second, this study was conducted among two semi-rural public high schools in Georgia, which may limit the external validity of our findings. Students in this region of the country may experience academic environments, social support, resources, and challenges that differ from those in other communities, which may impact their mental health in unique and perhaps unmeasurable ways. However, semi-rural students are poorly represented in the pre-existing research relative to urban adolescent populations, suggesting our results offer new intel into largely understudied youth. Third, this study did not evaluate or control for student's sleep hygiene or behaviors, which could have worsened in the context of heightened stress from the pandemic and impacted the mental health outcomes we investigated. In fact, poor sleep health has been linked to worse emotional wellbeing, depression, and anxiety^{68,69}, and therefore should be addressed in future research on adolescents' mental health. Finally, surveys were emailed to remote learners, which may have contributed to fewer responses from virtual relative to in-person learners, who made up 26% and 74% of the analyzed cohort, respectively. In-person learners also completed surveys during a structured period during their normal school day, while virtual learners were encouraged to complete the survey at their convenience, thereby raising the possibility for response bias. Given the lesser number of virtual learners in this sample, our results may not be entirely representative of remote students, and the responses of those students with more limited access to electronic devices may not have even been collected. It is possible those students who are resource-limited, and perhaps most vulnerable, were excluded from analysis. Future iterations of this work should therefore develop strategies to ensure more equitable access to the surveys to promote completion.

B. Future Directions

This study has provided meaningful groundwork upon which future research can build. Researchers ought to assess mental health outcomes in a larger group of students across multiple

different regions of the country, with a particular focus on recruiting a greater sample of minority and underprivileged students. Additional investigation is also needed to better understand the factors contributing to students' depression and the degree to which these forces may influence mood disturbances, most notably among virtual, female, lower socioeconomic, and racial minority students. Among virtual learners, for instance, the impact of social isolation, loneliness, obstacles to virtual instruction, and the level of psychological and physical resources relative to in-person learners should be investigated. Among racial minorities and those from lower socioeconomic strata, the influence of social dynamics at home, financial strain, and access to mental and physical health services ought to be more thoroughly explored.

In addition, the discrepancies between rates of depression and anxiety among students warrant further attention, as over half of students reported no anxiety at all, while over 40% of students experienced moderate to severe depression. While mood and anxiety symptoms are clinically distinct, depression and anxiety commonly co-occur⁷⁰, making our findings interesting and perplexing. Retrospective studies on the impact of social isolation in the context of different infections (H1N1, severe acute respiratory syndrome, and avian flu) have found the most frequently reported diagnoses among adolescents were acute stress disorder, adjustment disorder, and posttraumatic stress disorder (PTSD)⁷¹. Perhaps assessing key symptoms of these disorders would more adequately capture how the stress of COVID-19 manifests in adolescent mental health outcomes.

Furthermore, the cross-sectional nature of this study necessitates assessment of how mental health outcomes among virtual and in-person learners compare to pre-pandemic times, and whether there are future ramifications of having engaged in virtual learning. Given most schools have transitioned back to in-person instruction, the long-term effects of either learning modality during the height of COVID-19 are worth exploring. Notably, the impact of distance learning on future academic performance, social development, physical health, and sleep patterns would be particularly meaningful to inform targeted interventions for the present and during future pandemics if virtual learning is reinstated. Additionally, ongoing research into the impact of distance learning on psychological outcomes, as well as strategies to address these disturbances, are essential to mitigating mental health disparities among vulnerable students.

C. Implications

This study has notable implications and provides stakeholders with clearer insight into the prevalence and risk factors of poor mental health outcomes among high-school aged students during COVID-19. Our findings further support that the psychological well-being of our youth has suffered during this pandemic, with females, virtual learners, lower-income, and minority students particularly at risk. As students return to in-person learning, our findings highlight the need for securing comprehensive access to mental health screening and therapeutic resources, especially among these high-risk students. Our results should also be leveraged to inform interventions at the school, county, and state level during this era and future crises. Finally, our research necessitates future investigation into the long-term academic, social, and psychological effects of virtual learning. As most psychiatric disorders develop in childhood or adolescence and increase the risk for poor outcomes in adulthood, eliminating barriers to mental health support now is more necessary than ever to protect the mental health and well-being of future generations.

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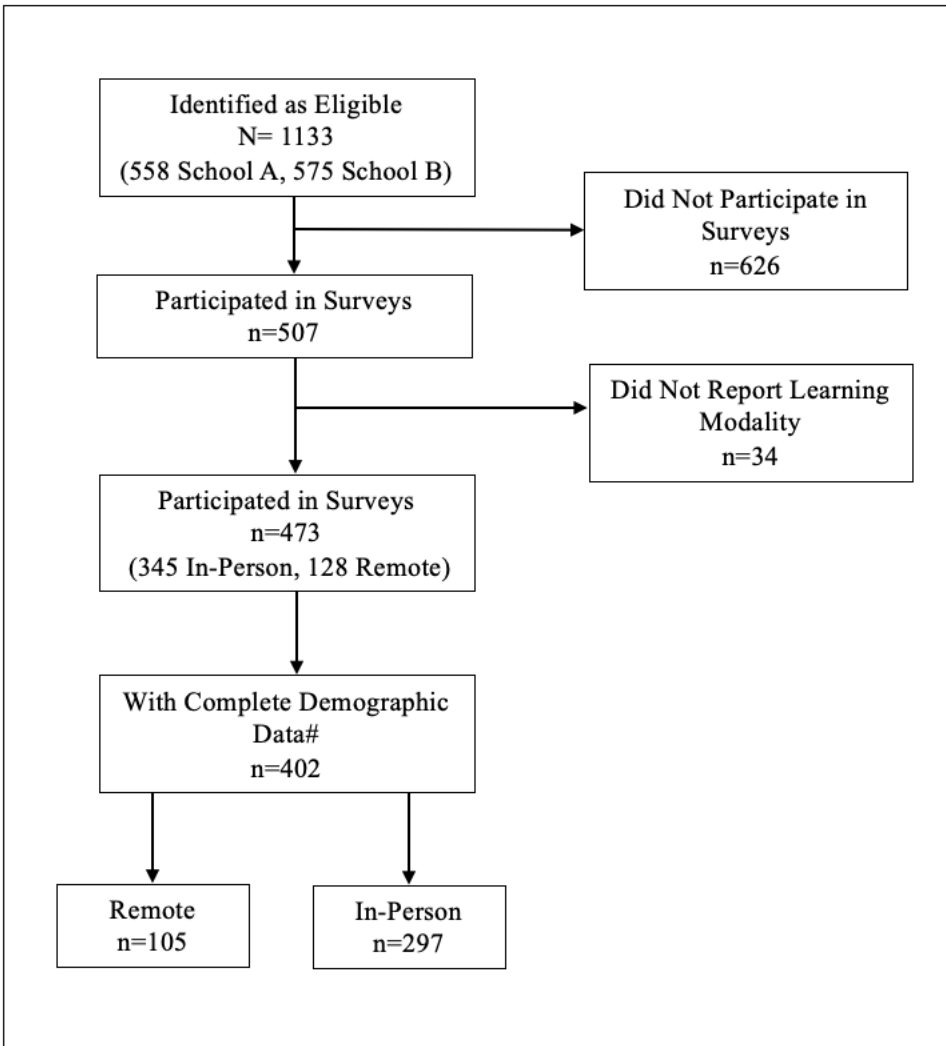
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Figure 1. Breakdown of 10th graders at two high schools in semi-rural Georgia who participated in this study



#=Complete Demographic Data provided by school district, including sex, race, and FRL.

Table 1: Demographics of 10th grader participants[^] at two high schools in semi-rural Georgia, n=402

Characteristic	Total	
	n	%
Race		
Asian	18	4.5
Black	46	11.4
Hispanic	82	20.4
Multiracial	14	3.5
White	242	60.2
Sex		
Female	212	52.7
Male	190	47.3
FRL		
Yes	182	45.3
No	220	54.7
School		
School A	250	62.2
School B	152	37.8
English Learners		
No	393	97.8
Yes	9	2.2
Learning Modality		
In-Person	297	73.9
Remote	105	26.1
Depression Severity^{\$}		
None	111	32.4
Mild	81	23.6
Moderate to Severe	151	44.0
Anxiety Severity[#]		
None	187	55.0
Mild	83	24.4
Moderate to Extreme	70	20.6

[^]Remote vs. in-person status as reported by students participating in the survey.

^{\$} n=343

[#] n=340

Table 2: Comparison of demographics of remote and in-person 10th graders^ at two high schools in semi-rural Georgia, n=402

Characteristic	Remote (n=105)		In-Person (n=297)		p value
	n	%	n	%	
Race					.0286
Asian	8	7.6	10	3.4	
Black	14	13.3	32	10.8	
Hispanic	24	22.9	58	19.5	
Multiracial	7	7.6	7	2.4	
White	52	49.5	190	64.0	
Sex					.0019
Female	69	65.7	143	48.2	
Male	36	34.3	154	51.8	
FRL					.3087
Yes	52	49.5	130	43.7	
No	53	50.5	167	56.2	
School					.1166
School A	72	68.6	178	60.0	
School B	33	31.4	119	40.0	
English Learners					.7878
No	103	98.1	290	97.6	
Yes	2	1.9	7	2.3	

Table 3: Depression and anxiety severity prevalence among remote and in-person 10th graders at two high schools in semi-rural Georgia

Characteristic	Remote		In-Person		p value
Depression Severity	(n=102)		(n=241)		.0468
	n	%	n	%	
None	24	23.5	87	36.1	
Mild	24	23.5	57	23.7	
Moderate to Severe	54	53.0	97	40.2	
Anxiety Severity	(n=103)		(n=237)		.5293
	n	%	n	%	
None	52	50.5	135	57.0	
Mild	27	26.2	56	23.6	
Moderate to Extreme	24	23.3	46	19.4	

Table 4: Depression and anxiety severity prevalence by race across all 10th graders at two high schools in semi-rural Georgia

	Total		White		Black		Hispanic		Asian		Multiracial		p value
	n	%	n	%	n	%	n	%	n	%	n	%	
Depression Severity	(n=299)		(n=178)		(n=30)		(n=62)		(n=17)		(n=12)		.0865
None	101	33.8	70	39.3	11	36.7	16	25.8	4	23.5	0	0.0	
Mild	72	24.0	39	21.9	5	16.7	18	29.0	6	35.5	4	25.0	
Moderate to Severe	126	42.2	69	38.8	14	46.6	28	45.2	7	41.2	8	75.0	
Anxiety Severity	(n=296)		(n=178)		(n=29)		(n=61)		(n=16)		(n=12)		.9059
None	165	55.7	100	56.2	17	58.6	34	55.7	10	62.5	4	33.3	
Mild	74	25.0	45	25.3	7	24.1	14	23.0	3	18.7	5	41.7	
Moderate to Extreme	57	19.3	33	18.5	5	17.3	13	21.3	3	18.8	3	25.0	

Table 5: Proportion of all 10th grade students at two high schools in semi-rural Georgia reporting depressive symptoms[#] by demographic[§] variables

Characteristic	Total		%with depressive symptoms		p value
	n	%	n	%	
Race					.0240
Asian	17	5.7	13	76.5	
Black	30	10.0	19	63.3	
Hispanic	62	20.7	46	74.2	
Multiracial	12	4.0	12	100.0	
White	178	59.5	108	60.7	
Sex					<.0001
Female	162	54.2	126	77.8	
Male	137	45.8	72	52.6	
FRL					.0422
Yes	137	45.8	99	72.3	
No	162	54.2	99	61.1	
School					.1445
School A	203	67.9	140	69.0	
School B	96	32.1	58	60.4	
Learning Modality[^]					.0229
In-Person	241	70.3	154	63.9	
Remote	102	29.7	78	76.5	

[#]Depressive symptoms=report of mild to severe depression.

[§]Demographics (Race, Sex, FRL, School) as reported by school for assenting students (n=299).

[^]Learning modality as reported by students (n=343).

Table 6: Proportion of all 10th grade students at two high schools in semi-rural Georgia reporting anxiety symptoms[#] by demographic^s variables

Characteristic	Total		% with anxiety symptoms		p value
	n	%	n	%	
Race					.5832
Asian	16	5.4	6	37.5	
Black	29	9.8	12	41.4	
Hispanic	61	20.6	27	44.3	
Multiracial	12	4.0	8	66.7	
White	178	60.1	78	43.8	
Sex					<.0001
Female	160	54.1	89	55.6	
Male	136	45.9	42	30.9	
FRL					.9740
Yes	133	44.9	59	44.2	
No	163	55.1	72	44.4	
School					.4258
School A	203	68.6	93	45.8	
School B	93	31.4	38	40.9	
Learning Modality[^]					.2700
In-Person	237	69.7	102	43.0	
Remote	103	30.3	51	49.5	

[#]Anxiety symptoms=report of mild to extreme depression.

^sDemographics (Race, Sex, FRL, School) as reported by school for assenting students (n=296).

[^]Learning modality as reported by students (n=340).

Table 7. Odds ratios of depressive symptoms among 10th graders at two high schools in semi-rural Georgia by demographic variables, n=299

Characteristic	Unadjusted OR	95% CI	p value	Adjusted OR	95% CI	p value
Race#						
Asian	2.11	0.66-6.72	.2082	1.82	0.54-6.15	.3331
Black	1.12	0.50-2.49	.7824	0.68	0.29-1.62	.3865
Hispanic	1.86	0.98-3.55	.0580	1.56	0.78-3.13	.2057
White	Ref	-	-	Ref	-	-
Sex						
Female	3.16	1.92-5.21	<.0001	2.91	1.71-4.97	<.0001
Male	Ref	-	-	Ref	-	-
FRL						
Yes	1.66	1.02-2.71	.0440	1.32	0.76-2.27	.3230
No	Ref	-	-	Ref	-	-
Learning Modality						
Remote	1.84	1.08-3.11	.0240	1.49	0.82-2.72	.1926
In-person	Ref	-	-	Ref	-	-

#100% of Multiracial students reported depressive symptoms and are therefore excluded from this table.

Table 8. Odds ratios of anxiety symptoms among 10th graders at two high schools in semi-rural Georgia by demographic variables, n=296

Characteristic	Unadjusted OR	95% CI	p value	Adjusted OR	95% CI	p value
Race#						
Asian	0.77	0.27-2.21	.6258	0.76	0.25-2.31	.6333
Black	0.91	0.41-2.01	.8058	0.68	0.30-1.57	.3676
Hispanic	1.02	0.57-1.83	.9521	0.95	0.51-1.79	.8727
Multiracial	2.56	0.75-8.83	.1355	2.00	0.56-7.19	.2879
White	Ref	-	-	Ref	-	-
Sex						
Female	2.81	1.74-4.53	<.0001	2.92	1.76-4.85	<.0001
Male	Ref	-	-	Ref	-	-
FRL						
Yes	1.01	0.64-1.60	.9740	0.84	0.51-1.41	.5116
No	Ref	-	-	Ref	-	-
Learning Modality^						
Remote	1.30	0.82-2.07	.2705	1.07	0.62-1.81	.8113
In-person	Ref	-	-	Ref	-	-