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Longitudinal change in adolescent depression and anxiety symptoms from before to during the COVID-19 pandemic

Running head (50 characters)

COVID-19 pandemic and adolescent mental health

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Abstract (120 words max)

This study aimed to examine changes in depression and anxiety symptoms from before to during the first six months of the COVID-19 pandemic in a sample of 1,339 adolescents (9-18 years old, 59% female) from three countries. We also examined if age, race/ethnicity, disease burden, or strictness of government restrictions moderated change in symptoms. Data from 12 longitudinal studies (10 U.S., 1 Netherlands, 1 Peru) were combined. Linear mixed effect models showed that depression, but not anxiety, symptoms increased significantly (median increase=28%). The most negative mental health impacts were reported by multiracial adolescents and those under 'lockdown' restrictions. Policy makers need to consider these impacts by investing in ways to support adolescents' mental health during the pandemic.

Keywords: COVID-19; depression and anxiety; collaborative

Introduction

There is widespread concern that child and adolescent mental health has worsened during the COVID-19 pandemic (Branje & Morris, 2021; Golberstein et al., 2020; Guessoum et al., 2020; Holmes et al., 2020; Lee, 2020; Racine et al., 2020). Adolescence is a period of vulnerability to mental health disorders in general and internalizing (i.e., depression and anxiety) disorders in particular (Costello et al., 2011), with these disorders impacting health and functioning in other domains of life into adulthood (Ormel et al., 2017). The pandemic caused many large changes in factors that are known to be relevant to mental health, such as routines, family finances, and opportunities to socialize (Branje & Morris, 2021). Exploration of the social environment outside of the family and forming more adult-like social relationships are key to healthy adolescent development (Nelson et al., 2016; Orben et al., 2020) and were complicated by pandemic-related restrictions.

In the context of the COVID-19 pandemic, several cross-sectional studies from China showed higher anxiety and depression symptoms than expected based on statistics from pre-pandemic studies in Chinese children and/or adolescents (Duan et al., 2020; Xie et al., 2020; Zhou et al., 2020), and one longitudinal study showed increases in depression and anxiety symptoms in 13- to 16-year-old Australian adolescents (Magson et al., 2020). A British study reported longitudinal increases in depressive symptoms but not anxiety symptoms in late childhood (age 7 to 11 years; Bignardi et al., 2020). However, other papers reported no change in internalizing symptoms (Achterberg et al., 2021) or a reduction in risk for anxiety in early adolescents (Widnall et al., 2020). There is still limited evidence of longitudinal changes in mental health from before the pandemic to during the COVID-19 pandemic in a large, diverse sample spanning all of adolescence (age 9 to 18). *Therefore, we aimed to examine to what extent depression and anxiety symptoms of adolescents have changed from before the pandemic*

to during the first six months of the COVID-19 pandemic within a collaborative sample of over 1,300 adolescents from three countries.

Changes in youth mental health from before the pandemic to during the pandemic might differ by individual-level factors, such as age and race/ethnicity. Testing these factors as moderators can help elucidate who is most at risk and requires support. Cross-sectional studies have reported higher anxiety/depression symptom levels in older adolescents than in younger adolescents early in the pandemic (Duan et al., 2020; Zhou et al., 2020), but older adolescents are also at increased risk of depression and several anxiety disorders (e.g., generalized anxiety and panic disorder) outside of the context of the pandemic (Kessler et al., 2012). Therefore, previously-reported results do not necessarily mean older adolescents show greater *change* in mental health symptoms during the pandemic than younger adolescents. However, there might still be reason to think different age groups have experienced the pandemic differently. For example, although perceived importance of friend social support remains the same from earlier to later adolescence (Demaray & Malecki, 2003), older adolescents spend more time with peers than younger adolescents (Richards et al., 1998), which may be complicated by pandemic-related restrictions. In addition, older adolescents might have higher needs for autonomy and independence (Wray-Lake et al., 2010).

Similarly, racial disparities in the mental health of U.S. adolescents have been reported (Anderson & Mayes, 2010; McLaughlin et al., 2007), although there are inconsistent findings about which group is at highest risk (Bitsko et al., 2022). Surveys on mental health in U.S. adults show continued racial disparities during the COVID-19 pandemic, with the 'other race or multiple races' group having the highest levels of depression and anxiety symptoms (Centers for Disease Control and Prevention, 2021). However, it is unknown if Black, Indigenous, and People of Color (BIPOC) adolescents disproportionately display a difference in mental health during the pandemic relative to before the pandemic. If this is the case, it might reflect

discrepancies in the exposure to stressors, such as family financial stress, having family with (severe) COVID-19 and discrimination, which may be associated with adolescents' well-being. To elucidate these potential moderators, the second research question was: *Is any change in anxiety and depression symptoms moderated by the current age of the adolescent or by their race/ethnicity?*

Disease burden and government regulations may also be associated with youth mental health. Thus, given the potential implications for policy decisions, it is important to test the extent to which disease burden and government regulation moderate any extant association between change in youth mental health from before to during the pandemic. For example, if government regulations are a significant moderator, mental health symptoms are more likely related to increased physical distancing; if disease burden is a moderator, stress about one's own or loved ones' health is a potential mechanism. Cross-sectional studies on Chinese youth reported that those from the hardest hit region, Hubei, had elevated mental health symptoms compared to the rest of the sample (Duan et al., 2020; Xie et al., 2020; Zhou et al., 2020). On the other hand, one of the few studies with multiple time points of mental health data during the pandemic included adolescents and adults from China and found no change in anxiety or depression symptoms from early February to March, when cases dramatically increased (although, only 19% of 1,738 participants had longitudinal data and no longitudinal analysis was done; Wang et al., 2020). Further, social support has been found to buffer against adolescents' internalizing symptoms during the pandemic (Bernasco et al., 2021; Magson et al., 2020). Social support is a general protective factor against mental illness (Taylor, 2011). Since adolescents are developmentally primed to explore the social environment outside of their family (Nelson et al., 2016; Orben et al., 2020), increased governmental restrictions that limit opportunity for explorative behavior and social contact might be particularly impactful for adolescents. Therefore, the final research question was: *Is any change in anxiety and*

depression symptoms from before the pandemic to during the first six months of the pandemic moderated by the disease burden or strictness of government restrictions in the adolescents' county of residence?

To answer these questions, we combine data from 12 research groups across three countries (17 states and D.C. in the U.S., as well as the Netherlands and Peru), which measured anxiety and depression symptoms of 1,339 adolescents longitudinally before and during the first six months of the COVID-19 pandemic.

Methods

Samples and participants

We used data from 12 ongoing longitudinal studies on adolescent development. Studies were required to primarily or solely include adolescent participants, have conducted at least one assessment prior to the pandemic and at least one assessment during the pandemic that inquired about anxiety or depression symptoms, and be willing and able to share data in the collaboration by summer 2020. All anxiety and depression measures were adolescent self-report, except when this was not available (see Table 1). Participants aged 9.0-18.0 as of March 2020 were included. We chose this age range because we were interested in adolescence, which is generally considered to start at the onset of puberty and end when adult rights and responsibilities are obtained (Dahl et al., 2018). The final total sample included 3,948 data points (65% pre-pandemic) from 1,339 participants (59% female). Mean age at participants' earliest time point was 13.5 years (*SD*=2.0; range 8.2-17.6) and mean age at participants' most recent time point was 15.4 years (*SD*=1.8; range 9.4-19.0). Race/ethnicity in the total sample was distributed as follows: 42.7% White, 15.9% Latino/Hispanic, 9.2% Biracial/Multiracial, 7.7% Black/African American, 2.5% Asian, 1.4% other race/ethnicity (including American Indian or Alaskan Native), 20.5% missing. See *Measures* for information on the categorization of race/ethnicity. Within the Biracial/Multiracial group, 54% did not have full details of the

racial categories, but for the subgroup that had this information, all racial categories were represented (77% had White as one of their categories, 31% Latino/Hispanic, 38% Black/African American, 24% Asian, 33% other). The studies from Peru and the Netherlands (*N*=180) did not collect race/ethnicity information; considering that and the context-dependent meaning of racial/ethnic group differences, participants from non-U.S. studies are in the 'missing' category and were not included in race/ethnicity moderation analyses. For information on race/ethnicity (and socioeconomic status) by study, see Supplementary Table 1.

Since this paper describes a post-hoc collaborative analysis, studies unsurprisingly varied in their sample characteristics such as the age range and number of time points. Table 1 summarizes the sample characteristics for each study. For more detailed information on study design, inclusion and exclusion criteria of each study, see Supplement 1. All studies were approved by their local ethics review committees and data sharing for combined analyses was done in compliance with Health Insurance Portability and Accountability Act guidelines. Participants provided assent to participate and a parent/guardian provided informed consent, except for participants who were 18 years old, who provided informed consent.

Measures

Anxiety and depression measures varied between samples (see Table 1), therefore we made the a priori decision to convert scores into proportion of maximum score (POMS), which can range from 0 to 1. The POMS is calculated as follows: (participant's score - minimum of scale) / (maximum of scale - minimum of scale). We chose POMS because it avoids problems inherent in creating z-scores for longitudinal data, which, depending on how standardization is done, can for example include obfuscation or removal of mean level differences, mean changes, or relative rank information (Moeller, 2015).

Any assessments completed prior to March 11, 2020, the day the World Health Organization declared a pandemic, were considered pre-pandemic symptoms. Age in all analyses was defined as the age of the adolescent in March 2020 in years with one decimal. Race/ethnicity information was available for samples from the U.S. only. If race and ethnicity were collected as separate variables, adolescents identifying as white Latino/Hispanic or Mexican/South-American Latino/Hispanic were categorized as Latino/Hispanic, whereas Latino/Hispanic with another racial identity was categorized as multiracial.

Disease burden was measured as the number of daily cases and deaths per 1M people in the participant's county (U.S.) or city/province (outside U.S.) averaged over the seven days up to the date of assessment. This information was pulled from the database of the Johns Hopkins University for U.S. data (Dong et al., 2020) and based on national government reporting for studies outside the U.S. (OpenInfo, n.d.; Peru Ministerio de Salud, n.d.). If participants had multiple mid-pandemic time points, case rates and death rates were averaged across those. The final case rate and death rate variables were square-root transformed to reach an approximate Gaussian distribution.

The strictness of government restrictions on the date of assessment was measured at the state and county level for each participant using a scale from 1 to 5. Both state- and county-level restrictions were coded to account for restrictions at both levels (e.g., a state-wide stay-at-home order plus a county-wide mask mandate). The most stringent restrictions in the participant's location were coded, such that, if county restrictions were more stringent than state restrictions, county restrictions were coded. If participants had multiple mid-pandemic time points, the median was calculated across those. Level 1 indicated 'no restrictions', 2 'a few closures of businesses or public facilities, limited restrictions', 3 'some business closures, restrictions in the size of gatherings', 4 'more extensive business closures, gathering restrictions, social distancing and masks' and 5 'a stay at home order, non-essential businesses

closed, enforced masks and social distancing'. Ratings were conducted by one of the lead authors of the paper (CC). A doctoral graduate assistant was asked to blind code a random sample of 150 of the data points, and the intraclass correlation coefficient (single measures) was .776.

Analyses

Analyses were conducted with lmerTest in R version 3.6.3 (Bates et al., 2015). Scripts are available on DOI: 10.5281/zenodo.4495773. We modeled the change in symptom levels (i.e., POMS) with the following linear mixed effects model: *symptoms ~ Before_vs_DuringPandemic + timespan + Before_vs_DuringPandemic*timespan + sex + age + (1 | Study/ID)* and comparing this to a baseline model without *Before_vs_DuringPandemic* and its interaction with *timespan*. Anxiety and depression symptoms were modeled separately. The *Before_vs_DuringPandemic* factor specifies if an observation was made before or during the pandemic and *(1 | Study/ID)* reflects the random intercept by participant within study, since the model has three levels (time points within participants within studies). The covariate *timespan* represents time passed between a participant's earliest and latest assessment in years, and its main effect plus interaction with *Before_vs_DuringPandemic* allow us to test whether changes in symptoms occur independently of how much older a participant has gotten. We examined moderating effects of race/ethnicity by adding that variable and its interaction with *Before_vs_DuringPandemic*, using White as the reference racial category. We examined moderating effects of age by adding the interaction between age and *Before_vs_DuringPandemic*. Moderating effects of case rate, death rate and government restrictions were tested by adding that (scaled) individual-level variable and its interaction with *Before_vs_DuringPandemic*. Model fit of each of these interaction models was compared to the main model, laid out in the equation above, with likelihood ratio tests. This is to examine if model fit significantly improves with the addition of the new predictors; if not, then we prefer

the simpler model. Fit statistics of the best fitting model are reported. Since we used two measures to examine the construct disease burden, a Bonferroni correction was applied across the models for case rate and death rate, adjusting the significance threshold to .025.

We additionally ran exploratory analyses to better understand if the observed changes in internalizing symptoms are distinguishable from general developmental increases in symptom levels. We calculated the slope of general developmental change in depression and anxiety symptoms by predicting symptom levels from age in pre-pandemic data only, controlling for sex. We then compared this to the *Before_vs_DuringPandemic* change from the main change model described above.

Finally, we ran post-hoc 'leave one out' (LOO) analyses as well as a meta-analysis of the main change in depression and anxiety. We did this to examine if any of the samples unduly impacted the findings or if they are robust to variations between studies in sample composition, study design, and measures. For the LOO analyses we repeated each of the analyses while leaving out one of the study samples at a time and reported whether the findings remained consistent with the analysis that includes all samples with data for that analysis. For the meta-analysis, models of main change in depression and anxiety were run for every study sample separately, controlling for sex, age and a random intercept by participant. Next, pooled estimates were calculated using the metagen command in the meta package in R v3.6.3, applying restricted maximum likelihood to estimate between-study variance. Considering the variation in study designs and the substantial between-study variance, we focused on the random-effects model.

Results

Descriptive information

The number of time points per participant ranged from 1 to 10 (median=2). See Table 1 for information by study. Data were collected between January 2016 and September 2020.

The median date of collection (DOC) for pre-pandemic data was 2nd of December 2018 and the median DOC of timepoints during the pandemic was 28th of May 2020.

Daily case rates per 1M (averaged over the week before assessment) ranged from 0 to 438.7 and daily death rates per 1M ranged from 0 to 60.4. Case and death rates correlated moderately (rho=.51). Government restriction levels ranged from 2 to 5 (i.e., all adolescents faced at least some restrictions). The restriction levels were negatively correlated with case rates (rho= -.22) and not correlated with death rates (rho=.00).

Main change and interaction with age

The results demonstrated that depression, but not anxiety, symptoms significantly increased from before to during the pandemic (See Table 2 and 3, and Figure 1 and 2). The median POMS of depression symptoms, adjusted for repeated measures, increased from 0.195 to 0.250 (a 28% increase). The median POMS of anxiety symptoms was 0.234 pre-pandemic and 0.250 during the pandemic. Current age of the adolescent did not moderate the change in depression or anxiety symptoms. There was a significant interaction with timespan for anxiety symptoms: adolescents who were followed for a shorter time showed a decrease in anxiety symptoms from before to during the pandemic (See Tables 2 and 3). However, after removing the three samples that used a different anxiety symptom questionnaire pre-pandemic versus during the pandemic, this interaction disappeared and the baseline model was the best fitting model.

Race/ethnicity

There was a significant interaction with race/ethnicity for both depression and anxiety symptoms. Biracial/multiracial adolescents were more likely to show increases in depression and anxiety symptoms, but Latino/Hispanic adolescents were less likely to increase in depression symptoms and more likely to decrease in anxiety symptoms. See Table 2 and Table 4, as well as Figure 4 for details. Note that the models to test a race/ethnicity interaction were

fit on a smaller dataset with only samples from the U.S. We reran the analysis without the three samples that used a different questionnaire pre-pandemic versus during the pandemic for anxiety symptoms, and the interaction model remained significant.

Disease burden

We examined interactions between time and local case rates as well as death rates, which both reflect average daily rates across the week before assessment. For depression symptoms, there was a significant interaction with case rates, but not death rates: symptoms increased more for participants in areas with lower case rates (see Table 2 and Table 5, as well as Figure 5). The average within-person increase in depression symptoms was 0.07 (on a scale from 0 to 1) for those in regions with <100 cases per 1M people in the week before assessment, but 0.01 for those in regions with >200 cases per 1M. For anxiety symptoms, there was no significant interaction with case rates or death rates. The analysis for death rates was repeated without participants from the TAB study (from New York), since they were outliers, but this did not change the significance of the results.

Government restrictions

Change in both anxiety and depression symptoms was moderated by the strictness of government restrictions in the participant's county/region (see Tables 2 and 6, as well as Figure 6). Depression symptoms increased more and anxiety symptoms decreased less for participants in regions with higher levels of government restrictions.

Developmental trends

For the depression model, the regression coefficient for *Before_vs_DuringPandemic* was 0.04, meaning that symptoms were 0.04 higher (on a scale from 0 to 1) during the pandemic compared to before. However, the time passed between the average pre-pandemic DOC (28th of September 2018) and the average DOC during the pandemic (31st of May 2020) was longer than a year (1.68 years), so the adjusted slope was 0.04/1.68=0.024. The regression coefficient

of the model predicting pre-pandemic depression symptoms from age was 0.001, showing that the increase per year from before to during the pandemic was greater compared to the increase per year in pre-pandemic data. For the anxiety model, the adjusted slope for *Before_vs_DuringPandemic* was -0.05/1.68=-0.03, whereas the age slope in pre-pandemic data was 0.01.

Post-hoc 'leave one out' analyses and meta-analysis

Table 7 reports the findings of the 'leave one out' (LOO) analyses. These analyses suggest that the reported findings are largely stable for depression, but less stable for main change, age interaction and case rate interaction in relation to anxiety. Results of meta-analytic tests of the main change in depression and anxiety symptoms confirmed that there was a significant increase in depression, but not in anxiety (see Supplementary Table 2).

Discussion

In the current study, we examined to what extent adolescents' depression and anxiety symptoms changed from before to during the first six months of the COVID-19 pandemic. We also investigated to what extent any change in anxiety or depression symptoms was moderated by the current age or race/ethnicity of the adolescent, by the disease burden, or by the strictness of government restrictions in the adolescents' county of residence. Depression symptoms increased significantly, with a median increase of 28%. Although we cannot be certain that the pandemic *caused* this increase in depression symptoms, and these symptoms also tend to rise with age outside of the context of the pandemic, the reported increase was independent of age at the start of the pandemic, it was independent of how much (or little) time had passed between the earliest and latest assessment, and it was greater in absolute terms than the age slope in pre-pandemic data. Importantly, this is one of the first studies to report longitudinal change in mental health symptoms from before relative to during the COVID-19 pandemic in a large

sample of adolescents, spanning three continents and the full developmental span of adolescence.

Longitudinal assessment is crucial to understanding change in youth mental health over time. For example, Pan and colleagues (2020) reported that, cross-sectionally, adults with a prior diagnosis of anxiety and/or depressive disorders had the greatest self-perceived impact of the COVID-19 pandemic on their well-being. However, a longitudinal assessment of their symptoms showed that depression, anxiety, loneliness, and worry decreased or did not change, whereas each of these domains increased in adults without a history of mental illness. Although our sample differed from Pan and colleagues' (e.g., participants were primarily drawn from community samples; we did not distinguish based on history of mental illness; our findings reflect an increase in subthreshold depression symptoms), our results were similar: youth depression symptoms, but not anxiety symptoms, increased on the aggregate.

Our results indicate anxiety symptoms decreased during the early months of the COVID-19 pandemic, at least for those where the time between earliest and latest assessment was relatively short. However, this result was unstable in the LOO analyses, and showed high variability between studies. This finding contrasts with previous cross-sectional studies (Duan et al., 2020; Xie et al., 2020; Zhou et al., 2020) and a longitudinal study (Magson et al., 2020) which used a variety of anxiety scales (e.g., Spence Children's Anxiety Scale; Screen for Child Anxiety Related Emotional Disorders; Generalized Anxiety Disorder scale) among adolescents. There are several explanations for this discrepancy. First, anxiety is multifaceted: it is possible that some types of anxiety increased during the pandemic, whereas other types might have declined. For example, social anxiety may have temporarily subsided with fewer opportunities for social interactions and reduced social pressures, whereas generalized anxiety may have increased with the global pandemic, as well as several other local, national, and global events that took place during this time, especially in the U.S. The use of broad screening

questionnaires in the majority of the included studies limited our opportunity to look at changes in specific forms of anxiety. Second, anxiety may have fluctuated during the course of the pandemic based on the contexts to which adolescents were exposed. For example, several standardized measures of anxiety include items that are difficult to endorse under local restrictions, (e.g., "I get stomach aches at school") and therefore may underreport experienced anxiety or may mask anxiety that has no behavioral expression when youth are largely at home. At the same time, returning to school and social activities might come with an increase in anxiety symptoms because of missed opportunities for exposure (Frenkel et al., 2015).

For both anxiety and depression, increases were strongest in multiracial adolescents, whereas Hispanic/Latino adolescents reported decreases/weaker increases than White adolescents, Black/African American adolescents showed smaller increases in depressive symptoms, and Asian American adolescents decreased in anxiety. Although studies varied in their racial distribution (see Supplementary Table 1), these findings remained largely stable under the LOO analyses. These findings align with representative surveys in adults, which report the highest levels of depression and anxiety symptoms in the 'other race or multiple races' group (Centers for Disease Control and Prevention, 2021). However, they do not align with the idea of a disproportionate increase in symptoms in all BIPOC adolescents. Further research is needed to examine the risk and resilience factors that could explain this mixed picture of stronger increases in symptoms for multiracial adolescents, but weaker increases or decreases for Black/African American and Hispanic/Latino adolescents.

The change in depression symptoms was moderated by case rate, such that adolescents in areas with lower disease burden experienced a greater symptom increase. Although speculative, these results may be due to a mismatch between policies of restriction and actual case level. Restriction levels and case rates were *negatively* correlated in the current study, and stricter government restrictions were associated with more depression symptom increase. High

local case rates across the last week thus did not appear to increase worries or distress across the last one to two weeks. This could be because adolescents are not focused on them, adolescents might not be exposed as much to these numbers, or because they don't inform adolescents' mental state. Humans – particularly young people – often have difficulty intuitively understanding big numbers (Tretter et al., 2006), so case rates going from high to higher might not have a significant mental impact. Also, the risk for becoming physically ill from COVID-19 (or to see that happening to loved ones) may not be a major factor affecting mental well-being, as also shown by a study comparing older and younger adults' emotional well-being (Carstensen et al., 2020): emotional well-being during the pandemic was better in older adults than in young adults, despite older adults perceiving a higher risk of complications from COVID-19.

Moderation by restriction levels on the other hand showed the opposite pattern: adolescents in areas with stricter government restrictions reported a greater depression and anxiety symptom increase. This suggests that higher levels of government restrictions, and the social isolation and cancellations of in-person activities (including regular schooling) that are the result of such restrictions, might be burdensome on adolescents' mental health. This is supported by a study which reported that changes in depression and anxiety symptoms were stronger in adolescents who felt socially disconnected (Magson et al., 2020) and aligns with findings in the UK from March 2020 to March 2021 showing an association between rates of mental health difficulties and pandemic-related restrictions (Shum et al., 2021). It is also not surprising in light of the knowledge that adolescents are developmentally primed to explore their social environment and build connections outside their household (Nelson et al., 2016; Orben et al., 2020). A higher level of government restrictions, which captures for example limits on gathering sizes and social distancing (see *Methods*), directly limits the opportunities for this exploration and building of new connections. Future longitudinal research should

examine whether adolescents with lower levels of social connectedness or support before the pandemic are more negatively affected during the pandemic.

These findings highlight the importance of considering adolescents' emotional well-being in policy decisions for the remainder of the COVID-19 pandemic, and potentially future pandemics. Public health policy makers need to explicitly consider mental health impacts of their policies. For example, the American Academy of Pediatrics recommends the return to in-person schooling and states that "School policies should be guided by supporting the overall health and well-being of all children [and] adolescents" (https://bit.ly/2BMPtW5). Although the present study was not equipped to test the impact of school closures on adolescents' mental health specifically, Lee (2020) found that school closures exacerbated existing mental health issues among youth. Taken together with the results of the present study, disruptions to structure and opportunities for social interaction may be detrimental to youth mental health. Further, investing in sources of support to buffer negative mental health impacts, especially under 'lockdown' or 'stay-at-home' mandates, is warranted. For example, a predictable, stable home environment was protective of mental health during the COVID-19 pandemic (Rosen et al., 2021). Overall, evidence is mounting that policy should focus on preserving normalcy and preventing disruptions in youth social structures, resources, and support to the extent that it is possible to do so in emergency situations.

Limitations

The findings of this study should be considered within the context of several limitations. Importantly, causality cannot be assumed from longitudinal studies like this one. Although depressive symptoms increased regardless of how much (or little) time had passed between the earliest and latest assessment, and the increase was greater in absolute terms than the slope in pre-pandemic data, we cannot be certain that these increases are caused by the pandemic. Further, the current dataset was a post-hoc collaboration of studies with varying inclusion

criteria, age ranges, and measures of anxiety and depression symptoms. We took several steps to correct for this site-level variablility as much as possible: converting symptom levels into proportion of maximum score, including a random intercept by study, correcting for sex and current age in all analyses, and conducting a LOO sensitivity analysis. Proportion of maximum score has several advantages over z-scores as described in the Methods, but we acknowledge that this approach also has limitations: maximums scores can have different meaning for different questionnaires. Also, unlike some studies in single samples, we applied mixed effects modeling, which reduces bias resulting from selective drop out or incomplete data compared to complete case analysis. Finally, the overall change in depression symptoms was also significant when tested with a meta-analytic approach, suggesting it might be robust to the various sources of site-level variability.

Also, some factors might have reduced the generalizability of the current findings. Most studies included a community sample, but four studies specifically recruited participants with or at-risk for mental illness. Although these studies did not emerge as particularly influential in the LOO analyses, it does indicate that the prior mental illness burden in our sample might be higher than in the general population of adolescents. Second, two studies specifically recruited girls, leading to 59% female participants in the total sample. However, we control for sex in all analyses and the sample still has 549 males. Third, participants were mostly from middle class families (see Supplementary Table 1 for socioeconomic status [SES] information by study; we did not provide this information for the total sample because of the variation in measures and categories). Since the economic impact of the pandemic has been mostly felt by lower SES families, the mental health effects of families' financial problems might not have been well-captured by the current study. Fourth, our racial distribution was close to that of the U.S. population of adolescents based on Census data of 10-17-year-olds (United States Census Bureau, 2019), with somewhat higher percentages of White and multiracial adolescents in the

current sample. This may be partly due to classifying non-White Latino/Hispanic adolescents as multiracial (7% of the multiracial group). We chose not to subdivide the group who identified as Latino/Hispanic, partly because not all studies had this data and partly because the number of racial categories was already large, limiting our power to detect differences. However, this means that differences found are unlikely to be trivial. For 2 out of the 10 studies with race/ethnicity data, racial diversity was somewhat lower among participants who completed the surveys sent out during the pandemic compared to the original sample (see Table 8), but there was no selective drop out for the majority of studies.

Further, we only used data collected up to September 2020, so the current study only covers the early phase of the pandemic. Finally, it is important to note that changes reported here might be temporary. It is beyond the scope of the present study to determine the long-term impacts of the pandemic on adolescents' mental health; however, this is an important area for future research.

Conclusion

The current study is one of the first studies to report longitudinal change in mental health symptoms from before to during the COVID-19 pandemic in a large, international sample spanning the full age range of adolescence. The COVID-19 pandemic appears to have impacted adolescent depression symptoms, and the impacts on depression and anxiety were felt most strongly by multiracial adolescents and those under 'lockdown' restrictions. Future research should examine the long-term impacts of the pandemic on adolescents' mental health and look for ways to boost adolescents' well-being under physical distancing conditions. Public health policy makers need to explicitly consider mental health impacts of their policies and invest in sources of support to buffer expected negative impacts.

Supplementary Material

https://docs.google.com/document/d/1iq_Ut4Fx_IRWOpCu885AdnvwT5RDqu6TiurlWp1TB2U/edit

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Table 1. See link
https://docs.google.com/document/d/1eKyJvp9I45jZojLNj1mwUkts7E_erMVzI8Sd6sUp_K0

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Table 2. Model fit comparisons

Model	AIC	BIC	Log likelihood	*p* (versus model one row up)
Depression symptoms				
Baseline	-1556.1	-1513.8	785.1	NA
Main effect Before_vs_DuringPandemic	-1602.3	-1547.9	810.1	**<.001**
Age interaction	-1600.4	-1539.9	810.2	.77
Main effect Before_vs_DuringPandemic (full race data)	-1482.3	-1429.0	750.2	NA
Race interaction	-1487.5	-1374.8	762.8	**.005**
Main effect Before_vs_DuringPandemic (full case rate data)	-1392.6	-1339.1	705.3	NA
Case rate interaction	-1410.5	-1345.1	716.2	**<.001**
Main effect Before_vs_DuringPandemic (full death rate data)	-1392.6	-1339.1	705.3	NA
Death rate interaction	-1394.5	-1329.1	708.2	.05
Main effect Before_vs_DuringPandemic (full restrictions data)	-1359.5	-1306.0	688.7	NA
Government restrictions interaction	-1364.3	-1299.0	693.2	**.01**
Anxiety symptoms				
Baseline	-1993.2	-1951.7	1003.6	NA
Main effect Before_vs_DuringPandemic	-2038.4	-1985.1	1028.2	**<.001**

Age interaction	-2039.2	-1979.9	1029.6	.10
Main effect Before_vs_DuringPandemic (full race data)	-1746.1	-1695.4	882.1	NA
Race interaction	-1757.2	-1650.1	897.6	**<.001**
Main effect Before_vs_DuringPandemic (full case rate data)	-1744.7	-1692.8	881.3	NA
Case rate interaction	-1745.1	-1681.7	883.5	.11
Main effect Before_vs_DuringPandemic (full death rate data)	-1744.7	-1692.8	881.3	NA
Death rate interaction	-1742.4	-1679.1	882.2	.41
Main effect Before_vs_DuringPandemic (full restrictions data)	-1730.0	-1678.2	874.0	NA
Government restrictions interaction	-1755.5	-1692.2	888.7	**<.001**

Note: AIC = Akaike information criterion; BIC = Bayesian information criterion

Table 3. Summaries of fixed effects of best fitting models of main time effect and age interaction

Model	Parameter	*b*	*SE*	*t*	*p*
Depression symptoms (level 3 ICC = 0.43)	Intercept	-0.005	0.07	-0.07	.95
	Before versus during the pandemic	0.04	0.01	2.70	**.01**
	Timespan	-0.01	0.007	-1.55	.12
	Timespan interaction	0.005	0.005	1.00	.32
	Sex (Male)	-0.09	0.01	-7.76	**<.001**
	Age	0.02	0.004	4.20	**<.001**

Anxiety symptoms (level 3 ICC = 0.56)	Intercept	0.17	0.06	3.11	**.002**
	Before versus during the pandemic	-0.05	0.01	-5.09	**<.001**
	Timespan	-0.03	0.006	-4.24	**<.001**
	Timespan interaction	0.03	0.005	7.00	**<.001**
	Sex (Male)	-0.08	0.01	-7.47	**<.001**
	Age	0.01	0.003	3.66	**<.001**

Note: ICC = intraclass correlation coefficient

Table 4. Summary of fixed effects of the model with race/ethnicity moderating the time effect on depression and anxiety symptoms.

Outcome	Parameter	*b*	*SE*	*t*	*p*
Depression symptoms (level 3 ICC = 0.41)	Intercept	-0.02	0.08	-0.25	0.80
	Before versus during the pandemic	0.04	0.02	2.60	**.01**
	Timespan	-0.01	0.01	-1.71	.09
	Timespan interaction	0.01	0.01	1.17	.24
	Sex (Male)	-0.08	0.01	-6.84	**<.001**
	Age	0.02	0.01	3.61	**<.001**
	Asian	-0.03	0.03	-0.93	.36
	Biracial/Multiracial	0.01	0.02	0.54	.59
	Black/African American	0.00	0.02	0.17	.87
	Latino/Hispanic	0.01	0.02	0.61	.55
	Other race	0.01	0.04	0.22	.83

	Interaction Asian and ‘before versus during the pandemic’	0.01	0.03	0.24	.81
	Interaction Biracial/Multiracial and ‘before versus during the pandemic’	0.05	0.02	2.31	**.02**
	Interaction Black/African American and ‘before versus during the pandemic’	-0.06	0.02	-2.57	**.01**
	Interaction Latino/Hispanic and ‘before versus during the pandemic’	-0.04	0.02	-2.13	**.03**
	Interaction Other race and ‘before versus during the pandemic’	-0.07	0.05	-1.39	.17
Anxiety symptoms (level 3 ICC = 0.58)	Intercept	0.24	0.07	3.61	**<.001**
	Before versus during the pandemic	-0.05	0.01	-3.91	**<.001**
	Timespan	-0.02	0.01	-3.21	**<.001**
	Timespan interaction	0.04	0.01	7.35	**<.001**
	Sex (Male)	-0.08	0.01	-7.08	**<.001**
	Age	0.01	0.00	1.91	.06
	Asian	0.02	0.03	0.79	.43
	Biracial/Multiracial	0.03	0.02	2.07	**.04**
	Black/African American	0.01	0.03	0.30	.76
	Latino/Hispanic	0.03	0.02	1.56	.12
	Other race	0.05	0.04	1.23	.22
	Interaction Asian and ‘before versus during the pandemic’	-0.05	0.03	-2.07	**.04**
	Interaction Biracial/Multiracial and ‘before versus during the pandemic’	0.04	0.02	2.20	**.03**
	Interaction Black/African American and ‘before versus during the pandemic’	-0.03	0.03	-1.04	.30
	Interaction Latino/Hispanic and ‘before	-0.05	0.02	-2.70	**.01**

	versus during the pandemic'				
	Interaction Other race and 'before versus during the pandemic'	-0.04	0.04	-0.88	.38

Note: 'White' was used as the reference category; no. of observations = 2782 for depression model and 2068 for anxiety model. ICC = intraclass correlation coefficient.

Table 5. Summaries of fixed effects of the significant models including the interaction with case rate

Outcome	Predictor	Parameter	*b*	*SE*	*t*	*p*
Depression symptoms (level 3 ICC = 0.44)	Case rate	Intercept	-0.02	0.08	-0.29	.77
		Before versus during the pandemic	0.03	0.01	2.42	**.02**
		Timespan	-0.01	0.009	-1.40	.16
		Timespan interaction	0.005	0.005	0.86	.39
		Sex (Male)	-0.09	0.01	-7.19	**<.001**
		Age	0.02	0.005	4.00	**<.001**
		Case rate	0.01	0.01	1.12	.26
		Case rate interaction	-0.03	0.007	-4.69	**<.001**

Note: ICC = intraclass correlation coefficient

Table 6. Summaries of fixed effects of the significant models including the interaction with government restriction level

Outcome	Parameter	*b*	*SE*	*t*	*p*
Depression	Intercept	-0.02	0.08	-0.28	.78

symptoms (level 3 ICC = 0.44)	Before versus during the pandemic	0.04	0.01	2.76	**.01**
	Timespan	-0.01	0.01	-1.49	.14
	Timespan interaction	0.00	0.01	0.51	.61
	Sex (Male)	-0.09	0.01	-7.52	**<.001**
	Age	0.02	0.01	4.05	**<.001**
	Government restriction level	-0.01	0.01	-0.66	.51
	Government restriction level interaction	0.02	0.01	2.97	**<.001**
Anxiety symptoms (level 3 ICC = 0.57)	Intercept	0.15	0.06	2.53	**.01**
	Before versus during the pandemic	-0.04	0.01	-4.32	**<.001**
	Timespan	-0.03	0.01	-3.74	**<.001**
	Timespan interaction	0.03	0.01	5.79	**<.001**
	Sex (Male)	-0.08	0.01	-7.16	**<.001**
	Age	0.01	0.00	3.95	**<.001**
	Government restriction level	-0.01	0.01	-1.28	.20
	Government restriction level interaction	0.03	0.01	5.45	**<.001**

Note: ICC = intraclass correlation coefficient

Table 7. Findings of 'leave one out' analyses, indicating the number of times findings remained consistent with the original analysis.

Analysis	Depression		Anxiety	
	#	Influential samples	#	Influential samples
Main change	9/9	none	4/11	ARC, EFC, KLG, LIS, MFS, SDS, TAB
Age	9/9	none	5/11	ARC, BLP, MFS, SDS, TAG, TGR
Race/ethnicity	7/8	TAG	9/9	none
Case rate	8/9	TAG	6/11	ARC, BLP, MFS, SDS, TAG, TGR
Death rate	5/9	MFS, LIS, NTTTP, TGR	9/11	TAB,TAG
Government restrictions	8/9	TAG	10/11	TAG

Table 8. Response rates and Covid-sample retention rates per study.

Study	Recruitment %	COVID Retention %	Difference by age	Difference by sex	Difference by race
ARC	Unknown	20.6	NS	NS	N/A[1]
BLP	82	37	NS	*[2] (fewer males)	NS[2]
EFC	Unknown	60	NS	NS	NS
KLG	Unknown	100	N/A	N/A	N/A
LIS	82.1	90.8	NS	NS	NS
MFS	Unknown	37.3/42	*[3] (lower age)/NS	NS	*/* (more White, fewer Black)
NT/TTP	76.2 /61	82/80.4	NS/NS	NS/*[4] (more males)	NS/NS
SDS	31.4	35.2	NS	NS	NS

TAB	22.0	56.3	NS	NS	NS
TAG	65	73	NS	NS	NS
TGR	MDD: 57.7, control: 73	53.2[*5]	NS	NS	NS
CAT	81	52	NS	NS	*[6] (fewer Latinx/ Hispanic)

Note: Percent recruitment rate is the percentage of people that indicated they were interested in the study out of the number of people originally contacted for the study at wave 1. For some studies that had exclusion criteria (e.g., MDD), the percent of people eligible to participate was smaller than total interest. Percent of COVID retention is the percentage of people who completed at least one COVID-related measurement, compared out of the number of people contacted to participate in the COVID data collection. Age, sex, and race differences were calculated based on who participated in COVID-related measurement versus those contacted for COVID-related measurement. NS = no significant difference between groups. N/A = not applicable; 100% contacted for COVID-study, participated. Unknown= this information was not available based on recruitment methods (e.g., flyers in the community, entire school districts). * = significant differences between people who participated in at least one COVID-survey versus who were contacted, but did not participate in COVID-surveys. For any group that had significant differences, the directions of those differences are shown below.

1. ARC did not collect information on race.

2. In BLP, females were more likely to respond to COVID-study than males (no/yes: females 48/42; males 41/11). The test of differences by race (NS) was based on country of birth.

3. The MFS study contains two sub-samples. University of Missouri sample: age (significantly lower age; COVID-study M = 12.36, SD = 1.62; not in COVID-study M = 12.92, SD = 1.65). Race: only difference was with Black/African American group: $t(242) = -2.94$, $p = .004$ (yes 8.8%, no 23.5%). University of South Florida Sample did not have significant age differences. Race: Higher percentage of White (yes 75%; no 54%) and lower percentage of Black/African American adolescents participated in COVID-study (yes 23%; no 47%).

4. NT/TTP contains two sub-samples. In TTP, males were more likely to complete COVID-survey than females (no/yes: females: 40/47; males: 24/65).

5.TIGER COVID-retention rate is reported as total. By sample it was 43.64% MDD sample; 75% control. No significant differences in demographics, but the MDD group had significantly lower retention than the control group.

6. For CAT, latino/Hispanic participants were less likely to complete COVID-surveys (0% versus not in COVID-sample 10%).

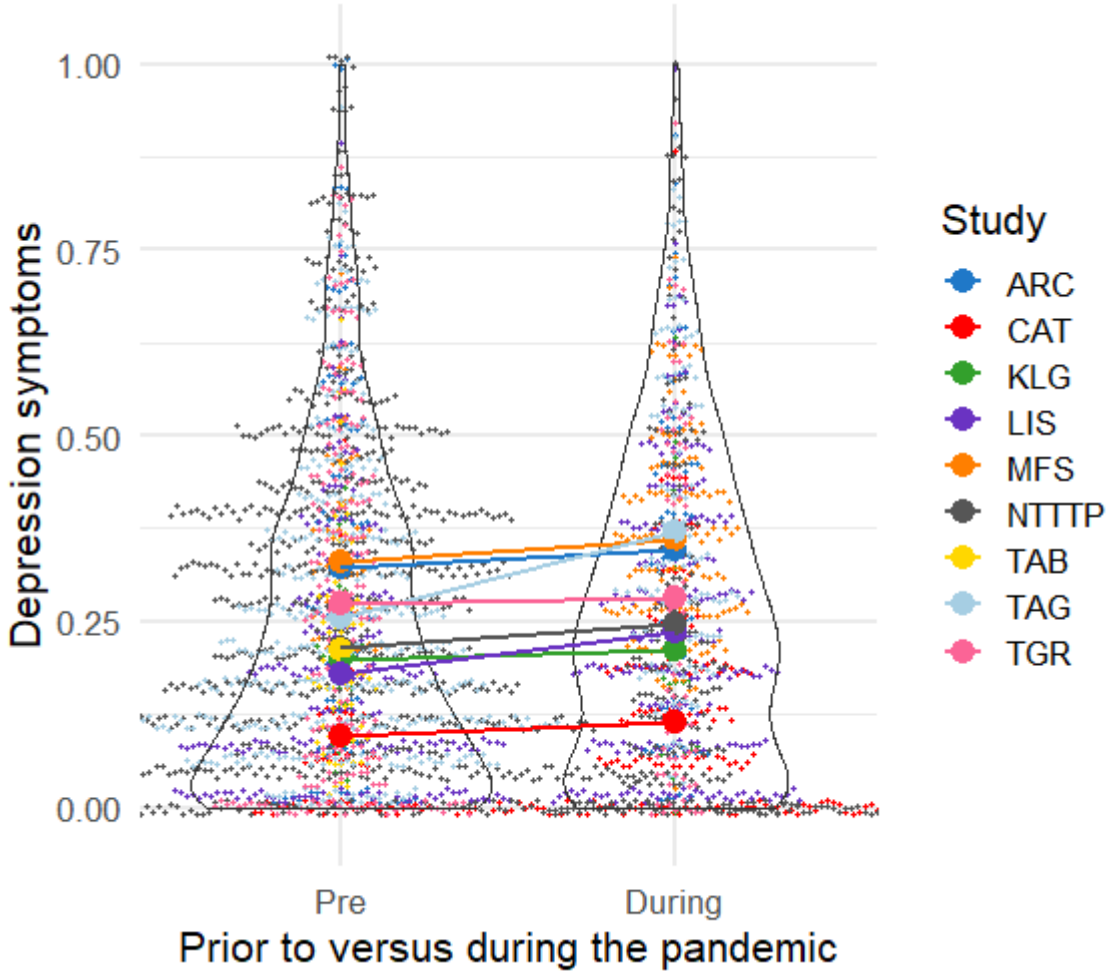

Figure 1. Depression symptoms prior to and during the pandemic in proportion of maximum score. Colors indicate which study the individual data points belonged to and the bigger dots depict means of each study at each time point, connected by a line. Note that jitter was added to visualize overlapping data points.

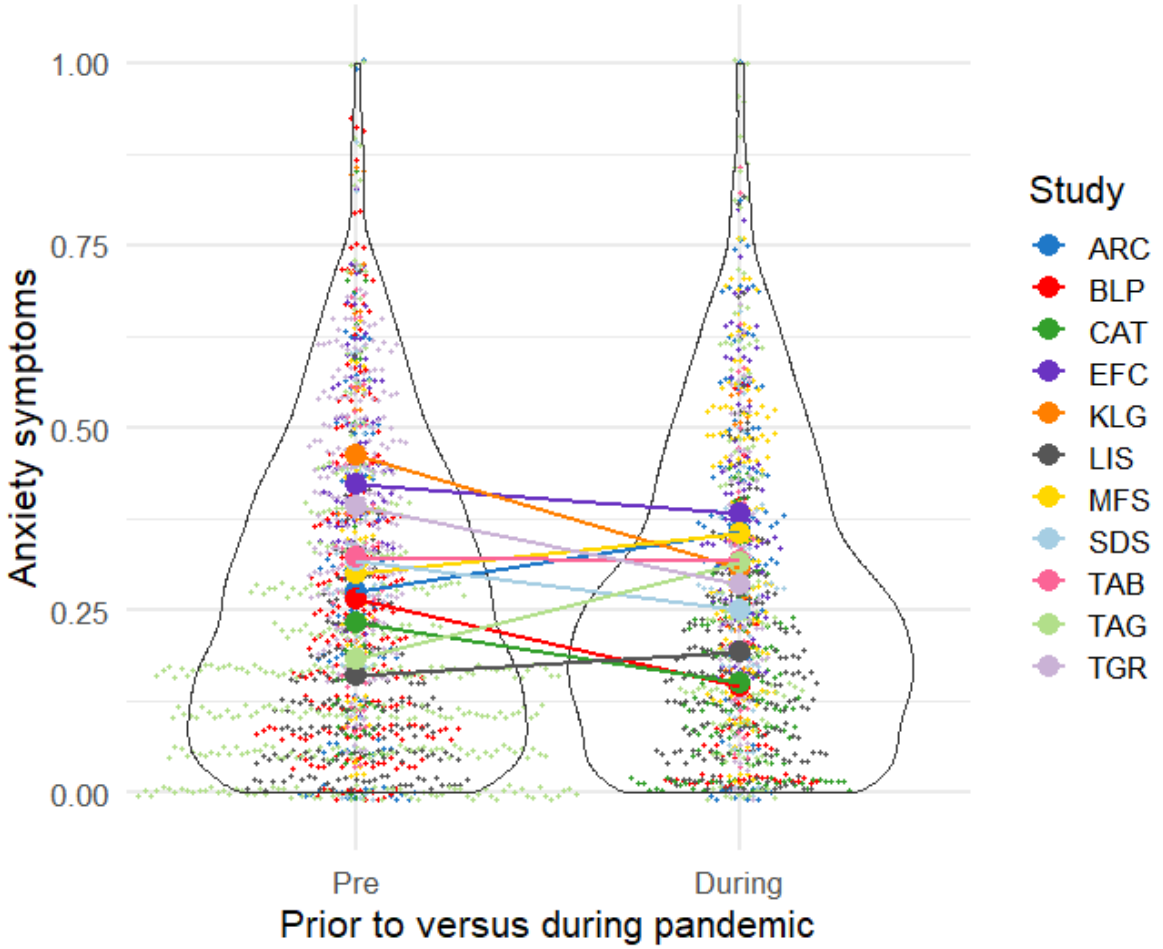

Figure 2. Anxiety symptoms prior to and during the pandemic in proportion of maximum score. Colors indicate which study the individual data points belonged to and the bigger dots depict means of each study at each time point, connected by a line. Note that jitter was added to visualize overlapping data points.

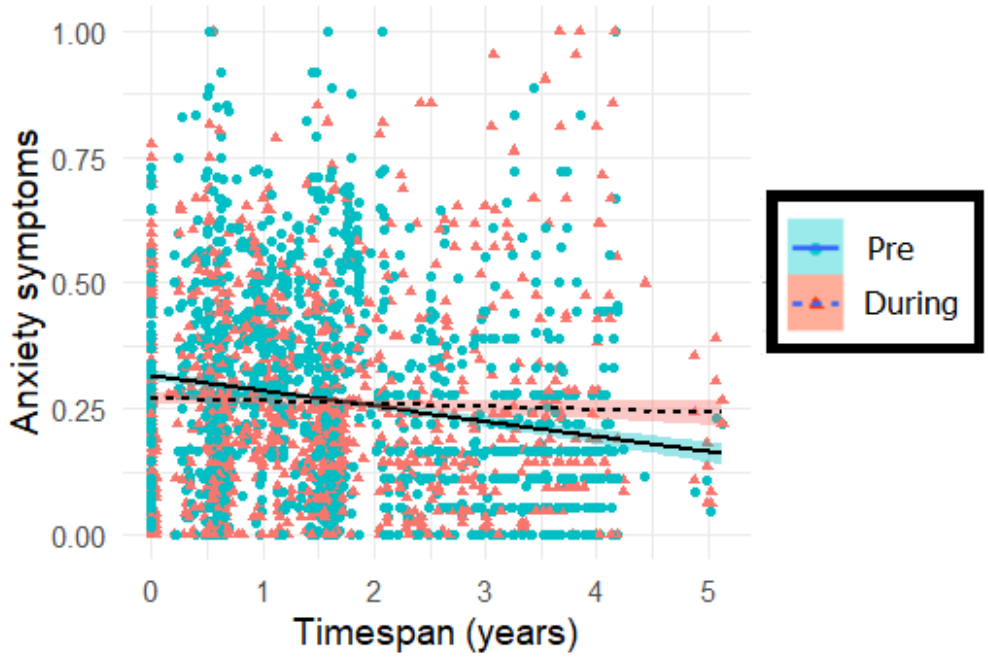

Figure 3. The change in depression and anxiety symptoms from prior to ("Pre") to during ("During") the pandemic in relation to adolescents' age at the start of the pandemic.

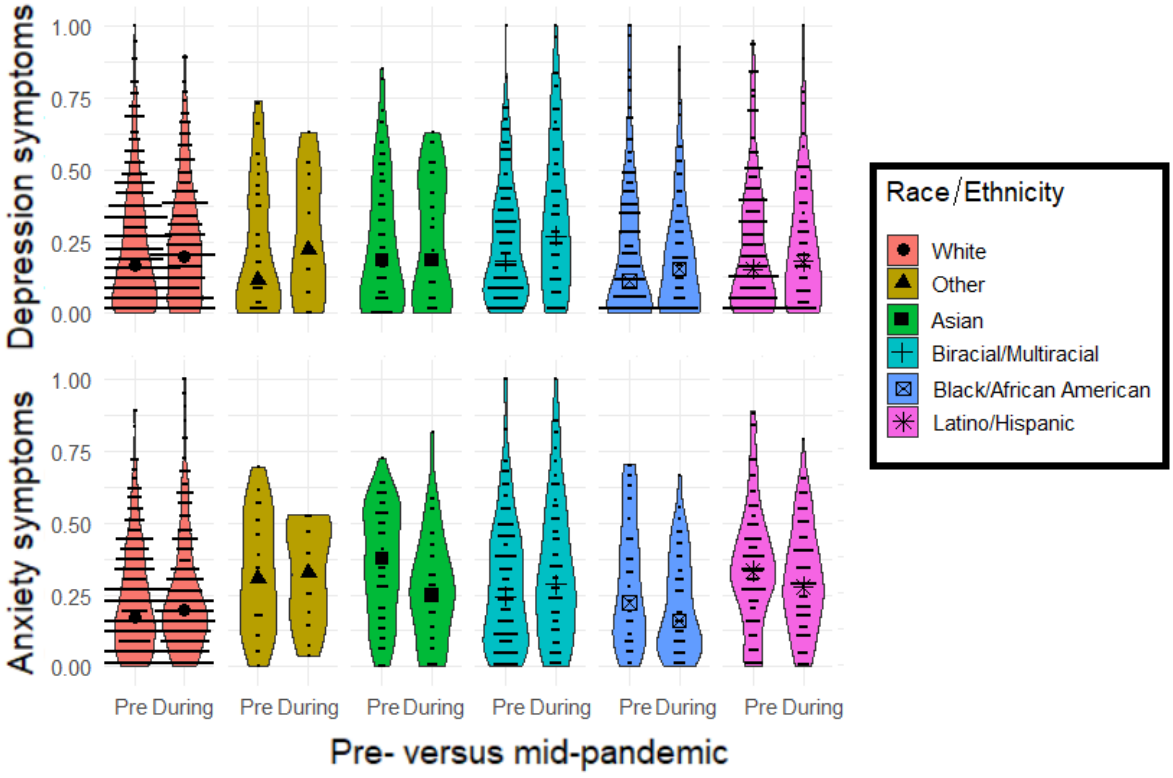

Figure 4. The change in symptoms from prior to ("Pre") to during ("During") the pandemic by race/ethnicity of the adolescent. The larger black symbol is the median for that racial/ethnic category and time point.

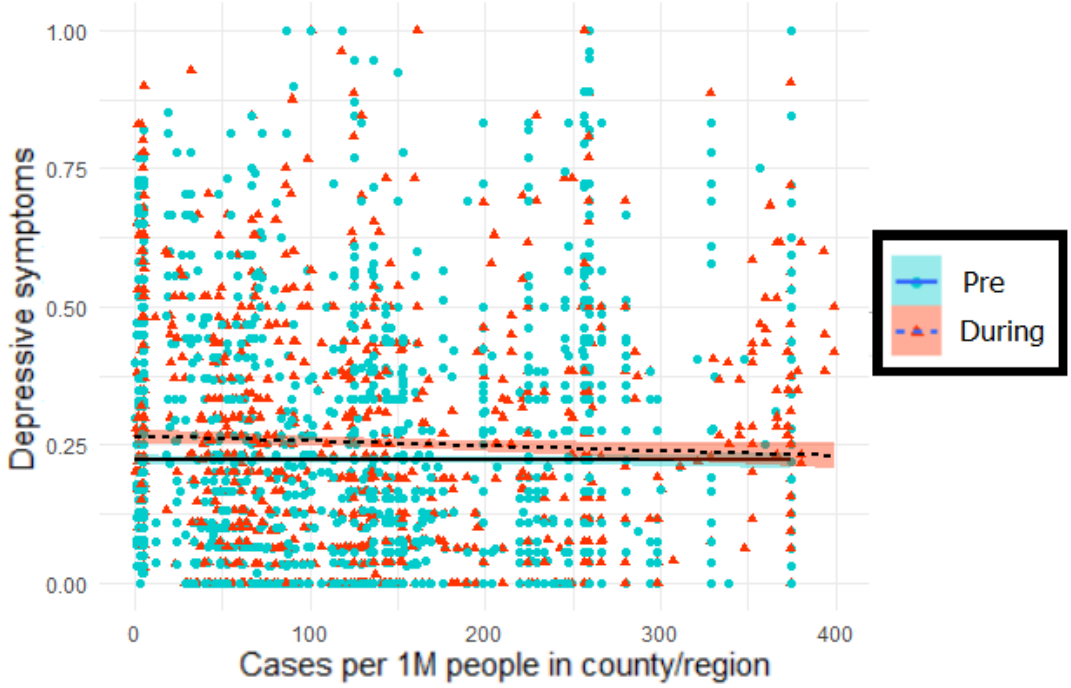

Figure 5. Changes in symptom levels in relation to case rates in the participant's county or region. Note that data from TAB were removed from this plot, since they formed an extreme outlier.

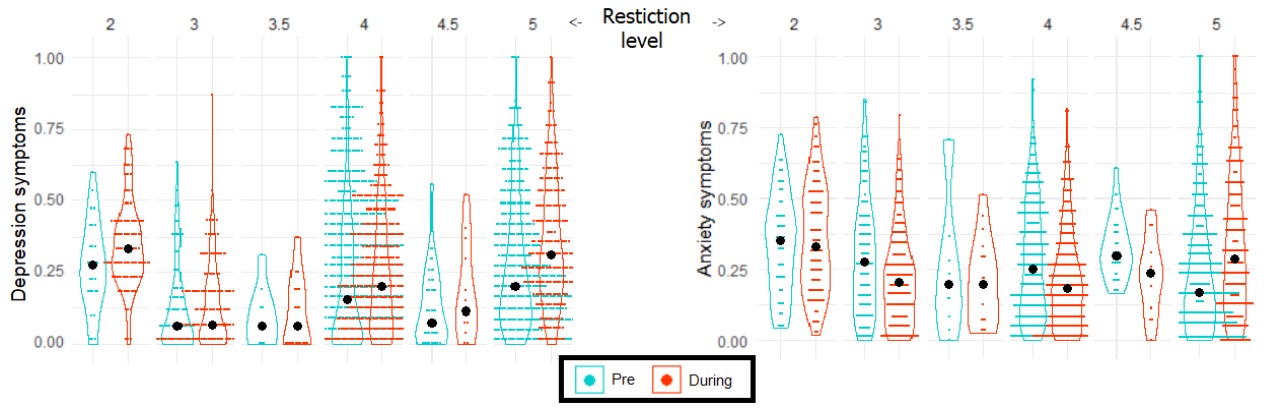

Figure 6. Changes in depression (left) or anxiety (right) symptoms in relation to government restriction levels in the participant's county or region. The larger black dots represent the median for that restriction level and time point.