Longitudinal change in adolescent depression and anxiety symptoms from before to during the COVID-19 pandemic: A collaborative of 12 samples from 3 countries

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Abstract

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 from three countries (9-18 years old, 59% female). 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 symptoms increased significantly (median increase=28%), whereas anxiety symptoms remained stable overall. 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; anxiety; adolescence

Introduction

There is widespread concern that child and adolescent mental health has been negatively impacted by the COVID-19 pandemic (Golberstein et al., 2020; Guessoum et al., 2020; Holmes et al., 2020; Lee, 2020; Racine et al., 2020), but thus far with limited empirical evidence. 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). Further, 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), tasks which are 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; Bignardi et al., 2020). However, a (non-peer-reviewed) paper reported no change in depression symptoms and reduction in risk for anxiety in British 13- to 14-year olds (Widnall et al., 2020), and another non-peer-reviewed report showed non-significant increases in the percentage of adolescents with a 'probable mental disorder' from 2017 to 2020, with no information by type of mental health problem (Vizard et al., 2020). There is still limited evidence of longitudinal changes in mental health from before 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 to during the first six months of the COVID-19 pandemic within a collaborative sample of over 1300 adolescents from 3 countries.

The pandemic might not affect the mental health of all adolescents to the same extent. Information on potential moderators such as age and race/ethnicity 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 been differentially impacted by the pandemic. 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 has been 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), which is likely the result of a myriad of factors, including socioeconomic status, cultural clashes and compounding exposure to stressors. 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 the mental health of Black, Indigenous, and People of Color (BIPOC) adolescents is disproportionately affected by the COVID-19 pandemic (i.e., if racial

disparities have widened). If this is the case, it might reflect discrepancies in the exposure to stressors, such as family financial stress and COVID-19-related discrimination, impacting 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?*

Moderation by disease burden or government regulations can generate hypotheses about mechanisms, with potential implications for policy decisions. 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 1738 participants had longitudinal data and no longitudinal analysis was done; Wang et al., 2020). Further, the aforementioned Australian study reported lower depression and anxiety symptoms in adolescents who felt more socially connected during the pandemic (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 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 and Analyses* for information on the categorization of race/ethnicity; 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 and retention of each study, see Supplement 1 and Supplementary Table 2. All studies were approved by their local ethics review committees and data sharing for combined analyses was done in compliance with HIPAA 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 scores were converted into proportion of maximum score (POMS), which can range from 0 to 1. The proportion of maximum score 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 participants' 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 John 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 ICC (single measures) was .776.

Table 1. Sample characteristics for each of the studies included in the collaborative analysis

Study	Main location(s)	N	No. of time points*	Dates of collection	% Female sex	Age range across all time points	Community or clinical sample	Measure of depressive symptoms	Measure of anxiety symptoms
ARC	Lima, Peru	109	2	Oct 2019 - May 2020	57	11.3-17.6	community	PROMIS Depression scale	PROMIS Anxiety scale
BLP	The Netherlands	71	8	July 2018- April 2020	62	10.6-18.0	community	none	POMS Tension
CAT	Maryland, US	66	4	June 2015- Sept 2020	53	8.4-17.8	Autism spectrum disorder and controls	CBCL withdrawn/ depressed (parent-report)	SCARED
EFC	Texas, US	108	2	Nov 2016- July 2020	48	8.2-18.2	Community (but over-sampled those with mental illness)	none	MASC (pre) /CASPE negative emotion (mid)
KLG	California, US	38	2	March 2018 - August 2020	100	8.3-13.2	Community, Latina-identifying	CDI-II	SCARED
LIS	Kentucky, US; Ohio, US; Virginia, US	237	2	August 2018 - June 2020	44	14.9-18.0	ADHD and controls	RCADS depressed mood scale	RCADS anxiety scale
MFS	Missouri, US; Florida, US	140	2	Feb 2016 - July 2020	51	10.0-18.0	community	CES-DC	RCMAS

NT/TTP	North Carolina, US	207	8 (n=68) or 5 (n=139)	Nov 2016 - August 2020	53	11.2-17.4	community	Short MFQ	none
SDS	Texas, US	63	2	Jan 2019 - July 2020	38	13.7-18.0	incarcerated youth, youth on probation, and non-arrested youth	none	RCADS generalized anxiety scale
TAB	New York, US	76	2	March 2018 - August 2020	55	12.0-16.4	High risk for anxiety disorders	CDI (pre)	SCARED
TAG	Oregon, US	174	4	Jan 2016 - April 2020	100	10.1-17.1	community	CES-DC	SCARED-R (pre) /GAD-7 (mid)
TGR	California, US	50	10	Oct 2017 - August 2020	60	13.6-18.2	Depression and controls	PHQ-9	MASC-2 (pre) /GAD-7 (mid)

*This is the number of assessment time points or waves, some participants might not have completed all of the time points. Also, how many of the time points were pre-pandemic and mid-pandemic could vary by participant within each study.

Note: CASPE=COVID-19 Adolescent Symptom & Psychological Experience; CDI=Child Depression Inventory; CES-DC=Center for Epidemiological Studies - Depression scale for Children; GAD-7=General Anxiety Disorder-7; MASC=Multidimensional Anxiety Scale for Children; MFQ= Mood and Feelings Questionnaire; PHQ-9=Patient Health Questionnaire-9; POMS Tension=Tension subscale of the Profile of

Mood States; PROMIS=Patient-Reported Outcomes Measurement Information System; RCADS=Revised Children's Anxiety and Depression Scale; RCMAS=Revised Children's Manifest Anxiety Scale; SCARED=Screen for Child Anxiety Related Emotional Disorders.

Analyses

Analyses were conducted with lme4 in R version 3.6.3 (Bates et al., 2015). Scripts are available on DOI: 10.5281/zenodo.4495772. We modeled the change in symptom levels (i.e., POMS) with the following linear mixed effects model: *symptoms ~ Before_vs_DuringPandemic + sex + age + (1 | Study/ID)* and comparing this to a baseline model without *Before_vs_DuringPandemic*. 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). Anxiety and depression symptoms were modeled separately. We then examined moderating effects of race/ethnicity by adding an interaction between that variable and *Before_vs_DuringPandemic*, using White as the reference racial category. We examined moderating effects of age, disease burden and government restrictions by adding an interaction between that (scaled) variable and *Before_vs_DuringPandemic*. Model fit was compared with likelihood ratio tests, and 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. This included rerunning main change models with an additional covariate representing the interaction between *Before_vs_DuringPandemic* and timespan. Timespan is time passed between a participant's earliest pre-pandemic assessment and their latest assessment (during the pandemic) in years. This allows us to test whether changes in symptoms occur independently of how much older a participant has gotten. We also 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, using the same model set up as described above except that *Study* was removed from the random effects (i.e., *(1 | ID)* instead of *(1 | Study/ID)*). 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 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 0.24 pre-pandemic and 0.25 during the pandemic. Current age of the adolescent did not moderate the change in depression symptoms. However, there was a significant interaction with age for anxiety symptoms: younger adolescents (<13 years old) showed a decrease in anxiety symptoms from before to during the pandemic (See Tables 2 and 3, and Figure 3). Removing the three samples that used a different questionnaire pre-pandemic versus during the pandemic for anxiety symptoms did not change the significance of the results, so reported results include these samples.

Table 2. Model fit comparisons

Model	AIC	BIC	Log likelihood	*p* (versus model one row up)
Depression symptoms				
Baseline	-1555.8	-1519.5	783.9	NA
Main time effect	-1603.6	-1561.3	808.8	**<.001**
Age interaction	-1601.7	-1553.3	808.9	.71
Main time effect (full race data)	-1484.0	-1442.5	749.0	NA
Race interaction	-1488.1	-1387.2	761.0	**.007**
Main time effect (full case rate data)	-1395.0	-1353.4	704.5	NA
Case rate interaction	-1412.3	-1358.8	715.1	**<.001**
Main time effect (full death rate data)	-1395.0	-1353.4	704.5	NA
Death rate interaction	-1396.9	-1343.4	707.5	.05

Main time effect (full restrictions data)	-1361.5	-1319.9	687.7	NA
Government restrictions interaction	-1365.9	-1312.5	692.0	**.01**
Anxiety symptoms				
Baseline	-1954.4	-1918.9	983.2	NA
Main time effect	-1953.8	-1912.3	983.9	.25
Age interaction	-1961.4	-1914.0	988.7	**.002**
Main time effect (full race data)	-1638.8	-1599.4	826.4	NA
Race interaction	-1666.6	-1570.8	850.3	**<.001**
Main time effect (full case rate data)	-1666.2	-1625.9	840.1	NA
Case rate interaction	-1695.2	-1643.4	856.6	**<.001**
Main time effect (full death rate data)	-1666.2	-1625.9	840.1	NA
Death rate interaction	-1670.2	-1618.3	844.1	**.02**
Main time effect (full restrictions data)	-1648.8	-1608.5	831.4	NA
Government restrictions interaction	-1736.2	-1684.4	877.1	**<.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	Intercept	0.05	0.07	0.72	.48
	Before versus during the pandemic	0.05	0.007	7.09	**<.001**
	Sex (Male)	-0.08	0.01	-7.70	**<.001**

	Age	0.02	0.004	3.97	**<.001**
Anxiety symptoms	Intercept	0.33	0.03	10.9	**<.001**
	Before versus during the pandemic	0.005	0.006	0.90	.36
	Sex (Male)	-0.07	0.01	-7.25	**<.001**
	Age	0.03	0.006	4.49	**<.001**
	Age interaction	0.02	0.005	3.11	**.002**

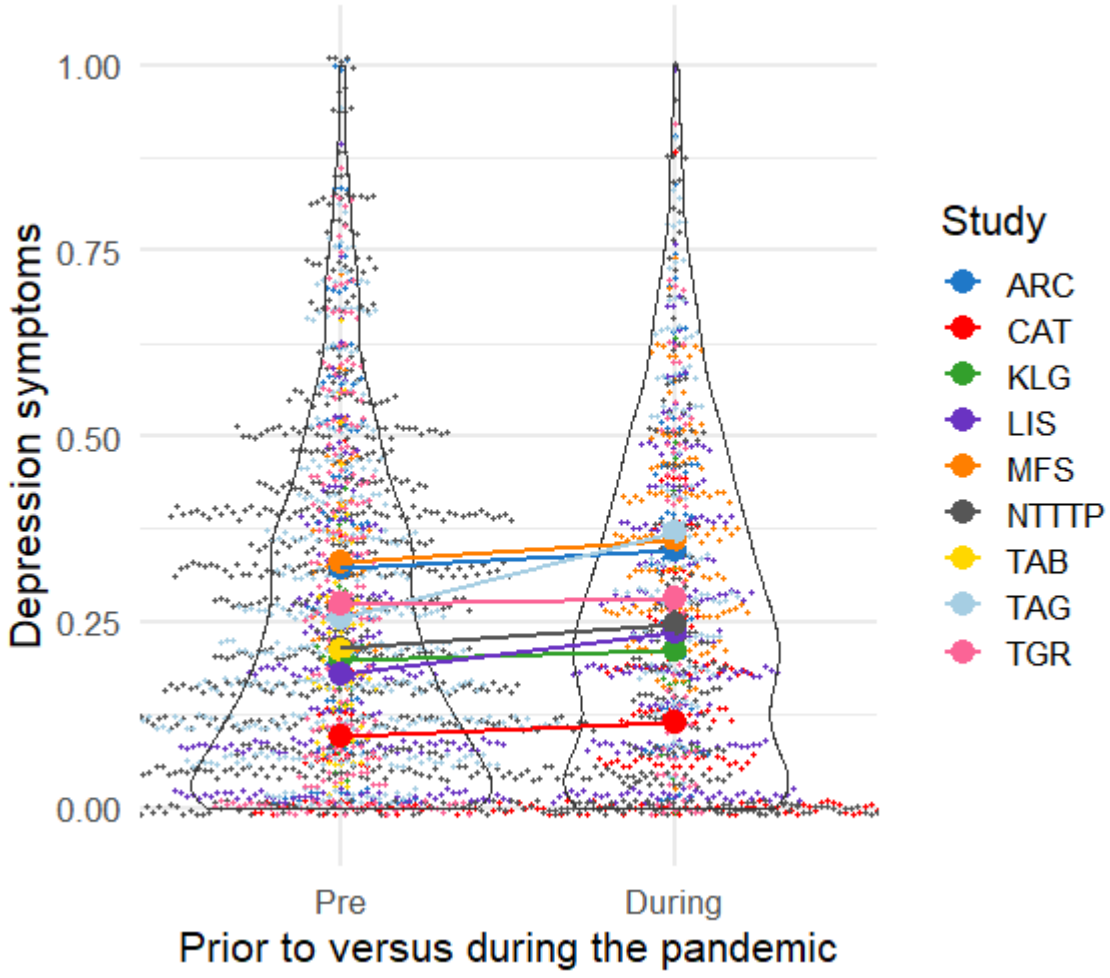

Figure 1. Depression symptoms prior to and during the pandemic in proportion of maximum score. Colors indicate which study the individual data points belonged to and the bigger dots depict means of each study at each time point, connected by a line. Note that jitter was added to visualize overlapping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

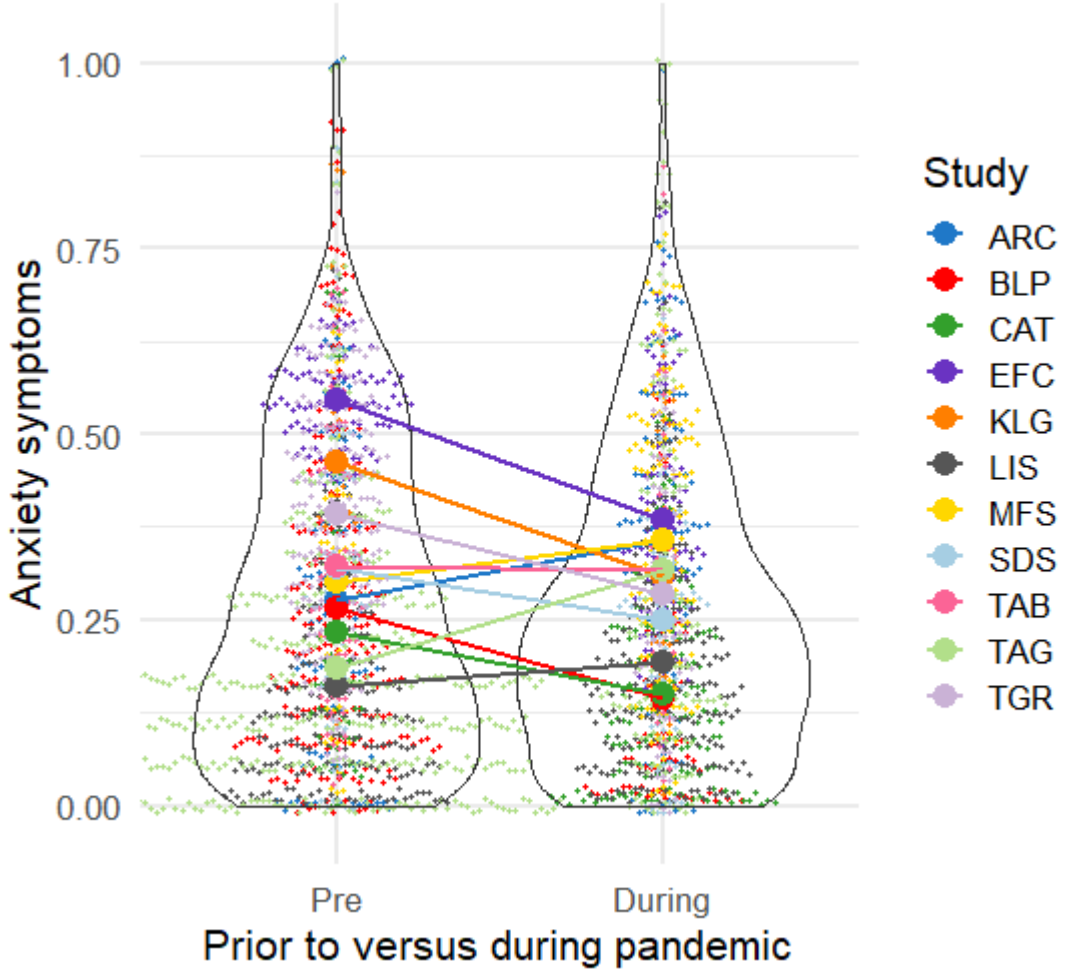

Figure 2. Anxiety symptoms prior to and during the pandemic in proportion of maximum score. Colors indicate which study the individual data points belonged to and the bigger dots depict means of each study at each time point, connected by a line. Note that jitter was added to visualize overlapping data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

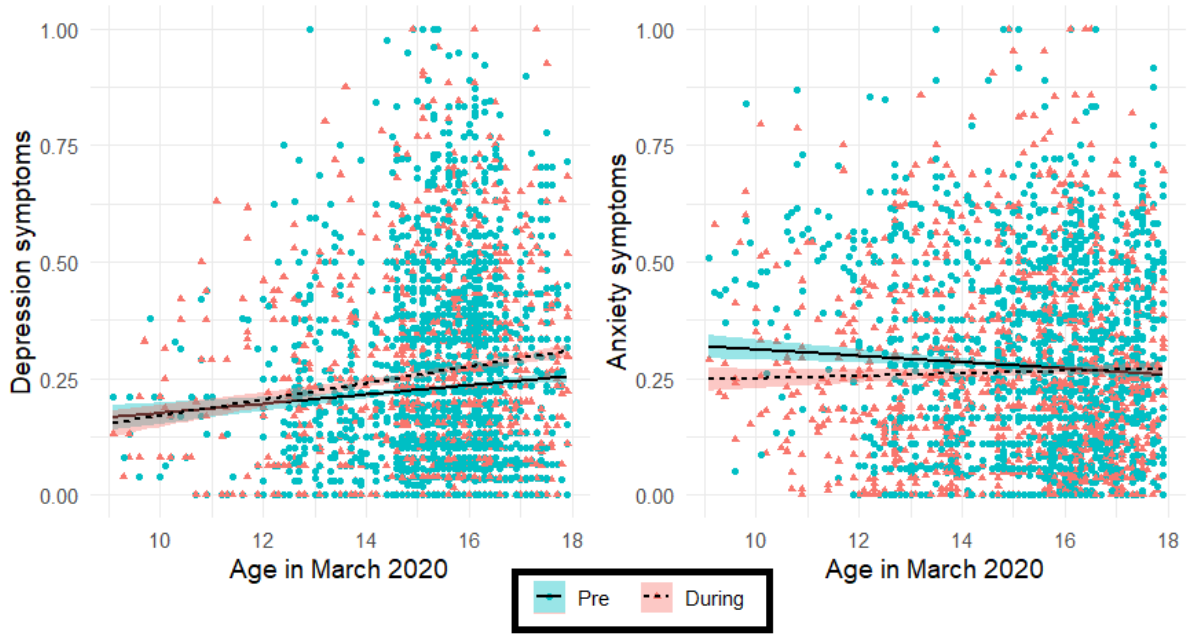

Figure 3. The change in depression and anxiety symptoms from prior to ("Pre") to during ("During") the pandemic in relation to adolescents' age at the start of the pandemic.

Race/ethnicity

There was a significant interaction with race/ethnicity for depression symptoms, with the strongest increase in depression symptoms found among biracial/multiracial adolescents. For anxiety symptoms, there was also an increase in symptoms in biracial/multiracial adolescents, but a decrease in Latino/Hispanic adolescents. 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.

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	Intercept	-0.01	0.08	-0.12	.90

symptoms	Before versus during the pandemic	0.06	0.01	6.13	**<.001**
	Sex (Male)	-0.08	0.01	-6.76	**<.001**
	Age	0.02	0.005	3.31	**.001**
	Asian	-0.03	0.03	-0.85	.40
	Biracial/Multiracial	0.01	0.02	0.62	.54
	Black/African American	0.002	0.02	0.12	.90
	Latino/Hispanic	0.01	0.02	0.57	.57
	Other race	0.005	0.04	0.13	.89
	Interaction Asian and ‘before versus during the pandemic’	0.002	0.03	0.06	.95
	Interaction Biracial/Multiracial and ‘before versus during the pandemic’	0.05	0.02	2.30	**.02**
	Interaction Black/African American and ‘before versus during the pandemic’	-0.05	0.02	-2.40	**.02**
	Interaction Latino/Hispanic and ‘before versus during the pandemic’	-0.04	0.02	-2.00	.05
	Interaction Other race and ‘before versus during the pandemic’	-0.06	0.05	-1.30	.19
Anxiety symptoms	Intercept	0.22	0.07	3.35	**.001**
	Before versus during the pandemic	0.002	0.008	0.27	.78
	Sex (Male)	-0.08	0.01	-6.92	**<.001**
	Age	0.007	0.004	1.89	.06
	Asian	0.02	0.03	0.59	.55
	Biracial/Multiracial	0.03	0.02	1.69	.09
	Black/African American	0.003	0.03	0.12	.90

	Latino/Hispanic	0.04	0.02	1.67	.10
	Other race	0.05	0.04	1.13	.26
	Interaction Asian and 'before versus during the pandemic'	-0.05	0.03	-1.81	.07
	Interaction Biracial/Multiracial and 'before versus during the pandemic'	0.06	0.02	3.07	**.002**
	Interaction Black/African American and 'before versus during the pandemic'	-0.02	0.03	-0.85	.39
	Interaction Latino/Hispanic and 'before versus during the pandemic'	-0.07	0.02	-4.25	**<.001**
	Interaction Other race and 'before versus during the pandemic'	-0.04	0.04	-0.81	.42

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

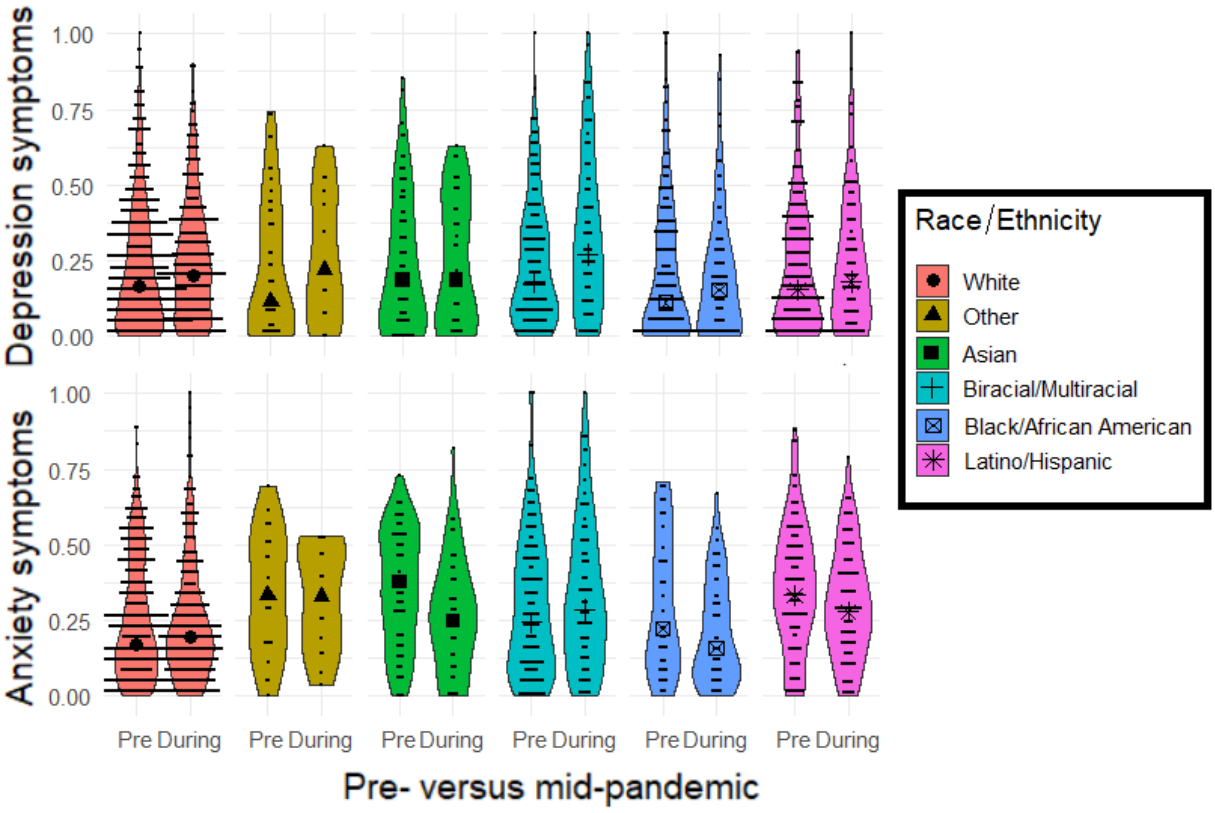

Figure 4. The change in symptoms from prior to ("Pre") to during ("During") the pandemic by race/ethnicity of the adolescent. The larger black symbol is the median for that racial/ethnic category and time point.

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. 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.

For anxiety symptoms, there was a significant interaction with case rates and death rates: symptoms decreased for participants in areas with higher rates (see Table 2 and Table 5, as well as Figure 5). The average within-person increase in anxiety symptoms was 0.01 point for those in regions with <100 cases per 1M people in the week before assessment, but -0.05 for those in regions with >200 cases per 1M. The analysis for death rates was again repeated without participants from the TAB study, but this did not change the significance of the results.

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

Outcome	Predictor	Parameter	*b*	*SE*	*t*	*p*
Depression symptoms	Case rate	Intercept	-0.02	0.08	-0.22	.82
		Before versus during the pandemic	0.05	0.007	6.49	**<.001**

		Sex (Male)	-0.08	0.01	-7.13	**<.001**
		Age	0.02	0.005	3.78	**<.001**
		Case rate	0.01	0.01	1.25	.21
		Case rate interaction	-0.03	0.007	-4.63	**<.001**
Anxiety symptoms	Case rate	Intercept	0.14	0.06	2.27	**.03**
		Before versus during the pandemic	-0.008	0.006	-1.36	.17
		Sex (Male)	-0.08	0.01	-6.91	**<.001**
		Age	0.01	0.004	3.75	**<.001**
		Case rate	0.02	0.008	1.88	.06
		Case rate interaction	-0.04	0.006	-5.73	**<.001**
	Death rate	Intercept	0.13	0.06	2.21	**.03**
		Before versus during the pandemic	-0.008	0.006	-1.33	.19
		Sex (Male)	-0.08	0.01	-6.86	**<.001**
		Age	0.01	0.003	3.75	**<.001**
		Death rate	0.01	0.008	1.46	.14
		Death rate interaction	-0.02	0.006	-2.79	**.005**

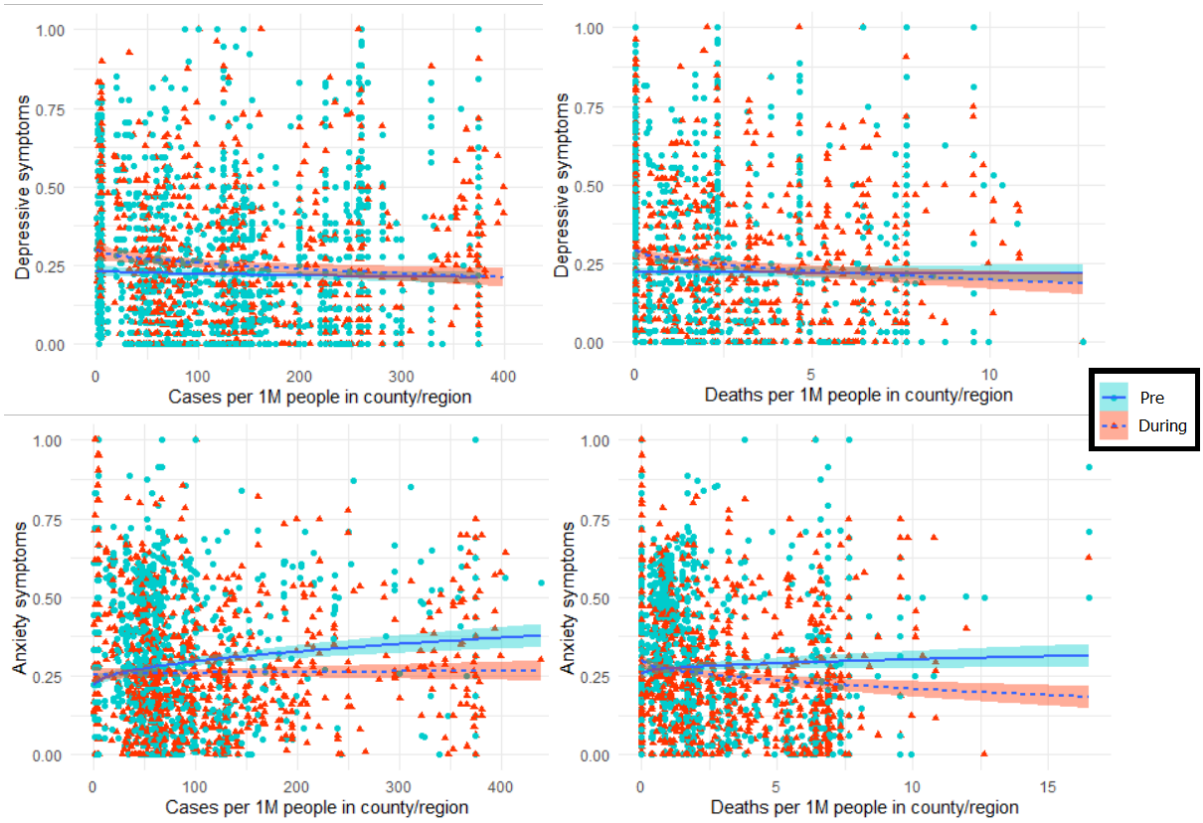

Figure 5. Changes in symptom levels in relation to case rates (left) and death rates (right) in the participant's county or region. Note that data from TAB were removed from this plot, since they formed an extreme outlier.

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.

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	-0.01	0.08	-0.14	.89

symptoms	Before versus during the pandemic	0.05	0.007	6.48	**<.001**
	Sex (Male)	-0.09	0.01	-7.44	**<.001**
	Age	0.02	0.005	3.76	**<.001**
	Government restriction level	-0.006	0.01	-0.55	.58
	Government restriction level interaction	0.02	0.008	2.90	**.004**
Anxiety symptoms	Intercept	0.14	0.06	2.36	**.02**
	Before versus during the pandemic	-0.009	0.006	-1.54	.12
	Sex (Male)	-0.08	0.01	-7.05	**<.001**
	Age	0.01	0.004	3.72	**<.001**
	Government restriction level	-0.02	0.009	-2.76	**.006**
	Government restriction level interaction	0.05	0.005	9.72	**<.001**

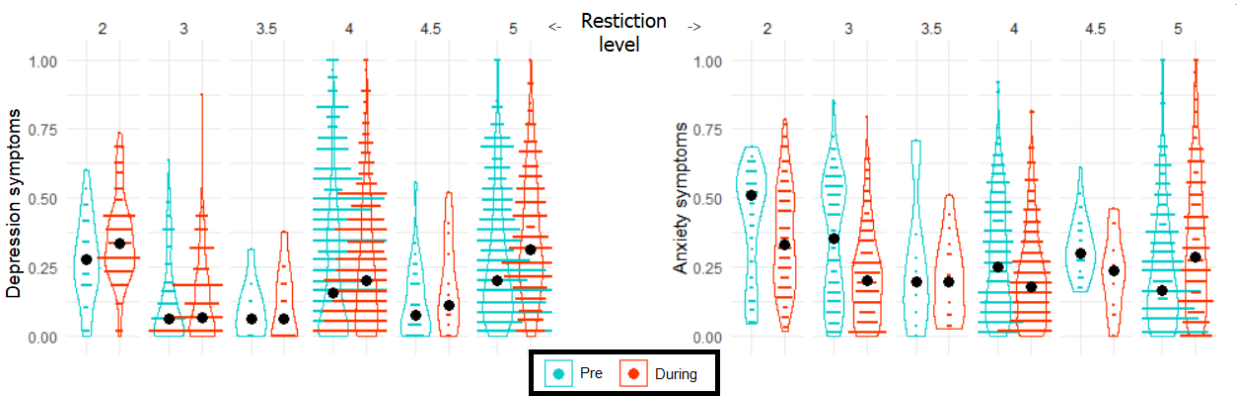

Figure 6. Changes in depression (left) or anxiety (right) symptoms in relation to government restriction levels in the participant's county or region. The larger black dots represent the median for that restriction level.

Timespan and developmental trends

Change in depression symptoms remained significant when adding an interaction between timespan and *Before_vs_DuringPandemic* (see Supplementary Table 3). In other words, depression increased no matter how much (or little) time had passed between the earliest pre-pandemic and latest post-pandemic assessment. For anxiety, there was a significant interaction between timespan *Before_vs_DuringPandemic* (see Supplementary Table 3), showing that anxiety was more likely to decrease if there was a relatively short time between a participant's earliest and latest assessment.

For the depression model, the regression coefficient for *Before_vs_DuringPandemic* was 0.05, meaning that symptoms were 0.05 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 0.05/1.68=0.03. 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 0.005/1.68=0.003, 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, with the noteworthy exception being analyses of death rate. Results of meta-analytic tests of the main change in depression and anxiety symptoms were consistent with the findings from the mixed-effect models: there was a significant change in depression, but not in anxiety (see Supplementary Table 4).

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	8/11	ARC, LIS, TAG
Age	9/9	none	8/11	EFC, KLG, LIS
Race/ethnicity	7/8	TAG	9/9	none
Case rate	8/9	TAG	9/11	EFC, TAG
Death rate	5/9	MFS, LIS, NTTTP, TGR	1/11	ARC,BLP,CAT, EFC,KLG,LIS, MFS,SDS,TAB,TGR
Government restrictions	8/9	TAG	11/11	none

Discussion

In the current study, we examined to what extent depression and anxiety symptoms of adolescents 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, but not anxiety 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, as also shown in a recent report of mental health of adults with and without internalizing disorders during the COVID-19 pandemic (Pan et al., 2020). 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 symptoms showed that their symptoms of depression, anxiety, loneliness, and worry decreased or did not change, whereas each of these domains increased in adults without a history of mental illness. Depression symptoms, but not anxiety symptoms, increased across the whole sample, which is consistent with our findings in adolescents. Although we did not distinguish based on history of mental illness, the current study was largely a community sample, and findings reflect an increase in subthreshold depression symptoms.

The lack of an overall change in anxiety symptoms during the early months of the COVID-19 pandemic (as compared to prior to the pandemic) is in contrast to previous cross-sectional studies and a longitudinal study in adolescents (Duan et al., 2020; Magson et al., 2020; Xie et al., 2020; Zhou et al., 2020). This finding might be explained by the fact that anxiety is multi-faceted: 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 general 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 studies limited our opportunity to look at changes in specific forms of anxiety. Further, anxiety may have fluctuated within the course of the pandemic and is likely to depend on the contexts adolescents are exposed to. 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 with their families. At the same time, return to school and daily (social) activities might come with an increase in anxiety symptoms because of missed opportunities for exposure (Frenkel et al., 2015; Mellick et al., 2019).

For both anxiety and depression, increases were strongest in multiracial adolescents, whereas Hispanic/Latino adolescents reported decreases in anxiety symptoms and Black/African American adolescents showed smaller increases in depressive symptoms than White adolescents. Although studies varied in their racial distribution (see Supplementary Table 1), these findings remained largely stable under the LOO analyses. Inequities in the U.S. that disproportionately add stress and hardship on BIPOC groups have led to racial disparities in anxiety and depression risk outside of the context of the COVID-19 pandemic (Anderson & Mayes, 2010) and representative surveys in adults report the highest levels of depression and anxiety symptoms in the ‘other race or multiple races’ group (Centers for Disease Control and Prevention, 2021). Further research is needed to examine mechanisms that could explain why internalizing symptoms have increased most strongly from before to during the COVID-19 pandemic for multiracial adolescents.

The change in depression symptoms was moderated by case rate, and the change in anxiety symptoms was moderated by both case rate and death rate, such that adolescents in areas with lower disease burden experienced a greater symptom increase. However, the moderation by death rate was shown to be unstable in the LOO analyses. 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 symptom increase (although findings

remained largely consistent when restriction level and disease burden were combined in the same model, see Supplementary Table 5). High local case rate and death 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, they are not communicated on platforms that adolescents follow, or because they don't inform adolescents' mental state. Humans often have difficulty intuitively understanding big numbers, so case rates going high to higher might not have a significant mental impact. Adolescents are also at lower risk, compared to older age groups, of becoming severely ill from COVID-19. 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 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 very recent study which reported that changes in depression and anxiety symptoms were stronger in adolescents who felt socially disconnected (Magson et al., 2020). 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 explicitly

test this mechanism and 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). Further, investing in sources of support to buffer negative mental health impacts, especially under 'lockdown' or 'stay-at-home' mandates, are warranted.

Limitations

The findings of this study should be considered within the context of several limitations. Importantly, causality cannot be assumed from longitudinal, observational 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. 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, 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 does not cover the wave of cases and renewed educational and social restrictions in fall 2020 to winter 2021. Finally, it is important to note that changes in depression symptoms and lack of changes in anxiety 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 internalizing 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.

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