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Fear and depression linked to COVID-19 exposure A study of adult twins during the COVID-19 pandemic

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ABSTRACT

Millions of people have been impacted by the novel coronavirus (COVID-19) pandemic worldwide. High infection rates and death tolls, combined with social distancing measures, may have unintended psychological consequences on individuals. The goal of this study was to examine the interrelations between COVID-19 exposure, fear of COVID-19, and depression among a community-based sample of adult twins. We further explored whether fear of COVID-19 mediated the association between COVID-19 exposure and depression. 732 same-sex adult twin pairs (78.1% MZ, 21.9% DZ) completed an online survey examining their feelings in May 2020. About one-fifth of the participants reported having any COVID-19 exposure. Most participants (>80%) were somewhat concerned about themselves or their household members being infected by COVID-19. The average depression level was relatively low (M = 0.9 out of 6). We found that COVID-19 exposure was related to increased fears of COVID-19 and depression, and that depressive feelings increased with fear of COVID-19. The correlation between COVID-19 exposure and depression was partially mediated by fear of COVID-19. However, these associations were confounded by familial influences. As society navigates through the pandemic, it is essential to implement public health strategies to help individuals cope with the concerns and fears about COVID-19.

1. Introduction

Since the first outbreak reported in Wuhan, China in December 2019 (Hui et al., 2020), the novel coronavirus (COVID-19) has quickly became a global concern. The World Health Organization declared the virus outbreak a pandemic on March 11, 2020 (World Health Organization., 2020). At the time of this writing, more than 10 million individuals have been infected by COVID-19, with over 500,000 deaths worldwide (Worldometer., 2020). In an attempt to slow the rates of infection and mortality, governments in most countries have implemented a variety of unprecedented public policies, ranging from social distancing, travel restrictions, and quarantine to more draconian measures such as isolation and city/country-wide lock-downs (Anderson et al., 2020). The COVID-19 pandemic has been, and is still, covered widely in different media and social media platforms (Parkpour & Griffiths, 2020). In the US, the number of infections (cases) and associated deaths are often the headlines of mainstream news media. As a result, almost everyone in the world has been impacted by the COVID-19 pandemic in some form or another.

The widespread contagion and high mortality rate of COVID-19 and drastic changes in daily lives due to mitigation strategies combined with uncertainties about economic outcomes, can have a profound impact on all individuals. Even prior to the COVID-19 being declared a pandemic, 30% out of 1,354 sampled Canadian adults reported being concerned about personally being sick from the coronavirus. Almost two-fifths (39%) said they were concerned about friends or family becoming sick from the COVID-19 (Angus Reid Institute., 2020). Among adults in the US, surveys in March and April showed that almost one-in-five (17-18%) said they have had a physical reaction (e.g., sweating, trouble breathing, nausea, or a pounding heart) when thinking about their experience with the outbreak at least some or a little of the time, and 7-9% said they felt depressed most or all of the time (Pew Research Center, 2020a; Pew Research Center 2020c). However, the extent to which fear of COVID-19 is associated with exposure to the virus, and whether fear of COVID-19 is correlated with feelings of depression, remains unclear.

The purpose of the current study was two-fold. First, we aimed to examine the associations between exposure to COVID-19, fear of COVID-19, and depression among a community-based sample of adult twins

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living in the US. A co-twin design offers a powerful alternative for understanding uncontrolled confounds in non-experimental data that is otherwise not possible among unrelated individuals. Monozygotic (MZ), or identical, twins share 100% of their genes, and dizygotic (DZ), or fraternal, twins share 50% of their segregating genes, on average. Twins from the same family, if reared together, share family background and experiences during childhood and adolescence. If the effect of COVID-19 exposure on fear or depression is truly causal, then we would expect this association to be present between twins (i.e., pairs with COVID-19 exposure would have less fear and less depressed) as well as within twins (i.e., the member of the pair with COVID-19 exposure would have less fear/depression than their co-twin without COVID-19 exposure). If the association is due to uncontrolled confounding variables such as shared genetic background or socioeconomic status, the relation will only be observed between twins but not within twins, as twin pairs share their family background and either all (for MZ twins) or half (for DZ twins) of their genetic background. Nonetheless, twin studies cannot fully control for all potential confounds. We refer to associations that have survived genetically informed tests as "quasi-causal," suggesting that the twin analysis allowed a more robust test of the causal underpinning of the association (Turkheimer and Harden, 2014).

We expected higher levels of depression among those with more exposure to COVID-19, and those who were more afraid of being infected with COVID-19. We also expected that individuals with more exposure to COVID-19 may be more worried about the virus, compared to those with less exposure. Second, we aimed to investigate whether the association between exposure to COVID-19 and depression is mediated by fear of COVID-19. The expectation was that individuals with more exposure to COVID-19 would be more worried about COVID-19, which, in turn, would be linked to higher depression levels.

2. Method

2.1. Participants

Data from the current study was obtained from a sample of 732 same-sex twin pairs (78.1% MZ, 21.9% DZ) from the Washington State Twin Registry (WSTR) who participated in an online survey examining feelings about COVID-19 and social issues related to the pandemic. The WSTR is a community-based Registry of twin pairs primarily recruited through Washington State Department of Licensing (DOL) records. Details about the WSTR's recruitment procedures and additional information are reported elsewhere (Afari et al., 2006; Duncan et al., 2019; Strachan et al., 2012). Zygosity was determined using five questions in the WSTR enrollment survey asking about childhood similarity. Compared to biological zygosity indicators, the survey items correctly classify zygosity with at least 95% accuracy (Eisen et al., 1989; Torgersen, 1979).

2.2. Procedures

Invitations to participate in this online study were sent via email to 9,562 individuals registered and active in the WSTR between May 15 and May 31, 2020. Only individuals with an US residential address were invited in order to limit the sample to US adults. The invitation email included information about the study and a link for them to complete the survey online. Participation was voluntary and no incentive was offered. The study was approved by the IRB at Washington State University. A waiver of documentation of consent was obtained, and consent was assumed by completing the questionnaire.

Response rates of the current study (31.3% and 17.4% for individual and pairwise, respectively) were comparable to other online studies conducted by the WSTR. Of the 2989 individuals who completed the survey, 20 reported that they were currently residing outside of the US and were subsequently excluded from the analyses.

2.3. Measures

2.3.1. COVID-19 exposure

Participants were asked if they have any specific experience with COVID-19 as (i) a healthcare provider, (ii) diagnosed with COVID-19, (iii) tested for COVID-19, and (iv) have had respiratory symptoms and/or fever since March 2020. Participants who checked at least one of the items were coded as having (any) COVID-19 exposure, whereas those who checked none of the items were coded as not having COVID-19 exposure.

2.3.2. Fear of COVID-19

Fear of COVID-19 was operationalized with two questions asking participants how concerned they were about (i) being infected by COVID-19, and (ii) their household members being infected by COVID-19. The three possible response categories were: 1 = not at all concerned, 2 = somewhat concerned, and 3 = very concerned. A total fear of COVID-19 score was computed by summing the two items (range = 2 – 6), with higher scores reflecting more fear of COVID-19.

2.3.3. Depression

The 2-item Patient Health Questionnaire (PHQ-2) (Kroenke et al., 2003) was used to assess depression. Participants were asked, over the past two weeks, how often they have been bothered by the following problems: (i) little interest or pleasure in doing things, and (ii) feeling down, depressed, or hopeless, on a 4-point Likert-type scale (0 = not at all, 1 = several days, 2 = more than half the days, 3 = nearly every day). A total PHQ-2 score was computed by summing the scores on the two items, with a possible total depression score ranging from 0 to 6, where higher scores reflect higher levels of depression.

2.3.4. Covariates

Participants' age, sex, race, household income, marital status, and number of children in the household were included as covariates in the statistical analyses. Age referred to individuals' age at which they completed the survey, computed based on their reported date of birth upon enrollment with the WSTR. Sex was self-reported as male or female. Race was coded as White or non-White based on participants' self-report on six response categories. Household income was self-reported on 11 response categories, ranging from less than $20,000 to $150,000 or more. Participants self-reported their marital status in six possible response categories (1 = single, never married, 2 = married, 3 = widowed, 4 = divorced, 5 = separated, 6 = living with partner). A dichotomous variable was created to categorize participants into married/cohabiting (married or living with partner) and not married/cohabiting (single and never married, widowed, divorced, and separated). Children in the household was assessed with the question, "Currently, how many children (under the age of 18) live in your household?" Possible response categories ranged from 0 to 10 or more.

2.4. Statistical analysis

We used the classical twin model to decompose the variances of each of the phenotypes (COVID-19 exposure, fear of COVID-19, and depression) into additive genetics (A), shared environmental (C), and non-shared environmental (E) components (Supplementary Figure 1). The A variance components represent the additive effect of genes; they correlate r = 1.0 between MZ twins (who share 100% of their genetic sequence) and r = 0.5 between DZ twins (who share 50% of their segregating genes, on average). The C variance components represent common, or shared, environmental experiences that make members of the same family more similar; they correlate at r = 1.0 for both MZ and DZ twins. The E variance components represent non-shared, or unique, environmental experiences; they do not correlate between twins and include measurement error.

We next used a series of bivariate twin models to examine the

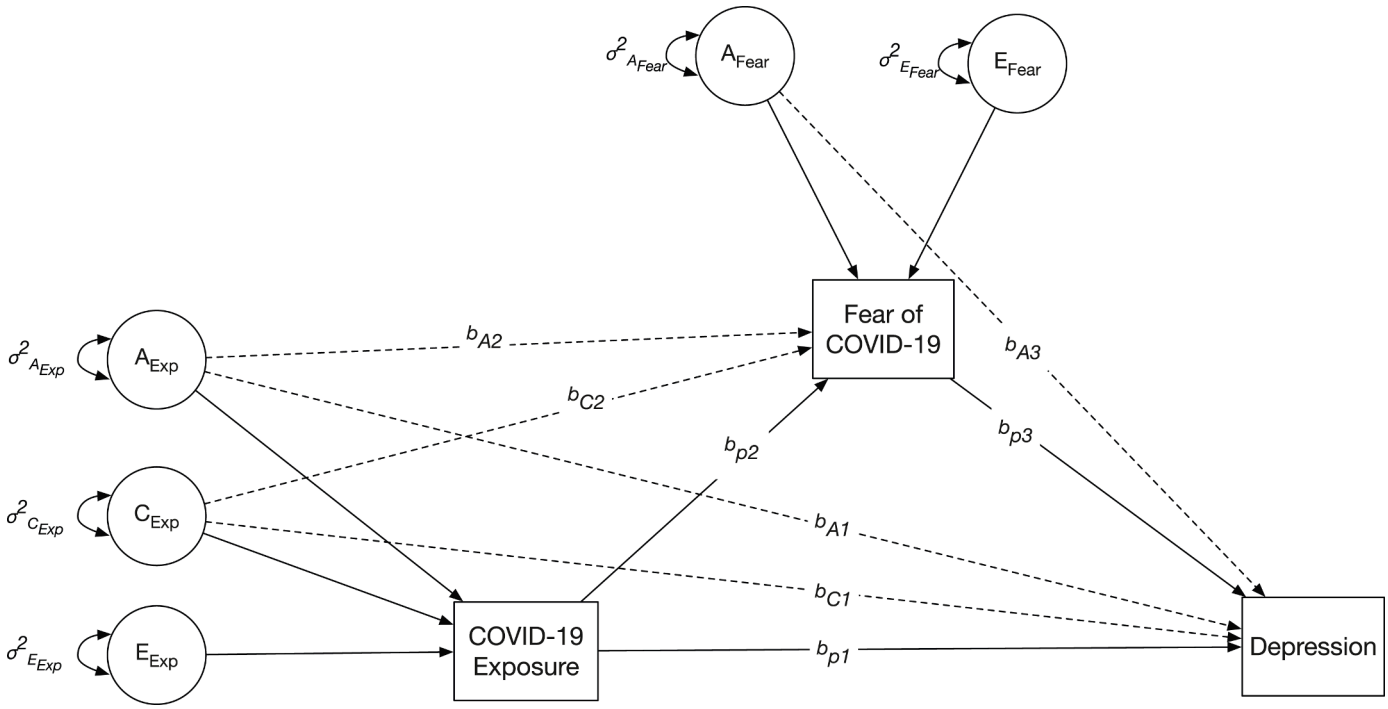

Fig. 1. Path diagram of the association between COVID-19 exposure and depression, mediated through fear of COVID-19.
Only one twin is shown for clarity. The A, C, and E latent variables (in circles) are the additive genetic, shared environmental, and non-shared environmental variance of COVID-19 exposure and fear of COVID-19. The shared environmental variance of fear of COVID-19 was fixed to zero and therefore not shown. b_{p1} represents the direct phenotypic effect of COVID-19 exposure on depression; b_{A1} and b_{C1} represent the confounding genetic and shared environmental effect of COVID-19 exposure on depression, respectively. b_{p2} and b_{p3} denote the phenotypic effect of COVID-19 exposure on fear of COVID-19, and fear of COVID-19 on depression, respectively. b_{A2} and b_{A2} represent the confounding genetic and shared environmental effect of COVID-19 exposure on fear of COVID-19; b_{A3} denotes the confounding genetic effect of fear of COVID-19 on depression. In the phenotypic model (Model 1), b_{A1}, b_{C1}, b_{A2}, b_{C2}, and b_{A3} are fixed to zero. In Model 2, all paths are estimated to evaluate the phenotypic effects, controlling for genetic and shared environmental confounds.

associations between (i) COVID-19 exposure and depression, (ii) COVID-19 exposure and fear of COVID-19, and (iii) fear of COVID-19 and depression. Supplementary Figure 2 depicts the association between COVID-19 exposure and depression as an illustrative example. COVID-19 exposure and depression are partitioned into the ACE components using the classical twin method described above. Depression is regressed on phenotypic COVID-19 exposure (b_p), the shared genetic (b_A) and common environmental (b_C) components of COVID-19 exposure. In Model 1, b_A and b_C are set to zero, and only the simple regression of depression on COVID-19 exposure (b_p) at the individual level is estimated. This model is referred to the phenotypic model (Turkheimer & Harden, 2014); it examines the association between COVID-19 exposure and depression, without controlling for genetic or shared environmental confounds.

The model is then re-estimated including estimates of b_A and b_C, which controls for genetic and shared environmental confounds, in the estimation of the phenotypic effect (Model 2). This model is referred to as a quasi-causal model (Turkheimer & Harden, 2014). If the phenotypic association between COVID-19 exposure and depression (b_p) remains significantly different from zero, after controlling for genetic and shared environmental confounds, it would be interpreted as a quasi-causal effect, meaning that depression levels differ within a pair of identical twins with different levels of COVID-19 exposure. If b_p is no longer statistically significant and reduced in magnitude after considering genetic and shared environmental confounds, a selection hypothesis is supported, meaning that there is no difference in depression levels between a pair of identical twins with different levels of COVID-19 exposure. The quasi-causal model is next estimated by including the set of covariates (age, gender, race, household income, marital status, and number of children in the household) previously described (Model 3).

Next, we investigated whether fear of COVID-19 mediates the association between COVID-19 exposure and depression (Figure 1). COVID-19 exposure and fear of COVID-19 are partitioned into ACE components using the classical twin model. Depression is regressed on the phenotypic COVID-19 exposure (b_{p1}), the shared genetic (b_{A1}) and shared environmental (b_{C1}) components of COVID-19 exposure. These are the direct effects of COVID-19 exposure on depression. The indirect effects are the regression paths of fear of COVID-19 on COVID-19 exposure (b_{A2}, $b_{C2,}$ and b_{p2}), and those of depression on fear of COVID-19 (b_{A3}, b_{C3}, and b_{p3}). In the phenotypic mediation model (Model 1), only b_{p1}, b_{p2}, and b_{p3} are estimated. This model estimates the phenotypic association between the three phenotypes, without controlling for genetic or shared environmental confounds. In Model 2, the quasi-causal mediation model includes b_{A1}, b_{c1}, b_{A2}, b_{C2}, b_{A3}, and b_{C3}, which re-estimates the phenotypic associations controlling for genetic and shared environmental confounds. The set of covariates described above are included in Model 3.

Depression is positively skewed; therefore, depression is square root transformed. Age is divided by 10 to allow variables to be on similar scales. The univariate twin model showed 0% of the variance of fear of COVID-19 was attributed to C. The C component for fear of COVID was subsequently fixed at 0, and no shared environmental confounds (b_c) were included in the models estimating the effect of fear of COVID-19 on depression. The shared genetic and environmental confounds (b_As and b_Cs) were initially estimated with large standard errors, suggesting that the parameters were not estimated with precision, indicating insufficient power to distinguish between shared genetic and shared environmental influences. Therefore, we constrained b_As and b_Cs to equality, meaning that only between-family confounds are estimated (i.e., $b_{between} = b_A = b_C$) in all subsequent models.

Descriptive statistics were performed in the statistical program R 3.5.3 (R Core Team, 2013). All latent variable path analyses were

Table 1
Descriptive statistics of select demographic characteristics of the current Washington State Twin Registry (WSTR) same-sex twins sample.

	N = 1464
Age	52.8 (15.9) Range = 21.3 – 92.7
White	1354 (92.8%)
Gender (women)	1096 (74.9%)
Zygosity (MZ)	1144 (78.1%)
Household income	
< $20,000	18 (2.1%)
$20,000-$29,999	57 (4.1%)
$30,000-$39,999	64 (4.6%)
$40,000-$49,999	70 (5.0%)
$50,000-$59,999	84 (6.0%)
$60,000-$69,999	95 (6.8%)
$70,000-$79,999	108 (7.7%)
$80,000-$89,999	88 (6.3%)
$90,000-$99,999	101 (7.2%)
$100,000-$149,999	327 (23.4%)
$150000+	368 (26.3%)
Married/living with a partner	1020 (69.7%)
Number of children in household	.5 (1.0) Range = 0 – 7
Do you have any specific experience with COVID-19? [a]	
Health care provider	170 (11.7%)
Diagnosed with COVID-19	4 (0.3%)
Tested for COVID-19	74 (5.1%)
Have had respiratory symptoms and/or fever since March 2020	73 (5.0%)
COVID-19 exposure (any) [b]	280 (19.2%)
How concerned are you about…[c]	
Being infected by COVID-19	2.0 (0.6)
Your household members being infected by COVID-19	2.0 (0.6)
Fear of COVID-19 [d]	4.0 (1.2)
Depression [e]	0.9 (1.3)

Note. Means (standard deviations) are presented for continuous variables. Frequencies (proportions) are presented for categorical variables. MZ = monozygotic twins.
[a] Participants were asked to choose all that apply for the following four items.
[b] COVID-19 exposure was coded as "yes" if participants responded "yes" to any of the four items above.
[c] Participants responded to these questions on three possible response categories (1 = not at all concerned; 2 = somewhat concerned; 3 = very concerned).
[d] Fear of COVID-19 was computed by summing the two items above (range = 2 – 6).
[e] Depression was assessed using the two-item Patient Health Questionnaire (PHQ-2).

conducted using the computer program Mplus v. 8.1 (Muthén & Muthén, 2012). The alpha level for testing hypotheses was set to 0.05. Twin-based regression models are generally saturated[1]; the only source of reduced fit involves incidental issues such as differences between twins arbitrarily assigned as Twin 1 and Twin 2 within pairs. All reported models fit the data closely using standard "goodness of fit" tests.

3. Results

3.1. Descriptive statistics

Table 1 shows the descriptive statistics of select demographic characteristics COVID-19 exposure, fear of COVID-19, and depression in the current same-sex twins sample. About one-fifth of our sample reported having any COVID-19 exposure. Most participants reported being somewhat concerned about themselves or their household members being infected by COVID-19. The average depression level was relatively low (M = 0.9 out of a possible PHQ-2 score of 6).

[1] A saturated model is one where there are as many estimated parameters as there are data points. As such, the fit of a saturated model has the best possible fit.

Table 2
Twin correlations and standardized variance components for COVID-19 exposure, fear of COVID-19, and depression among same-sex twin pairs.

	rMZ	rDZ	a^2	c^2	e^2
COVID-19 exposure[a]	.29 (.08)	.28 (.16)	.02 (.36)	.27 (.34)	.71 (.08)
Fear of COVID-19	.35 (.04)	.18 (.02)	.35 (.04)	-	.65 (.04)
Depression	.30 (.04)	.15 (.02)	.30 (.04)	-	.70 (.04)

Note. Standard errors are presented within parentheses. rMZ: monozygotic twin correlations; rDZ: dizygotic twin correlations. a^2, c^2, and e^2: standardized biometric variance components obtained from classical twin model decomposing the variance of the phenotype into additive genetic, shared environment, and non-shared environment variance, respectively.
[a] Tetrachoric correlations are presented for COVID-19 exposure due to the dichotomous nature of the variable.

3.2. Univariate twin models

Twin correlations and standardized variance components for COVID-19 exposure, fear of COVID-19, and depression are shown in Table 2. A large proportion of the variance of COVID-19 exposure is attributable to non-shared environmental influences (E = 71%), with smaller proportions attributable to shared environmental (C = 27%) and additive genetic (A = 2%) factors. The variance of fear of COVID-19 was attributable to 65% non-shared environmental and 35% additive genetic influences. The variance of depression was primarily attributable to non-shared environmental components (70%), with a smaller proportion attributable to additive genetic influences (30%).

3.3. Bivariate twin models

3.3.1. COVID-19 exposure and depression

We found a phenotypic association between exposure to COVID-19 and depression (b_p = .083, SE = .022, p < .001; Table 3). Twins with exposure to COVID-19 had, on average, higher levels of depression than those without COVID-19 exposure. However, the difference in depression levels between those with and without COVID-19 exposure was small (less than one-unit difference). After controlling for between-family confounds, the difference in depression levels between those with and without COVID-19 exposure was not different from zero (b_p = .053, SE = .047, p = .256). This suggests that the association between COVID-19 exposure and depression was confounded by between-family factors.

Results remained similar after controlling for covariates. Older individuals had, on average, lower levels of depression than younger individuals (b = -.106, SE = .014, p < .001). Depression levels were slightly higher among women than men (b = .122, SE = .038, p = .001). Those with higher household income had lower depression levels (b = -.035, SE = .007, p < .001), and participants who are married or living with a partner had lower levels of depression (b = -.087, SE = .039, p = .027).

We illustrate these results by plotting the average depression of COVID-19 by twin pairs concordant (neither twins with exposure, or both twins with exposure) and discordant (one twin with exposure, their co-twin without exposure) in COVID-19 exposure in Figure 2a. Among MZ twins (left panel), concordant twin pairs with COVID-19 exposure (rightmost bar) had higher depression levels than concordant twin pairs without COVID-19 exposure (leftmost bar). This reflects the significant phenotypic association in Model 1. Among MZ twins discordant in COVID-19 exposure (middle two bars), there was no visible difference in depression levels between the twin with and their co-twin without COVID-19 exposure, suggesting that the association between COVID-19 exposure and depression was confounded by between-family factors. We observe no visible differences in fear of COVID-19 between DZ twin pairs with and without COVID-19 exposure (right panel).

Table 3
Unstandardized parameter estimates for phenotypic and biometric models estimating the effects of COVID-19 exposure on depression and fear of COVID-19, and the effect of fear of COVID-19 on depression.

	COVID-19 exposure -> depression			COVID-19 exposure -> fear of COVID-19			Fear of COVID-19 -> depression		
	Est	SE	p	Est	SE	p	Est	SE	p
Model 1: Phenotypic model									
b_p	.083	.022	<.001	.116	.035	.001	.068	.013	<.001
Model 2: Quasi-causal model									
$b_{between}$	.091	.142	.522	.106	.222	.634	.172[a]	.074	.020
b_p	.053	.047	.256	.081	.071	.255	.014	.026	.587
Model 3: Quasi-causal model									
$b_{between}$	.036	.142	.803	.091	.229	.691	.203[a]	.074	.006
b_p	.061	.046	.189	.083	.071	.242	.012	.026	.649
Covariates									
Age	-.106	.014	<.001	-.006	.020	.767	-.096	.011	<.001
Sex (F)	.122	.038	.001	.127	.058	.029	.129	.034	<.001
Race (White)	.134	.078	.088	-.272	.143	.058	.123	.070	.078
Household income	-.035	.007	<.001	<.001	.010	.970	-.026	.006	<.001
Marital status (Married/cohabiting)	-.087	.039	.027	.232	.062	<.001	-.113	.037	.002
Number of children in household	-.016	.019	.409	-.073	.029	.013	.002	.016	.905
Goodness-of-fit									
RMSEA [90%CI]	.017 [0, .026]	.016 [0, .025]	.024 [.016, .031]						

$b_{between}$: between-family effect, it represents the cumulative effect of genetic and environmental factors shared between both twins. b_P: phenotypic associations. SE = standard error.

[a] $b_{between}$: shared genetic effect of fear of COVID-19 on depression was estimated as the 0% of the variance of fear of COVID-19 was attributable to shared environmental components.

3.3.2. *COVID-19 exposure and fear of COVID-19*

There was a positive phenotypic association between fear of COVID-19 and COVID-19 exposure (b_p = .116, SE = .035, p = .001; Table 3). Twins who reported having exposure to COVID-19 were more likely to be more fearful of COVID-19 than those with no exposure to COVID-19. This relationship was reduced and was not statistically significant after controlling for between family confounds (b_p = .081, SE = .071, p = .255). Results suggested that the phenotypic association between exposure and fear of COVID-19 was confounded by factors shared within twin pairs of the same family.

Similar results were obtained in Model 3, after controlling for covariates (Table 3). Fear of COVID-19 was higher among women (b = .127, SE = .058, p = .029), those who are married or living with a partner (b = .232, SE = .062, p < .001), and those with fewer children in the household (b = -.073, SE = .029, p = .013). However, the magnitudes of these effects were small (less than one-unit difference in fear).

As shown in Figure 2b, concordant MZ twins with COVID-19 exposure (rightmost bar in left panel) had higher fear of COVID-19 levels than concordant MZ twins without COVID-19 exposure (leftmost bar in left panel). However, there was no difference in fear of COVID-19 levels among MZ twins discordant in COVID-19 exposure (middle two bars). There was no visible difference in fear of COVID-19 levels among DZ twins with and without COVID-19 exposure (right panel).

3.3.3. *Fear of COVID-19 and depression*

There was a significant phenotypic association between fear of COVID-19 and depression (b_p = .068, SE = .013, p < .001; Table 3). Compared with twins with less fear of COVID-19, those with more fear of COVID-19 were more depressed, though the effect was small (less than one-unit increase in depression per one-unit increase in fear). This relationship was reduced and became not statistically significant after considering between-family influences (b_p = .014, SE = .026, p = .587). There was a significant between-family effect ($b_{between}$ = .172, SE = .074, p = .020), suggesting that there was a significant between-family confound common to fear of COVID-19 and depression.

In Model 3, results are similar after controlling for covariates (Table 3). On average, older individuals had lower levels of depression than younger individual (b = -.096, SE = .011, p < .001). Women had slightly higher depression levels than men (b = .129, SE = .034, p < .001). Participants with lower household income had higher levels of depression (b = -.026, SE = .006, p < .001), though the effect was small (less than one-tenth unit difference in depression per category increase in household income). Individuals who were married or living with a partner had, on average, lower levels of depression than those who were single, divorced, widowed, or separated (b = -.113, SE = .037, p = .002).

As shown in Figure 3a, the average depression levels increased with increasing fear of COVID-19, reflecting the phenotypic association between fear of COVID-19 and depression. Figure 3b plotted the within-pair difference in fear of COVID-19 against the within-pair difference in depression, which is analogous to considering between-family confounds. Within a pair of MZ twins (left panel), there was no substantial difference in depression levels between the member with more fear than their co-twin with less fear of COVID-19. A similar pattern was observed among DZ twins (right panel). These results suggest that the phenotypic association observed at the population level (Figure 3a) was confounded by between-family factors.

3.4. *Mediation model*

In Model 1, the phenotypic associations were consistent with the bivariate analyses described in the previous section (Table 4). The direct effect of COVID-19 exposure on depression was statistically significant (b_{p1} = .059, SE = .020, p = .002). There was also an indirect effect of COVID-19 exposure on fear of COVID-19 (b_{p2} = .089, SE = .031, p = .004), which, in turn, had an influence on depression (b_{p3} = .079, SE = .014, p < .001). Results suggest that the phenotypic association between COVID-19 exposure and depression was partially mediated by fear of COVID-19.

In Model 2, the direct effect of COVID-19 exposure on depression was reduced to zero (b_{p1} = -.007, SE = .035, p = .840), after considering between-family confounds ($b_{between1}$ = .320, SE = .158, p = .043). The indirect phenotypic effects were not statically significant after controlling for between-family influences (b_{p2} = -.018, SE = .055, p = .741; b_{p3} = -.007, SE = .029, p = .820). Results remained similar after further controlling for covariates in Model 3.

4. Discussion

The current study investigated the interrelations between COVID-19 exposure, fear of COVID-19, and depression among a sample of adult twins currently living in the US. We predicted that individuals with exposure to COVID-19 would be more depressed and more concerned

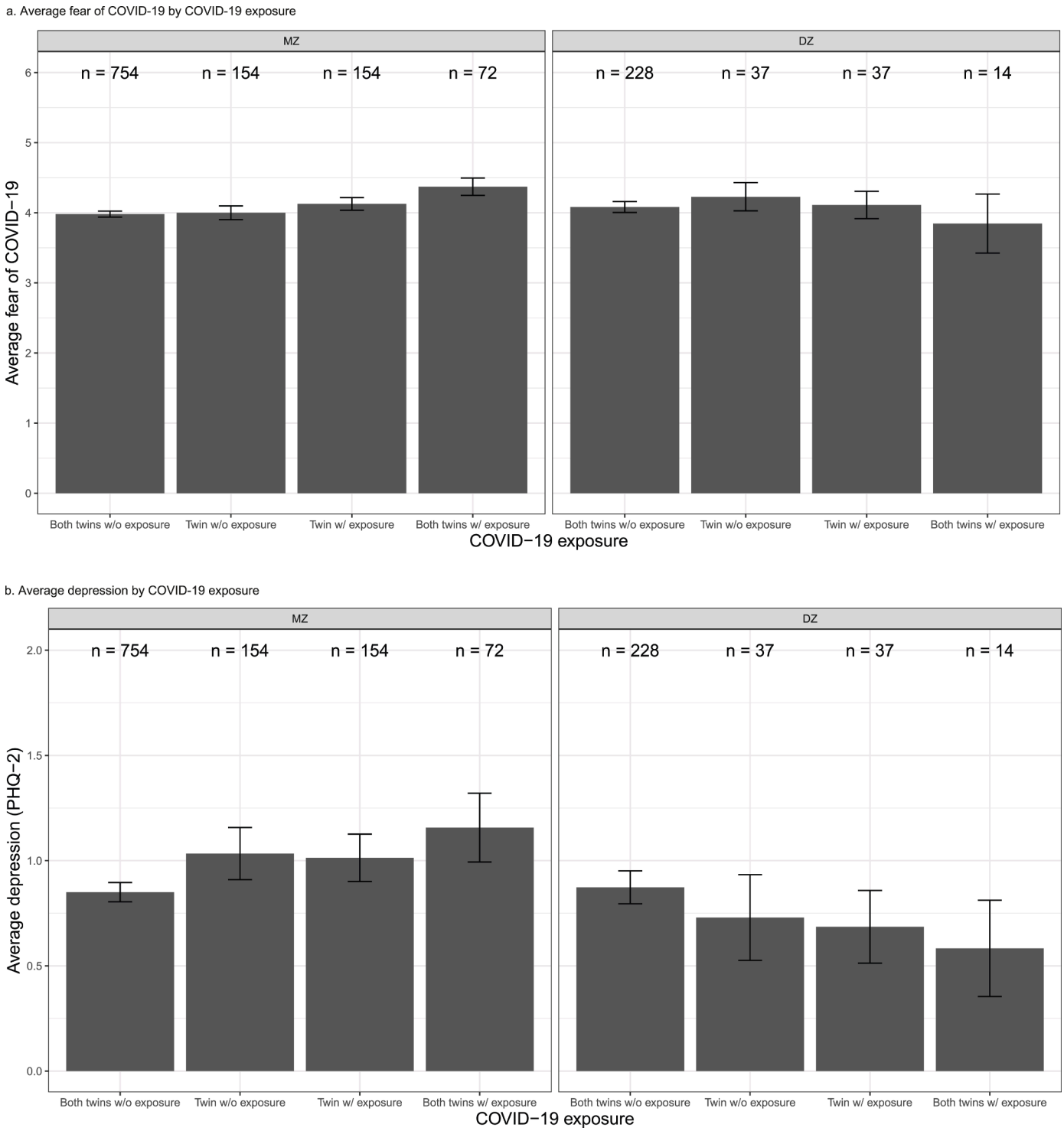

Fig. 2. Average fear of COVID-19 and depression among same-sex twin pairs concordant and discordant on COVID-19 exposure.
Note. MZ = monozygotic twins. DZ = dizygotic twins.
Average fear of COVID-19 by COVID-19 exposure.
Average depression by COVID-19 exposure.

about getting sick from the virus than those without any COVID-19 exposure. We hypothesized that participants who were more worried about COVID-19 would have higher levels of depression than those less worried about COVID-19, which was supported in the bivariate phenotypic model. Our hypothesis that the relation between COVID-19 exposure and depression would be mediated by fear of COVID-19, such that individuals with exposure to COVID-19 were more likely to be more worried about getting sick from the virus, and subsequently would have higher levels of depression, was partially supported. Results from the phenotypic mediation model showed that the association between COVID-19 exposure and depression was partially mediated by fear of COVID-19, and that there remained a significant direct association of COVID-19 exposure on depression.

However, none of these associations remained significant after

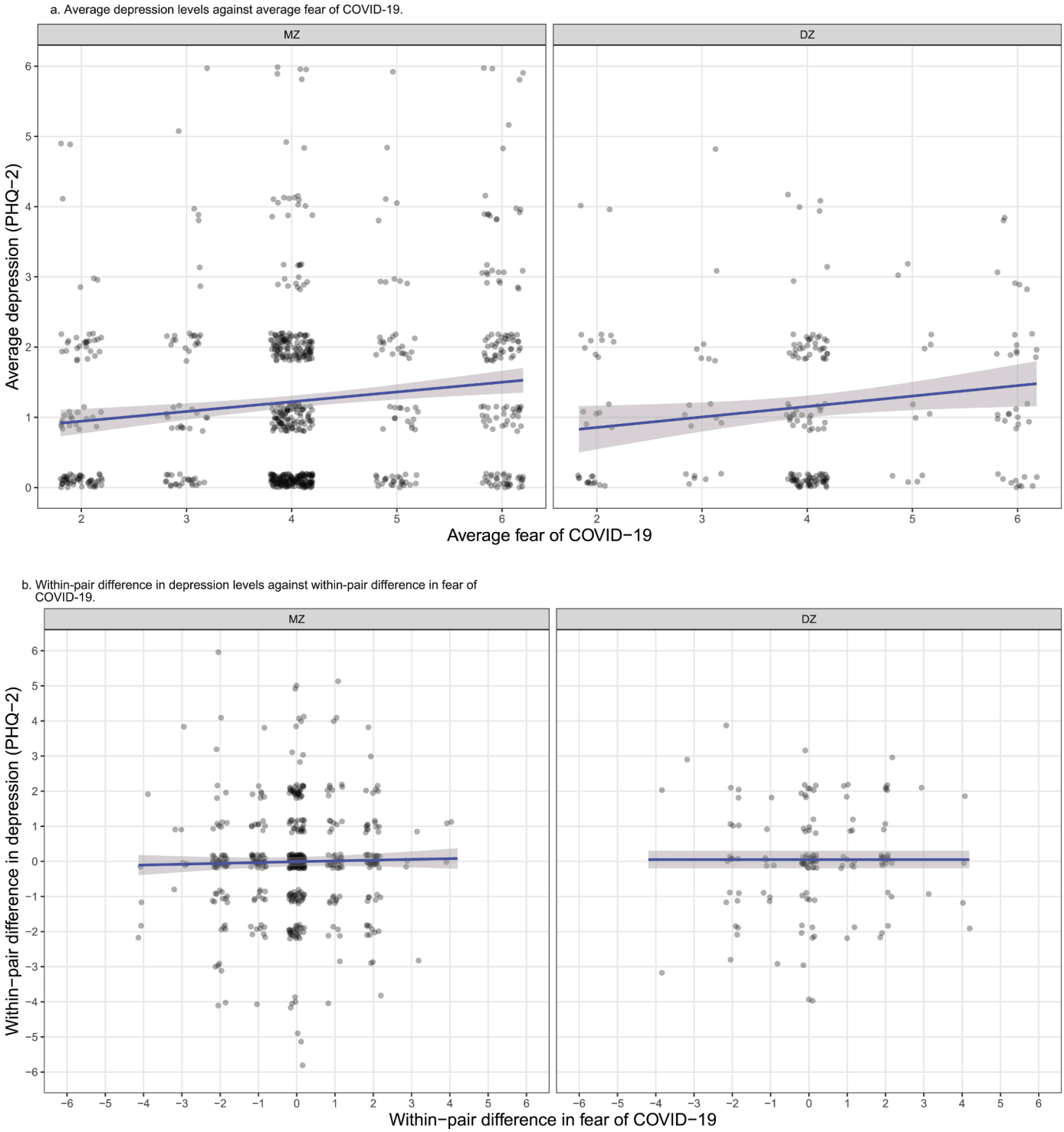

Fig. 3. Association between fear of COVID-19 and depression among same-sex twin pairs.
Note. MZ = monozygotic twins. DZ = dizygotic twins.
Average depression levels against average fear of COVID-19.
Within-pair difference in depression levels against within-pair difference in fear of COVID-19.

accounting for between-family factors, suggesting that relations observed at the population level (i.e., the phenotypic models) were confounded by genetic and environmental factors within twin pairs. The current genetically informed study provided evidence that the observed relations between (i) COVID-19 exposure and depression, (ii) COVID-19 exposure and fear of COVID-19, and (iii) fear of COVID-19, were all due to confounding familial factors. For instance, it is possible that individuals who were more health conscious and altruistic were more likely to become healthcare providers and more knowledgeable about the impact of the COVID-19 in general, thus accounting for the observed group differences in fear of COVID-19 and COVID-19 exposure. It is also likely that individuals with pre-existing medical conditions (e.g., chronic lung disease, heart conditions) were more concerned about getting sick in general and more aware about COVID-19 symptoms,

Table 4
Unstandardized parameter estimates for phenotypic and biometric models estimating the indirect effects of COVID-19 exposure on depression through fear of COVID-19.

	Model 1 Phenotypic model			Model 2 Quasi-causal model			Model 3 Quasi-causal model		
	Est	SE	p	Est	SE	p	Est	SE	p
COVID-19 exposure -> depression									
$b_{between1}$				.320	.158	.043	.209	.141	.137
b_{p1}	.059	.020	.002	-.007	.035	.840	.006	.036	.869
COVID-19 exposure -> fear of COVID-19									
b_{A2}				.466	.232	.045	.373	.255	.098
b_{p2}	.089	.031	.004	-.018	.055	.741	-.005	.056	.928
Fear of COVID-19 -> depression									
$b_{between3}$				.166	.089	.062	.181	.085	.033
b_{p3}	.079	.014	<.001	-.007	.029	.820	.004	.029	.883
Covariates									
Age							-.106	.014	<.001
Sex (F)							.133	.038	<.001
Race (White)							.128	.080	.110
Household income							-.034	.007	<.001
Marital status (Married/cohabiting)							-.090	.040	.024
Number of children in household							-.011	.019	.570
Goodness-of-fit									
RMSEA [90%CI]	.033 [.021, .044]	.028 [.015, .040]	.019 [.010, .026]						

$b_{between}$: between-family effect, it represents the cumulative effect of genetic and environmental factors shared between both twins; b_{A2}: shared genetic effect; b_p: phenotypic association. SE = standard error.
Note. Depression is square root transformed. Age is divided by 10.

which are mostly respiratory symptoms, which attributes to the group differences in COVID-19 exposure (i.e., more likely to get tested for COVID-19) and fear of COVID-19.

A majority of our participants reported 'somewhat' or 'very concerned' about being infected with COVID-19 (82.5%), and a similar proportion reported being 'somewhat' or 'very concerned' about their household member getting sick from COVID-19 (81.1%). These rates were substantially higher (< 50%) than those previously reported among Canadian (Angus Reid Institute., 2020) and US adults (Pew Research Center, 2020a; Pew Research Center 2020c). The higher proportions of concern may, in part, be attributable to the increased number of infections and deaths since the prior surveys were administered in February among Canadians, and March and April among Americans. Although older individuals (65 years and older) were at higher risk for COVID-19 (Centers for Disease Control and Prevention 2020c), we did not find significant associations between fear of COVID-19 and age in the present study. Women were, in general, more worried about getting sick from COVID-19 than men. Those who are married and/or living with are partner were also more concerned about being infected by COVID-19 than those who are single, divorced, separated and/or widowed. Interestingly, individuals with more children in the household were less concerned about themselves or their household members getting sick from COVID-19. It was recently reported that individuals 20 years old or younger are about half as likely to be infected with the virus (Davies et al., 2020). With fewer known COVID-19 cases among children (Centers for Disease Control and Prevention., 2020b), it is possible that individuals with children were less worried. It is also likely that individuals with children in the household took more preventative measures (e.g., keeping children at home, frequent handwashing), and were thus less concerned. However, it is unclear whether this trend would persist over time as approximately 100 children in the US were affected by multisystem inflammatory syndrome (MIS-C), a condition linked with COVID-19 (Centers for Disease Control and Prevention., 2020a).

In our sample, 8.1% of the respondents met the screening criteria for depression (PHQ-2 $\geq$ 3), a rate comparable to earlier surveys (Pew Research Center, 2020a; Pew Research Center 2020c). Consistent with existing studies, we found that younger adults and those with lower household income were more depressed (Pew Research Center, 2020b; Pew Research Center 2020c). Individuals with more children in the household had more depressive feelings than those with fewer children, though the effect was very small. Additionally, we showed that individuals who were married and/or living with a partner were less depressed than those not married or living with a partner, suggesting that being in a close relationship may provide social support that may be protective against negative feelings (Horn et al., 2013), especially during the stressful times of a pandemic.

5. Limitations

A few limitations about the current study should be noted. First, the assessment of COVID-19 exposure was somewhat limited. It is possible that individuals in other lines of employment (e.g., first responders), primary caregivers of high-risk family members, and/or family members of health care workers may have had higher likelihoods of COVID-19 exposure. Second, fear of COVID-19 was operationalized using only participants' concern of getting sick for themselves and for their family members. Other components of fear (Schimmenti et al., 2020), such as information or lack of information (e.g., uncertainty of the effectiveness of protective measures) and action or inaction (e.g., going out to purchase essential items), were not assessed in the current study. Future research, in addition to investigating whether there were changes in the interrelations between COVID-19 exposure, fear of COVID-19, and depression over time, should consider including more comprehensive assessment of the exposure and fear phenotypes. Third, we estimated between-family confounds in our analyses rather than testing for shared genetic and environmental influences separately. With only one-quarter of the sample as DZ twins, the current study did not have sufficient statistical power to distinguish between shared genetic and environmental confounds. Fourth, the current sample, despite being community-based, was primarily white (92.8%), meaning that the present findings may not be generalizable to other non-white populations. Finally, with no information available for non-responders, it is possible that the current results may be biased by self-selection.

6. Conclusions

The present study is the first genetically informed study to examine the associations between COVID-19 exposure, fear of COVID-19, and depression during the COVID-19 pandemic. We showed that exposure to COVID-19 was linked to increased levels of fear of COVID-19 and

depression, and that depression levels increased with fear of COVID-19. The association between COVID-19 exposure and depression was partially mediated by fear of COVID-19. These phenotypic associations were confounded by between-family influences from shared genetic and environmental factors within twin pairs. Future research should investigate whether certain personality traits (e.g., conscientiousness, neuroticism) may be related to COVID-19 exposure and fear. As the numbers of COVID-19 cases and deaths continued to increase worldwide, it is essential to allocate public health resources to help individuals cope with the concerns and fears about COVID-19, with the ultimate goal of alleviating associated stigma, anxiety, stress, and other negative feelings surrounding the pandemic.

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Declaration of Conflicting Interests

The authors declare that they have no competing interests.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2020.113699.

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