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Mother and child hair cortisol during the COVID-19 pandemic: Associations among physiological stress, pandemic-related behaviors, and child emotional-behavioral health

Nicole B. Perry^{a,*}, Bonny Donzella^b, Michael F. Troy^c, Andrew J. Barnes^d

^a Human Development and Family Sciences, The University of Texas at Austin, USA

^b Institute of Child Development, University of Minnesota, USA

^c Children's Minnesota, USA

^d Department of Pediatrics, University of Minnesota, USA

A B S T R A C T

The current study assessed the associations between pandemic-related stressors and physiological stress, as indexed by hair cortisol concentration (HCC), for mothers and their children (N = 180) aged 5–14-years old (M = 8.91). The associations between maternal HCC and children's HCC and children's behavioral adjustment were also examined. Mothers reported on COVID-19-related behaviors and children's adjustment, and both mother and child participants collected and mailed hair samples between August and November of 2020. Results indicated that higher maternal HCC was correlated with living in a more urban environment, job loss, working from home, exposure to pandemic-related news, and social isolation. Child HCC was correlated with family job loss and social isolation. Mother HCC and child HCC were significantly associated, and this association was moderated by child age; younger children's HCC was more strongly associated with mothers' HCC than older children's HCC. Finally, maternal HCC was associated with greater child internalizing symptoms, but was not associated with children's externalizing symptoms. Child HCC was not associated with child behavior.

As the coronavirus disease 2019 (COVID-19) began to spread rapidly, the World Health Organization declared a global pandemic in March of 2020. Although the immediate concern was for physical illness, rapidly implemented lockdowns changed daily life for people across the United States in ways that were both unforeseen and unpredictable. What was expected to last weeks extended to over a year, raising the issues of both acute and chronic stress at a population level. Indeed, a nationally representative sample of U.S. adults showed higher reports of depressive symptoms, with over 25% reporting moderate to severe anxiety (Fitzpatrick et al., 2020). Americans also reported a significant increase in psychological distress during 2020 relative to 2018 (McGinty et al., 2020), underscoring the significant toll the COVID-19 pandemic has taken on individuals' psychological well-being.

Parents may be particularly vulnerable to pandemic-related stress. In addition to worrying about the health and safety of themselves and their children, compounded by confusing and often misleading information about disease transmission and prevention, parents were required to cope with unmet childcare needs and crisis schooling, as daycares, schools, and recreational facilities closed. Anxiety was likely exacerbated for those living in dense, highly populated areas where infection

rates rose rapidly, and for those living in multi-generational homes with at-risk loved ones. Many parents were left worrying about job loss, reduced income, and loss of healthcare for themselves and their family. A substantial number of parents experienced the added burden of accommodating remote-learning for their children, often while attempting to work from home themselves, and possibly without the internet or physical space requirements to do so. It is particularly noteworthy that families had to cope with these challenges without the normal social support structure provided by in-person contact with family and friends.

A considerable amount of recent empirical work has documented higher pandemic-related stress as reported by parents (e.g., Brown et al., 2020; Goldberg et al., 2020; McCormack et al., 2020; Miller et al., 2020; Spinelli et al., 2020). For example, Calvano et al. (2021) found that parental stress increased significantly during the pandemic, and more than 50% of parents reported being stressed by social distancing and the complications that resulted from the closure of schools and childcares (Calvano et al., 2021). In a longitudinal study of parents with children aged 5–18 years-old, researchers found that parent's stress increased from before the pandemic, and remained elevated above pre-pandemic values. Moreover, 71% of parents reported an increase in

* Correspondence to: Human Development and Family Sciences University of Texas at Austin, 108 E Dean Keeton, St. Austin, TX 78712, USA.

E-mail addresses: Nicole.perry@utexas.edu (N.B. Perry), donzella@umn.edu (B. Donzella), Mike.Troy@childrensmn.org (M.F. Troy), drbarnes@umn.edu (A.J. Barnes).

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parenting-specific stress in response to common pandemic-related challenges such as children's routines, health worries, and virtual learning demands (Adams et al., 2021).

Taken together, this growing body of literature makes clear that the COVID-19 pandemic is associated with an increase in parental-perceived stress surrounding common parenting-specific stressors that emerged post-pandemic. What is unknown, is whether pandemic-related stressors are associated with parents' stress at a biological level. Significant stressors and threats to well-being, whether actual or perceived, lead to a biological cascade resulting in increased cortisol, a glucocorticoid widely known as a stress-sensitive hormone. Therefore, measuring parents' cortisol levels is one way of assessing the effect of pandemic-related stress on parents' stress biology. While cortisol elevations are necessary for adaptive functioning, prolonged elevations can have deleterious effects on body (Fries et al., 2005) and brain functioning (Lupien et al., 1999). Thus, gaining insight into whether pandemic-related stressors, that continue to be present across many months, are associated with parents' cortisol elevations is of considerable importance.

In contrast to salivary cortisol, which is an acute measure of cortisol that is narrowly locked to sampling time (i.e., reflecting reaction to a stressor or diurnal variation), hair cortisol concentration (HCC) reflects a longer period and is a marker of chronic stress. As hair grows, circulating cortisol is continuously deposited into the hair shaft. Thus, basal cortisol levels, as well as cortisol increases in response to stressors, all contribute to HCC and as such it can serve as a biomarker of integrated hypothalamic-pituitary-adrenocortical (HPA) axis activity across weeks or months (Meyer and Novak, 2012). By obtaining a segment of hair close to the scalp, it is possible to reliably examine cumulative stress across a 3-month period that coincides with the beginning of the pandemic in the United States. To our knowledge, no study has examined parents' cortisol levels or stress biology during the COVID-19 pandemic. Thus, the first aim of the current study was to assess the associations between mothers' HCC collected during the pandemic and pandemic-related stressors.

Children have also experienced unprecedented interruptions to their daily lives which may be precipitants of mental illness, including anxiety, depression, and stress (Lee, 2020). Though the body of work is smaller, empirical studies have documented that youth indeed report increased mental health difficulties in relation to COVID-19 pandemic stressors (Tang et al., 2021; Xie et al., 2020). A large study from China, for example, found that 22% of children reported depressive symptoms and 19% of children reported anxiety symptoms (Xie et al., 2020). A second large-scale study conducted in China found that the prevalence of depressive and anxiety symptoms in youth 12–18-years old was 44% and 37%, respectively (Zhou et al., 2020). Thus, similar to parents, it is clear that pandemic stressors are associated with youths' perceived mental health. However, whether pandemic-related stress is associated with children's stress biology is not clear. To date, only one study has investigated hair cortisol concentrations in children during the COVID-19 pandemic. Hastings and colleagues followed 52 predominantly lower-income Jordanian and Syrian families with young children over the first 9 months of the pandemic and found that more negative changes to family life predicted greater HCC in youth (Hastings et al., 2021). Therefore, a second aim of the current study was to extend this work with a larger U.S. sample and test the association between children's HCC and specific pandemic related stressors most salient to children's daily lives such as social distancing from friends and family and familial resources.

In addition to common pandemic challenges that have altered children's daily routines and social support networks, such as school closures and social distancing, increased parental stress may be one mechanism in which the COVID-19 pandemic might negatively impact children's stress and emotional health. Empirical work provides preliminary evidence supporting this hypothesis (Brown et al., 2020; Chung et al., 2020). Spinelli et al. (2020), for example, found that parents'

increased pandemic-related stress was subsequently associated with children's behavioral and emotional problems (Spinelli et al., 2020). Similarly, researchers found that higher levels of parenting stress were associated with children's poorer emotional coping via less parental involvement, and that these effects were stronger for lower-income families (Spinelli et al., 2021).

Overall, these findings suggest that parents' perceived and reported psychological pandemic-related stress is associated with deleterious behavioral and emotional outcomes for children. Again, however, it is unclear whether parental pandemic-related stress at a biological level is associated with children's own stress biology or whether parent's biological stress is associated with children's emotional and behavioral health. Understanding these associations not only provides greater insight into stress biology associated with the COVID-19 pandemic for both parents and children, but it is a first step in helping to identify whether physiological stress serves as a mechanism linking COVID-19 challenges to families' mental health and adjustment. Thus, the third aim of the current study was to examine the associations between mothers' HCC and children's HCC and emotional-behavioral health.

Previous work has shown evidence of heritability in HCC. In one study of mothers and children, modest correlations emerged in infancy and toddlerhood, but became non-significant when children were 5 and 8 years old (Karlén et al., 2013). Other work examining mothers and children has reported no association between parent and child HCC (e.g., Ursache et al., 2017). Therefore, regardless of the contextual backdrop of the COVID-19 pandemic, we expected a modest correlation between maternal and child HCC due to heritability alone. However, within the shared experience of pandemic-related stressors, we hypothesized that larger correlations between maternal and child HCC might emerge; because caregiver behavior and the home environment are salient contextual factors for child development, increased physiological stress experienced by mothers during the COVID-19 pandemic may create an environment that fosters increased physiological stress and behavioral maladjustment in children. We also considered child age as a potential moderator of these associations, questioning whether younger children's HCC and emotional-behavioral adjustment may be more strongly tied to mothers' HCC given their increased time together.

Finally, it is unclear whether children's pandemic-related stress-physiology is associated with their own emotional functioning and behavior. Pre-pandemic research has shown salivary cortisol to be linked to internalizing and externalizing behavior problems (e.g., Bagner et al., 2010; Ruttie et al., 2011; Shirtcliff et al., 2005), but a growing body of empirical work shows mixed evidence of an association between HCC and children's behavioral outcomes. For example, researchers have reported no direct association between HCC and externalizing (Grotzinger et al., 2018; Kao et al., 2018) or internalizing (Ursache et al., 2017; Kao et al., 2018) symptoms, while other researchers have shown some evidence of a potential association between HCC and children's behavioral adjustment (DePasquale et al., 2021; Ferro and Gonzalez, 2020; Golub et al., 2019; Pauli-Pott et al., 2019; Schloss et al., 2018; White et al., 2017). Thus, the fourth and final aim of the current study was to add to this body of literature and examine whether child HCC during the COVID-19 pandemic was associated with parental reports of children's internalizing and externalizing symptoms.

1. The Current Study

The first aim of the current study was to assess the associations between mothers' HCC collected during the pandemic and pandemic-related stressors. We hypothesized that factors such as urbanicity, job loss, working from home, exposure to pandemic-related news, and social isolation would each be associated with mothers' increased HCC. The second aim was to test the association between children's HCC and pandemic-related stressors. We hypothesized that social isolation from family and friends and a loss of family financial resources would be associated with increased HCC for children, as these factors are most

salient to children's daily lives. The third aim was to examine the associations between mothers' HCC and children's HCC and emotional-behavioral health. We expected a modest correlation between maternal and child HCC due to heritability but hypothesized that larger correlations between maternal and child HCC might emerge given a shared environment characterized by increased pandemic-related stressors. We also hypothesized that younger children, who spend more time with caregivers, may have HCC levels and emotional behavioral health problems that are more strongly associated with mothers' HCC than older children. The fourth and final aim of the current study was to examine whether child HCC during the COVID-19 pandemic was associated with maternal reports of children's internalizing and externalizing symptoms. Given the mixed findings shown by previous work investigating association between HCC and child outcomes, a specific hypothesis was not made.

2. Method

2.1. Participants

Participants were part of a community sample of 235 mothers and their children 5–14 years of age ($M = 8.91$, $SD = 2.28$; 42% male) from a Midwestern area of the United States; 87% of children were white, 2% Asian, 2% Black, and 9% multiracial. Mothers were on average 41 years-old ($SD = 5.88$), and highly educated (45% had a 4-year degree; 50% had a master's degree or higher). The majority of mothers reported substantial financial resources (10% of families earned less than \$69,000 per year, 21% of families earned between \$70,00 and \$99,000 per year, 29% of families earned \$100,000–\$149,000 per year, 20% of families earned \$150,000–\$199,000 per year, and 20% of families earned over \$200,000 per year).

186 mothers returned hair samples for themselves and their children. Of these 186, six had significant developmental delay per parent report. Thus, the current sample included 180 mothers and their typically-developing children who had available HCC data. Mothers who returned hair samples did not differ from the overall sample on internalizing symptoms ($t(221) = 0.77$, $p = .96$), externalizing symptoms ($t(221) = 1.31$, $p = .17$), urbanicity ($t(221) = -0.10$, $p = .96$), social distancing ($t(232) = 0.14$, $p = .98$), in-person conversations ($t(232) = -0.66$, $p = .23$), income ($X^2(9, N = 235) = 9.38$, $p = .40$), job loss ($X^2(1, N = 234) = 0.03$, $p = .86$), previous health diagnosis ($X^2(1, N = 234) = 1.98$, $p = .17$), or working from home status ($X^2(1, N = 234) = 6.78$, $p = .14$).

Child participants did not have a high incidence of parent-reported COVID-19 infections during the study period. Six percent of children ($N = 10$) had a positive test/medical diagnosis, 6% ($N = 10$) had some symptoms but no diagnosis, and 88% had no signs or symptoms. However, 59% had someone in their family, or a close friend, with a positive test/medical diagnosis of COVID-19 ($N = 106$). Only two participants reported losing an extended family member to COVID-19.

2.2. Procedures

Mothers and children were recruited via emails sent to a community participant pool; community flyers; and social media. Mothers completed a consent form online and were asked to read over the assent form with their children. Upon completion of the consent processes, and

verification of child assent, mothers were given an online survey focused on their family's COVID-19 experiences and behaviors, as well as their children's emotional-behavioral health. This first assessment took place from August to September, 2020. After completion of the survey, mothers were mailed hair collection instructions and materials and asked to use a postage paid envelope to mail hair samples back to the laboratory for assay. Mothers were sent email reminders every week until the hair samples were received. Three months following the completion date of the first survey, mothers were contacted again and asked to fill out a condensed version of the same survey. This second assessment took place from November, 2020 to March, 2021. This study was approved by the Institutional Review Board at the University of Minnesota (IRB protocol number 00010012).

2.3. Measures

2.3.1. Home hair cortisol concentration (HCC) collection

Participants were mailed an illustrated booklet outlining instructions for hair collection, as well as the materials needed to collect and return the sample (see DOI [10.17605/OSF.IO/ZE69A](https://doi.org/10.17605/OSF.IO/ZE69A) for downloadable materials). The instruction booklet identified, with detailed photos, the vertex of the head as the spot for sample collection. Participants were told to cut as close to the scalp as possible. Once the hair was cut, typically with the help of someone in residence, participants were instructed to wrap the sample in aluminum foil marking the scalp end with a paperclip. Next, participants placed the wrapped sample in a sealed pre-labeled plastic bag and then returned the sample in a postage paid envelope by mail to the university. Follow-up correspondence was done weekly until samples were returned, declined, or the collection period ended. Upon arrival, samples were stored in a dry, dark cabinet. This method of unsupervised home hair collection has been validated in previous work (Skoluda et al., 2021).

Cortisol increases to pandemic conditions were obtained from both mother and child, and was determined from 3 cm of hair proximal to the scalp. Endogenous cortisol secretes into hair, and based on an average hair growth rate of 1 cm/mo, 3 cm is thought to reflect roughly 3 months of experience (Wei et al., 2013). Prior to assay, hair was cut with fine scissors into approximately 3 cm segments, retaining the portion proximal to the scalp. Variations in length result from short hair or difficult-to-measure curly hair; mother $M = 3.14$ cm, $SD = 0.35$, child $M = 3.10$ cm, $SD = 0.44$. Because HCC is a concentration measure, the length of hair does not affect the value; instead, it relates to the approximate duration of the chronic stress period. Samples from the same family were assayed in the same immunoassay batch.

Hair processing procedures for cortisol were as described in previous studies (Greff et al., 2019); 7.5 mg of hair per duplicate was submitted to luminescence immunoassay for cortisol determination, and all participants had sufficient volume for assay. Cortisol units are reported in picograms per milligram (pg/mg). Following convention (Greff et al., 2019), 8 mother and 6 child samples, or 3.2% and 4.3% respectively, were excluded as outliers, all greater than 3 SD above the mean. HCC values were transformed on the natural logarithm scale ($\ln HCC$) to approximate normality; transformed data are presented in Table 1. Descriptive statistics for raw HCC values are presented here. Mother: min = 0.52, max = 46.94, $M = 6.58$, $SD = 7.08$, child: min = 0.40, max = 49.87, $M = 6.04$, $SD = 8.08$.

Table 1
Correlations and Descriptive Statistics.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Child age	–														
2. Child Sex	-0.06	–													
3. Family Income	-0.06	0.06	–												
4. Physical Health	0.13	-0.11	-0.03	–											
5. Previous beh/emo diagnosis	0.04	-0.04	-0.06	0.08	–										
6. Covid-19 Family Job Loss	-0.04	-0.01	-0.10	0.02	-0.09	–									
7. Following Social Distancing	0.07	-0.04	0.00	0.03	0.07	-0.04	–								
8. Urban Neighborhood	0.15	0.12	-0.01	0.05	-0.06	-0.13	-0.14	–							
9. Reading about Covid-19	0.05	-0.10	-0.07	0.03	0.12	0.20*	0.21*	0.10*	–						
10. In-person Conversations	0.06	-0.10	0.00	-0.08	0.01	-0.05	-0.15*	-0.25*	-0.10*	–					
11. Mother HCC	0.01	-0.06	0.01	-0.04	0.06	0.16*	0.23*	0.18*	0.16*	-0.18*	–				
12. Child HCC	-0.17*	-0.14	-0.15	0.06	-0.02	0.22*	0.19*	0.11	0.05	-0.05	0.40*	–			
13. Externalizing Symptoms	-0.11	-0.15*	-0.14	0.13	0.31*	-0.02	-0.01	0.02	-0.01	-0.10	0.03	0.01	–		
14. Internalizing Symptoms	0.01	0.04	-0.08	0.21*	0.35*	-0.04	-0.05	0.09	0.08	-0.14	0.18*	-0.03	0.41*	–	
15. Working from Home	-0.07	-0.05	0.12	-0.12	0.01	-0.11	0.08	-0.02	0.04	-0.07	0.18*	0.11	0.05	0.11	–
Mean	8.91	1.57	7.94	1.39	0.13	0.05	4.45	1.99	3.38	9.42	1.48	1.22	00	00	0.76
Standard Deviation	2.28	0.496	1.75	0.61	0.33	0.21	0.62	0.80	0.71	10.1	0.88	1.03	1	1	0.42
Minimum	5	1	2	1	0	0	2	1	2	0	-0.66	-0.92	-1.03	-1.40	0
Maximum	14	2	10	3	1	1	5	5	5	50	3.85	3.91	5.40	3.06	1
N	180	180	180	180	180	180	179	180	180	180	174	172	180	180	180

Note: *p < .05

2.3.2. Hair treatments and medications

To assess potential covariates and contaminants to the HCC, participants reported on regular and current medication use, as well as hair treatments including frequency of shampoo, conditioner, chlorinated water, curl/straighten, chemical treatment such as straightener, color, highlight, permanent, hat or wig wearing habit, tanning booth exposure, and daily duration of outdoor light.

2.3.3. Youths' internalizing symptoms

Children's internalizing symptoms were assessed at assessment 1 and assessment 2 via mother report using the *Internalizing Scale* of the MacArthur Health and Behavior Questionnaire (HBQ-P 2.1 I; Essex et al., 2002). The internalizing subscale is comprised of 42 items across three subscales (Depression, Separation Anxiety, and Overanxious). Mothers selected (0) "never or not true," (1) "sometimes or somewhat true," or (2) "often or very true" for each item. The Internalizing subscale had good internal reliability within our sample at the first assessment ($\alpha = 0.92$) and the second assessment ($\alpha = 0.93$). There was a very high stability between mother's reports of children's internalizing symptoms at the first assessment and the assessment given 3 months later ($r = 0.80$). Due to the high correlation, and because participants provided a hair sample in the middle of assessment 1 and assessment 2, a composite of internalizing subscales across both assessments was created by averaging the z-scores associated with each measure. Higher values indicated greater internalizing symptoms.

2.3.4. Youths' externalizing symptoms

Children's externalizing symptoms were assessed at assessment 1 and assessment 2 via mother report using the *Externalizing Scale* of the MacArthur Health and Behavior Questionnaire (HBQ-P 2.1 I; Essex et al., 2002). The externalizing subscale is comprised of 38 items across four subscales (Opposition/Defiance, Conduct Problems, Overt Hostility, and Relational Aggression). Mothers selected (0) "never or not true," (1) "sometimes or somewhat true," or (2) "often or very true" for each item. The Externalizing subscale had good internal reliability within our sample at the first assessment ($\alpha = 0.93$) and the second assessment ($\alpha = 0.93$). There was a very high degree of stability between mother's reports of children's externalizing symptoms at the first assessment and the assessment given 3 months later ($r = 0.80$). Due to the high correlation, and because participants provided a hair sample in the middle of assessment 1 and assessment 2, a composite of externalizing subscales across both assessments was created by averaging the z-scores associated with each measure. Higher values indicated greater externalizing

symptoms.

2.3.5. COVID-19 experiences and behaviors

Mothers reported family experiences and behaviors regarding pandemic related practices. Because many responses to many COVID-19 variables remained unchanged from assessment 1 to assessment 2, and we wanted to capture whether participants ever experienced specific COVID-19 related events (i.e., ever lost a job, or ever worked from home), we used COVID-19 responses from assessment 2 in all analyses. The specific variables used in the current study are described below.

2.3.5.1. Previous emotional-behavioral health diagnosis. Mothers were asked "Has a health professional ever diagnosed your child with emotional or mental health problems such as depression or anxiety?" A response of "yes" was coded (1) and no was coded (0). This variable was used as a dichotomous indicator in analyses; 13% of the sample had been previously diagnosed with a mental health problem.

2.3.5.2. Urban living. Mothers reported on how large the community is in which they live. Mothers responded (1) for "large city," (2) for "suburbs of a large city," (3) for "small city," (4) for "town or village," and (5) for "rural area." For greater clarity, scores were reverse coded so that higher values reflected more urbanicity; 23% lived in a large city, 63% lived in the suburbs of a large city, 9% lived in a small city, 3% lived in a town, 2% lived in a rural area.

2.3.5.3. Reading and talking about COVID-19. Mothers reported on how often they were reading or talking about coronavirus in their family. Mothers responded (1) for "never," (2) for "rarely," (3) for "occasionally," (4) for "often," and (5) for "most of the time." Thus, higher values indicated more reading and talking about COVID-19 in the home.

2.3.5.4. Job loss. If mothers reported a loss of job within the household it was coded (1) and no job loss was coded (0). This variable was used as a dichotomous indicator in analyses; 5% of families reported a job loss due to COVID-19.

2.3.5.5. Working from home. If mothers reported working from home during the pandemic it was coded (1) and continuing to work outside the home was coded (0). This variable was used as a dichotomous indicator in analyses; 73% of mothers were working from home at the time of data collection.

2.3.5.6. *Social distancing.* Mothers were asked how often their family followed the rules about the social distancing or stay-at-home restrictions put in place in their community. Mothers responded (1) for “never,” (2) for “seldom,” (3) for “sometimes,” (4) for “often,” and (5) for “always.” Thus, higher values indicated that the family was more likely to follow social distancing or stay-at-home orders.

2.3.5.7. *In-person interactions.* Mothers were asked how many people outside their household their child had an in-person conversation with within the last two weeks. Higher numbers indicated more in-person contact.

3. Results

Descriptive statistics and correlations for all study variables can be found in Table 1. Mplus (Version 8; Muthén and Muthén, 2017) software was used to conduct analyses and Full Information Maximum Likelihood (FIML) was used to handle missing data where appropriate.

3.1. Aim 1: Pandemic-related stressors and mothers’ HCC

Family income, mother’s age, maternal steroid use, and maternal hair treatment were not associated with maternal HCC and therefore were not considered when examining associations between mothers’ HCC and COVID-19 variables. Correlations among the variables are presented in Table 1. Results showed that the extent to which mothers reported their neighborhood to be urban ($r = 0.18, p = .01$), and how often they reported reading about coronavirus ($r = 0.18, p = .03$), were associated with greater maternal HCC. Working from home ($r = 0.16, p = .04$) and pandemic-related job loss within the household were also associated with greater maternal HCC levels ($r = 0.16, p = .04$). Further, a greater compliance with following social distancing rules ($r = 0.23, p < .00$), and fewer in-person conversations ($r = -0.18, p = .02$), were associated with greater HCC.

3.2. Aim 2: Pandemic-related stressors and children’s HCC

Family income, children’s steroid use, and children’s hair treatment were not associated with children’s HCC and were therefore not considered when examining associations between children’s HCC and COVID-19 variables. Correlations among the variables are presented in Table 1. Results showed that child HCC was associated with the extent to which their family followed social distancing rules ($r = 0.18, p = .01$), and pandemic-related job loss within their household ($r = 0.22, p < .00$).

3.3. Aim 3: Mother HCC and Child HCC and emotional-behavioral health

As expected, maternal and child HCC values were significantly associated ($r = 0.40, p < .00$). Given findings from previous work (Karlén et al., 2013), we tested whether child age moderated this association using a multiple regression model controlling for child sex, child physical health, family income, child hair treatment, and child hair steroid use. For interpretability, child age and the natural log of maternal HCC were z-scored. The interaction term was created by

Table 2
Multiple regression model predicting child HCC.

Predictors	β (SE)	P value
Family Income	-0.12 (0.07)	0.08
Child Sex	0.10 (0.07)	0.13
Child Physical Health	0.07 (0.07)	0.27
Mother Steroid Use	-0.07 (0.07)	0.27
Mother Hair Treatment	-0.07 (0.07)	0.38
Child Age	-0.19 (0.07)	0.01
Maternal HCC	0.42 (0.07)	0.00
Child Age X Maternal HCC	-0.14 (0.07)	0.04

multiplying the z-scored variables. Results indicated a significant child age by maternal HCC interaction (see Table 2). To probe this interaction, simple slopes analyses were conducted (Liu et al., 2017). Testing simple slopes involves testing the conditional slope of Y on X at different values of the moderator (i.e., 1 SD above and below the mean). This approach has been shown to maintain acceptable Type 1 error rates and adequate coverage of confidence intervals (Liu et al., 2017). Simple slope coefficients are presented in Fig. 1, illustrating that younger children’s HCC was more strongly associated with maternal HCC than was older children’s HCC.

We then examined whether maternal HCC was associated with children’s internalizing and externalizing symptoms. Children’s internalizing and externalizing symptoms were correlated ($r = 0.45, p < .00$); thus, to account for collinearity, we ran a multivariate multiple regression and considered internalizing and externalizing symptoms in the same model. In our analyses, we controlled for maternal hair treatment, maternal steroid use, child age, child HCC, family income, and whether a medical professional had diagnosed the child with a previous emotional, behavioral, or mental health problem. Controlling for a previous mental health diagnosis strengthened the evidence suggesting that mother’s HCC was associated with children’s pandemic-related emotional-behavioral health outcomes. Regression statistics for this model can be found in Table 3. Results revealed no association between maternal HCC and child externalizing symptoms. However, greater mother hair HCC predicted greater child internalizing symptoms. Age did not significantly moderate the association between maternal HCC and children’s internalizing symptoms.

3.4. Aim 4: Child HCC and child emotional-behavioral health

Multivariate multiple regression revealed that child HCC was not associated with children’s internalizing or externalizing symptoms. Furthermore, there were no statistically significant interactions found between child age in the associations between child HCC and child internalizing and externalizing symptoms.

4. Discussion

Developmental scientists have taken on the responsibility of gaining a better understanding of the effects of the COVID-19 pandemic on child and family well-being. This is especially important since broad societal stressors are often experienced and expressed at the level of the individual family. Many policies and regulations to limit the spread of COVID-19 have resulted in drastic alterations to daily life, and research is continually demonstrating the psychological impacts of these pandemic-related changes. The increased demands on parents to provide care and support learning, coupled with social isolation and uncertainty, have significantly increased parental stress (Calvano et al., 2021), and may therefore hinder parents’ ability to meet children’s basic physical and psychosocial needs, subsequently placing children at higher risk for maladjustment.

The current study addresses important gaps in the existing literature by being the first, to our knowledge, to investigate how pandemic-related stressors are associated with HCC in both mothers and children. It is also the first to examine how maternal HCC during the COVID-19 pandemic is associated with children’s HCC and behavioral functioning. Finally, the current study adds to current literature by testing whether children’s HCC during the pandemic is associated with their observed behavior. Investigating these questions not only provides much needed clarity regarding how the COVID-19 pandemic is associated with stress at a biological level for both parents and children, but it is a first step in helping to identify whether HCC may serve as a mechanism linking COVID-19 challenges to families’ mental health and adjustment.

Results showed that for mothers, higher HCC was correlated with living in a more urban area, working from home, reading about COVID-

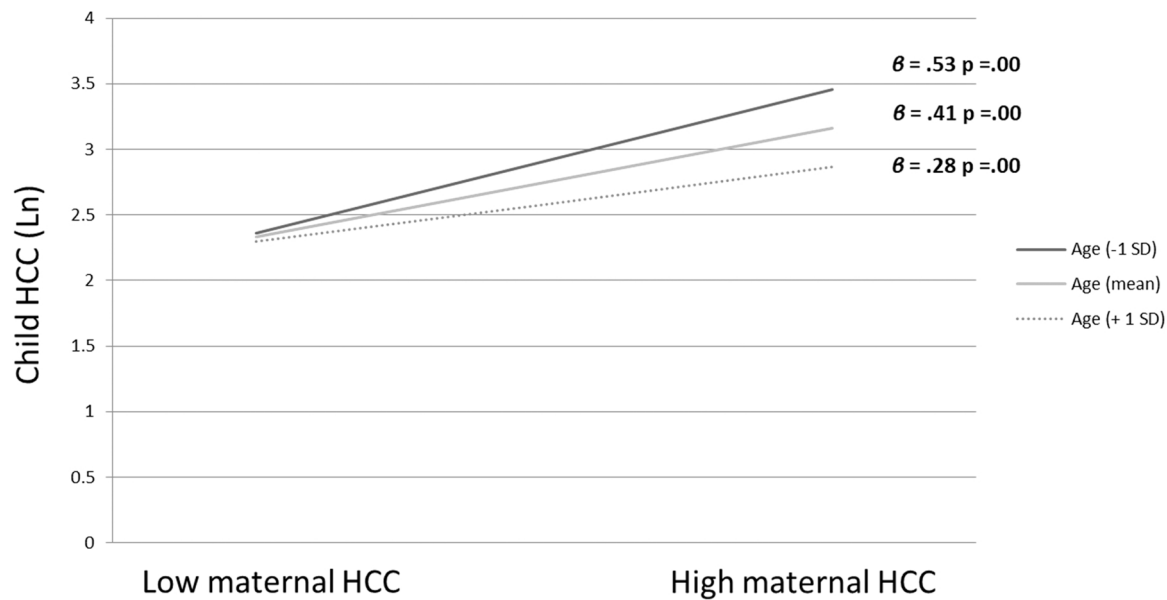


Fig. 1. Simple slopes plotted for mother hair cortisol by child age interaction.

Table 3
Multiple regression model predicting child internalizing and externalizing symptoms.

Predictors	Internalizing Symptoms		Externalizing Symptoms	
	β (SE)	P value	β (SE)	P value
Family Income	-0.09 (0.07)	0.26	-0.11 (0.07)	0.14
Child Sex	0.03 (0.07)	0.68	-0.17 (0.07)	0.02
Mother Steroid Use	0.12 (0.07)	0.11	0.07 (0.07)	0.36
Child pre-existing diagnosis	0.28 (0.07)	0.00	0.33 (0.07)	0.00
Child Age	-0.05 (0.07)	0.52	-0.14 (0.07)	0.06
Child HCC	-0.12 (0.07)	0.13	-0.13 (0.07)	0.10
Mother Hair Treatment	-0.06 (0.07)	0.42	-0.02 (0.07)	0.79
Mother HCC	0.21 (0.07)	0.01	0.09 (0.07)	0.28

* $p < .05$. * * $p < .01$.

19, job loss, and social isolation. Given that parents' reports of stress have been previously tied to these factors (Cusinato et al., 2020; Gianotti et al., 2021; Thorell et al., 2021), associations with maternal HCC are not surprising. Living in an area that is more densely populated often means greater exposure and stricter lockdowns. For parents, social distancing not only means a lack of social companionship, it also means the potential disappearance of social networks that provide childcare and support. Job loss comes with the stress of financial hardship and access to healthcare, both of which are especially stressful during a global health crisis. In recent work, Lee (2021) found that parents perceived isolation and employment loss were associated with child neglect and aggression even after controlling for parent depressive symptoms and sociodemographic factors. The current findings support that removal of social and financial resources may affect parental stress physiology which, in turn, may have significant consequences for parenting behavior and development.

Creating a work environment that is both productive and effective outside of the typical work context is also a source of significant stress. Notably, parents often had to combine employment responsibilities with managing online learning and childcare, a task they were not necessarily qualified or prepared for, therefore exacerbating the already challenging situation Garbe, Ogurlu, Logan, and Cook (Garbe et al., 2020). Reading about coronavirus-related issues may also induce additional stress and anxiety as information is continuously evolving, various news outlets may be contradictory, and the severity of disease in the area is being publicized.

For children, higher HCC was associated with parental job loss and social distancing. It is likely that these two factors are most salient to children's everyday lives. Job loss and the possibility of not being able to pay for food, housing, and healthcare poses a significant threat to family well-being, and therefore may permeate across every aspect of children's daily functioning, resulting in greater stress. Greater social distancing results in children spend less time with peers, close friends, and extended family. These social contexts are sources of support and enjoyment and sudden and unexpected changes in these social dynamics are likely stressful for youth of all ages. Overall, these findings are some of the first to demonstrate that pandemic stress may "get under the skin" for both parents and children and may be observed in human biology in the form of HPA functioning.

We tested whether maternal HCC during the COVID-19 pandemic was associated with children's concurrent HCC. Based on pre-pandemic work looking at the association between mothers and children's HCC, we hypothesized a significant correlation (Kao et al., 2019; Karlén et al., 2013). Indeed, we found a correlation coefficient of .40. Although this association is somewhat larger than what some have reported in previous studies, we cannot rule out that it is due to heritability alone. We found child age to be a significant moderator of this association. A simple slopes analysis revealed that although the association was significant above and below the mean of child age ($M = 8.91$), the relation between maternal HCC and child HCC was stronger for younger children.

There are several potential explanations for this finding. First, younger children are more heavily dependent on caregivers to meet basic needs. If mothers, who are often primary caregivers for young children, are experiencing increasing stress at a physiological level, this stress may be felt stronger by children who spend the majority of their time with them. It is also possible that epigenetically, children become less similar to their parents as the impact of varying environments on the genome becomes more influential across development. This is supported by significant correlations observed in infancy and non-significant correlations observed in childhood (Karlén et al., 2013; Ursache et al., 2017). Therefore, it is possible this finding is not reflective of pandemic-related "intergenerational stress transfer" at all. However, we continued to find a significant, albeit weaker, association between mothers' and children's HCC at older ages, suggesting the context of the COVID-19 pandemic may be playing a role in the relation between mother and child HCC in the current study. Future research is needed to

better elucidate the extent to which parent HCC is correlated with child HCC and how this association changes over time.

We found that maternal HCC was also associated with mothers' report of children's internalizing behavior, even after controlling for child HCC. This finding suggests that in addition to its association with children's HCC, maternal HCC may affect children's emotional functioning. There are multiple mechanisms through which this might occur. As previously stated, pandemic-related factors that increase maternal stress at a biological level such as job loss, social isolation, and working from home, could lead to changes in parental availability, parenting behaviors (i.e., supervision, patience, discipline strategies, consistency), and family resources, all of which may lead to increases in children's anxious and depressive symptoms. This work also coincides with previous research linking parental reports of stress during the pandemic to youth's internalizing symptoms (e.g., (Babore et al., 2021; Liang et al., 2021)). It is possible that mothers' report of children's behavior reflects, at least in part, her own increased anxiety and depression, rather than being an unbiased measure of child behavior. Unfortunately, we did not collect measures of maternal mental health or perceived stress and therefore were unable to test this possibility. It is also possible that children's increased anxiety and depression may be predictive of greater maternal stress, as those emotional-behavioral symptoms may be more challenging for parents. Because the current study is correlational, the true direction of effects is not known.

Age was also not a significant moderator in the association between mother HCC and child behavior, suggesting that the association held similarly for both younger and older youth. We found no evidence of an association between mother HCC and child externalizing behavior, highlighting that maternal HCC may be more strongly related to anxiety and depression than aggression or hostility. However, some empirical work has found evidence of the association between parenting stress and externalizing symptoms (Giannotti et al., 2021; Romero et al., 2020). Given that parents serve as external regulators for their children's behavior (Sameroff, 2010), it would be expected that greater physiological stress may be associated with less parental patience and fewer resources, making parents less able to serve as effective co-regulators. Thus, the lack of association between maternal HCC and child behavior is somewhat unexpected. Further work is needed to better understand the various predictors of externalizing type behaviors in response to COVID-19 pandemic related stressors.

Given the mixed literature regarding the association between child HCC and child behavior, the lack of association between child HCC and child emotional-behavioral health in the current study was consistent with some prior work in this area. Previous work has shown that caregivers have a strong regulatory or buffering effect on markers of children's HPA (Gunnar and Donzella, 2002; Gunnar, 2006; Hostinar et al., 2014). If parents are working from home and thus more physically present for their children, these buffering effects could weaken potential associations between children's HCC and their emotional-behavioral functioning. Importantly, the association might also go in the opposite direction; children's increased anxious and depressed feelings and/or behavioral problems may be an additional stressor that raises maternal HCC. Future research is needed to detangle these interpretations by measuring child behavior directly, and/or use multiple informants such as teachers, and use longitudinal data to probe child emotional-behavioral function and maternal HCC.

5. Limitations and conclusions

Although the current study has several notable strengths, it is not without limitations. First, in an effort to not further burden mothers, we restricted the majority of items to those directly related to COVID-19 and child emotional-behavioral health. Additional assessments of mother's prior and current mental health and current perceived stress would have allowed for more insight into the reported associations, and a comparison between perceived and biological stress as they related to pandemic

challenges. Second, because the study was conducted mid-lockdown, all measures besides HCC were based on maternal report instead of direct observation. Behavioral observations, even if virtual, might better able to capture maternal moderating factors on child adjustment. Finally, the participants were from largely white and highly-resourced families, with 95% of mothers having college degrees. Thus, findings from the current study may not be representative of families of color or families from economically disadvantaged backgrounds. While it is important to note that the sample used in the current study was likely not as negatively affected by pandemic-related stressors as more vulnerable populations, the fact that we still were able to find effects in this low-risk sample is telling and provides insight into possible stronger effects that may emerge in families for which pandemic stressors are even more profound.

The current study provides a preliminary investigation of mothers' and children's stress biology during the COVID-19 pandemic, and sheds light on the effect of pandemic-related parental HCC on child outcomes. A greater understanding of how the pandemic is associated with families' physical and mental health is critical in order to identify preventive factors to psychological distress, and to develop effective interventions for relieving the negative impact of pandemic-related stress on families' daily functioning and adjustment. This information may help practitioners and policy makers to better support families during and after the COVID-19 pandemic, potentially by providing additional access to services, bolstering children's social, emotional, and cognitive development, supporting parents' physical and psychological well-being, and understanding prevention measures.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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