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The COVID-19 Pandemic and Measurement of Preschoolers' Executive Functions

Kristin J. Perry[1], Gretchen R. Perhamus[2], Maria C. Lent[3], Dianna Murray-Close[3], and Jamie M. Ostrov[2]
[1] Edna Bennett Pierce Prevention Research Center, The Pennsylvania State University, University Park
[2] Department of Psychology, University at Buffalo, The State University of New York
[3] Department of Psychological Science, The University of Vermont

Given the far-reaching effects of the COVID-19 pandemic, it is important to investigate how executive function (EF) assessments were impacted by changes in measurement protocols, context, and timing due to the pandemic. The present study used data from two projects. The first project occurred prior to the pandemic ($N = 244$, 44.67% female; $M_{age} = 44.27$ months) with teacher ratings and objective EF measures collected in the spring of preschool, fall of prekindergarten (pre-K), and spring of pre-K. The second study was comprised of two cohorts, a transition cohort (i.e., Fall 2019 to Fall/Winter 2020) and a post-COVID lockdown cohort (i.e., Fall 2020 to Fall/Winter 2021). For both cohorts, data were collected in the fall of pre-K, spring of pre-K, and fall/winter of kindergarten ($N = 130$, 46.2% female, $M_{age} = 44.84$ months). Aims included: (1) evaluating the measurement characteristics of a virtual assessment of EF, (2) examining cohort differences in teacher and objective EF measures, (3) testing longitudinal mean-level change in EF, and (4) evaluating associations between COVID impact and change in EF. Teachers reported a marginal decrease in EF for the transition cohort and no change in the post-COVID cohort, whereas objective measurements demonstrated the expected increase in EF. Child and family COVID-19 impact emerged as risk factors for reduced EF for the transition cohort but not the post-COVID cohort. Overall, this study provides novel evidence that the timing and type of EF assessment differentially impacted estimates of children's EF.

Public Significance Statement
The COVID-19 pandemic influenced children's executive function (EF) skills and changed how assessments of these skills were administered. Results suggest that teacher perceptions of EF may have changed across the pandemic. In addition, there was some evidence using an objective measure that children who transitioned to kindergarten immediately following the COVID lockdown demonstrated lower levels of EF skills.

Keywords: executive function, self-regulation, preschool, COVID-19 pandemic

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Kristin J. Perry https://orcid.org/0000-0002-7138-019X
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Data used in the present study are available by contacting the authors. Most measures or methods used in the methods section are available by contacting the original authors of the scales or methods. The study was not preregistered.

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Correspondence concerning this article should be addressed to Kristin J. Perry, Edna Bennett Pierce Prevention Research Center, The Pennsylvania State University, University Park, 314 Biobehavioral Health Building, University Park, PA 16802, United States. Email: kjp6046@psu.edu

Researchers have documented both short- and long-term effects of sociohistorical events such as wars, economic recessions, and pandemics on the developmental trajectories of children (Benner & Mistry, 2020). In 2020, the COVID-19 pandemic presented major disruptions in nearly all facets of children's lives, such as school closures, family stress and loss (e.g., financial stress, job loss, remote work, and death of family members due to COVID), social relationship interruptions (e.g., loss of social connections with peers due to social distancing), and reduced access to services and support (e.g., medical care visits, access to early intervention, and access to school lunches for low-income youth; Benner & Mistry, 2020; González-Calvo et al., 2022). These disruptions appear to have had far-reaching implications for youth development and adjustment, including learning loss (e.g., Engzell et al., 2021) and mental health difficulties (e.g., Panchal et al., 2021).

The impact of the pandemic may be particularly severe among young children, in part because of loss of access to early childhood education programs and because beginning formal schooling represents a critical developmental transition that may magnify the impact of significant societal events (Benner & Mistry, 2020; González-Calvo et al., 2022). Indeed, emerging research documents a number of negative outcomes associated with the pandemic for young children, including lower school readiness (González-Calvo et al., 2022). One area of functioning that may have been particularly influenced by the pandemic is preschool children's executive function (EF) abilities. Researchers have demonstrated that preschoolers exhibited increased dysregulation during the pandemic lockdown (Di Giorgio et al., 2021; Hanno et al., 2022), and children under three experienced striking reductions in cognitive function with scores around 20-points lower (approximately 2 *SD*) on the Mullen Scales of Early Learning for children tested during the pandemic relative to those tested prior to the pandemic (Deoni et al., 2022). The pandemic has been theorized to impact cognitive abilities through indirect processes such as reduced social interaction, disturbed sleep, increased screen time, and increased psychopathology and directly through a diagnosis of COVID-19, which can impact cognitive functioning (Ceban et al., 2022; Deoni et al., 2022; Di Giorgio et al., 2021; Schmidt et al., 2021; Singh et al., 2020; Susilowati et al., 2021).

The school closures and social distancing associated with the pandemic introduced new challenges for researchers investigating preschoolers' development, including an inability to conduct in-person assessments (Weiland & Morris, 2022). Although many researchers moved to remote assessment procedures during lock-downs, questions remain regarding the reliability and validity of these methods (Weiland & Morris, 2022). Evaluating measurement characteristics across the pandemic is critical because objective measurements were administered in novel formats (i.e., virtual assessments and socially distanced assessments) and informants were reporting on different contexts (e.g., teachers reporting on children's behavior while teaching virtually) than prior to the pandemic. Prior research has also been limited by cross-sectional designs raising questions related to the effects of COVID on EF skills over time. The present study addressed these limitations by examining the measurement characteristics of a virtual objective assessment and teacher ratings of preschoolers' EF, evaluating individual mean-level change in these two measures across the transition to kindergarten, and assessing the role of COVID-19 impact in predicting individual differences across this transition. Importantly, we examined these aims across two studies comprised of three cohorts: a pre-COVID cohort, with all data collected prior to the pandemic; a COVID transition cohort, with data collected in the fall of 2019 to the fall/winter of 2020; and a post-COVID shutdown cohort, with data collected in the fall of 2020 to the fall/winter of 2021 (for a description of the studies and cohorts, see Table 1).

Executive Function Skills

EF skills are a series of interrelated, higher order cognitive abilities such as working memory (i.e., holding and manipulating information in one's mind), inhibitory control (i.e., deliberately stopping an automatic reaction to enact a different one), and planning (Thorell & Nyberg, 2008). Flexible attention (e.g., focusing and shifting attention; Ponitz et al., 2008) is also sometimes categorized as an EF skill (Anderson & Reidy, 2012). EF first emerges in infancy (Anderson & Reidy, 2012) with these early skills; then skills improve with typical developmental processes and formal education (Miller-Cotto et al., 2022). Growth is particularly rapid in early childhood and the preschool period (see Diamond, 2002; Reilly et al., 2022; Zelazo et al., 2003), and there is enormous individual variability in developmental trajectories of EF growth, especially among young children (Anderson & Reidy, 2012). Both individual child factors (e.g., brain maturation) and contextual factors (e.g., poverty, parenting) may influence children's EF trajectories (Carlson, 2005). Given the importance of contextual factors in the development of EF, it is unsurprising that previous research has demonstrated that the pandemic has had a negative influence on preschoolers' EF skills (e.g., Di Giorgio et al., 2021; Hanno et al., 2022).

An important limitation of research focused on documenting the effects of COVID-19 on young children's EF skills is challenges associated with measuring EF. In fact, even prior to the pandemic, studies on the development of EF in early childhood have had to contend with measurement issues. There are a variety of ways to measure EF ranging from questionnaires to performance-based assessments. Questionnaires have the advantage of sampling a wide range of behaviors over time, whereas performance-based tasks may lack ecological validity for real-life home and school settings (Anderson & Reidy, 2012). However, questionnaires are more likely to be subject to reporter biases and cultural expectations of behavior, whereas performance-based tasks have been linked to the neurobiological foundations of EF (Obradović & Willoughby, 2019). Therefore, continued study of objective and other-reported EF within pandemic conditions is necessary to understand whether bias occurred as the assessment context and procedures shifted.

The Present Study

In the present study, we included both teacher ratings and objective assessments of EF. Specifically, we used the Childhood Executive Functioning Inventory (CHEXI) report questionnaire to assess working memory and inhibition as an index of teacher-rated EF. In addition, we used the Head–Toes–Knees–Shoulders (HTKS) task, an ecologically valid structured observation procedure of children's behavioral regulation based on children's responses to verbal commands (HTKS; McClelland et al., 2007, 2014; Ponitz et al., 2008; Ponitz et al., 2009), as an objective measure of EF.

The HTKS and CHEXI are well-validated assessments of children's EF. However, no prior research has considered how the COVID pandemic may have influenced the reliability, validity,

Table 1
Study and Data Guide

Cohort	Study time point				
	Preschool spring	Preschool summer	Prekindergarten fall	Prekindergarten spring	Kindergarten fall/winter
Study 1: pre-COVID	HTKS (n = 40) CHEXI (n = 158)	HTKS (n = 52)	CHEXI (n = 111)	CHEXI (n = 194)	X
Study 2, Cohort 1: COVID transition	X	X	Pre-COVID (Fall 2019) HTKS (n = 71) CHEXI (n = 71)	Pre-COVID (Feb/Mid-March 2020) HTKS (n = 20) Post-COVID (April-June 2020) CHEXI (n = 72) COVID impact measures (n = 35)	Post-COVID (Fall/Winter 2020) HTKS (n = 47) CHEXI (n = 44)
Study 2, Cohort 2: post-COVID	X	X	Post-COVID (Fall 2020) HTKS (n = 38) CHEXI (n = 53) COVID impact measures (n = 46)	Post-COVID (Spring 2021) HTKS (n = 31) CHEXI (n = 44)	Post-COVID (Fall/Winter 2021) HTKS (n = 31) CHEXI (n = 36)

Note. HTKS = Head–Toes–Knees–Shoulders task and CHEXI = The Childhood Executive Function Inventory. This table shows the assessments available at each time point for each study. An X indicates that no assessments were available at that time point. The n refers to the number of participants at each time point that have data for each measure.

or mean-level change in these assessments across the preschool years. The present study evaluated these questions in preschool pre-COVID, transition, and post-COVID shutdown cohorts across two studies. Aim 1 of the study tested whether a virtual administration of the standard HTKS demonstrated similar reliability and validity to an in-person school and lab administration. Aim 2 evaluated whether there were mean-level differences in objective and teacher-rated EF skills among the pre-COVID, transition, and post-COVID shutdown cohorts using data from both studies. We hypothesized that children in the transition cohort may show poorer EF abilities relative to those in the post-COVID shutdown cohort or the pre-COVID cohort, congruent with research suggesting that the initial COVID lockdown may have impacted children's EF skills (Di Giorgio et al., 2021; Hanno et al., 2022). Aim 3 examined how change in objective and teacher-reported EF skills varied across three time points. We hypothesized that EF scores would linearly increase over time across the transition to kindergarten. Similar to the Aim 2 hypothesis, this increase in EF skills may be attenuated for the transition cohort relative to the post-COVID shutdown cohort. Finally, Aim 4 tested whether child and family COVID impact (i.e., child well-being and family resources affected by the pandemic) were related to change in EF. We hypothesized that greater family and child pandemic impact would be related to slower linear increases in EF skills.

Method

Study 1—Pre-COVID Cohort

Participants and Procedure

Study 1 (N = 244, 44.67% female; M_{age} = 44.27 months, SD = 4.06) was a subsample of participants who had EF data from a larger study of preschoolers recruited from high-quality early childhood education centers in a large city in the northeastern United States (for details, see Ostrov et al., 2023). The participants' race/ethnicity (3.69% African American/Black, 8.61% Asian/Asian American/Pacific Islander, 0.80% Hispanic/Latinx, 11.07% multiracial, 72.54% White, and 3.29% missing/unknown) was similar to the larger county from which the sample was drawn (14.0% African American/Black, 4.5% Asian/Asian American/Pacific Islander, 2.1% multiracial, 5.8% Hispanic/Latinx, and 79.3% White; U.S. Census Bureau, 2021). Parental occupation was coded using Hollingshead's (1975) four-factor index 9-point scoring system (i.e., 9 = executives and professionals and 1 = service workers). Parents had the opportunity to enter two occupations, in which case the higher occupation code was taken. Parents' education was not collected and thus was not included in the total factor score. Values ranged from 2 to 9 with a 7.93 average, indicating that a typical family in our sample was from the second- to third-highest occupation group (i.e., 7 = small business owners, farm owners, managers, minor professionals; 8 = administrators, lesser professionals, proprietors of medium-sized businesses), which suggests our sample was on average, middle to upper middle class. Parents' annual income was available for a subset of the sample (n = 126) and was congruent with Hollingshead's codes (65.9% reported household income of > \$100,000, 23.0% reported household income of \$55,000–\$100,000, 6.3% reported household income of \$36,000–\$54,999, and 4.8% reported household income of < \$36,000).

Participants were recruited in the spring of their preschool year before prekindergarten (T1), and followed in the summer (T1 summer), fall of prekindergarten (i.e., pre-K; T2), and the spring of pre-K (T3). All children in participating preschool classrooms were invited to participate through consent forms distributed to families by teachers, and parents signed and returned these consents to teachers if they wished to participate. Teachers also consented to participation prior to completing teacher ratings, and children provided verbal assent prior to interviews. Teachers received \$5–\$30 based on the number of enrolled children in their classroom. Procedures were approved by the local institutional review board (IRB).

Measures

Heads–Toes–Knees–Shoulders Task. Participants completed the HTKS task (McClelland et al., 2007, 2014; Ponitz et al., 2008; Ponitz et al., 2009) in the spring and summer of preschool. The task was administered by trained graduate students and postbaccalaureate level staff and involves observation of children's behavioral regulation based on children's responses to verbal commands conducted in a game-like format consisting of three sections. In the first two sections, children first respond naturally to up to four paired behavioral rules (i.e., "Touch your head," "Touch your toes," "Touch your shoulders," and "Touch your knees") and then are told to respond by doing the opposite of the command (e.g., touch their toes when told to touch their head). The pairs are then switched in the third section (e.g., touch their knees when told to touch their head). There are 18 practice questions and 30 test items with scores of 0 (incorrect), 1 (self-correct), or 2 (correct) for each item. In the present study, scores were summed with the practice items included to reduce floor effects consistent with prior administrations (Fung et al., 2019). The HTKS has demonstrated acceptable reliability and validity in prior work (e.g., Graziano et al., 2015; Ponitz et al., 2008). Performance on the task has also been shown to be moderately correlated with standard working memory tasks and observed self-regulation at school, and the task is a recommended assessment of executive functioning in the early school years for research purposes (Graziano et al., 2015).

In the spring of preschool, participants completed the assessment in-person in a quiet, private location at their preschool. At the preschool summer time point, participants completed the assessment in the lab. In the summer, interrater reliability was collected for 21.15% of the sample (for interrater reliability for all time points, see Table 2). Notably, the spring and summer assessments were highly correlated ($r = .71$, $p < .001$) for the 18 participants who had data for both assessments, providing evidence for the validity of the measure in the lab and school contexts.

Childhood Executive Functioning Inventory. Teachers completed the CHEXI (Thorell & Nyberg, 2008) at all time points. This questionnaire contains 24 items assessing difficulties with working memory (e.g., "When asked to do several things, he/she only remembers the first or last") and inhibition (e.g., "Has a tendency to do things without first thinking about what could happen") rated on a 5-point scale from 1 (*definitely not true*) to 5 (*definitely true*; Catale et al., 2015). The scales were reverse coded so that higher scores indicate better EF skills, consistent with the HTKS. Given the high correlations between the inhibition and working memory subscales in Study 1 (i.e., $r = .73$ at preschool spring, $r = .74$ at pre-K fall, and

Table 2
HTKS Interrater Reliability Estimates

Cohort	Study time point				
	Preschool spring	Preschool summer	Prekindergarten fall	Prekindergarten spring	Kindergarten fall/winter
Study 1: pre-COVID	Classroom setting Interrater reliability not collected	Lab setting Average κ = .85	X	X	X
Study 2, Cohort 1: COVID transition	X	X	Classroom setting Average κ = .93	Classroom setting Interrater reliability not collected	Virtual setting Average κ = .80
Study 2, Cohort 2: post-COVID	X	X	Virtual setting Average κ = .87	Virtual setting Average κ = .85	Virtual setting Average κ = .83

Note. HTKS = Head–Toes–Knees–Shoulders task. To calculate the average κ, the Cohen's κ for each item was calculated and then averaged within time point. For Study 1, the interrater reliability was collected for 21.15% of the sample and only calculated for the first two sections of the HTKS in the lab setting given that there was limited data available for the third section as most children had discontinued by that point. For Study 2, in the fall of pre-K, interrater reliability was collected for 26.76% of the sample. At all other time points, interrater reliability was collected for all sessions. An X indicates that no HTKS data are available at that time point.

r = .66 at pre-K spring) and in Study 2 (see below), these two subscales were averaged to compute a total EF score. Prior work has demonstrated that this scale has acceptable psychometric properties and adequate test–retest reliability in multiple cultures (Catale et al., 2015; Thorell et al., 2013; Thorell & Nyberg, 2008). Scores on this measure are weakly to moderately correlated with performance on EF tasks (e.g., Thorell & Nyberg, 2008). The measures demonstrated strong internal consistency (Cronbach's α's for each subscale at each time point ranged from .93 to .98).

Child Behavior Questionnaire–Short Form. To provide a further assessment of the validity of the CHEXI and HTKS, we examined associations with parent-reported inhibitory control. In the fall of pre-K, parents rated inhibitory control using six items from the Child Behavior Questionnaire–Short Form (Putnam & Rothbart, 2006; e.g., "Can wait before entering into new activities if asked to") rated on a 7-point Likert scale from 1 (*extremely untrue*) to 7 (*extremely true*). Reliability was acceptable (Cronbach's α = .69).

Study 2—Transition and Post-COVID Shutdown Cohorts

Participants and Procedure

Study 2 (N = 130, 46.2% female, M_{age} = 44.84 months) included a somewhat diverse sample (9.2% Asian, 5.4% African American/ Black, 65.4% White, 8.5% multiracial, 0.7% other, and 10.8% missing) of preschoolers recruited from high-quality early childhood education centers in a large city in the northeastern United States. Parents were middle to upper middle class (58.5% reported household income of > $100,000, 18.5% reported household income of $55,000–$100,000, 6.9% reported household income of $36,000–$54,999, and 2.3% reported household income of < $36,000; 13.8% missing income data). Participants were recruited in the fall of their pre-K year (T1), and followed in the spring of pre-K (T2), and fall/ winter of kindergarten (T3). The present study uses data from two cohorts—a transition cohort recruited pre-COVID (T1 Fall 2019) and followed into the emergence of COVID (T2 Spring 2020 and T3 Fall/ Winter 2020), and another recruited post-COVID shutdown (T1 Fall 2020, T2 Spring 2021, and T3 Winter 2021). All children anticipating entering kindergarten the following year were invited to participate through consent forms distributed to families by teachers, and parents signed and returned these consents to teachers if they wished to participate. Teachers also consented to participation prior to completing teacher reports. Teachers received a $5 gift card for each child report they completed. Procedures were approved by the local IRB.

Measures

Heads–Toes–Knees–Shoulders Task. The participants in the transition cohort in the fall of pre-K (i.e., Fall 2019) completed the HTKS assessment in-person in a quiet, private location at their preschool using the same methods as Study 1. In the spring of pre-K, in-person assessments were completed for 20 children prior to the COVID-19 shutdown. At all subsequent time points and for the post-COVID cohort, the assessment was administered remotely over video conferencing software due to school closures and social distancing requirements. Although parents were present in the room with the child during remote assessments, they were instructed not to provide any answers or hints to the child, and only to assist with behavioral management (e.g., having the child stay within the camera frame) as needed. Parents were asked to minimize distractions in the environment as much as possible during the assessment. Children were given time to acclimate to being on video, and parents were asked at the end of the assessment whether or not they thought the child's performance was reflective of their typical abilities. Any perceived discomfort related to the virtual format was noted. Parents provided consent and children provided verbal assent before all HTKS assessments. Otherwise, the same HTKS procedures (e.g., number of items and instructions given) were followed in both in-person and virtual administrations.

Interrater reliability was collected for 26.76% of the sample for the transition cohort in the fall of pre-K, which used school-based data collection. For virtual assessments, interrater reliability was collected for all assessments, given that two research assistants were present on all virtual calls. The values for interrater reliability for each cohort and each time point are included in Table 2. Overall, interrater reliability was excellent for all formats.

Childhood Executive Functioning Inventory. Teachers completed the CHEXI (Thorell & Nyberg, 2008) at all time points. Consistent with Study 1, there were strong correlations between the inhibition and working memory subscales at all time points (i.e., r = .77 at pre-K fall, r = .81 at pre-K spring, and r = .81 at kindergarten fall/winter) so these two subscales were averaged to compute a total EF score. Similar to Study 1, the subscales showed good internal consistency at all time points (Cronbach's α's for each subscale range from .92 to .98).

Family and Child COVID Impact. Parents reported on the impact of COVID-19 on their family on the Resource Acquisition subscale of the Coronavirus Impact Questionnaire (Conway et al., 2021). The subscale includes four items assessing negative impacts of COVID-19 on the family's finances, mental health, and access to basic goods (e.g., toilet paper), each rated on a 7-point scale from 1 (*not true*) to 7 (*very true*) with higher scores indicating more negative COVID impact. The subscale showed good internal consistency in a prior study (Conway et al., 2021) and in the present study (Cronbach's α = .71). Parents also completed three items assessing the impact of COVID-19 on child well-being [e.g., "My child has become sad or withdrawn (e.g., crying, smiling less) because of the coronavirus (COVID-19)"]. These items were rated on a 7-point scale from 1 (*not true of my child*) to 7 (*very true of my child*) with higher scores indicating more negative COVID impact. The subscale showed good internal consistency (Cronbach's α = .85). The transition cohort completed the impact questionnaires in Summer 2020 and reported on current COVID impact. The post-COVID cohort completed these questionnaires in Fall 2021 and reported on impact over the past 6 months.

Study and Cohort Differences

For both studies, children were recruited from National Association for the Education of Young Children accredited or previously accredited early childhood education centers. Nine schools participated in both studies. Four additional schools were added to the second study to boost the racial and socioeconomic diversity of the sample. One school only participated in the first study. The three cohorts did not differ by race or ethnicity, $\chi^2(8, N = 345) = 7.74$, $p = .46$; gender, $\chi^2(2, N = 374) = .51$, $p = .78$; or SES,

$\chi^2(10, N = 238) = 10.34$, $p = .41$. In addition, from Study 2, the transition and post-COVID cohorts did not vary by age in the fall of pre-K ($F[1, 127] = 0.40$, $p = .53$, adjusted $R^2 = -.01$) or SES resources ($F[1, 113] = 0.46$, $p = .50$, adjusted $R^2 = -.01$).

In terms of procedures, the studies have the same measures available in the fall and spring of pre-K (for a summary, see Table 1), so between-group differences between the cohorts were examined at these two time points. Study 1 has unique data in the spring and summer of preschool, and Study 2 has unique data in the fall/winter of kindergarten. Due to differences in study design, there were no kindergarten data available for Study 1 and no spring/summer preschool data available for Study 2. Therefore, these time points were used to examine within-cohort changes and study specific analyses.

Data Analysis

Descriptive statistics and zero-order correlations were examined for all study variables in SPSS. The equivalence of the covariance between the HTKS and CHEXI at each time point was assessed to determine whether these validity correlations varied for the transition and post-COVID cohort. After adjusting outlier values to ±3 standard deviations from the mean, skew and kurtosis statistics were within typical ranges (skew statistics ranged from −1.62 to 1.53 and kurtosis values < 2.47; B. Muthén & Kaplan, 1985). In addition, an analysis of outliers demonstrated that there were not multivariate outliers (for more detailed analysis of outliers, see supplemental materials). It was expected that data would be missing at random (MAR) because missingness was not randomly assigned based on the study design (Baraldi & Enders, 2010). The MAR assumption was tested using analyses of variance for continuous variables and chi-squared tests for categorical variables to examine if missing data were related to any of the pertinent study variables. Missing data were accommodated using full information maximum likelihood (FIML) estimation and sources of systematic missingness within our data set were included in models to facilitate the maximum likelihood process (Baraldi & Enders, 2010).

All models were estimated in Mplus Version 8.7 (L. K. Muthén & Muthén, 1998–2022) using the maximum likelihood with robust standard errors estimator to account for skewness. Model fit was evaluated using the likelihood ratio χ^2 test of overall model fit where $p > .05$ indicates good fit. Alternative fit indices were also used. The comparative fit index (CFI), where values greater than .90 suggest acceptable fit, the standardized root-mean-square residual (SRMR) fit index, where values less than .08 represent adequate fit, and the root-mean-square error of approximation (RMSEA), where values greater than .10 represent poor fit and values less than .08 represent mediocre fit were considered (Hu & Bentler, 1999).

To examine Aim 2 focused on between-group differences in CHEXI scores, a regression was examined, with cohort dummy-coded and the pre-COVID cohort serving as the reference group. Pre-K spring CHEXI scores were regressed on pre-K fall CHEXI scores and the dummy-coded cohort variables. For the HTKS, between-group differences were evaluated for the transition and post-COVID cohorts.

To evaluate Aim 3 and determine change in mean CHEXI and HTKS scores, latent growth modeling (LGM) was used. LGM techniques evaluate the trajectories (e.g., fixed effects) and the variability in these trajectories (e.g., random effects). Change was modeled as a function of time point given that data collection was consistent across child. First, a linear model was specified to the data, but in the event that the linear model did not provide an acceptable fit, a free-loading model was used, which does not impose a shape on the data (Bollen & Curran, 2006). The equivalence of the means of the intercept and slope values in the final model were tested across cohort. Wald tests were used to determine if means differed across cohort.

To address Aim 4, given the high level of HTKS missing data for the transition cohort in the spring of pre-K and the timing of the HTKS assessment for children who did have HTKS data at this time point (i.e., assessments occurred prior to the pandemic), we used a regression framework to examine the effect of the COVID impact predictors for each cohort. For the transition cohort, we examined the role of child and family COVID impact, assessed in the summer of 2020, on HTKS scores in kindergarten (fall of 2020), controlling for HTKS scores in the fall of pre-K (fall of 2019) and child age, gender, and SES. For the post-COVID cohort, we used a regression model to examine the role of child and family COVID impact over the past 6 months, assessed in the fall of pre-K (fall of 2020) on HTKS scores in kindergarten controlling for stability in HTKS scores and covariates.

Because the CHEXI was administered at the end of the spring/beginning of summer for the COVID transition cohort (i.e., after the start of COVID), the missing data and data collection time differences were not present for the CHEXI as they were for the HTKS. A multigroup model with cohort as the grouping variable was examined that regressed the intercept and slope latent variables on the demographic covariates and COVID impact variables. Age and SES were also allowed to correlate with each other to facilitate the FIML process. All predictors were mean centered. The constraints from the previous CHEXI multigroup model were retained in this model. For Aim 4 analyses, SES, child age, and child gender were included as covariates because these variables have been identified as important factors that may influence trajectories of EF.

Transparency and Openness

All data, program code, and methods developed by others are cited in the text and are compliant with APA style journal article reporting standards. Syntax and data for the analyses are available by contacting the authors. Most measures or methods used in the method section are available by contacting the original authors of the scales or methods. This study was not preregistered.

Results

Preliminary Results

The descriptive statistics and correlations for each cohort are presented in Tables 3 and 4. There was no difference in the strength of the association between the HTKS and the CHEXI at each time point for the transition and post-COVID cohorts (see supplemental materials). Regarding missing data for Study 1, missing data in the spring of preschool were related to age ($F[1, 240] = 4.34$, $p = .04$, adjusted $R^2 = .01$), such that older children were more likely to have missing data in the spring of preschool. For Study 2, children were more likely to have missing COVID impact data if they had lower HTKS scores in kindergarten ($F[1, 76] = 13.50$, $p < .001$, adjusted $R^2 = .14$), and lower CHEXI scores in the fall of pre-K ($F[1, 122] = 4.43$, $p = .04$, adjusted $R^2 = .03$). In addition, four children were

Table 3
Study 1, Pre-COVID Cohort Descriptive Statistics and Correlations

Variable	1	2	3	4	5	6	7	8
1. Age (months) T1	—							
2. Child gender	.06	—						
3. SES resources	−.10	.02	—					
4. HTKS preschool spring	.09	.28	−.10	—				
5. CHEXI-TR preschool spring	.15	.14	−.10	.32*	—			
6. HTKS preschool summer	.19	−.04	.22	.71**	.28*	—		
7. CHEXI-TR Pre-K fall	.10	.32**	−.19*	.17	.39**	.24	—	
8. CHEXI-TR Pre-K spring	.12	.36**	−.06	.24	.45**	.21	.79**	—
M (*SD*)	44.24 (4.07)	55.3% female	7.93 (1.39)	11.43 (14.90)	42.47 (9.32)	24.94 (24.23)	45.64 (9.18)	44.05 (8.07)

Note. Pre-K = prekindergarten; SES = socioeconomic; TR = teacher ratings; HTKS = Head–Toes–Knees–Shoulders task; and CHEXI = Childhood Executive Functioning Inventory. For the CHEXI, higher scores indicate greater executive function (EF), and for the HTKS, higher scores indicate better EF. Child gender was coded 1 = boy, 2 = girl. SES resources were measured using Hollingshead's code. Descriptive statistics and correlations were calculated for participants who have data at each time point.
* $p < .05$. ** $p < .01$.

missing data in the spring of pre-K, and this missingness was related to lower CHEXI scores (F[1, 122] = 5.95, p = .02, adjusted R^2 = .04). Overall, results from Study 2 indicate that worse EF is associated with greater missing data, underscoring the importance of using FIML to accommodate these missing data.

For Study 1, correlations between parent report of inhibitory control in the summer of preschool, the HTKS in the summer of preschool, and CHEXI scores in the fall of pre-K were examined for each cohort. Parent report of inhibitory control was moderately and significantly correlated with the CHEXI in the spring of preschool (r = .26, p = .02) and moderately but nonsignificantly associated with the HTKS in the summer of preschool (r = .24, p = .09).

Between-Group Differences

HTKS

Cohort differences in the HTKS were examined for the transition and post-COVID cohorts controlling for gender and age. Kindergarten HTKS scores were regressed on fall of pre-K HTKS scores and both time points were regressed on age, gender, and cohort. The variance for age was freed to help facilitate the FIML process. The model provided an acceptable fit to the data, $\chi^2(2) = 0.43$, $p = .81$, CFI = 1.00, RMSEA = .00, and SRMR = .02. In the fall of pre-K (β = −.00, p = .98; ΔR^2 = .00[1]), there was no difference in EF scores between the cohorts. After the transition to kindergarten, the post-COVID cohort had marginally significantly higher scores than the scores in the transition cohort when controlling for fall pre-K scores (β = .15, p = .06, ΔR^2 = .004).

CHEXI

A regression was conducted to determine whether there were between-group differences in CHEXI scores. Spring pre-K scores were regressed on fall pre-K scores, gender, age, and two dummy-coded cohort variables. Fall pre-K scores were also regressed on the dummy-coded cohort variables, gender, and age. In addition, the variance of age was freely estimated to facilitate the FIML process. The model provided a good fit to the data, $\chi^2(3) = 1.30$, $p = .73$, CFI = 1.00, RMSEA = .00, and SRMR = .02. In the fall of pre-K, the post-COVID cohort had higher EF scores than the pre-COVID cohort (β = .15, p = .01), and there was a marginal difference between the transition and pre-COVID cohorts (β = .09, p = .06). In the spring of pre-K, the pre-COVID cohort had significantly lower EF scores than the transition (β = .18, p < .001) and post-COVID (β = .07, p = .04) cohorts. The dummy-coded cohort variables explained a small amount of variance in EF scores in the fall (ΔR^2 = .02) and spring (ΔR^2 = .03) of pre-K.

In addition, cohort differences were compared for the transition and post-COVID cohorts after the transition to kindergarten when controlling for spring pre-K scores, gender, and age. The model provided an acceptable fit to the data, $\chi^2(2) = 0.43$, $p = .81$, CFI = 1.00, RMSEA = .00, and SRMR = .02. The transition cohort had marginally lower levels of EF skills relative to the post-COVID cohort (β = .18, p = .08, ΔR^2 = .02).

Latent Growth Models

Study 2

HTKS. Given that 73% of the transition cohort was missing data in the spring of pre-K due to the onset of the COVID pandemic, only children from this cohort with complete data at this time point were included in the HTKS LGMs for a total sample size of 62. A linear model with the pre-K fall and spring residual variances held to equivalence and the kindergarten residual variance set to zero (residual variance = −.004, p = .98) provided a poor fit to the data, $\chi^2(3) = 5.53$, $p = .14$, CFI = .96, RMSEA = .12, and SRMR = .08. Given this poor fit, we tested the specified model separately for each cohort. These analyses were considered exploratory given the small sample size for the transition cohort (n = 21). The model provided an acceptable fit to the data for the transition cohort, $\chi^2(3) = 1.80$, p = .61, CFI = 1.00, RMSEA = .00, and SRMR = .07, and a marginal fit for the post-COVID cohort, $\chi^2(3) = 4.11$, p = .25, CFI = .97, RMSEA = .095, and SRMR = .08, providing support for the

[1] Mplus provides an overall R^2 value for each endogenous variable but does not calculate an R^2 value for the effect of each predictor on the outcome. R^2 values were estimated by subtracting the overall R^2 value from the model with that path removed from the overall R^2 value with the path included. Therefore, these R^2 estimates are analogous to ΔR^2 seen in hierarchical regression. This procedure has been used in the prior research (e.g., McQuade, 2017).

Table 4
Study 2, COVID Transition and Post-COVID Cohorts Descriptive Statistics and Correlations

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Age (months) T1	—										
2. Child gender	.03/−.07	—									
3. SES resources	−.16/−.01	−.01/−.01	—								
4. HTKS pre-K fall	.48**/.32*	.07/−.23	.08/−.05	—							
5. CHEXI pre-K fall	.16/.30*	−.18/.25	.20/.33*	.07/.11	—						
6. HTKS pre-K spring	.40/.21	.31/.02	.13/−.27	.72**/.68**	−.01/.26	—					
7. CHEXI pre-K spring	.11/.27	−.21/.39**	.23/.32	.16/.10	.71**/.89**	.36/.28	—				
8. HTKS fall/winter kindergarten	.30*/−.05	.31*/.18	.12/−.16	.44**/.52**	.02/.01	.82**/.63**	.08/.20	—			
9. CHEXI fall/winter kindergarten	.01/.16	−.36*/.22	.24/.41*	.05/.06	.15/.40*	.15/.24	.23/.46*	.11/.14	—		
10. Family COVID impact	−.23/.21	.38*/.23	−.15/−.28	−.43*/−.02	.21/.02	X/−.06	.16/−.22	−.45*/.24	−.26/−.15	—	
11. Child COVID impact	−.08/.22	.17/.33*	.00/.09	.02/−.06	−.02/.12	X/−.07	.02/.07	.02/.04	−.45*/.13	.44*/.30*	—
Transition cohort *M* (*SD*)	51.34 (3.83)	48.6% female	0.80 (0.16)	37.27 (27.32)	47.48 (7.42)	59.10 (28.99)	49.41 (7.71)	69.91 (22.70)	45.79 (9.02)	2.81 (1.50)	2.18 (1.47)
Post-COVID cohort *M* (*SD*)	51.78 (4.05)	42.9% female	0.78 (0.17)	39.13 (27.42)	49.06 (10.25)	63.26 (26.48)	48.11 (9.54)	78.74 (14.02)	49.14 (9.41)	2.55 (1.18)	1.92 (1.24)

Note. Pre-K = prekindergarten; SES = socioeconomic; HTKS = Head–Toes–Knees–Shoulders task; and CHEXI = Childhood Executive Functioning Inventory. Numbers on the left are the correlations for the transition cohort and numbers on the right are the correlations for the post-COVID cohort. For the CHEXI and HTKS, higher scores indicate better executive function (EF). Child gender was coded 0 = boy, 1 = girl. Data were collected from Fall 2019 to the Fall/Winter 2020 for the transition cohort and from the Fall 2020 to the Fall/Winter of 2021 for the post-COVID cohort. Descriptive statistics and correlations were calculated for participants who have data at each time point.
* $p < .05$. ** $p < .01$.

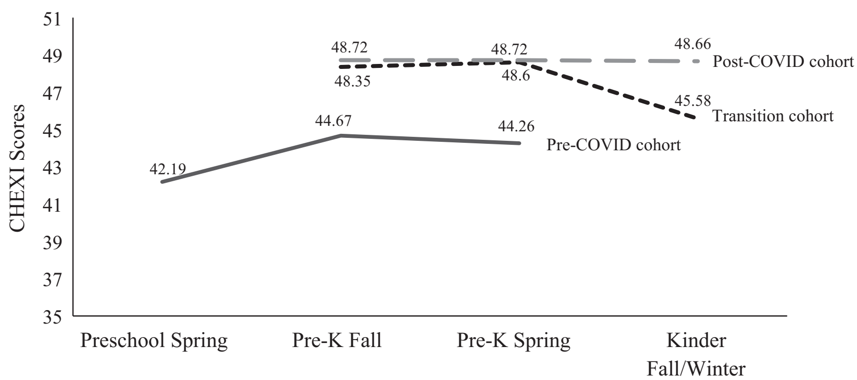
original linear model. There was a significant intercept and variance for both cohorts (transition cohort: M = 40.96, $p < .001$; σ^2 = 549.94, $p < .001$; post-COVID cohort: M = 42.51, $p < .001$; σ^2 = 641.86, $p < .001$) and a significant linear increase in EF scores across time with significant variance for both cohorts (transition cohort: M = 13.61, $p < .001$; σ^2 = 82.51, $p < .001$; post-COVID cohort: M = 18.70, $p < .001$; σ^2 = 84.57, $p < .001$). There was a significant negative covariance between the intercept and slope for both cohorts (transition cohort: standardized covariance = −.52, $p < .001$; post-COVID cohort: standardized covariance = −.81, $p < .001$). Wald tests in a multigroup analysis demonstrated that the intercept mean, Wald $\Delta\chi^2(1) = 0.04$, $p = .84$; slope mean, Wald $\Delta\chi^2(1)$ = 2.52, p = .11; and covariance between the slope and intercept, Wald $\Delta\chi^2(1)$ = 1.00, p = .32, did not vary by cohort. Therefore, children in both cohorts experienced an increase in EF skills over time.

CHEXI. When examining a linear model of the CHEXI for Study 2, with the residual variances constrained to equivalence, model fit was poor, $\chi^2(3) = 35.53$, $p < .001$, CFI = .77, RMSEA = .29, and SRMR = .18. Modifications to the model, such as freeing the residual variances, led to errors that suggested the model was misspecified (e.g., residual variances significantly negative). Therefore, a free-loading model was tested with pre-K fall coded as 0, kindergarten coded as 1, pre-K spring free to vary, and the residual variances constrained across time. This model provided an acceptable fit to the data, $\chi^2(2) = 4.25$, $p = .12$, CFI = .98, RMSEA = .09, and SRMR = .02. Results demonstrated a significant intercept and variance (M = 48.56, $p < .001$; σ^2 = 59.83, $p < .001$) and a significant slope variance with no significant mean-level change (M = −1.24, p = .27; σ^2 = 76.58, $p < .001$). There was a significant negative covariance between the intercept and slope (standardized covariance = −.48, $p < .001$). Wald tests in a multigroup analysis demonstrated that the intercept mean, Wald $\Delta\chi^2(1) = 0.06$, $p = .82$; slope mean, Wald $\Delta\chi^2(1) = 1.49$, p = .22; and covariance between the slope and intercept, Wald $\Delta\chi^2(1) = 1.31$, $p = .25$, did not vary by cohort. However, when examining the means and variances across cohorts, there was a decrease in EF scores from the fall of pre-K to kindergarten that approached significance for the transition cohort (M = −2.77, p = .06; σ^2 = 66.45, p = .007), but no change for the post-COVID cohort (M = −0.06, p = .97; σ^2 = 86.99, p = .001). Therefore, even though there was no significant difference between the two slopes, for the transition cohort there was a marginal decrease in EF skills from the fall of pre-K to kindergarten, whereas there was no change for the post-COVID cohort. In subsequent analyses, the slope mean was freed across cohort. See Figure 1 for a graph of each cohort's CHEXI trajectory.

Study 1

The decrease in EF skills seen in the transition cohort was in the opposite direction of our hypotheses, which were generated based on developmental theories of EF positing that EF should increase over time. In addition, these findings were in the opposite direction of the growth model findings of the HTKS, an objective assessment, which suggested that children experienced an increase in EF skills into kindergarten for both cohorts. This finding may reflect an initial COVID onset effect given that the increase in scores from the fall of pre-K to kindergarten was only seen for the transition cohort and not the post-COVID cohort. To further examine these alternative

Figure 1
CHEXI Model Estimated Means



Note. Pre-K = prekindergarten; Kinder = kindergarten; and CHEXI = Childhood Executive Functioning Inventory. Higher CHEXI scores indicate greater executive function.

explanations, we ran a post hoc alternative model in the pre-COVID cohort testing change in the CHEXI across three time points (i.e., preschool spring, pre-K fall, and pre-K spring). These analyses are provided in the supplemental materials, but results demonstrated that there was a significant increase in EF from the spring of a child's preschool year to the spring of their pre-K year, congruent with developmental theory ($M = 2.07$, $p = .004$; $\sigma^2 = 49.85$, $p < .001$).

In sum, an objective measure of EF showed a linear increase across preschool to kindergarten congruent with hypotheses. Teacher ratings indicated a marginal decrease in EF skills from preschool to kindergarten for the transition cohort, contrary to patterns seen in a pre-COVID and post-COVID sample.

Study 2 Demographic and COVID Predictors

HTKS

For the transition cohort, kindergarten HTKS scores were regressed on child COVID impact, family COVID impact, and the fall pre-K demographic variables. Child and family COVID impact were also regressed on the demographic variables and allowed to correlate. The model provided a good fit to the data, $\chi^2(2) = 0.06$, $p = .97$, CFI = 1.00, RMSEA = .00, and SRMR = .01; see Table 5. In terms of the demographic variables, gender was associated with kindergarten EF scores, such that girls had higher EF scores than boys ($\beta = .34$, $p = .005$, $\Delta R^2 = .09$). In addition, older children ($\beta = .51$, $p < .001$, $\Delta R^2 = .26$) and children with greater SES resources ($\beta = .20$, $p = .04$, $\Delta R^2 = .04$) had higher EF scores in the fall of pre-K. There was not stability in EF scores from fall of pre-K to kindergarten ($\beta = .19$, $p = .16$, $\Delta R^2 = .02$). Family COVID impact was negatively associated with kindergarten EF scores ($\beta = -.50$, $p = .03$, $\Delta R^2 = .15$). There was no association between child COVID impact and kindergarten EF scores ($\beta = .22$, $p = .19$, $\Delta R^2 = .04$).

For the post-COVID cohort, pre-K fall, pre-K spring, and kindergarten EF scores were regressed on child COVID impact, family COVID impact, and the pre-K fall demographic variables. Stability estimates were also specified. Child and family impact were regressed on the demographic variables and allowed to correlate. The model provided a good fit to the data, $\chi^2(2) = 0.22$, $p = .90$, CFI = 1.00, RMSEA = .00, and SRMR = .01. In terms of demographic variables, age was positively associated with fall pre-K EF scores ($\beta = .38$, $p = .006$, $\Delta R^2 = .10$) but negatively associated with EF scores at kindergarten ($\beta = -.31$, $p = .008$, $\Delta R^2 = .03$). There was stability in EF scores from the fall of pre-K to kindergarten ($\beta = .30$, $p = .03$, $\Delta R^2 = .04$), from the fall to spring of pre-K ($\beta = .70$, $p < .001$, $\Delta R^2 = .42$), and from the spring of pre-K to kindergarten ($\beta = .51$, $p = .001$, $\Delta R^2 = .12$). Family COVID impact was not associated with EF scores at fall pre-K ($\beta = -.04$, $p = .82$, $\Delta R^2 = .00$) or spring of pre-K ($\beta = -.19$, $p = .27$, $\Delta R^2 = .03$) but was positively associated with kindergarten EF scores ($\beta = .34$, $p = .01$, $\Delta R^2 = .09$). Child COVID impact was not associated with EF scores in the fall of pre-K ($\beta = -.07$, $p = .66$, $\Delta R^2 = .00$), spring of pre-K ($\beta = -.03$, $p = .87$, $\Delta R^2 = .00$), or kindergarten ($\beta = .07$, $p = .51$, $\Delta R^2 = .01$).

CHEXI

Wald tests were used to examine cohort differences for the various parameters in the conditional LGM. The associations between gender and the CHEXI slope, Wald $\Delta\chi^2(1) = 4.49$, $p = .03$, and age and family COVID impact, Wald $\Delta\chi^2(1) = 4.69$, $p = .03$, varied across cohort. Cohort differences in the association between child COVID impact and the CHEXI slope approached significance, Wald $\Delta\chi^2(1) = 3.06$, $p = .08$. A model with these paths freed and other paths constrained across cohort provided a marginal fit to the data, $\chi^2(36) = 40.57$, $p = .28$, CFI = .98, RMSEA = .05, and SRMR = .095; see Table 6. Of the demographic covariates, gender (transition cohort, $\beta = .30$, $p = .01$, $\Delta R^2 = .05$; post-COVID cohort, $\beta = .23$, $p = .01$, $\Delta R^2 = .03$), age (transition cohort, $\beta = .27$, $p = .006$, $\Delta R^2 = .07$; post-COVID cohort, $\beta = .22$, $p = .006$, $\Delta R^2 = .07$), and SES (transition cohort, $\beta = .36$, $p = .002$, $\Delta R^2 = .11$; post-COVID cohort, $\beta = .30$, $p = .002$, $\Delta R^2 = .10$) were associated with the CHEXI intercept, such that girls, older children, and children with greater SES resources had higher levels of EF skills in the fall of pre-K. No demographic variables were associated with the CHEXI slope. Of the COVID impact variables, the effect of child COVID impact was marginally different across cohort such that for the transition cohort higher levels of child COVID impact were related to greater decreases in EF scores from the fall of pre-K to

Table 5
HTKS Standardized Regression Estimates

Study 2, transition cohort				Study 2, post-COVID cohort			
	β	*p*	Overall R^2		β	*p*	Overall R^2
HTKS kindergarten			$.43^{**}$	HTKS kindergarten			$.60^{**}$
HTKS Pre-K spring	X			HTKS Pre-K spring	$.51^{**}$	.001	
HTKS Pre-K fall	.19	.16		HTKS Pre-K fall	$.30^{*}$	.03	
Gender	$.34^{**}$	.005		Gender	.15	.28	
Age Pre-K fall	.08	.55		Age Pre-K fall	$-.31^{**}$	.008	
SES Pre-K fall	−.06	.69		SES Pre-K fall	.03	.84	
Family COVID impact	$-.50^{*}$	.03		Family COVID impact	$.34^{*}$	.01	
Child COVID impact	.22	.19		Child COVID impact	.07	.51	
				HTKS Pre-K spring			$.56^{**}$
				HTKS Pre-K fall	$.70^{*}$	<.001	
				Gender	.20	.16	
				Age Pre-K fall	.00	.98	
				SES Pre-K fall	−.31	.14	
				Family COVID impact	−.19	.27	
				Child COVID impact	−.03	.87	
HTKS Pre-K fall			$.27^{**}$	HTKS Pre-K fall			.15
Gender	.03	.77		Gender	−.13	.39	
Age Pre-K fall	$.51^{**}$	<.001		Age Pre-K fall	$.38^{**}$	.006	
SES Pre-K fall	$.20^{*}$	.04		SES Pre-K fall	.03	.88	
				Family COVID impact	−.04	.82	
				Child COVID impact	−.07	.66	

Note. Pre-K = prekindergarten; HTKS = Head–Toes–Knees–Shoulders task; and SES = socioeconomic resources. Child gender was coded 0 = boy, 1 = girl. Data were collected from Fall 2019 to the Fall/Winter 2020 for the transition cohort and from the Fall 2020 to the Fall/Winter of 2021 for the post-COVID cohort. The COVID impact variables were collected in late Spring/Summer 2020 for the transition cohort and Fall 2020 for the post-COVID cohort. For the transition cohort, analyses were not examined for the HTKS in the spring given that the majority of the sample was missing data at this time point.
$^{*}p < .05$. $^{**}p < .01$.

kindergarten (β = −.32, $p = .045$, $\Delta R^2 = .11$), whereas there was no impact of child COVID impact on teacher-rated EF for the post-COVID cohort (β = .16, $p = .36$, $\Delta R^2 = .00$).

Discussion

The overarching goal of the present study was to leverage data from two longitudinal projects to evaluate whether the COVID-19 pandemic influenced teacher ratings and observational measures of preschool children's EF skills. Overall, results suggested that the pandemic had the largest negative impact on EF for the transition cohort, who transitioned to kindergarten after the spring 2020 lockdown. These children had marginally lower EF skills in kindergarten as evidenced through objective observational and teacher report assessments, experienced a marginal decrease in teacher-rated EF from the fall of pre-K to kindergarten, and had the greatest negative effects due to COVID impact. However, these children still demonstrated an increase in EF skills using an objective assessment from the fall of pre-K to the fall of kindergarten. Therefore, the marginal decrease in EF skills observed for teacher ratings, a subjective measure of EF, may reflect reduced validity of teacher ratings or changes in teachers' perceptions due to the changing classroom contexts associated with the pandemic.

The first aim of the study was to test the reliability and validity of various formats of the HTKS and the CHEXI. The virtual administration of the HTKS showed similar interrater reliability to the school and lab formats. Notably, there was stability in the CHEXI correlations and HTKS regressions for the post-COVID cohort but not the transition cohort, suggesting greater malleability in EF across the initial COVID shut down period. The CHEXI and HTKS were weakly to moderately correlated for all time points and cohorts, congruent with prior research which has found weak to moderate correlations among teacher ratings of EF and tasks (e.g., Graziano et al., 2015; Thorell & Nyberg, 2008). In addition, the strength of these validity correlations did not vary by cohort, suggesting that there was similar concordance among the measures for the transition and post-COVID cohort. This is the first study that provides evidence for the reliability and validity of the HTKS when standard procedures are observed virtually.

Next, we evaluated whether there were between-group differences for each cohort in the fall and spring of pre-K, when all three studies had data collected. Results demonstrated that in the fall of pre-K, teachers rated children higher on EF skills in the post-COVID cohort relative to the transition cohort. In the spring of pre-K, teachers rated children higher on EF skills in the COVID transition and post-COVID cohorts relative to the pre-COVID cohort. These findings may be the result of changes in class settings as a result of the pandemic (i.e., teachers were engaged in hybrid, virtual, or limited in-person settings) and suggest that teacher ratings of EF may have reduced validity when teachers observe preschool children in virtual or limited in-person settings. In kindergarten,

Table 6
CHEXI Conditional Latent Growth Model Standardized Estimates

	Study 2 transition cohort/post-COVID cohort		
	β	*p*	Overall R^2
CHEXI intercept			.25**/.18*
Gender	.30*/.23*	.01	
Age Pre-K fall	.27*/.22**	.006	
SES Pre-K fall	.36**/.30**	.002	
Family COVID impact	.15/.10	.34	
Child COVID impact	−.13/−.08	.37	
CHEXI slope			.16/.09
Gender	**.20/−.18**	**.20/.36**	
Age Pre-K fall	−.13/−.15	.26	
SES Pre-fall	−.02/−.02	.89	
Family COVID impact	−.17/−.17	.25	
Child COVID impact	**−.32*/.16**	**.045/.36**	

Note. SES = socioeconomic resources; Pre-K = prekindergarten; and CHEXI = Childhood Executive Functioning Inventory. Child gender was coded 0 = boy, 1 = girl. The estimates for the transition cohort are listed first, followed by estimates from the post-COVID cohort. Bolded estimates were significant or marginally significant across cohort and were free to vary across cohort. All other paths were constrained to be equivalent across cohort. All constrained unstandardized estimates were the same across cohort with the same *p* value, but there were minor differences in standardized estimates due to the standardization process. Therefore, standardized estimates are presented for both cohorts but the *p* values are the same for each cohort unless the estimates were significantly different.
* $p < .05$. ** $p < .01$.

children in the transition cohort had marginally lower teacher-reported EF skills relative to children in the post-COVID cohort. Similarly, when using an objective assessment across the transition to kindergarten, there was a marginally significant difference between cohorts, with higher scores for the post-COVID cohort relative to the transition cohort. Taken together, this indicates that across teacher and objective reports of EF, there is some evidence that children in kindergarten had lower EF skills in the fall of 2020 relative to the fall of 2021, although these effects were small. This is consistent with prior research on the COVID pandemic which suggests that children may have experienced impairments in EF skills as a result of the pandemic (Deoni et al., 2022; Di Giorgio et al., 2021; Hanno et al., 2022). Furthermore, the novel results from this study indicate that the entrance to kindergarten at the height of the COVID pandemic had particularly deleterious effects on children's EF. The transition to kindergarten may be a sensitive period where COVID effects are more salient. However, caution is warranted when interpreting these effects given that these findings were small in magnitude and nonsignificant.

Aim 3 of the present study evaluated how change in EF skills varied across three time points in early childhood when using objective and teacher-reported instruments. Congruent with hypotheses, objective scores linearly increased over time (i.e., an increase in EF from the fall of pre-K to the fall/winter of kindergarten) for the transition and post-COVID cohorts. These findings are consistent with prior research which suggests that growth in EF and self-regulation increase rapidly across early childhood, with particular increases in the preschool period (see Diamond, 2002; Reilly et al., 2022; Zelazo et al., 2003). Contrary to developmentally informed hypotheses and LGM results using an objective measure of EF, there was a marginal decrease in teacher-reported EF from the fall of pre-K to kindergarten for the transition cohort and no change in scores for the post-COVID cohort. As a follow-up analysis, we examined a growth model of teacher-reported EF in the pre-COVID sample. Results from this model demonstrated an increase in EF from the spring of preschool to the spring of pre-K, congruent with hypotheses. Overall, these results suggest that teachers are reporting a decrease in EF for the transition cohort, but objective measures are showing the expected improvements in EF. Teachers experienced unique stressors during the COVID pandemic including new modes of instruction and new forms of communication with caregivers and students (Robinson et al., 2023). Preschool teachers also reported difficulties with managing children's behavior within hybrid or virtual formats because they could not use typical methods for helping children attend to content or calm down if upset (Chen & Adams, 2023; Yildiz et al., 2023). This changing context of instruction and communication, in addition to heightened stress, may have sensitized teachers to EF impairments, resulting in reports of decreased EF skills over time.

No cohort demonstrated mean-level change in teacher-reported EF skills from the fall to spring of pre-K despite linear increases in the HTKS. Teachers may have difficulty parsing out earlier experiences of children's EF when reporting on spring EF. Interestingly, teacher ratings of other behaviors, such as aggression, have demonstrated an increase from the fall to spring within the Study 1 sample (Perry & Ostrov, 2023), potentially suggesting that teachers may have more difficulty identifying change in EF. These findings suggest that the transition to a new classroom may serve as a period in which change in teacher-rated EF is best captured.

The final aim of the study was to examine whether individual child or family COVID impact was associated with change in EF. For the transition cohort, who entered kindergarten a few months after the onset of the COVID pandemic, higher levels of family COVID impact were associated with lower objective EF scores after the transition to kindergarten. Moreover, higher child COVID impact was associated with decreases in teacher-rated EF skills from the fall of pre-K to the fall/winter of kindergarten. These findings are congruent with hypotheses and indicate that children in the transition cohort whose caregivers reported greater COVID impact had significant reductions in EF skills into kindergarten. Researchers have theorized that virtual instruction, reduced social interaction, disturbed sleep, increased screen time, increased child and parental anxiety and depression, and change in exercise and diet may contribute to this reduced cognitive function for young children (Deoni et al., 2022; Di Giorgio et al., 2021; Schmidt et al., 2021; Singh et al., 2020; Susilowati et al., 2021). In addition, a diagnosis of COVID-19 can have a direct, long lasting impact on fatigue and cognitive functioning, although these long-term symptoms are less common for children (for a meta-analysis, see Ceban et al., 2022). Therefore, COVID-19 and associated lockdowns likely impacted children's EF skills through a number of direct and indirect pathways. No prior research has empirically tested these pathways across time. Understanding these pathways and whether growth in children's EF skills returns to prepandemic levels is a critical area for future research.

For the post-COVID cohort, family COVID impact was positively associated with higher objective ratings of EF skills in kindergarten, but not in pre-K which were more proximal to the time family COVID impact was being reported. In addition, child COVID impact was not associated with change in teacher-reported EF scores over time. The finding that COVID impact was positively associated with objective ratings of EF in kindergarten was unexpected. It is possible that there were protective factors, such as increased access to resources, which were available to families highly impacted by the pandemic at the transition to kindergarten for the post-COVID cohort but not the transition cohort. In addition, children in this sample experienced a mild-to-moderate level of COVID stress (i.e., a mean around 2 on a 1–7 Likert scale). A mild-to-moderate amount of stress can increase resilience to subsequent stressors and improve EF performance over time (Homaifar et al., 2014). The transition cohort may not have exhibited this resilience because the stressor (i.e., the pandemic) was still salient in kindergarten, whereas the post-COVID cohort had more time to adjust. Future research should examine these results in samples highly impacted by COVID to parse out these explanations. Overall, this study provides novel evidence that COVID impact at the family and child level influenced children's EF in early childhood.

Constraints on Generality

Participants were recruited from high-quality childcare centers in a middle- to upper middle-class sample and experienced mild-to-moderate COVID impact, which limits the generalizability of the findings to high-risk samples, where children may demonstrate different trajectories of EF and where COVID risk factors, such as low levels of SES resources may have a greater impact. Similarly, even though participant racial and ethnic backgrounds were similar to the larger county from which the sample was drawn, results may not be generalizable to other geographic regions or cultures. Most EF measures have been developed in high-income countries (Obradović & Willoughby, 2019) and normed on White populations, which may lead them to underestimate the skills of low income or racial/ethnic minority children (Miller-Cotto et al., 2022). In addition, the response to the COVID pandemic varied between regions of the United States and different countries. Therefore, this pattern of effects may not be generalizable to other geographic regions. We have no other reason to believe that the results depend on other characteristics of the participants, materials, or context.

Limitations and Future Directions

Consistent with a natural experiment like the COVID pandemic, the ability to replicate the present findings may be limited. For this reason, specific a priori hypotheses were derived and rigorous and conservative models were selected. Some caution should be exercised in the interpretation of the post hoc follow-up models as they were guided by the unanticipated pattern of findings. In general, despite numerous strengths including the longitudinal, multi-informant, and multimeasure study that includes pre- and postpandemic data, there are some key limitations. Central among these is a relatively homogenous and advantaged sample. Given the role that SES resources play in the development of executive functioning skills (e.g., Vrantsidis et al., 2020), it will be important for the core aims of this study to be tested with a more diverse (SES and race/ethnicity) sample. Future research should also evaluate these topics in a clinical sample, for whom the pandemic may have had a greater impact on EF skills. Regarding procedures, the changing contexts related to COVID are on the one hand, a key strength of the study, but these educational contexts are rare and unlikely to generalize to typical postpandemic settings. In addition, the pre-COVID sample did not include a kindergarten assessment, which limits our ability to determine how pre-COVID growth in EF compares with growth in the post-COVID and transition cohorts across the transition to kindergarten.

There were also several measurement limitations that should be noted. The weak to moderate degree of convergence between the direct observational task (i.e., HTKS) and the teacher-rated measure (i.e., CHEXI) of EF is consistent with prior literature testing the validity of the HTKS in preschool classrooms (Graziano et al., 2015) but warrants some caution. There are several versions of the HTKS including a recently introduced revised version to reduce floor effects (i.e., HTKS-R; Gonzales et al., 2021) and future work should evaluate this version of the measure. The COVID impact measure included seven items and therefore narrowly assesses COVID impact on children and their families. Objective assessments, such as local rates of COVID infection (e.g., Shelleby et al., 2022), may be particularly useful in future research when evaluating the impact of COVID on outcomes in a wider geographic range. To further examine the measurement effects found in the present study, future research should include parent reports of EF across time, consider discriminant validity, and evaluate whether the structure of these assessments is equivalent across subgroups in the population (e.g., across cultures, gender, and race/ethnicity).

Finally, there were statistical limitations in the present study. There are some concerns regarding power given the smaller sample size for Study 2. These concerns are reduced given the robust, longitudinal pattern of findings, but nevertheless warrant some caution. Missing data were present for both studies and raise some additional concerns with the robustness of study models. However, missing data procedures were used to capitalize on the full sample. Future work that addresses these issues and continues to examine the clinical and educational value of administering these tasks in efficient and convenient formats (e.g., virtually) is important. Future work must also consider the contextual differences in conducting virtual assessments within the homes of families with a parent quietly observing rather than in a school setting where the parent is not typically present.

Conclusions

The present study leveraged two longitudinal data sets to evaluate the measurement characteristics of objective and teacher-rated assessments of EF in a pre-COVID cohort (i.e., data collected prior to 2020), a transition cohort (i.e., data collected from the Fall 2019 to Fall/Winter 2020), and a post-COVID transition cohort (i.e., data collected from the Fall 2020 to Fall/Winter 2021). Results demonstrated that virtual administration of the standard HTKS showed similar measurement characteristics to a school and lab in-person administration. In terms of longitudinal change in EF across preschool, teacher and objective reports demonstrated a different pattern of findings. Teacher ratings of EF showed a marginal decrease in the transition cohort and no change in the post-COVID cohort, whereas objective measurements demonstrated the expected increase in EF. Teachers may be less reliable informants of EF in the context of virtual or reduced in-person instruction. Furthermore, child COVID impact was associated with decreases in teacher-rated EF across time, and family COVID impact was associated with reduced objective measurement of EF in kindergarten for the transition but not the post-COVID transition cohort. Overall, this study provides novel evidence that the pandemic differentially impacted teacher and objective measures of EF across the transition to kindergarten with the largest effect of the pandemic for children who transitioned to kindergarten in the fall of 2020.

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