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Executive Function Mediates the Association Between Cumulative Risk and Learning in Ghanaian Schoolchildren

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Research on the associations among adversity, executive function (EF), and academic outcomes in low- and middle-income countries, where developmental risk factors are more prevalent and impoverished environments are more widespread than in high income countries, is sparse. This study examines the relations among cumulative risk, EF, and learning outcomes measured 2-years later in Ghanaian third- and fourth-graders (N = 371; 49% female), shedding light on underlying mechanisms of how risk can undermine learning. A cumulative risk index was created based on a set of four child-reported risk factors: home aggression, unsafe home neighborhood, hunger, and having worked for pay. Cumulative risk and EF were negatively correlated. Learning outcomes (literacy and math test scores) were negatively correlated with earlier measures of cumulative risk and positively correlated with earlier measures of EF. EF mediated the association between cumulative risk and later learning outcomes, accounting for 65.3% of the total effect for literacy and 100% for math. This mediated pathway was robust to controls for child and household sociodemographic characteristics. The findings contribute to a small evidence base on the mediating role of EF in linking adversity and learning outcomes in a global context.

Keywords: executive function, middle childhood, cumulative risk, sub-Saharan Africa, Ghana

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Executive function (EF) refers to a set of top-down cognitive processes involved in planning and goal-directed activity. Three distinct but related elements of EF are include working memory (being able to hold and mentally manipulate information), cognitive flexibility (thinking flexibly and switch attention between competing demands), and inhibitory control (being able to ignore distractions and control attention and behavior; Miyake et al., 2000). Together, these skills help children concentrate, manage behaviors and emotions, and ignore distractions (Diamond, 2013). Children's EF begins to emerge during early childhood, increases markedly during this time, and continues to develop through adolescence (Best & Miller, 2010). Age-related advancements in EF persist through middle childhood (Davidson et al., 2006), as well as continued links between EF and school achievement (Cortés Pascual et al., 2019). These findings are important as older children are increasingly introduced to more complex attentional and cognitive demands as engagement with out-of-home environments increases (i.e., with teachers and peers) and they begin to receive less direct scaffolding from parents.

Children develop EF within the constraints and opportunities provided by their environments. The ecological theory of development (Bronfenbrenner & Morris, 2006) highlights that the interplay of multiple contexts with enabling or constraining factors can positively or negatively affect children's EF development. Exposure to childhood adversity—defined as environmental circumstances at home, community, or school that can threaten healthy development (McLaughlin, 2016)—can disrupt children's academic learning and hinder the development of EF (Blair & Raver, 2012). Although there are substantial cross-national differences in the amount and types of adversity children experience, most of the

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research on EF comes from a small set of high-income countries. Compared with other global regions, sub-Saharan Africa (SSA) has the highest proportion of young children exposed to extreme poverty and stunting, key risk factors that can affect development (Black et al., 2017; Lu et al., 2020). Within contexts characterized by widespread and elevated rates of risk—relative to high-income countries—the degree to which variability of children's exposure to multiple risks in low- and middle-income countries (LMICs) matter for EF development remains an open question.

A small body of research from the United States has shown that EF partially explains the negative associations between adversity and children's academic outcomes in early and middle childhood (Lawson & Farah, 2017; Waters et al., 2020). Extending this line of work generally—and to SSA and other LMICs in particular—is a fruitful area of investigation. Despite increased access to basic schooling, many children do not have early learning opportunities (i.e., access to quality teachers and reading materials at home) that could promote educational success and consequently reach adulthood without foundational literacy and numeracy skills (World Bank, 2018). Global education agencies have spotlighted this learning crisis and prioritized efforts to boost children's basic academic skills. At the same time, in SSA where the prevalence of adversity is higher relative to other global regions (Black et al., 2017), focusing on strengthening children's EF could be another worthy avenue of intervention to improving school success that can be accomplished in- or out-of-school contexts and in culturally sensitive ways. This theory of whether EF can, at least partially, explain how adversity relates to lower learning has yet to be tested in SSA; thus, this study aims to shed light on this gap in the literature by testing whether EF mediates the associations between cumulative risk and literacy and math outcomes in Ghanaian third- and fourth-graders.

Executive Function and Learning Outcomes

Recent research in LMICs points to the universality of EF in supporting children's development and learning (Obradović & Willoughby, 2019). In early and middle childhood, EF has been cross-sectionally and longitudinally associated with better literacy, language, and mathematics skills in high-income countries (Allan & Lonigan, 2011; Clark et al., 2010; Cortés Pascual et al., 2019; Weiland et al., 2014). The particular mechanisms for how EF affects academic learning has not yet been explicated in the literature nor have causal relations been ascertained (e.g., Miller-Cotto & Byrnes, 2020). Nonetheless, meta-analytic studies have revealed significant, medium-sized correlations between EF and reading and math in elementary school children (Spiegel et al., 2021). A similar pattern emerges with geographically diverse samples of young children, including in SSA. In Kenyan and Ghanaian preschoolers, direct assessments of EF robustly predicted stronger literacy and numeracy skills (Willoughby et al., 2019; Wolf & McCoy, 2019). Likewise, in a diverse sample of Brazilian 6- to 8-year-olds, EF predicted children's reading abilities (Engel de Abreu, 2011). Lastly, in young children in Albania, EF was positively correlated with academic achievement (von Suchodoletz et al., 2015).

Children's Exposure to Risk

Developmental risks are individual and environmental factors that are associated with a greater likelihood of developing undesired outcomes. Cumulative risk has been studied extensively in high-income countries (Evans et al., 2013). Yet, in SSA, where certain risks may be more prevalent and impoverished environments are more widespread, much less is empirically known about the association between adversity and EF. To illustrate, estimates in SSA indicate that 15.4% of young children had poor nutrition (Danaei et al., 2016) and over 70% were exposed to physically or psychologically aggressive punishment (Cuartas et al., 2019).

Cumulative risk theory posits that the effect of risk exposure is compounded when children face multiple co-occurring risks. Exposure to multiple risks is one of the most powerful predictors of unfavorable child outcomes, and has been shown to be more strongly predictive than any single risk factor (Evans et al., 2013; Green et al., 2010). A common approach to measuring exposure to multiple risks is to calculate a cumulative risk index that captures the presence of risk in an summative manner (Evans et al., 2013). To create the risk index, each risk is dichotomized so that exposure equals one and no exposure equals zero, and the binary risk indicators are summed into a single risk index. Cumulative risk indices have largely been used in high-income countries; the majority of global research to date has studied how individual risk factors affect children's development (e.g., Kim et al., 2020). Yet, given the widespread nature of risk exposure in SSA, an additive approach may be useful to apply to child development.

Exposure to Risk and Executive Function

In high-income countries, adversity undermines the development of EF (Blair & Raver, 2012). The physiological stress response is a biological mechanism that explains how adversity affects EF development (Evans & Fuller-Rowell, 2013) through changes in the structure and connectivity of brain regions that support EF (Hackman & Farah, 2009; Lawson et al., 2013). Examples of risks that have been shown to compromise EF include living in a high-poverty neighborhood (McCoy et al., 2015), low socioeconomic status (SES; Lawson et al., 2018), high residential mobility (Roy et al., 2014), and food insecurity (Grineski et al., 2018).

Similar associations between adversity and EF have been found in LMICs, including SSA countries. For example, poverty was associated with working memory in adolescent Syrian refugees in Jordan (Chen et al., 2019). Another study found that household wealth and maternal education both indirectly affected EF in Zambian 6-year-olds (McCoy et al., 2017). In contrast, maternal education, but not household wealth, was positively related to EF in preschoolers in rural Pakistan (Obradović et al., 2016, 2019). And lastly, malnutrition and food insecurity are widely studied, although fewer studies have examined the consequences for children's EF. In a study with this sample, following children for 3 years, Aurino and colleagues (Aurino et al., 2020) found that transitory spells of household food insecurity negatively predicted short-term memory and behavioral regulation in primary schoolchildren. In rural Pakistan, food insecurity had a small-to-moderate bivariate association with 24-month-old children's EF, but this relation did not hold after the inclusion of a robust and proximal set of covariates (i.e., height-for-age; Obradović et al., 2016, 2019).

And finally, across diverse country contexts, girls were generally found to have better EF than boys (Matthews et al., 2009; Thorell et al., 2013). Yet, it is possible that the reverse may be true in SSA, such that research from Kenya and Ethiopia has found

that girls tend to perform worse on cognitive assessments than boys. Whether this pattern holds to the specific cognitive skills of EF is unknown. One possible explanation for this divergence in findings could be related to broader gender disparities in SSA, such as how girls and boys spend their time, with girls on average having more home-based responsibilities and bearing the burden of greater household responsibilities than boys (e.g., Escueta et al., 2014; Pells, 2011).

Exposure to Risk and Learning Outcomes

Previous research in SSA has linked a range of risk factors with children's educational abilities. For one, household food insecurity predicted lower educational outcomes in both early and middle childhood in Ghanaian and Ethiopian children (Aurino et al., 2020; Belachew et al., 2011). In addition, physical aggression in the home was negatively associated with young children's literacy skills in Ghana (Wolf & Suntheimer, 2020), and mothers' experience of interpersonal violence has been linked to worse early childhood development across 11 LMICs (Jeong et al., 2020). Lastly, child labor in LMICs can also affect learning. One possible way could be through detrimental influences on physical and mental health (Ibrahim et al., 2019); alternatively, child labor may also reduce the amount of time children have to attend school and to study. Exposure to community violence and residing in a neighborhood characterized by poor physical qualities (e.g., water, air, and noise pollution) has also been shown undermine children's learning and mental health in diverse samples of children (Cuartas & Roy, 2019; Sherr et al., 2016). And notably, one recent study linked a cumulative risk index with lower literacy and numeracy outcomes in Ghanaian kindergarteners (Ibekwe-Okafor & Wolf, 2021).

The Mediating Role of EF

EF is associated with both risk exposure and academic outcomes; thus, it may serve as a potential mechanism connecting the two. Several studies using samples of children from the United States and United Kingdom have explored how EF mediates the association between SES and academic skills. EF mediated the link between SES and math and literacy achievement in two separate studies of kindergarteners from the United States (Fitzpatrick et al., 2014; Nesbitt et al., 2013), whereas a third study found a similar association to only be true for math (but not literacy) skills in preschoolers (Dilworth-Bart, 2012). Crook and Evans (2014) found that third graders' EF mediated the association between an income-to-needs ratio and fifth graders math and reading, with stronger associations for math. Lawson and Farah (2017) found that that SES predicted significant *changes* in reading and math over a 2-year period for 6- to 15-year-olds, and that EF significantly mediated the relation for math only. Further, in a sample of children in the United Kingdom, children's EF during middle childhood mediated the association between family income—from birth to 5 years—to a composite measure of academic achievement in adolescence (Deer et al., 2020).

Whether such associations exist in SSA or other LMICs is an open question that is in need of further exploration. One recent study examined seven individual, household, and community risk factors in Syrian refugees in Lebanon and found that working memory (but not inhibitory control) mediated the relation between two risk factors (age-for-grade and perceived community safety) and literacy and numeracy skills in primary school-age children (Kim et al., 2020). Extending this work to SSA is needed, as are different operationalizations of risk (e.g., a cumulative risk index) to provide more nuance to the nascent research base. It is possible cumulative risk effects are amplified in disadvantaged settings, where not only is the prevalence of child poverty and risk higher, but the availability of quality education is much lower.

The Ghanaian Context

Ghana is a lower-middle income country in West Africa, with 57% of its population younger than 25 years (CIA, 2020). Historically, the education system in Ghana has employed an instructional approach that emphasizes rote instruction and memorization (Agbenyega, 2018; Ghana Education Service, 2016). Put differently, teachers' techniques are often rigid with limited opportunities for classroom engagement. Likewise, children's knowledge acquisition is assessed in a similarly prescriptive fashion (Agbenyega, 2018). In 2019, approximately 87% of Ghanaian children were enrolled in primary school (serving 6- to 11-year-olds; World Bank, 2020b). Yet, despite high enrollment rates, students' reading and math performance was very low (Ghana Education Service, 2016). By the end of Primary 2 (analogous to second grade in the United States), more than 80% of children were unable to read a single word and nearly 70% of students unable to correctly answer a subtraction (e.g., 19 minus 6) problem (Ghana Education Service, 2016). The role of EF in supporting learning in such teacher-directed, low-quality educational contexts is understudied. While this study does not examine teaching practices in Ghana as they relate to EF development, these points are important to keep in mind because little is known about specific factors that promote EF outside of the United States and how school-based processes could moderate the role of EF in supporting learning. Our findings can inform the role of nonacademic skills in improving learning outcomes across diverse educational contexts.

Ghana has made tremendous progress in closing gender gaps in access and enrollment to primary schooling, and in 2018 attained a score of 1.01 on the Gender Parity Index, with a value of 1 indicating equality (UNESCO, 2020). At the same time, Ghanaian girls remain at a greater risk across several domains, such as exposure to sexual and school gender-based violence without concrete, local policies in place for protection (UNESCO, UNICEF, & UNGEI, 2019) and educational inequities emerge at the tertiary education level (UNESCO, 2020). Further, although caregivers' gender socialization practices are an understudied area in Ghana, deeply rooted gender norms (Mann & Takyi, 2009; Sikweyiya et al., 2020) may differentially shape educational investments in boys and girls and protection from adversity. This study begins to examine gender differences in key learning processes by testing gender differences in how cumulative risk relates to EF and learning, and whether EF operates differently for girls and boys in explaining the link between adversity and learning outcomes. While our sample is not representative of the broader community, given high rates of enrollment in primary school for both boys and girls in Ghana (UNESCO, 2020) it is likely that the girls in our sample do not differ substantially from girls in the broader community.

The Present Study

The primary aim of this study was to empirically test the mediating role of EF in explaining the link between exposure to adversity

and learning during middle childhood in Ghana where such associations have not yet been studied. Using longitudinal data, we hypothesize that EF would be a significant mediator linking lifetime risk exposure to children's future literacy and math outcomes. We extend prior work on risk and child development in SSA by applying a cumulative risk framework to operationalize risk exposure and examine whether EF mediates the relation between exposure to adversity and later learning outcomes. Moreover, while the knowledge base on EF is geographically diversifying, many of the samples in these studies include preschool- or kindergarten-aged children. We contribute by drawing on a sample of older Ghanaian children in middle childhood, a development period during which EF continues to grow (Best et al., 2011), and examine potential environmental constraints that could hinder EF and learning. Moreover, we examine whether these processes differ for boys and girls, without specific hypotheses in the direction of effects.

Method

Participants and Procedure

Our sample is drawn from a randomized trial of a teacher training and parental awareness program to improve preprimary school quality and children's primary school readiness. The program was implemented in the 2015–2016 school year, with partnerships between Ghana's Ministry of Education, Innovations for Poverty Action, Sabre Education, and university-based researchers (see Wolf et al., 2019, for details). In the summer of 2015 (Wave 1), 240 public and private schools were randomly sampled from six districts in the Greater Accra Region of Ghana. Schools were randomly assigned to three conditions: (a) teacher training (TT); (b) teacher training plus parental-awareness meetings (TTPA); or (c) "business as usual" control group. The primary treatment arm (TT) was an in-service training and coaching program for kindergarten (KG; for 4- and 5-year-olds) teachers that focused on creating higher-quality child-centered learning opportunities and more positive classroom interactions (i.e., behavior management and teacher–child relationships). The secondary treatment arm (TTPA) had an additional component that included three parental-awareness meetings, which were video screenings that educated caregivers on the importance of play-based learning and caregiver involvement in education (see Wolf, 2019, and Wolf et al., 2019, for experimental findings).

In each school, 15 preprimary students were randomly sampled from class rosters. The full sample at baseline (Wave 1) comprised of 3,435 children, and six waves of follow-up data have been collected between 2015 and 2021 (subsequently referred to as Waves 2–7, respectively). Notably, Wave 5 was collected with a subset of children in October 2019, of which we randomly sampled 407 children from the 2,701 children that participated at all four previous time points, stratified by treatment arm (31% control; 35% TT; 34% TTPA). Data used in this study come from Wave 1 (October 2015; M_{age} = 5.2 years), Wave 2 (May 2016; M_{age} = 5.8 years), Wave 5 (October 2019; M_{age} = 9.3 years), and Wave 7 (July 2021; M_{age} = 11.0 years); data from Wave 6 are not used in this study, as only a limited assessment of child outcomes was conducted via phone survey due to the coronavirus disease 2019 (COVID-19) pandemic.

At each of these time points, child assessments were administered by trained Ghanaian assessors at the child's school in a comfortable space away from the classroom. The original study sample was representative of school-going children across the six original study districts. The subsample for the current study consisted of children who were less mobile and easier to track over several years. Comparison analyses of this subsample to children who were part of the original sample in the first year of the project but did not participate in this study revealed that children in the current subsample had higher academic and social-emotional scores in Year 1 of the study, with no differences found on child age, child sex, school type, EF, motor skills, or approaches to learning (see Table S1 in online supplemental materials).

EF data were missing for 42 of the 407 (9.3%) children sampled in the Wave 5 study due to a programming error that resulted in lost data. Our final analytic sample was composed of 371 children with EF data. Among participating children, 49% were female, 90.2% attended Primary 3 or Primary 4 (equivalent to third and fourth grade in the United States), 54% attended public schools, and the average age was 9.28 years (SD = 1.27). This research was approved by the University of Pennsylvania's Institutional Review Board (Protocol Number: 825679; Project Title: An Intervention to Improve Preschool Quality in Peri-urban Ghana) and the Innovations for Poverty Institutional Review Board (Protocol Number: 1328; Project Title: Quality Preschool for Ghana).

Measures

Lifetime Exposure to Cumulative Risk

At Wave 5, children reported on four risk factors from the International Social Emotional Learning Assessment, which was developed and tested in Uganda and Kenya (ISELA; D'Sa, 2019) and captured children's lifetime exposure to different types of risk factors. For each of the four risk factors, we created a binary indicator variable (0 = no, 1 = yes). The questions included: (1) *worked for pay* (16%), "Have you ever had to work to get money to support your family?"; (2) *lived in unsafe neighborhood* (20%), "Have you ever lived in an area or a town where you did not feel safe?"; (3) *experienced hunger* (40%), "Have you ever gone hungry because there was not enough food to eat?"; and (4) *lived in an aggressive home* (64%), "Have you ever lived in a home where people shout or yell at each other; or where people push, slap, or throw something at each other?." On average, children in this study were exposed to 1.40 (SD = 1.06) risks. Correlations between individual risks ranged from .12 to .25 (see Table 1).

Learning Outcomes

At Wave 7, *literacy* was measured via an adapted version of the Early Grade Reading Assessment (EGRA; RTI International, 2015). EGRA was developed by RTI International in 2006 to assess foundational literacy skills and has been translated into eleven local Ghanaian dialects and is used at the national level in Ghana to provide data to key policy stakeholders about students' performance in Primary 2. Three subtasks were used: (1) letter-sound identification (measures letter-sound correspondence); (2) nonword reading (ability to decode unfamiliar nonwords); and (3) listening comprehension (assesses overall listening comprehension competence). We adapted the EGRA assessment in that the listening comprehension passage was substituted for a slightly more difficult one that was administered as part of

Table 1
Descriptive Statistics and Bivariate Correlations Among Main Study Variables

No.	Variable	*M* or %	Range	1	2	3	4	5	6	7	8	9	10	11
1	EF (*z*-scored)	0.00	−3.2–2.2	—										
2	Literacy[b]	0.52	0–0.95	*.36*	—									
3	Math[b]	0.44	0–0.94	*.42*	*.67*	—								
4	Cumulative risk index	1.40	0–4	*−.15*	*−.14*	*−.16*	—							
5	Home aggression	64.2%	0–1	*−.14*	*−.23*	*−.17*	*.68*	—						
6	Work for pay	15.7%	0–1	*−.11*	*−.13*	*−.11*	*.51*	*.15*	—					
7	Unsafe neighborhood	20.0%	0–1	−.08	−.06	−.10	*.56*	*.13*	*.14*	—				
8	Hunger	40.4%	0–1	*−.12*	.03	.01	*.68*	*.26*	.10	*.17*	—			
9	Caregiver education[a]	3.17	1–6	.09	*.30*	*.22*	−.10	−.03	*−.17*	−.05	−.03	—		
10	Child female	49.1%	0–1	−.05	*.13*	.10	*−.11*	−.08	.00	−.06	*−.11*	−.05	—	
11	Child age	9.3	5–14	.07	*−.15*	−.11	.09	.01	*.18*	.04	.03	*−.32*	−.05	—
12	Public school	52.0%	0–1	*−.15*	*−.34*	*−.42*	*.20*	*.13*	*.13*	*.16*	.08	*−.32*	.00	*.33*

Note. Italicized coefficients are significant at $p < .05$.
[a] Caregiver education categories: 1 = Less than primary school, 2 = Primary school, 3 = Junior high school, 4 = Secondary high school, 5 = O/A level, vocational, or diploma, 6 = At least a bachelor's degree. [b] Literacy and math scores can be interpreted as percent correct scores.

the Young Lives Study (Cueto & León, 2012) because children were in Primary 3 and 4. As an example, children were asked to read made-up words in English for the nonword decoding subtask, such as "dif" and "mab." A composite literacy variable was created by averaging the percent correct on each of the respective three scores (α = .67) and was standardized for analysis.

At Wave 7, *math* skills were measured using two subtasks from the Early Grade Math Assessment (EGMA; RTI International, 2014) and select items from the Young Lives School Survey (Cueto & León, 2012). Like EGRA, EGMA was developed by RTI International in 2006 to assess foundational numeracy skills and is used to monitor students' performance in Primary 2. The Young Lives math assessment was developed by Young Lives researchers, drawing on a bank of existing international testing programs for Grades 4 and 5. In the current study, the *math* composite comprised of two EGMA subtasks: (1) missing number (completing number patterns) and (2) word problems. Additionally, children were administered 12 numbers and operations mathematics problems (i.e., addition, multiplication, and fractions), adapted from the Young Lives School Survey. For example, the missing number EGMA subtasks provided children with three numbers and a blank space; they were asked to indicate which number goes in the blank space: "Here are some numbers. 5, 10, 15 and, . . . , what number goes here?" The composite math variable was created by averaging the respective three scores (α = .76) and standardized for analysis.

Executive Function

At Wave 5, EF was measured using a tablet-based direct assessment (Obradović, 2019) that included the Hearts and Flowers task and a spatial working memory task. *Hearts and Flowers* is a widely used task for school-age children that measures inhibitory control and cognitive flexibility (Davidson et al., 2006). Our *Hearts and Flowers* task included four blocks: hearts (congruent trials), flowers (incongruent trials), a slow mixed block, and a fast mixed block. The flowers block was used to measure inhibitory control and the mixed blocks were used to measure cognitive flexibility. Children were presented with an image of either a heart or a flower shown on one side of the tablet screen. For the Heart (congruent) trials, children were told to press the button on the same as the heart picture, whereas for the Flower (incongruent) trials, children were instructed to press the button on the opposite side of the flower picture. Performance was measured using children's accuracy (i.e., proportion correct) on the flowers and mixed blocks. Scores below 50% (chance) were set to a floor of 50% for each block to minimize the influence of outliers.

The *Memory Game* included two blocks that, respectively, measure short-term and working memory. In both blocks, children viewed a sequence of green-colored squares that would light up within a 3 × 3 square grid in an unpredictable pattern. In the forward (short term memory) block, children were instructed to touch the squares in the same order in which they lit up. In the backward block (working memory), children were instructed to touch the squares in the reverse order. In both blocks, this task starts with a sequence of two blocks and becomes progressively more difficult because the length of the sequences increases every three trials. After three consecutive incorrect trials, each block ended. The total number of correct answers were considered for performance assessment.

An EF composite variable was created by (a) standardizing the *Hearts and Flowers* "Flowers" accuracy score, *Hearts and Flowers* "Mixed" accuracy score, the number of Memory Game forward trials, and the number of correct Memory Game backward trials, and (b) subsequently taking the average of these four scores (α = .71); this composite EF approach is akin to other studies that aim to capture multiple skills (e.g., Miyake & Friedman, 2012). The composite EF variable was standardized for analysis.

Covariates

At the individual-level, we controlled for caregiver education level (1 = less than primary school; 2 = primary school; 3 = junior high school; 4 = secondary high school; 5 = O/A level, vocational, or diploma; 6 = bachelor's degree or more) and child age and gender. At the school-level, we controlled for school type (public vs. private) and for treatment assignment at baseline. Ongoing evaluation of data collection efforts revealed that 46 children assessed by one assessor scored lower on EF, on average, than the rest of the sample, despite a standard protocol that was to be followed. We include a dummy variable as an additional covariate to account for potential differences generated by this assessor. We maintained these cases in our analyses

to maximize sample size after confirming that excluding cases associated with this assessor did not alter our findings.

Analytic Strategy

Path analysis was used to test the associations between cumulative risk, EF, and academic outcomes. In addition to including direct paths between all study variables (cumulative risk to EF and literacy and numeracy; EF to literacy and numeracy), we also included covariates as predictors of literacy, numeracy, and EF. Analyses were conducted in M*plus* Version 8.0 (Muthén & Muthén, 2020). We used Full-Information Maximum Likelihood (FIML) so that participants with missing data for caregiver education (n = 51; 14.7%) and literacy and math outcomes (n = 71; 24%) could be included in the analyses. FIML is an extension of maximum likelihood estimation and is a recommended missing data approach in structural equation modeling as it utilizes all possible data points in the analysis and has been found to be superior to other approaches, such as listwise deletion or mean imputation (Enders & Bandalos, 2001). Three children were missing data for one risk item. In sensitivity analyses, excluding these participants from the analysis did not substantively change the results; these children remain in our final sample. Likewise, results were nearly identical when children with missing outcome data were excluded and these children are included in our final sample. Standard errors were adjusted using the CLUSTER command in M*plus* to account for the sampling of children in schools at baseline (Wave 1). This approach computes standard errors using the standard Huber-White procedure, which only assumes independence among school units (and not at the individual child level) and yields more precise estimates for the child- and school-level covariates included in our models. We used bias-corrected bootstrapped confidence intervals (Preacher & Hayes, 2008) with 10,000 draws to generate the most accurate confidence intervals (CIs) to test the strength of indirect effects of EF. Lastly, we used multigroup analysis to test if the relations between cumulative risk, EF, and learning differed by child gender. This study was not preregistered. Data, study materials, and analytic code are available upon request from the first author.

Results

Preliminary Analyses

Table 1 presents descriptive statistics and bivariate correlations for all variables, with literacy and math shown as percent correct (i.e., adding up the total number of items that a child scored correct in that subtask and then dividing by the total number of questions) and can be interpreted on a 0–1 scale. All four risks were associated with EF ($p < .001$), whereas only "home aggression" was correlated with literacy and math outcomes ($r = -.23$, $p < .001$ and $r = -.17$, $p = .004$, respectively) and "worked for pay" was only correlated with literacy ($r = -.13$, $p = .028$). EF was positively correlated with both literacy and math skills ($r = .36$ and $r = .42$, $p < .001$, respectively). The cumulative risk index had small-to-moderate negative correlations with EF ($r = -.18$, $p < .001$), literacy ($r = -.15$, $p < .008$), and math ($r = -.14$, $p = .014$).

In addition, bivariate analyses revealed several descriptive gender differences. Girls had more correct answers on the literacy assessment (55%) relative to boys (49%), $t(298) = -2.29$, $p = .023$, while boys reported higher levels of cumulative risk exposure on a scale of 0–4: ($M = 1.51$) in comparison to girls ($M = 1.28$), $t(370) = 2.09$, $p = .038$. Follow-up analyses were explored to further investigate whether specific risk factors were driving this gender difference in cumulative risk. Only "experiencing hunger" had statistically different gender differences ($M_{boys} = 46\%$, $M_{girls} = 34\%$, $t(370) = 2.29$, $p = .023$). No differences were found for EF and math skills between boys and girls.

Path Analyses

Table 2 presents the direct and indirect standardized coefficients of the path analysis model, and the direct paths are illustrated in Figure 1. As expected, cumulative risk negatively predicted EF ($\beta = -.15$, $SE = .05$, $p < .01$) and EF positively predicted both literacy and math skills ($\beta = .34$, $SE = .07$, $p < .001$; $\beta = .37$, $SE = .05$, $p < .001$, respectively). There was no direct effect of cumulative risk on literacy or math skills. EF mediated the path from the cumulative risk index to both literacy ($\beta = -.05$, 95% CI [−.10, −.01]) and math skills ($\beta = -.05$, 95% CI [−.10, −.02]), accounting for approximately 65.3% of the total effect of cumulative risk on literacy, and 100.0% of the total effect of cumulative risk on math.

Finally, we tested whether the mediation results differed by gender. We found no differences between girls and boys ($\chi^2(df = 2) = 1.32$, $p = .512$).

Discussion

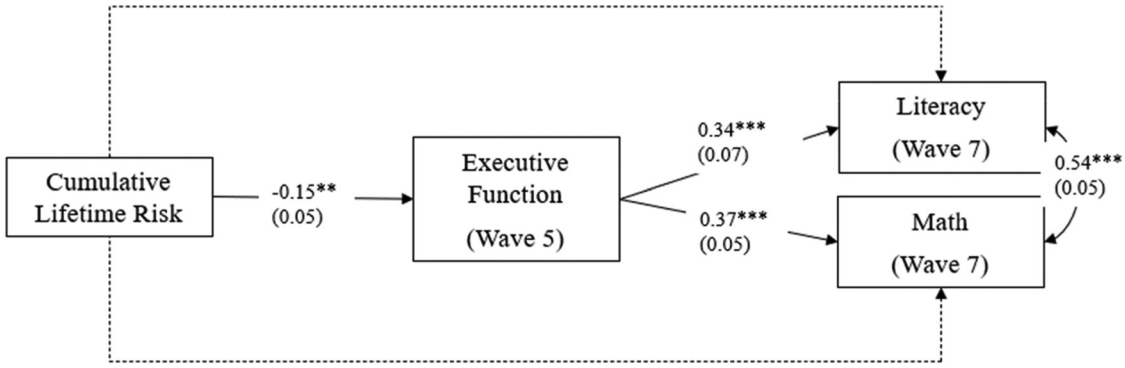
The purpose of this study was to examine the relations between cumulative risk, EF, and literacy and math skills among a sample of Ghanaian primary school-age children. In high-income

Table 2
Standardized Coefficients, Standard Errors, and Confidence Intervals of Direct and Indirect Effects

Pathway	β	*SE*	*p*	Bootstrap 95% CI Lower	Bootstrap 95% CI Upper
Direct effects					
Cumulative risk → Literacy	−0.026	0.050	.606	—	—
Cumulative risk → Math	0.001	0.044	.990	—	—
Indirect effects					
Cumulative risk → EF → Literacy	−0.049	—	—	−0.095	−0.012
Cumulative risk → EF → Math	−0.053	—	—	−0.096	−0.015

Note. N = 371. Child gender, child age, treatment status, caregiver education level, assessor, and school type included as covariates predicting child outcomes but not shown.

Figure 1
Standardized Coefficients and SEs of Direct Paths



Note. $N = 371$. Significant paths shown in solid lines with accompanying standardized coefficients and SEs. Nonsignificant paths shown using dotted lines without coefficients. Child gender, child age, treatment status, caregiver education level, assessor, and school type included as covariates predicting child outcomes but not shown.
** $p < .01$. *** $p < .001$.

countries, cumulative risk indices have been found to be powerful predictors of child wellbeing (Evans et al., 2013). We tested whether a similar association emerged in Ghana, where rates of risk are generally higher than in high-income countries. Moreover, we use a comprehensive measure of EF that does not rely on children's language or literacy abilities; with other modes of EF measurement (particularly in LMICs), this can be a challenge and introduce measurement error. Using path analysis and controlling for several confounding variables (including SES, school type, and child demographic characteristics) we found that EF significantly mediated the associations between cumulative risk and learning outcomes (i.e., math and reading). The results contribute to a small empirical evidence base on the role of EF in explaining the pathways through which adversity can affect children's learning.

Prevalence of Risk Exposure

Overall, in the present study, we find that children reported high rates of adversity with over three-quarters of children exposed to at least one of the four risks, with the most frequently reported risk being "ever experiencing verbal and/or physical aggression in the home" endorsed by nearly two thirds of the sample. Our sample of children is drawn from the Greater Accra Region of Ghana—a peri-urban setting—and is more advantaged relative to children in poorer regions in Ghana and other countries in SSA. In 2017, for example, 2.5% of households in the Greater Accra Region fell below the international poverty line versus 70.9% of households in the Upper West Region of Ghana (World Bank, 2020b). Thus, it is critical to not overgeneralize even within particular SSA countries. Future studies should consider how challenges are different in rural areas where child poverty, adversity, and low education rates are even more widespread (World Bank, 2020a). Despite our sample residing in a more advantaged region, we find that school-age children were exposed to a range of risk factors in their homes and communities. Documenting the prevalence of a broader range of risk exposure at different developmental stages across SSA and other LMICs (see Black et al., 2017, for an example) is needed to understand the developmental contexts children experience more fully.

Future research should also consider which risk factors are most salient for children's development in the specific context in which they are being studied. For SSA, that could mean expanding the ways in which adversity is measured or considering risk factors that are not commonly experienced in high-income countries. For example, rates of disease, infection, and maternal and infant mortality are much higher in SSA (as in other LMICs as well), and children are more likely to lose a caregiver or family member in comparison with children in high-income countries. Qualitative research with children may be necessary to ensure the types of risk children are exposed to are accurately measured and captured. Lastly, one study of children and young adolescents in South Africa examined two cumulative risk indices (psychosocial and sociodemographic) and found different associations with children's emotional and behavioral adjustment (Kliewer et al., 2017). These studies suggest that it is of interest to global educators and researchers to measure relevant risk factors in LMIC settings and understand how they are linked with children's development.

EF and Learning Outcomes

Decades of evidence highlight the importance of children's literacy and numeracy performance during primary school as two of the strongest predictors of later academic achievement (Jacob & Parkinson, 2015), highlighting the importance of bolstering children's early learning skills. It is worth reiterating that most of what is known about the EF and academic skill relation is based on research conducted in Western, educated, industrialized, rich, and democratic (WEIRD) contexts. Emerging geographically diverse research shows that children's EF promotes learning for young children, including countries in SSA such as Kenya and Ghana (Willoughby et al., 2019; Wolf & McCoy, 2019). Another recent study also found a positive association between EF and literacy and numeracy for 9-year-old Syrian refugee children in Lebanon (Kim et al., 2020). Together with our findings, this builds a case that the positive association between EF and literacy and

numeracy may be a universal pattern. One notable difference between this study and the small body of existing literature on EF and academic outcomes in SSA is that ours is the first study to examine these associations during middle childhood.

Although some studies support a stronger relation between EF and math than between EF and reading (Blair & Razza, 2007; Bull et al., 2008; Fuhs et al., 2014), a meta-analysis based primarily on WEIRD samples has not supported this difference (Spiegel et al., 2021). Similar to two other studies using samples of children from Ghana and Kenya (Willoughby et al., 2019; Wolf & McCoy, 2019), we found the magnitude of association between EF and math skills to be comparable in size to the association between EF and literacy skills. Our results provide further evidence that the association between EF and literacy and EF and math are comparable.

It is worth testing how specific components of EF mediate adversity and academic associations especially as children advance in their schooling. For example, one recent meta-analytic study found that working memory, relative to inhibitory control and cognitive flexibility, may be the strongest driver in promoting elementary children's academic skills (Spiegel et al., 2021). Whether working memory presents similarly in other contexts, such as SSA, remains open for future investigation. For the sake of creating a more reliable EF composite, we did not disaggregate our composite by EF subtasks. Future research could apply a latent variable approach with multiple EF subtasks to assess this idea.

Mediation Effects

EF as a mediator between adversity and academic outcomes is an understudied area of research, across country macroeconomic statuses. That said, overall, our results are consistent with findings from prior research that EF mediates the association between an adversity metric (such as low SES) and academic outcomes (e.g., Lawson & Farah, 2017). This suggests that, to an extent, the links between risk, EF, and learning are potentially generalizable outside of WEIRD countries. Our study expands existing work by adopting and testing a cumulative risk index as a mediator in SSA. Despite the use of different adversity indicators across studies, this similar pattern (EF mediating the link between risk and learning skills) reveals that analogous underlying processes are at play in linking adversity and learning outcomes across different contexts. More research is needed to deepen the evidence base related to the ways in which risk operates and influences child development in LMICs. For example, Kim et al. (2020) found that EF explained the negative association for only two of the seven individual risk factors—age-for-grade and perceived community safety—on children's literacy and numeracy skills. Further, similar to the direct effects between EF and math, studies drawing on samples of children from high-income countries have found a stronger mediating relation between risk, EF, and math than for literacy or language abilities (Lawson & Farah, 2017; Nesbitt et al., 2013; Waters et al., 2020). In line with this evidence, we found that EF explained a larger proportion of the relation between cumulative risk and math than for literacy (100.0% vs. 65.3%, respectively) in our sample.

Lastly, although girls have historically been marginalized regarding educational attainment in Ghana, we found no differences in EF skill level or in the mediation effects tested by gender. In other words, the relation between cumulative risk, EF, and learning operated similarly for boys and girls. That said, two noteworthy descriptive differences by gender were found: girls had higher literacy scores and boys were exposed to a greater number of risks. Relatedly, boys were more likely to report experiencing hunger than girls; this is in contrast to previous research with Ethiopian adolescents (Hadley et al., 2008); cultural differences or developmental stages may explain this difference. It is possible that boys' higher cumulative risk scores contributed to their lower literacy skills.

Limitations

Several important limitations of this study should be noted. First, while the data are longitudinal, showing relations between risk and EF with later learning outcomes, we are unable to draw causal conclusions about the relations observed. Future research could strengthen these longitudinal analyses by measuring risk, EF, and academic outcomes at three different time points to strengthen the conclusions about the temporal relations between these factors. Further, intervention studies that causally improve EF could be leveraged to examine associations in a causal framework.

Second, the sample of children is a convenience subsample from the larger project, resulting in a slightly more advantaged group that is not generalizable to the Greater Accra region in Ghana (see Table S1 in online supplemental materials). In addition, the sample is one of schoolchildren, not all children within the given communities. Our findings, however, provide a base from which studies with children from both urban and rural parts of Ghana—and other SSA countries—can build on. Additional research is needed in Ghana and other SSA countries to understand how adversity intersects with gender and EF as educational disparities between boys and girls widen over the course of schooling. Further, testing this in a broader sample of children (particularly girls and children who are not in school) as well as in more disadvantaged areas (e.g., rural, poorer regions), where gender disparities may be greater (FAO, 2012; Levy et al., 2020), warrants additional consideration.

Third, while we examined four contextually relevant risk factors, this was not a comprehensive list of all the risk factors children face that could affect learning and development. Additional sources of data, a more comprehensive list of risk factors and including measures that tap into both frequency and severity of risk exposure would have provided a fuller analysis of adversity in the sample and allowed for a more nuanced examination of the associations studied in this article (McLaughlin et al., 2021). Future studies could incorporate caregiver-reported exposure to risk or explore differences in risk perspectives across multiinformants. This will yield more information as to which factors are more intertwined with parenting styles that might relate to children's EF development. And finally, the field would benefit from qualitative research related to children's perceptions of adversity exposure, perhaps shedding light on unique risk and resilience processes not yet conceptualized (Smith & Pollak, 2021).

Implications for Practice

We highlight two practical implications of our findings for educational practice. The first includes directly improving the developmental outcomes of children exposed to adversity. Our findings that children with higher EF skills had higher literacy and math scores 2 years later point to the importance of supporting children's basic cognitive development in addition to literacy and math

skills. Currently, preservice teacher programs in Ghana emphasize didactic and teacher-centered approaches (Akyeampong, 2017; Armah, 2017), with a focus on developing content knowledge and an absence of strengthening children's more general basic cognitive skills. To address this gap, our results show that it would be critical to design teacher-training programs, or an intervention for in-service teachers, that focus on implementing classroom strategies to support children's EF development.

A second approach would be to reduce risk exposure. Children who reported higher rates of risk had lower levels of EF, which was in-turn related to lower literacy and math scores. Physical punishment remains one of the most common forms of aggression against children (Ministry of Gender, Children and Social Protection, 2018) and is considered an important part of the socialization process in Ghana (Twum-Danso Imoh, 2013), making efforts to change this difficult. Targeting interventions in a way that harness positive elements within the Ghanaian culture (e.g., children considered as gifts; Ministry of Gender, Children and Social Protection, 2018) could help promote a discourse around positive discipline as a learning opportunity. Further, the government's school-feeding program is an important social protection program addressing children's food insecurity, but policymakers might consider other strategies (e.g., cash transfers) that expand or supplement school-feeding programs that have the potential to further reduce household food insecurity and child labor.

Conclusions

As more children have enrolled in school around the world, global targets in education now focus on improving learning outcomes rather than school access (United Nations, 2015), particularly for marginalized children (Wagner et al., 2018). The field of developmental science has drawn attention to EF as a critical and universal skillset central to learning, where prior research has associated EF with a host of other positive health, behavioral, and economic outcomes. Yet, little empirical evidence exists on the role of EF for learning outcomes in SSA, where children face higher rates of adversity that threatens developmental potential (Black et al., 2017). Our findings show that EF is important for learning and that reducing adversity is a potential pathway to improving both EF and academic skills. It is also possible that interventions targeting EF in Ghanaian primary schoolchildren may support learning and reduce educational disparities for children who face adversity. While these findings hold promising potential, experimental studies are needed to determine how targeting EF skills directly would impact learning outcomes. Building out such a program of research could support global efforts to improve educational quality and child development and contribute to a cross-cultural research program that is critical for understanding child development and learning globally.

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