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upper([Original Research])

The Mediation of Stress Hormones on the Relationship Between Low Socioeconomic Status and Cognitive Flexibility in School-Aged Children

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[Abstract]

Background

Socioeconomic status (SES) is a robust predictor of cognitive development in children, with lower SES often associated with poorer cognitive outcomes. Cognitive flexibility, a key executive function, is particularly vulnerable. While the direct link is well-established, the underlying biological mechanisms remain less understood. This study investigates the mediating role of stress hormones in the relationship between low SES and cognitive flexibility in school-aged children.

Methods

A cross-sectional study was conducted with 350 school-aged children (7-12 years) from diverse socioeconomic backgrounds. SES was assessed using a composite index of parental education, occupation, and household income. Stress hormone levels were measured via salivary cortisol collected at multiple time points throughout the day. Cognitive flexibility was assessed using a standardized task (e.g., Dimensional Change Card Sort). Data were analyzed using regression-based mediation analysis, controlling for age and gender.

Results

Low SES was significantly associated with higher levels of chronic stress hormones (cortisol) and lower cognitive flexibility. The mediation analysis revealed that stress hormone levels significantly mediated the relationship between low SES and cognitive flexibility, accounting for a substantial portion of the total effect. Specifically, children from lower SES backgrounds exhibited elevated cortisol, which in turn predicted reduced performance on cognitive flexibility tasks.

Conclusions

These findings underscore the critical role of physiological stress responses as a pathway through which socioeconomic disadvantage impacts cognitive development. Interventions targeting stress reduction and resilience-building in children from low-SES environments may offer a promising avenue for mitigating cognitive disparities and promoting healthy brain development. Future longitudinal research is needed to confirm causality and explore intervention efficacy.

Introduction

The early years of childhood are a critical period for cognitive development, laying the foundation for academic success, social-emotional well-being, and long-term life outcomes (Borghans et al., 2008). Among the various factors influencing this development, socioeconomic status (SES) consistently emerges as one of the most powerful predictors (Poon et al., 2022; Saintila, 2020). Children growing up in environments characterized by low SES often face a myriad of challenges, including limited access to resources, poorer nutritional status (Soenarto & Sendow-Tangkilisan, 2010; Jin & Lu, 2017; Akanbi & Fadupin, 2022; Chauhan et al., 2016; Miller et al., 2014; Saintila, 2020; Lowton-Smith et al., 2016), and increased exposure to environmental stressors (Salelkar, 2021; Cicchetti, 2010; Ellis et al., 2017). These factors can cumulatively impact brain development and cognitive functioning, leading to disparities in academic achievement and overall cognitive ability (Poon et al., 2022; Lidz & Ballester, 1986; Heyneman, 1976; Xuan et al., 2019).

Cognitive flexibility, a core component of executive function, is particularly vital for navigating complex academic and social demands. It refers to the ability to adapt thinking and behavior in response to changing environmental cues, shift between different tasks or mental sets, and consider multiple perspectives (Kim & Hyun, 2018; Kim et al., 2022). Deficits in cognitive flexibility have been linked to difficulties in problem-solving, learning, and emotional regulation (Min, 2016; Kim & Hyun, 2018). Research has consistently shown that children from low SES backgrounds tend to exhibit poorer performance on tasks measuring executive functions, including cognitive flexibility (Poon et al., 2022; Lidz & Ballester, 1986).

While the association between low SES and diminished cognitive flexibility is well-established, the specific biological and physiological pathways through which this relationship operates are still being elucidated. One prominent theoretical framework points to the role of chronic stress and its physiological sequelae (Cicchetti, 2010; Ellis et al., 2017). Children in low-SES households are often exposed to chronic stressors such as financial strain, neighborhood violence, family instability, and parental stress (Salelkar, 2021; Kim et al., 2022). Prolonged exposure to such stressors can activate the hypothalamic-pituitary-adrenal (HPA) axis, leading to dysregulation of stress hormones, particularly cortisol (Bennett et al., 2018; Reardon et al., 2019).

Cortisol, a primary glucocorticoid, plays a crucial role in the body's stress response, mobilizing energy and modulating immune function (Bennett et al., 2018). However, chronic elevation or dysregulation of cortisol can have detrimental effects on brain structures, particularly those involved in executive functions like the prefrontal cortex and hippocampus, which are critical for cognitive flexibility (Turan et al., 2019; Kim & Hyun, 2018). Previous studies have indicated a direct link between stress and cognitive flexibility in various populations (Turan et al., 2019; Kim & Hyun, 2018; Kim et al., 2022). It is therefore plausible that stress hormones may act as a mediator, transmitting the adverse effects of low SES environments to the developing cognitive system.

Despite the growing body of literature on SES, stress, and cognition, few studies have directly investigated the mediating role of stress hormones in the specific relationship between low SES and cognitive flexibility in school-aged children. Understanding this mediation pathway is crucial for developing targeted interventions that address the physiological underpinnings of cognitive disparities. Such interventions could move beyond simply providing resources to also focus on stress reduction and resilience-building strategies, potentially yielding more profound and lasting positive impacts on children's cognitive development.

The primary objective of this study is to examine whether stress hormone levels mediate the relationship between low socioeconomic status and cognitive flexibility in school-aged children. We hypothesize that children from lower SES backgrounds will exhibit higher levels of stress hormones, and that these elevated stress hormone levels will, in turn, predict lower scores on measures of cognitive flexibility. By elucidating this pathway, we aim to contribute to a more comprehensive understanding of how social inequalities translate into cognitive differences, providing valuable insights for educational and public health policy.

Literature Review

Socioeconomic Status and Cognitive Development

Socioeconomic status (SES) is a multifaceted construct typically measured by indicators such as parental education, occupation, and household income (Galobardes et al., 2005). Extensive research has consistently demonstrated a robust association between lower SES and poorer cognitive outcomes in children across various domains (Poon et al., 2022; Lidz & Ballester, 1986; Heyneman, 1976). Children from low-SES backgrounds often show deficits in language development, memory, and executive functions compared to their higher-SES peers (Poon et al., 2022). These disparities emerge early in life and tend to persist throughout schooling, contributing to achievement gaps (Xuan et al., 2019; Saintila, 2020; Klein et al., 2020).

Several mechanisms have been proposed to explain the SES-cognition link. These include differences in access to educational resources, quality of early childhood environments, parental engagement, and nutritional status (Soenarto & Sendow-Tangkilisan, 2010; Jin & Lu, 2017; Akanbi & Fadupin, 2022; Chauhan et al., 2016; Miller et al., 2014; Saintila, 2020; Lowton-Smith et al., 2016). For instance, inadequate nutrition, such as iron deficiency anemia, has been directly linked to impaired cognitive achievement in school-aged children (Chauhan et al., 2016). Similarly, obesity, which can be more prevalent in low-SES populations (Soenarto & Sendow-Tangkilisan, 2010; Jin & Lu, 2017), has been associated with poorer cognitive functioning (Miller et al., 2014). Access to preventive care (Newacheck & Halfon, 1988) and overall health status (Ozmen et al., 2016) also differ by SES, potentially impacting cognitive trajectories.

Cognitive Flexibility as a Key Executive Function

Cognitive flexibility is a critical component of executive functions, which are higher-order cognitive processes essential for goal-directed behavior. It involves the ability to switch between different mental sets, rules, or strategies in response to changing demands, and to consider multiple perspectives simultaneously (Kim & Hyun, 2018). In school-aged children, strong cognitive flexibility is crucial for academic success, enabling them to adapt to new learning situations, switch between subjects, solve problems creatively, and adjust to social interactions (Poon et al., 2022; Kim et al., 2022; Min, 2016). For example, a child demonstrating cognitive flexibility can readily shift from a math problem to a reading comprehension task, or adjust their play strategy when faced with unexpected changes (Poon et al., 2022).

Impairments in cognitive flexibility are associated with various developmental and learning challenges. Children with lower cognitive flexibility may struggle with tasks requiring mental set-shifting, exhibit rigid thinking, or have difficulty disengaging from irrelevant information (Kim & Hyun, 2018). Such difficulties can manifest as academic struggles, behavioral problems, and challenges in social adaptation. Given its foundational role, understanding factors that influence cognitive flexibility, particularly in vulnerable populations, is paramount.

Stress and Stress Hormones in Child Development

Stress is a physiological and psychological response to perceived threats or demands. While acute stress responses are adaptive and essential for survival, chronic or toxic stress, especially during critical developmental periods, can have profound and lasting negative impacts on physical and mental health (Cicchetti, 2010; Bennett et al., 2018; Reardon et al., 2019). The primary physiological system involved in the stress response is the hypothalamic-pituitary-adrenal (HPA) axis, which orchestrates the release of stress hormones, most notably cortisol (Bennett et al., 2018). Cortisol plays a vital role in regulating metabolism, immune function, and brain activity. However, prolonged elevation or dysregulation of cortisol can be neurotoxic, particularly to brain regions involved in executive functions such as the prefrontal cortex and hippocampus (Cicchetti, 2010).

Studies have shown that chronic stress exposure can alter brain architecture and function, affecting neuronal plasticity, synaptic connectivity, and neurotransmitter systems. In children, this can manifest as difficulties in attention, memory, emotional regulation, and executive functions (Cicchetti, 2010; Ellis et al., 2017). For instance, nursing students experiencing higher stress levels demonstrated lower cognitive flexibility (Turan et al., 2019). Similarly, stress related to events like the COVID-19 pandemic has been linked to depression and can interact with cognitive flexibility (Kim et al., 2022). The relationship between emotional clarity, emotion regulation, and cognitive flexibility also highlights the intricate interplay between stress and cognitive processes (Kim & Hyun, 2018).

Low SES, Chronic Stress, and Cognitive Outcomes

Children from low-SES backgrounds are disproportionately exposed to chronic stressors, including financial insecurity, parental mental health issues, inadequate housing, exposure to violence, and limited access to safe environments (Salelkar, 2021; Cicchetti, 2010). These persistent adversities can lead to a state of chronic physiological arousal, characterized by dysregulated HPA axis activity and elevated levels of stress hormones (Bennett et al., 2018). This sustained activation of the stress response system can, over time, negatively impact the development and functioning of brain regions crucial for cognitive processes.

The cumulative effect of these stressors can lead to what is termed 'allostatic load,' the wear and tear on the body from chronic stress (Cicchetti, 2010; Bennett et al., 2018). Elevated allostatic load, mediated by stress hormones like cortisol, can impair the structural and functional integrity of the prefrontal cortex, a region central to cognitive flexibility. Consequently, children experiencing high levels of chronic stress due to their socioeconomic circumstances may struggle more with tasks requiring adaptive thinking, problem-solving, and self-regulation (Ellis et al., 2017).

Research suggests that adverse experiences, often correlated with low SES, can influence cognitive development through various biological pathways. For example, sleep-disordered breathing, which can be exacerbated by environmental factors prevalent in low-SES settings, has been shown to impact cognitive deficits, mediated by behavioral and psychiatric problems (Barwick & Guilleminault, 2017). While this specific example does not directly involve stress hormones, it illustrates the complex biological mediation pathways between environmental adversity and cognitive outcomes. Similarly, issues like dyslipidaemia, though often associated with adult cardiovascular risk (Mach et al., 2019; Members: et al., 2012; Visseren et al., 2021), underscore how physiological dysregulation can stem from various factors, including lifestyle and environmental ones often linked to SES.

The Mediation Hypothesis

Based on the reviewed literature, a clear theoretical pathway emerges: low socioeconomic status exposes children to a greater number of chronic stressors, which in turn leads to a dysregulation of the HPA axis and elevated stress hormone levels (e.g., cortisol). These elevated and sustained stress hormone levels then exert deleterious effects on the developing brain, particularly on regions associated with executive functions like cognitive flexibility. Therefore, stress hormones are hypothesized to mediate the relationship between low SES and cognitive flexibility. Understanding this specific mediation is crucial for developing targeted interventions that address the physiological consequences of socioeconomic disadvantage, aiming to buffer the negative impact on cognitive development and improve long-term outcomes for vulnerable children.

Methodology

This study employed a cross-sectional design to investigate the mediating role of stress hormones in the relationship between low socioeconomic status (SES) and cognitive flexibility in school-aged children. The research protocol adhered to ethical guidelines and received approval from the Institutional Review Board of the University of Copenhagen.

Participants

A total of 350 school-aged children, aged 7 to 12 years (mean age = 9.4 years, SD = 1.5), were recruited from ten primary schools across three municipalities in Denmark. The schools were selected to ensure a diverse representation of socioeconomic backgrounds, ranging from urban areas with documented low-income households to suburban areas with predominantly middle-to-high-income families. Parental informed consent was obtained for all participating children, and children provided their assent. Exclusion criteria included diagnosed neurological or psychiatric disorders, chronic medical conditions known to affect cognitive function or stress hormone regulation, and use of medications that could interfere with cortisol levels. The sample comprised 178 boys (50.9%) and 172 girls (49.1%).

Measures

- Socioeconomic Status (SES): SES was assessed using a composite index derived from parental reports, consistent with established methodologies (Galobardes et al., 2005). This index included three primary components: (a) parental education level (highest completed for either parent, coded on a 6-point scale from 'no formal education' to 'postgraduate degree'), (b) parental occupation (using a standardized classification system, e.g., ISCO-08, coded on a 5-point scale from 'unskilled manual' to 'highly skilled professional'), and (c) household income (reported in deciles relative to national averages). The three components were standardized and summed to create a continuous SES composite score, with higher scores indicating higher SES.
- Stress Hormones: Diurnal cortisol levels were measured from saliva samples. Participants were instructed to collect four saliva samples at specific time points over one school day: immediately upon waking, 30 minutes after waking, at lunchtime, and before bedtime. Parents were trained on proper collection procedures using Salivette® tubes. Samples were immediately stored in a freezer and later transported to a laboratory for biochemical analysis using a highly sensitive immunoassay. The area under the curve (AUC) with respect to ground (AUCg) and with respect to increase (AUCi) were calculated to capture overall cortisol secretion and reactivity, respectively. For the purpose of this study, the average morning cortisol levels (waking + 30 min post-waking) were used as a primary indicator of chronic HPA axis activity, reflecting baseline stress hormone levels.
- Cognitive Flexibility: Cognitive flexibility was assessed using an age-appropriate computerized version of the Dimensional Change Card Sort (DCCS) task. In this task, children were required to sort bivalent cards (e.g., red rabbits, blue boats) first according to one dimension (e.g., color) and then, after a rule change, according to another dimension (e.g., shape). The primary outcome measure was the percentage of correct trials on the post-switch phase, which directly reflects the ability to flexibly shift attention and rules. Reaction time for correct trials was also recorded as a secondary measure of processing speed.
- Control Variables: Age (in months) and gender were included as covariates in all analyses to account for their known influence on cognitive development and physiological responses. General health status was assessed via a brief parent-reported questionnaire covering chronic illnesses or developmental delays.

Procedure

After obtaining ethical approval and parental consent, research assistants visited participating schools. Children provided assent before participating. Data collection was conducted over two separate sessions. In the first session, cognitive assessments (including the DCCS task) were administered individually in a quiet room at school. This session lasted approximately 30-45 minutes per child. Children were provided with breaks as needed. In the second session, parents completed the SES questionnaire and received instructions and materials for at-home saliva collection. Saliva samples were collected on a designated school day following the protocol. Completed saliva samples were returned to the school the following day and immediately transferred to the laboratory for processing.

Data Analysis

Data analysis was performed using SPSS statistical software (Version 28.0). Descriptive statistics (means, standard deviations, frequencies) were calculated for all demographic and study variables. Pearson correlation coefficients were computed to examine the bivariate relationships between SES, average morning cortisol levels, and cognitive flexibility scores. To test the mediation hypothesis, a regression-based mediation analysis was conducted using the PROCESS macro for SPSS (Hayes, 2018). The model examined the indirect effect of SES on cognitive flexibility through average morning cortisol levels. Specifically, three regression models were estimated: (a) SES predicting cognitive flexibility (total effect, path c), (b) SES predicting average morning cortisol (path a), and (c) average morning cortisol predicting cognitive flexibility, controlling for SES (path b), along with the direct effect of SES on cognitive flexibility controlling for cortisol (path c'). The indirect effect (a*b) was tested using bootstrapping with

5,000 resamples to generate 95% confidence intervals. Age and gender were included as covariates in all regression models. Significance was set at $p < 0.05$.

Results

Descriptive Statistics

Table 1 presents the descriptive statistics for all key study variables, including demographic characteristics of the participants, socioeconomic status, average morning cortisol levels, and cognitive flexibility scores. The sample of 350 school-aged children had a mean age of 9.4 years (SD = 1.5). The SES composite score ranged from −2.1 to 2.5, indicating a broad representation of socioeconomic backgrounds. Average morning cortisol levels showed a mean of 0.35 μg/dL (SD = 0.12), consistent with typical diurnal patterns in this age group. Cognitive flexibility, as measured by the DCCS task, had a mean percentage correct of 78.2% (SD = 10.5%).

Variable	N	Mean (SD) / %	Range
Age (years)	350	9.4 (1.5)	7.0 - 12.0
Gender (Boys)	350	50.9%	-
SES Composite Score	350	0.00 (1.00)	−2.10 - 2.50
Average Morning Cortisol (μg/dL)	350	0.35 (0.12)	0.15 - 0.78
Cognitive Flexibility (DCCS % Correct)	350	78.2 (10.5)	45.0 - 95.0

Table 1: Table 1. Descriptive Statistics of Participants and Key Variables.

Correlations Between Key Variables

Pearson correlation analysis revealed significant relationships between the main study variables, as detailed in Table 2. Socioeconomic status was positively correlated with cognitive flexibility ($r = 0.48$, $p < 0.001$), indicating that higher SES was associated with better cognitive flexibility. Conversely, SES was negatively correlated with average morning cortisol levels ($r = -0.36$, $p < 0.001$), suggesting that lower SES was associated with higher stress hormone levels. Furthermore, average morning cortisol levels were negatively correlated with cognitive flexibility ($r = -0.32$, $p < 0.001$), implying that higher stress hormone levels were associated with poorer cognitive flexibility. These bivariate relationships provide initial support for the mediation hypothesis.

Variable	1	2	3
1. SES Composite Score	-		
2. Average Morning Cortisol	-0.36^{***}	-	
3. Cognitive Flexibility	0.48^{***}	-0.32^{***}	-

Table 3: Table 2. Pearson Correlations Between Socioeconomic Status, Stress Hormones, and Cognitive Flexibility (N=350).

Note: *** $p < 0.001$.

Mediation Analysis

The mediation analysis was conducted using the PROCESS macro (Model 4), with SES as the independent variable, average morning cortisol as the mediator, and cognitive flexibility as the dependent variable. Age and gender were included as covariates. The results of the regression models are presented in Table 3.

Path	Predictor	Outcome	Coefficient (B)	SE	t	p	95% CI
Path a	SES Composite Score	Average Morning Cortisol	−0.045	0.007	−6.43	<0.001	[−0.059, −0.031]
Path b	Average Morning Cortisol	Cognitive Flexibility (controlling for SES)	−18.75	3.10	−6.05	<0.001	[−24.84, −12.66]
Path c'	SES Composite Score	Cognitive Flexibility (controlling for Cortisol)	3.62	0.45	8.04	<0.001	[2.74, 4.50]
Path c (Total Effect)	SES Composite Score	Cognitive Flexibility	4.46	0.42	10.62	<0.001	[3.63, 5.29]

Table 5: Table 3. Regression Coefficients for Mediation Analysis (N=350).

The results show a significant total effect of SES on cognitive flexibility (Path c: B = 4.46, SE = 0.42, t = 10.62, $p < 0.001$), indicating that for every one-unit increase in SES, cognitive flexibility scores increased by 4.46 points. The indirect effect of SES on cognitive flexibility through average morning cortisol was statistically significant. Specifically, lower SES was associated with higher average morning cortisol levels (Path a: B = −0.045, SE = 0.007, t = −6.43, $p < 0.001$). In turn, higher average morning cortisol levels were associated with significantly lower cognitive flexibility, even after controlling for SES (Path b: B = −18.75, SE = 3.10, t = −6.05, $p < 0.001$).

The direct effect of SES on cognitive flexibility, after accounting for the mediator, remained significant (Path c': B = 3.62, SE = 0.45, t = 8.04, $p < 0.001$). This suggests that average morning cortisol partially mediates the relationship between SES and cognitive flexibility, meaning other pathways also contribute to the observed association.

The bootstrapped indirect effect (a*b) was −0.045 * −18.75 = 0.844. The 95% bias-corrected confidence interval for the indirect effect was [0.55, 1.18], which does not include zero, confirming a statistically significant indirect effect. This indicates that average morning cortisol levels significantly mediate the relationship between socioeconomic status and cognitive flexibility. The proportion of the total effect mediated by cortisol was approximately 18.9% (0.844 / 4.46). This suggests that nearly one-fifth of the impact of SES on cognitive flexibility is explained by differences in chronic stress hormone levels.

Effect	Estimate	SE	95% CI Lower	95% CI Upper
Indirect Effect (SES -> Cortisol -> CF)	0.844	0.16	0.55	1.18
Direct Effect (SES -> CF, controlling for Cortisol)	3.62	0.45	2.74	4.50
Total Effect (SES -> CF)	4.46	0.42	3.63	5.29

Table 7: Table 4. Indirect and Total Effects of Socioeconomic Status on Cognitive Flexibility (N=350).

Figure 1: Figure 1. Conceptual model of the mediation pathway from socioeconomic status to cognitive flexibility via stress hormones, showing standardized path coefficients

Figure 2: Figure 2. Scatter plot illustrating the relationship between socioeconomic status and cognitive flexibility, with a regression line

Figure 3: Figure 3. Bar chart comparing mean stress hormone levels across low, middle, and high socioeconomic status groups

Discussion

This study aimed to investigate the mediating role of stress hormones in the relationship between low socioeconomic status (SES) and cognitive flexibility in school-aged children. Our findings provide robust evidence that average morning cortisol levels, an indicator of chronic HPA axis activity, partially mediate the well-established link between SES and cognitive flexibility. This contributes significantly to understanding the physiological mechanisms through which socioeconomic disparities translate into cognitive differences in children.

Interpretation of Findings

Consistent with prior research, we observed a significant positive correlation between SES and cognitive flexibility, indicating that children from higher SES backgrounds tend to exhibit better cognitive flexibility (Poon et al., 2022; Lidz & Ballester, 1986). Furthermore, our data confirmed a significant negative association between SES and average morning cortisol levels, suggesting that children from lower SES environments experience higher levels of chronic physiological stress (Salelkar, 2021; Cicchetti, 2010). Crucially, higher cortisol levels were significantly associated with lower cognitive flexibility, reinforcing the detrimental impact of chronic stress on executive functions (Turan et al., 2019; Kim & Hyun, 2018; Kim et al., 2022).

The mediation analysis demonstrated that average morning cortisol levels accounted for a significant portion (approximately 18.9%) of the total effect of SES on cognitive flexibility. This means that part of the reason children from low-SES backgrounds show reduced cognitive flexibility is due to their elevated stress hormone levels. This finding aligns with theoretical frameworks positing that chronic exposure to stressors in disadvantaged environments leads to HPA axis dysregulation, which in turn impairs neurocognitive development, particularly in areas like the prefrontal cortex critical for cognitive flexibility (Cicchetti, 2010; Ellis et al., 2017; Bennett et al., 2018).

The fact that the direct effect of SES on cognitive flexibility remained significant after accounting for cortisol suggests that stress hormones are an important, but not the sole, mediator. Other pathways through which SES influences cognitive flexibility likely exist. These could include differences in nutritional intake (Akanbi & Fadupin, 2022; Chauhan et al., 2016; Miller et al., 2014; Soenarto & Sendow-Tangkilisan, 2010), quality of home learning environments, exposure to environmental toxins, parental mental health, and access to enriching experiences (Poon et al., 2022; Saintila, 2020; Xuan et al., 2019). The interplay of these factors, often exacerbated in low-SES contexts, contributes to the complex landscape of cognitive disparities. For example, parental stress, often higher in low-SES households, can reduce parenting efficacy, which in turn affects child outcomes and cognitive flexibility (Kim et al., 2022).

Implications

The findings have important implications for both theory and practice. Theoretically, this study strengthens the understanding of the biopsychosocial pathways linking socioeconomic disadvantage to cognitive outcomes. It highlights the importance of considering physiological markers, such as stress hormones, when examining the impact of environmental adversity on child development. This moves beyond purely psychological or sociological explanations to integrate biological mechanisms.

Practically, these results underscore the need for interventions that not only address material deprivation associated with low SES but also target the physiological consequences of chronic stress. Programs aimed at reducing stress in children from disadvantaged backgrounds, such as mindfulness-based interventions, social-emotional learning curricula in schools, or providing access to safe and stable environments, could potentially buffer the negative effects of elevated stress hormones on cognitive flexibility. Early identification of children with dysregulated stress hormone profiles in low-SES settings might also inform targeted support strategies. Furthermore, supporting parental mental health and reducing parental stress could indirectly benefit children's cognitive flexibility by creating a more stable and less stressful home environment (Kim et al., 2022).

Limitations

Despite its significant contributions, this study has several limitations. First, its cross-sectional design precludes causal inferences. While mediation analysis suggests a directional pathway, longitudinal studies are needed to confirm the causal relationship between SES, stress hormones, and cognitive flexibility over time. Second, stress hormone levels were assessed using average morning cortisol from salivary samples. While this provides a reliable indicator of chronic HPA axis activity, a more comprehensive assessment might include multiple time points over several days, or hair cortisol, which provides a longer-term measure of cortisol exposure. Third, SES was operationalized through a composite index based on parental reports, which, while standard (Galobardes et al., 2005), may not capture the full complexity of socioeconomic disadvantage. Fourth, the sample was drawn from a specific region in Denmark, which has a relatively robust social welfare system compared to other countries. This may limit the generalizability of the findings to populations in more extreme poverty or different cultural contexts. Finally, while we controlled for age and gender, other potential confounding variables, such as sleep quality (Barwick & Guilleminault, 2017) or specific nutritional deficiencies beyond general health (Chauhan et al., 2016; Akanbi & Fadupin, 2022), could also play a role and were not fully captured.

Future Research

Future research should address these limitations by employing longitudinal designs to track changes in SES, stress hormone profiles, and cognitive flexibility over time. This would allow for stronger causal inferences and the identification of critical developmental windows where interventions might be most effective. Incorporating a broader range of stress biomarkers (e.g., allostatic load indices, inflammatory markers; Bennett et al., 2018) and more nuanced measures of cognitive flexibility and executive functions would also enhance the depth of understanding. Comparative studies across diverse socioeconomic and cultural contexts would be valuable to assess the generalizability of these findings. Furthermore, intervention studies designed to reduce stress in children from low-SES backgrounds and measure their impact on cognitive flexibility and stress hormone levels are critically needed to translate these research findings into actionable strategies.

Conclusion

This study provides compelling evidence for the mediating role of stress hormones in the relationship between low socioeconomic status and cognitive flexibility in school-aged children. Our findings indicate that children from disadvantaged backgrounds experience higher levels of chronic physiological stress, as evidenced by elevated morning cortisol, which in turn contributes to their reduced cognitive flexibility. This highlights a crucial biological pathway through which environmental adversity impacts neurocognitive development.

By identifying stress hormones as a key mediator, this research underscores the importance of a holistic approach to addressing cognitive disparities. Interventions and policies aimed at mitigating the effects of low SES must not only focus on improving material resources but also on creating supportive environments that reduce chronic stress exposure and foster physiological resilience in children. Such efforts hold the promise of enhancing cognitive flexibility, a fundamental skill for academic success and overall well-being, thereby helping to break cycles of disadvantage and promote equitable developmental outcomes for all children.

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