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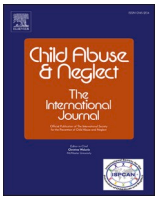

Does it add up? Educational achievement mediates child maltreatment subtypes to allostatic load☆

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ABSTRACT

Background: Childhood maltreatment (CM) has been linked to higher levels of allostatic load (AL) and educational achievement is a possible pathway and may differ across gender. It is also critical to determine if CM severity or specific subtypes of CM are more or less influential.
Objective: This study examined educational achievement as a mediator linking cumulative and individual types of CM to AL and examined gender as a moderator.
Participants and setting: Using two waves of data, 897 adults from the study Midlife in the United States were analyzed.
Methods: Multiple group structural equation models stratified across gender to test were used cumulative maltreatment and maltreatment subtypes to AL and test gender as a moderator.
Results: Overall CM was associated with educational achievement ($\beta = -0.12$, $p < .01$) and AL ($\beta = 0.11$, $p < .05$) and education was inversely associated with AL ($\beta = -0.17$, $p < .001$) in men but not women. The subtypes model revealed that physical abuse predicted lower level of education achievement ($\beta = -0.20$, $p < .001$) and among men. Educational achievement, in turn, was associated with lower levels of AL ($\beta = -0.02$, $p = .002$). Educational achievement was a possible pathway linking physical abuse to AL ($\beta = 0.02$, 95 % CI [0.001, 0.040]) among men but was non-significant in women. Gender did not moderate any of the pathways.
Conclusions: Educational achievement is a potentially modifiable social determinant of health that can be a focus of prevention and intervention efforts among men who were maltreated, particularly for those who experienced physical abuse.

1. Introduction

Allostatic load (AL) is a cumulative measure of multisystem physiological dysfunction (Finlay et al., 2022) that has been implicated in mental and physical morbidity as well as all-cause mortality (see Beckie, 2012; Guidi et al., 2021 for reviews). The association

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between allostatic load and health becomes increasingly salient among midlife and older adults (Ghimire et al., 2019). Research on social determinants of health have underscored that childhood adversity (Danese & McEwen, 2012; Milaniak & Jaffee, 2019) and lack of educational attainment (Graves & Nowakowski, 2017) are distal risk factors for physiological dysfunction and AL and could be modifiable sources of prevention.

Various studies have separately considered pathways linking maltreatment, an interpersonal form of childhood adversity, and education to AL; however, several notable issues remain. First, research has predominately combined reports of maltreatment and other forms of childhood adversity into composite indicators (Barboza Solís et al., 2015; Widom et al., 2018) and have seldom considered whether discrete types of maltreatment influence educational achievement and AL. This is of critical importance because research has questioned whether the cumulative index of adverse childhood experiences (ACEs) is appropriate (see McLennan et al., 2020; Negriff, 2020) as different types of maltreatment may uniquely impact outcomes, such as educational achievement. Second, studies have predominantly used educational achievement as a covariate when modeling the relationship from maltreatment to distal health outcomes (e.g., Author Citation; Barboza Solís et al., 2015) rather than it being an integral social determinant of AL. Lastly, sex differences are seen for individual markers and total allostatic load (Yang & Kozloski, 2011) and prevalence of maltreatment subtypes (Moody et al., 2018) and may impact the relationship between childhood maltreatment, educational attainment, and allostatic load. To address existing limitations and advance scientific knowledge, the current study examined educational achievement as a mediator linking cumulative and individual types of childhood maltreatment to AL using a large sample of midlife adults drawn from the general population. Additionally, we assessed gender as a moderator.

1.1. Childhood maltreatment and allostatic load

Human biological systems are open systems (e.g., affected by the social environment) and when psychosocial stress occurs the body engages in adaptive physiological responses via a stress response cascade (e.g., hypothalamic-pituitary-adrenal (HPA) axis). Although these responses are beneficial in acute situations, chronic stress can extend the physiology beyond its capacity to successful adapt and cause "wear and tear" on physiological systems including nervous, endocrine, and inflammatory systems (Danese & McEwen, 2012). This cumulative burden is known as AL. Not surprisingly, theoretical (Danese & McEwen, 2012) and empirical work (Finlay et al., 2022) has linked adverse childhood experiences (ACEs) to AL. ACEs are forms of childhood adversity and maltreatment which result in chronic stress known to effect various systems involved in physiological responses to stress (Danese & McEwen, 2012; Teicher et al., 2003). Cumulative disadvantage models highlight that early adversity potentiates poor health through chains of disadvantage where individuals who experienced maltreatment are at increased risk for continued adversity through the biological, social, emotional, and cognitive consequences that ultimately lead to health disparities (Author Citation; Ferraro et al., 2016; Umberson et al., 2014).

Studies utilizing the cumulative disadvantage model have tended to combine varying forms of maltreatment and other childhood adversities to create a composite index; however, there is evidence that individual forms of maltreatment are associated with AL. Friedman et al. (2015) examined early life adversity in relation to allostatic load and found that childhood socioeconomic adversity and physical abuse were significantly associated with higher levels of AL. Widom et al. (2015) found that children with documented cases of child abuse and neglect had higher levels of AL in middle adulthood compared to a matched control group. Scheuer et al. (2018) assessed allostatic load as a mediator between childhood abuse and depression. Physical abuse, but not emotional abuse, was associated with higher levels of allostatic load. These findings not only suggest a significant relationship between physical abuse and AL, but also indicate differences among the subtypes which suggests that composite indices of adversity may lead to erroneous conclusions.

Congruent with increased attention on the associations between childhood maltreatment and AL, studies have examined mediators to explain this association and long-term outcomes (Barboza Solís et al., 2015; Horan & Widom, 2015; Priest et al., 2019). For example, using a prospective cohort design Barboza Solís et al. (2015) found that ACEs were significantly associated with AL in midlife adults and the association was mediated by health behaviors, education, and wealth in early adulthood, but failed to consider which forms of maltreatment are the driving forces behind the associations.

1.2. Mediating role of educational achievement

Educational achievement is often used as one variable of a composite score to assess socioeconomic status, which is generally associated with health outcomes and mortality (Bosworth, 2018; Stringhini et al., 2017). When assessed independently, higher educational attainment is associated with higher self-rated health and lower AL in midlife adults (Hansen et al., 2022). A longitudinal study of 11,807 participants found that education moderated the relationship between race/ethnicity, gender, and allostatic load highlighting its importance as a modifiable factor that may serve as a pathway to understand health inequities (Richardson et al., 2021). This supports findings from Case and Deaton (2021) which reported education is a robust predictor of life expectancy.

Childhood maltreatment has been found to be associated with lower educational achievement (Hong et al., 2018; Horan & Widom, 2015; Houtepen et al., 2020). Children who experience maltreatment are at higher risk of developmental delays (e.g., speech), involvement in special education interventions, poor academic performance (e.g., GPA, test scores), grade retention, and more frequent absenteeism (Romano et al., 2015; Ryan et al., 2018). Further, more frequent maltreatment and polyvictimization were associated with worse academic performance (Romano et al., 2015) and poorer cognitive functioning (Young & Widom, 2014). Childhood maltreatment may be related to reduced educational attainment through several pathways. Childhood maltreatment has also been associated with decreased cognitive function, altered memory, literacy and verbal comprehension, executive functioning, processing speed, perceptual reasoning, and non-verbal reasoning, all of which may impact a child's success in school and lower

educational achievement (Su et al., 2019).

Further, different types of maltreatment lead to changes in brain structure, function, and connectivity which alters numerous physiological systems (Teicher et al., 2016), which may differentially impact the ability to learn. Lack of physical resources and available parents to help with homework and learning as found in neglect may decrease educational achievement (Manly et al., 2013). Children who experienced physical and sexual abuse were over twice as likely to experience poor educational outcomes by age 18 (Jaffee et al., 2018) which has been attributed to psychopathology, delinquent and criminal behavior, and more negative peer relationships (Lansford et al., 2021; Yoon et al., 2018). Not surprisingly, those who experienced physical abuse were less likely to graduate high school (Boden et al., 2007). The connection of specific forms of maltreatment to long term physical health, however, remains understudied in the context of education (Misiak et al., 2022; Turner et al., 2016).

Educational achievement is a critical social determinant of health, with a documented relationship with allostatic load (Friedman et al., 2015; Gruenewald et al., 2012; Howard & Sparks, 2015; Westerlund et al., 2013), physical health (Brown et al., 2012; Grzywacz et al., 2004), and mortality (Hayward et al., 2015). Education is a particularly robust factor as it demonstrates a stronger influence on AL compared to personality characteristics, intelligence, social relationships, and mental health factors (Christensen et al., 2018). In fact, prior research has noted that adult socioeconomic status mediates the relationship between childhood adversity and AL (Barboza Solís et al., 2015; Christensen et al., 2018; Misiak et al., 2022). Those with greater educational achievement have more effective problem-solving strategies, which can aid recovery from stressful events and greater cognitive reappraisal of stressful events (Baker et al., 2011). For example, although individuals with higher levels of education reported significantly more stressors on a regular basis, they were less likely to report these stressful experiences as severe (Grzywacz et al., 2004). Second, education enhances health literacy, or the ability to identify, access, and engage in health-related resources. Health literacy has been found to be the strongest and most consistent mediator linking educational achievement to health (Stormacq et al., 2019). Third, there are notable differences in health behavior between those in high and low socioeconomic status (Kraft & Kraft, 2021) including greater alcohol and tobacco use, poorer diet, and a sedentary lifestyle among those with lower educational achievement (Calling et al., 2019; Pedron et al., 2021). Fourth, educational attainment mediates the role between childhood maltreatment and unemployment rates (Liu et al., 2013) which could lead to fewer job opportunities, more periods of unemployment that ultimately culminates in greater AL (Wahrendorf et al., 2022).

1.3. Present study

The current study will examine educational achievement as a mediator linking childhood maltreatment to AL using two modeling strategies. First, we examined cumulative reports of maltreatment, in congruence with the cumulative disadvantage and ACEs frameworks (e.g., dose-response), to examine whether greater experiences of maltreatment are predictive of educational achievement and allostatic load. Second, due to scrutiny related to the proposed dose-response relationship within the ACEs framework (Negriff, 2020), we also examined whether specific forms of maltreatment exerted a greater or small effect on educational achievement and AL. An exploratory aim of the study was to examine gender as a moderator of the associations (Teicher et al., 2003) using a multiple group structural equation modeling. This is among the first studies to investigate maltreatment, educational achievement, and AL stratified across gender (Misiak et al., 2022). While it is noted that gender may be an influential factor (e.g., O'Shields & Gibbs, 2021), the interrelationships among the proposed variables stratified across gender are novel; therefore, no directional hypotheses were made. The current study controlled for numerous possibly confounding factors including psychopathology (anxiety and depressive symptoms) (Newbury et al., 2018), demographics (age) (Scheuer et al., 2018), health factors (chronic health conditions) (Guidi et al., 2021), and other adversities (welfare, living with an alcoholic in childhood) (Houtepen et al., 2020) to capture the unique contributions of maltreatment on AL.

2. Materials and methods

The current study used data from the Midlife in the United States (MIDUS) study, a multiwave, national study (https://www.icpsr.umich.edu/web/ICPSR/series/203). The MIDUS data are free, de-identified, and publicly available, thus IRB approval was not required for the current study. All participants provided written informed consent. The aim of the MIDUS study was to understand predictors and consequences related to physical health, mental wellbeing, and social relationships. The first wave of the MIDUS study (MIDUS 1) was conducted from 1995 to 1996 and included 7108 non-institutionalized, English-speaking adults. Participants were mailed a self-administered questionnaire (SAQ) and contacted via telephone. A follow-up wave, MIDUS 2 (n = 4963 adults), was conducted from 2004 to 2006 using the same data collection methods at MIDUS 1. A biomarker subproject was included from 2005 to 2009 as a part of the MIDUS 2 data collection, which included 1054 adults who completed both the SAQ and telephone interview at MIDUS 1 and MIDUS 2 as well as a sample of 201 racial minorities who did not participate in MIDUS 1 or MIDUS 2. The current study utilized individuals who participated in the MIDUS 2 biomarker sample (n = 897) and excluded the racial minority sample because they did not have information related to educational achievement and covariates. We randomly removed one twin or sibling as to not violate assumptions of statistical non-independence of residuals and to account for shared childhood environment which will likely attenuate associations.

Missing data in the current study was minimal with no missing data in the biomarker sample other than four participants who were missing data on childhood maltreatment. Modern methods of missing data do not typically have a meaningfully increase statistical power or reduce standard errors when missingness is rare. One variable in our model demonstrated levels of missingness that may not be ignorable (education, 8.8 % missing). To address missingness, we conducted linear regressions to identify variables correlated with missingness, or auxiliary variables. Auxiliary variables are those that are correlated with missingness and provide information on the

values the missing data would have taken on if they were not missing (Enders, 2022). When auxiliary variables are entered into the model the missing values are assumed to be missing at random, which is when missingness is predicted by other variables and not due to the questions themselves (missing not at random). We identified several variables existing in the model were identified as auxiliary variables for educational achievement (chronic conditions, maltreatment, and household dysfunction) and were included in the model.

2.1. Participants

The following are the participant characteristics for those in the current study (n = 897). Participants tended to be white (92.4 %; n = 829), female (53.4 %; n = 479), and reported a mean age of 55.62 (SD = 11.84). The majority of participants were married (95 %, n = 852). The mean household income was $80,417 (*SD* = 66,125). Regarding educational achievement, 23.7 % of participants reported a high school education or less, 21.4 % reported some college but no degree, 22.5 % reported a college degree, 4.8 % reported graduate school but no degree, and 19.7 % reported a master's degree or professional degree (e.g., PhD, MD, JD).

2.2. Measures

Childhood maltreatment. Childhood maltreatment was assessed with the Childhood Trauma Questionnaire (CTQ; Bernstein et al., 2003) collected as part of the MIDUS 2 biomarker follow-up. The CTQ is a 25-item scale that assesses childhood physical, sexual, and emotional abuse and physical and emotional neglect prior to the age of 18. Each of the items were scored from (1) Never to (5) Very Frequently. Childhood maltreatment was operationalized for this study in two ways. First, the 25 items were summed together to capture a total score indicating the overall severity of childhood maltreatment. Overall score could range from 25 to 125. Second, the five items on each of the subscales were summed together to provide a score ranging from 5 to 25 with higher scores being reflective of more severe maltreatment. Cronbach's Alpha of the five subscales ranged from 0.70 to 0.94.

Educational attainment. During the telephone interview, participants responded to one question regarding educational attainment. Responses ranged from 1 "no school/some grade school" to 12 "PhD, MD, JD, or other professional degree."

Allostatic load. During the biomarker study, participants stayed overnight in one of three general research centers (UCLA, Wisconsin-Madison, and Georgetown) and provided biological samples (see Ryff et al., 2022 for a detailed description). Allostatic load scores were calculated based on risk scores of seven physiological systems. Physiological systems and their associated biomarkers included cardiovascular (systolic blood pressure, diastolic blood pressure, and pulse), sympathetic nervous system (epinephrine and norepinephrine), parasympathetic nervous system (low frequency heart rate variability, high frequency heart rate variability, standard deviation of R-R intervals, and the root mean square of successive differences), hypothalamic-pituitary-adrenal axis (cortisol level and dehydroepiandrosterone sulfate), inflammation (blood C-reactive protein, fibrinogen, serum interleukin-6, serum *E*-selectin, and serum intracellular adhesion molecule-1), lipid metabolism (high density lipoprotein cholesterol, low density lipoprotein cholesterol, triglycerides, body mass index, and waist-hip ratio), and glucose metabolism (hemoglobin, glucose, and insulin resistance).

High-risk quartile ranges determined risk scores for each individual biomarker. Those in the top 25 % were at risk and received a score of 1, except for six measures where low scores indicated higher risk, in which the lowest 25 % received a score of 1. System scores were calculated by summing risk scores of individual biomarkers and dividing the score by the number of biomarkers in the system (i.e., system scores ranged from 0 to 1). Scores were calculated for those who had values for at least half of the biomarkers. Finally, allostatic load scores were calculated by summing system scores, and could range from 0 to 7. Allostatic load scores were calculated for those who had values for at least 6 of the systems. Determining allostatic load using the quartile method is a commonly accepted approach for operationalizing physiological risk (Gruenewald et al., 2012; Priest et al., 2019).

2.3. Covariates

Gender. Gender was coded as either male (0) or female (1).

Age. Participants age was entered as a continuous variable.

Childhood Household Dysfunction. Household dysfunction was measured with two items summed together. The items asked if participants if they grew up in a household where someone was an alcoholic and participants responded either yes (1) or no (0) or were on welfare yes (1) or no (0).

Chronic Health Conditions. Participants were asked to respond to a list of 29 chronic health conditions. The number of affirmative responses were summed together to create a count variable indicating the total number of chronic conditions.

Anxious Arousal. The Mood and Anxiety Symptom Questionnaire (MASQ) (Watson & Clark, 1991) was used to measure a range of symptoms related to anxiety and depression experienced by participants over the past week. The MASQ has good psychometric properties (Watson et al., 1995). The current study used the anxious arousal subscale which includes 17 questions rated on a five-point Likert-type scale ranging from (1) Not at all to (5) Extremely. Higher scores reflect higher levels of anxious symptoms. Cronbach's alpha = 0.81.

Depressive Symptoms. The Center for Epidemiologic Studies Depression (CES-D; Radloff, 1977) was used to measure depressive symptoms over the past week. The CES-D has demonstrated strong psychometric properties including good reliability and validity (Roberts & Vernon, 1983). The CES-D is a 20-item scale rated on a four-point Likert-type scale ranging from (0) Rarely or none of the time to (3) Most or all of the time with three reverse coded items. Items were summed together to obtain an overall index of depressive symptoms and higher scores reflect higher levels of depressive symptoms. Cronbach's alpha = 0.89.

Table 1
Bivariate correlations, means, and standard deviations of independent, mediating, outcome, and control variables stratified across gender.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	M (SD) Males
1. CTQ Total	–	0.85***	0.75***	0.50***	0.86***	0.69***	−0.14**	0.14**	−0.13**	0.24***	0.17***	0.33***	0.20***	35.86 (11.01)
2. Emotional Abuse	0.86***	–	0.66***	0.29***	0.66***	0.41***	−0.08	0.14**	−0.18***	0.17***	0.14***	0.28***	0.18***	7.28 (3.27)
3. Physical Abuse	0.80**	0.67***	–	0.23***	0.50***	0.38***	−0.17***	0.10**	−0.17**	0.22***	0.08	0.14***	0.12*	6.83 (2.73)
4. Sexual Abuse	0.68***	0.39***	0.46***	–	0.26***	0.24***	−0.01	0.01	−0.01	0.06	0.02	0.14**	0.09	5.63 (2.19)
5. Emotional Neglect	0.84***	0.73***	0.56***	0.36***	–	0.57***	−0.12*	0.13**	−0.09	0.18***	0.15***	0.34***	0.17***	9.46 (4.04)
6. Physical Neglect	0.77***	0.58***	0.62***	0.38***	0.61***	–	−0.13**	0.11*	0.01	0.29***	0.21***	0.28***	0.16**	6.64 (2.34)
7. Education	−0.10**	−0.06	−0.10*	−0.08	−0.06	−0.14*	–	−0.20**	−0.04	−0.14*	−0.13*	0.09*	−0.12**	7.98 (2.43)
8. Allostatic Load	0.08	0.06	0.09	0.07	0.02	0.10*	−0.13***	–	0.16***	0.01	0.21***	0.07	0.17***	2.02 (1.04)
9. Age	−0.11*	−0.15***	−0.17**	−0.04	−0.08	0.01	−0.13**	0.18***	–	−0.20***	0.16***	−0.11*	.0.11*	56.49 (12.10)
10. Household Dysfunction	0.40***	0.38***	0.34***	0.27***	0.30***	0.34***	−0.18***	−0.00	−0.27***	–	0.12*	0.05	−0.05	0.22 (0.42)
11. Chronic Conditions	0.28***	0.25***	0.26*	0.23***	0.16***	0.20***	−0.10*	0.21***	0.10*	0.19***	–	0.24***	0.30***	1.90 (2.22)
12. Depression	0.32***	0.31***	0.20**	0.15**	0.32***	0.22***	−0.08	0.08	−0.13**	0.27***	0.31***	–	0.48***	7.76 (7.30)
13. Anxiety	0.27***	0.28***	0.22**	0.15***	0.24***	0.16**	−0.11**	0.16***	−0.01	.0.23***	0.48***	0.50***	–	21.13 (4.40)
M (SD) Females	39.52 (15.70)	8.60 (4.57)	6.98 (4.57)	7.24 (4.56)	9.96 (4.72)	6.90 (2.90)	7.61 (2.45)	1.68 (1.01)	54.86 (11.57)	0.37 (0.57)	2.71 (2.33)	8.62 (8.34)	22.43 (5.81)	

Note. Females are displayed below the diagonal and males are above the diagonal. * $p < .05$, ** $p < .01$, *** $p < .001$.

2.4. Statistical analysis

First bivariate analyses were conducted and included descriptive statistics, Pearson correlations, and one-way ANOVAs to examine the graded relationship between education and AL. Following bivariate results, structural equation models were run in Mplus using maximum likelihood. First, we ran a single group analysis was run with males and females in the same model. We operationalized maltreatment from a dose-response relationship by summing the maltreatment subscales together as well as testing the five subtypes of abuse and neglect. Following the single group analysis, a multiple group analysis was run stratified across gender to determine whether gender was a moderator of the associations among maltreatment, educational achievement, and AL via constraining paths to be equal in the male and female model and using a chi-square differences test to examine moderation. Model-data fit was assessed using several fit statistics: Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Standardized Root Mean Square Residual (SRMR), Root Mean Square Error Approximation (RMSEA), and a chi-square test. Adequate fit is generally described as having CFI and TLI values >0.90, SRMR and RMSEA values <0.08, and a non-significant chi-square test. Bootstrapped indirect effects yield bias-corrected point estimates and 95 % confidence intervals and were used to examine the indirect effects. All structural equation models included the covariates.

3. Results

3.1. Bivariate results

Correlations stratified across gender are presented in Table 1. Prevalence rates of individual forms of maltreatment and *t*-tests examining gender differences are presented in the online supplemental material.

3.2. Cumulative maltreatment structural equation model

Our initial approach was to first test the indirect effects from childhood maltreatment to allostatic load via lower educational achievement in a single group model and a multiple group model; however, inclusion of gender as a covariate led to a non-positive definite matrix making the hypothesized model inadmissible, which is likely due to multicolinearity. Consequently, we estimated only the multiple group models across gender. First, a cumulative model of child maltreatment was examined where the CTQ total score (severity) was used in the prediction of educational achievement and allostatic load (See Fig. 1). The multiple group structural equation model was a saturated model (zero degrees of freedom), thus model-data fit could not be examined. In the male model, childhood maltreatment was associated with educational achievement ($\beta = -0.12$, $p = .01$) and allostatic load ($\beta = 0.11$, $p = .03$), indicating that more severe maltreatment is associated with lower levels of educational achievement and higher levels of allostatic load. Men who reported higher levels of educational achievement also reported lower levels of allostatic load ($\beta = -0.17$, $p = .001$). The indirect effects were examined next. The bias-correct bootstrapped indirect association between childhood maltreatment to AL through educational achievement was not significant ($\beta = 0.02$, 95 % CI [0.000, 0.042]). Overall, the model accounted for 3.8 % of the variation in educational achievement and 10.5 % of the variance in allostatic load. Results of the structural equation model can be found in Fig. 1. In the female model, childhood maltreatment severity was not associated with educational achievement ($\beta = -0.05$, $p = .39$) where more severe maltreatment was not significantly associated with educational achievement. Likewise, maltreatment severity was not directly associated with allostatic load ($\beta = 0.05$, $p = .38$) and neither was educational achievement ($\beta = -0.11$, $p = .06$). Given that the overall experience of maltreatment was not a significant predictor of educational achievement and AL and the indirect effects were non-significant ($\beta = 0.01$, 95 % CI [0.004, 0.019]). Overall, the model accounted for 6.7 % of the variation in educational achievement and 8.3 % of the variance in allostatic load. The indirect effects are displayed in Table 2.

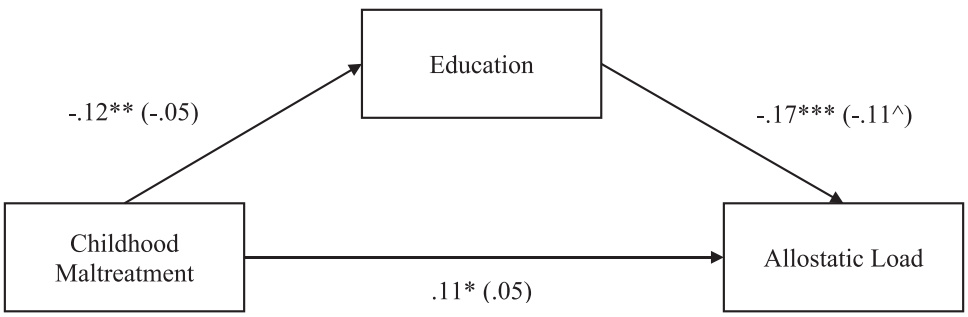

Fig. 1. Results from the structural equation mediational model examining educational achievement as a mediator linking childhood maltreatment severity to allostatic load.
Note: Standardized regression coefficients are presented. Male parameter estimates are presented outside the parenthesis and women are inside. ^ = $p < .10$, * $p < .05$, p *** $< .001$.

3.3. Subtypes structural equation model

Childhood maltreatment was broken down into five subscales to discern whether specific forms of abuse and neglect exert a differential impact on educational achievement and AL (See Fig. 2). The structural equation model demonstrated adequate model-data fit (χ^2 (10) = 13.97, p = .18, RMSEA = 0.03, CFI = 0.99, TLI = 0.95). We did not expect there to be direct effects from childhood maltreatment to allostatic load as the effects would be accounted for by overlapping variance of the maltreatment subtypes, educational achievement, and the covariates. First, we report the results from the male model. Specifically, physical abuse was associated with lower educational achievement (β = −0.20 p = .003) while the other forms of maltreatment were not significantly associated including emotional abuse (β = 0.10, p = .21), sexual abuse (β = −0.04, p = .56), physical neglect (β = −0.04, p = .49), and emotional neglect (β = −0.06, p = .40). Educational achievement (β = −0.18, p = .01) was inversely associated with levels of AL. The indirect effects were examined next. The bias-correct bootstrapped indirect association between childhood physical abuse to AL through educational achievement was significant (β = 0.02, 95 % CI [0.001, 0.040]), indicating a significant indirect effect from physical abuse to allostatic load via educational achievement. Overall, the model accounted for 4.5 % of the variation in educational achievement and 9.4 % of the variance in allostatic load.

In the female model, none of the maltreatment subtypes were associated with educational achievement, including emotional abuse (β = 0.05, p = .55), physical abuse (β = −0.07, p = .29), sexual abuse (β = −0.00, p = .97), emotional neglect (β = 0.05, p = .48), and physical neglect (β = 0.09, p = .20). For women, educational achievement remained non-significant in the maltreatment subtypes model in the prediction of allostatic load (β = −0.09, p = .06). Indirect effects for females were not calculated due to nonsignificant direct effects. Overall, the model accounted for 7.8 % of the variation in educational achievement and 8.1 % of the variance in allostatic load.

3.4. Post-hoc moderation analysis across gender

Next, in both the cumulative model and the maltreatment subtypes model, we tested gender as a moderator via constraining the specified pathway to be equal in the male and female models and if the chi-square was significant ($\chi^2 < 3.84$) then gender moderated the pathway. In the cumulative model, the pathway from childhood maltreatment to allostatic load was not moderated by gender (χ^2 (1) = 1.68). Likewise, the path from educational achievement to allostatic load was not moderated by gender χ^2 (1) = 1.71 nor was the pathway from maltreatment to educational achievement significant χ^2 (1) = 2.30. In the subtypes model, gender moderated the relationship between educational achievement and allostatic load such that the protective effect of educational achievement was not significantly stronger for men χ^2 (1) = 2.14. Likewise, the chi-square differences test for the physical abuse to educational achievement pathway was not significantly stronger for men χ^2 (1) = 2.10.

4. Discussion

The objectives of the current study were to 1) examine education as a possible pathway linking child maltreatment to AL, 2) discern whether educational achievement was associated with specific types of maltreatment, and 3) explore gender differences. We found that overall maltreatment was indirectly related to allostatic load via educational achievement in men but not women and that physical abuse in men was a particularly important form of maltreatment that potentially contributes to educational achievement and AL in midlife. Likewise, for maltreatment severity remain directly associated with AL in men after accounting for educational achievement.

Table 2
Bootstrapped indirect effects from maltreatment severity and subtypes to allostatic load via educational achievement.

	β	95 % CI
Male		
Maltreatment Severity Model		
Maltreatment - > Education - > Allostatic Load	0.02	[0.000, 0.042]
Maltreatment Subtypes Model		
Emotional Abuse - > Education - > Allostatic Load	−0.01	[−0.036, 0.016]
Physical Abuse - > Education - > Allostatic Load	0.02	[0.001, 0.043]
Sexual Abuse - > Education - > Allostatic Load	−0.01	[−0.026, 0.012]
Emotional Neglect - > Education - > Allostatic Load	0.01	[−0.016, 0.038]
Physical Neglect - > Education - > Allostatic Load	0.01	[−0.018, 0.033]
Female		
Maltreatment Severity Model		
Maltreatment Severity - > Education - > Allostatic Load	0.01	[−0.004, 0.019]
Maltreatment Subtypes Model		
Emotional Abuse - > Education - > Allostatic Load	−0.01	[−0.021, 0.009]
Physical Abuse - > Education - > Allostatic Load	0.01	[−0.004, 0.027]
Sexual Abuse - > Education - > Allostatic Load	0.00	[−0.009, 0.012]
Emotional Neglect - > Education - > Allostatic Load	−0.00	[−0.019, 0.011]
Physical Neglect - > Education - > Allostatic Load	0.01	[−0.009, 0.019]

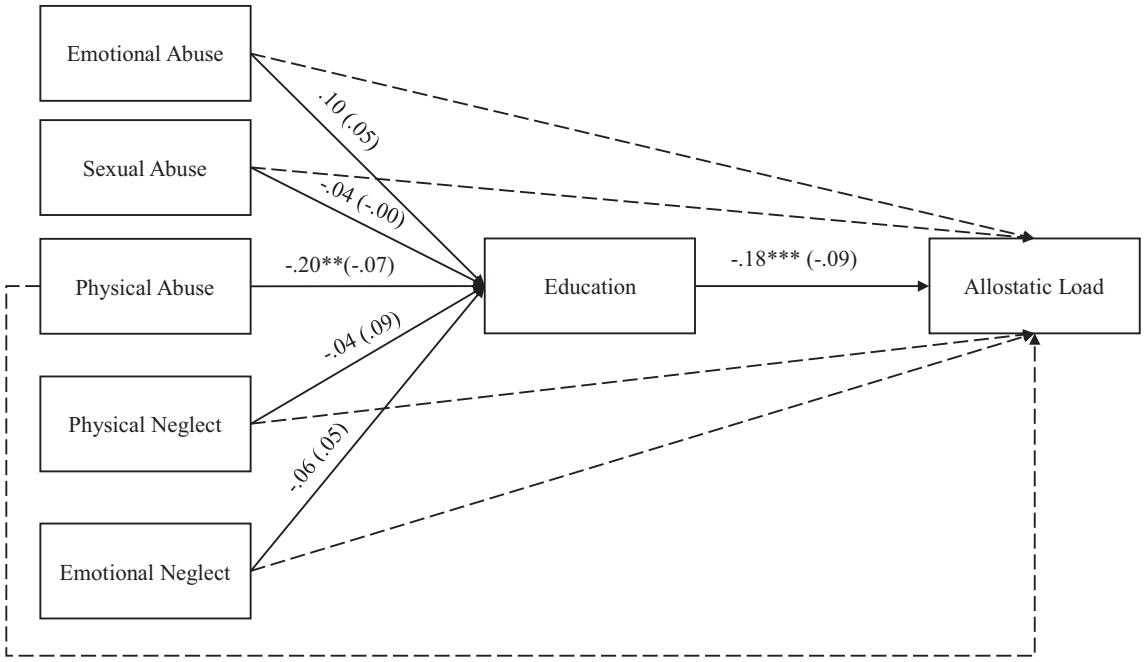

Fig. 2. Results from the structural equation mediational model examining educational achievement as a mediator linking childhood maltreatment subtypes to allostatic load.
Note: Dashed lines represent paths that were non-significant and removed from SEM mediational model. Male parameter estimates are presented outside the parenthesis and women are inside * p < .05, ** p < .01, p *** < .001.

Although the parameter estimates within the SEM models were larger for men, we found no evidence of moderation in either the cumulative maltreatment model or the maltreatment subtypes model.

One notable contribution is that the maltreatment severity scores (CTQ total score) were associated with educational achievement, but, only for men. Men who reported higher overall levels of maltreatment tended to also tended to have lower levels of educational achievement (Misiak et al., 2022; Myat Zaw et al., 2022). This is particularly interesting given that women actually reported higher levels of maltreatment, but maltreatment was not associated with educational achievement. This indicates that it is not the severity of the maltreatment, but maltreatment may impact boys and girls differently. Thus, the relationship between maltreatment and educational achievement may have gendered pathways. Males tend to report more externalizing behavior compared to girls (Leban & Gibson, 2020) and externalizing symptoms such as aggression, conduct disorder, criminality, and substance use (De Sanctis et al., 2012; Porche et al., 2011) may more readily impact educational achievement compared to internalizing symptoms (Masten et al., 2005). Additionally, externalizing symptoms, compared to internalizing (e.g., depression, anxiety) tend to be more stable in adolescents (van Lier et al., 2012). Likewise, maltreatment has been associated with reduced social competence, which can impede the completion of significant developmental milestones in childhood and adolescents resulting in aggressive or delinquent behavior (Author Citation). Thus, it is likely that the relationship between maltreatment and educational achievement may be related to sequelae that is more common among males. Despite both direct effects being significant, the relationship between maltreatment and AL was not significant, indicating that the joint effect of maltreatment and educational achievement on AL was not significant, which can be a reflection of a small effect size, sampling error, and numerous other factors that require additional research.

To provide a more nuanced approach to understanding the association between maltreatment and educational achievement, we tested specific maltreatment subtypes. Our findings expanded on previous findings that ACEs are linked to AL through educational achievement (Misiak et al., 2022) by documenting that childhood physical abuse is uniquely associated with AL through reduced educational achievement among men. These findings contribute to a more nuanced understanding on how inherently broad concepts such as maltreatment and childhood adversity may influence social determinants of health and ultimately AL. This supports previous studies indicating that adults who experienced greater physical abuse reported lower levels of education achievement (Lansford et al., 2021) and increased risk for not graduating high school (Boden et al., 2007). For example, men who are physically abused than women (Thompson et al., 2004) and physical abuse is associated with risk factors for reduced educational achievement including attachment issues, aggressive behavior, deviant peer affiliations, and reduced prosocial behavior with peers (Trickett & McBride-Chang, 1995; Yoon et al., 2020). In addition to social and behavioral consequences, males and children who were physically abused are more likely to be diagnosed with ADHD (Fuller-Thomson et al., 2014) which can potentiate academic difficulties through difficulties in concentration, hyperactivity, and impulsivity. Thus, the impact of physical abuse is likely to be multifaceted and include behavioral responses to abuse that threaten educational achievement, but also abuse may impede learning via psychological disorders such as ADHD.

The link between educational achievement and AL is fairly well established. Adults with lower educational achievement is a vulnerability to physical health consequences, including AL (Adler & Ostrove, 1999; Misiak et al., 2022). Educational achievement affords numerous advantages that can help account for stark differences in adult physical health (Choi et al., 2011; Pathirana & Jackson, 2018; Zajacova & Lawrence, 2018). Those with lower educational achievement tend to experience more individual stressors and psychopathology, reduced healthcare literacy, greater exposure to environmental risk that disproportionately and negatively associated with physical health (Adler & Ostrove, 1999). Lower educational achievement has been connected opt exposure to toxic chemicals, greater injury, and more severe stressors (Grzywacz et al., 2004; Kivimäki et al., 2020) risk and these may be particularly pronounced risk factors among men who were physically abused in childhood. The psychological, educational, social, and community mechanisms by which educational achievement may influence AL, the current study findings evidence from a cumulative disadvantage framework where early adversity increases risk for additional adversities over the life course where physical abuse may influence AL through the diverse consequences of reduced educational achievement.

4.1. Limitations and future directions

Despite the strengths of the study which included a longitudinal design, the current study's findings and conclusions should be interpreted in light if it's limitations. First, childhood abuse and neglect were measured using retrospective reports which are subject to recall bias as well as reporting bias. Second, although the current study used adults sampled from the general population, it contained mostly White middle-class adults, which is of significant importance as child maltreatment (Sedlak et al., 2010) and AL (Howard & Sparks, 2015) vary by race. This may overshadow the impact of intersectionality between race/ethnicity, gender, educational attainment and allostatic load that has been reported (Richardson et al., 2021). Thus, conclusions about other populations are limited and should be a goal for future research. Third, the relationship between physical abuse and education needs to be further elucidated. It could be that parental physical abuse is a response to poor educational achievement or it could be that physical abuse is associated with educational deviancies. Fourth, although we measured educational achievement and AL longitudinally, we were unable to examined cross lagged effects of AL so the relationship between educational achievement and AL cannot be fully discerned.

4.2. Conclusion

Findings from the current study indicate that AL and educational achievement are inversely associated; however, there is not a dose-response relationship between cumulative maltreatment and educational achievement or AL. When assessing types of maltreatment individually, we did find that childhood physical abuse was associated with reduced educational achievement, leading to higher levels of AL. These findings may have important implications for prevention and intervention as educational achievement is a social determinant of health and potentially modifiable factor that can aid physical abuse survivors in reducing physiological dysfunction.

Declaration of competing interest

None.

Data availability

The MIDUS data are free, de-identified, and publicly available.

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