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Longitudinal associations between early-life adversity and accelerated molar eruption: the dimensional and cumulative approach

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Abstract

Background Early-life adversity (ELA) has been linked to accelerated biological development. This study aimed to explore the cumulative effects of different dimensions of early-life adversity (ELA) on accelerating biological aging, as indicated by the accelerated eruption of the second permanent molar (M2).

Methods Participants were drawn from an ongoing cohort of 1,448 children aged 7–12 years who were recruited following a 2-year follow-up and 1,191 children were ultimately included in this study. A multi-informant assessment of exposure to threat-related, deprivation-related, and unpredictability-related ELA was performed at baseline. Statistical analyses were performed via an accelerated failure time (AFT) model.

Results The analysis revealed that parents of 1,558 children (mean [*SD*] age, 9.2 [1.3] years) reported exposure to different types of ELA dimensions (threat, deprivation, and unpredictability) in their offspring. During a 2-year follow-up, three waves of physical and dental examinations were administered to the participants. The M2 accelerated eruption rate was 13.4% (209/1,558) at baseline and increased to 34.7% (444/1,280) at wave 3, with no significant sex difference (boys: 25.8%, girls: 26.3%). Deprivation-related (HR = 1.07, 95%CI: 1.12–2.29, $P = 0.046$) and unpredictability-related ELA (HR = 1.15, 95%CI: 1.06–1.25, $P = 0.001$) were found to be associated with M2 accelerated eruption over a two-year follow-up period, whereas threat-related ELA showed no such association. Notably, high ELA exposure in each dimension resulted in an increased risk of M2 accelerated eruption. These associations remained stable after controlling for covariates.

Conclusions The findings suggest that ELA-induced acceleration of biological aging can be detected at the time of molar eruption in a dimension-specific and dose-specific manner. These results emphasize the importance of considering the different dimensions and levels of ELA exposure when evaluating its impact on biological aging.

Keywords Threat, Deprivation, Unpredictability, Early life adversity, Molar eruption, Development

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Background

Early-life adversity (ELA) is highly prevalent and represents a departure from a child's expected physical and psychological environment, requiring some form of adaptation [1]. It can serve as a chronic stressor throughout a child's developmental period and is strongly associated with an elevated risk for long-term negative health outcomes, including poor physical health and widespread mental health problems. Understanding ELA is critical for mitigating its well-documented negative effects on children's development.

Emerging evidence suggests that accelerated biological aging might serve as a potential mechanism linking exposure to ELA with a broad spectrum of physical and mental health issues. ELA exposure in early life may alter the rate of development, leading to faster aging. To date, various nonoral-related metrics, such as accelerated telomere attrition [2, 3], DNA methylation [4, 5], earlier pubertal timing, and age at menarche [6, 7], have been used to measure biological aging following ELA. While a long-term connection between ELA and poor oral health has been established, few studies have discussed accelerated biological aging in the oral cavity as an early biological manifestation of ELA [8].

Davis et al. [9] recently introduced the TEETH (Teeth Encoding Experiences and Transforming Health) conceptual model, suggesting that ELA disrupts multiple developmental processes, potentially involving tooth formation, leading to time-resolved biological imprints that can be objectively captured early in life. ELA-induced disruptions in tooth formation may result in macrolevel alterations as well as microlevel biological signatures, such as dental enamel hypoplasias and changes in chemical composition [9]. Preliminary evidence suggests that greater exposure to ELA is significantly associated with earlier eruption of molars [10], and that this acceleration further mediates the association between stress risk and cognition [11]. Therefore, the timing of tooth development may serve as an early indicator of a broad pattern of accelerated maturation due to ELA. The second permanent molar (M2) takes the longest time to develop from the onset of development to eruption, with tooth germ formation occurring in the first year of life and eruption partially overlapping with the onset of puberty. Thus, the permanent tooth phenotype holds promise as a noninvasive, low-cost, and easily assessable biomarker for identifying individuals at risk of accelerated development.

From a life course perspective, the effects of ELA are presumed to accumulate, implying that exposure to multiple ELA increases the risk of encountering adversity later in life, with this accumulation following a dose-response pattern. Recently, an integrated model was proposed based on the Dimensional Model of Adversity and Psychopathology (DMAP) [12] and the Life History (LH) models [13], identifying three core fundamental dimensions: threat, deprivation, and unpredictability [14]. These dimensions encompass a broad spectrum of adverse experiences commonly encountered in childhood. The paradigm shift from cumulative adversity to the dimensional model of adversity facilitates a better understanding of the mechanisms that link specific types of adversity to particular developmental outcomes [15]. However, the associations between different dimensions of the ELA and biological aging remain to be determined.

The present study aimed to extend previous findings by exploring the cumulative effects of various dimensions of the ELA on accelerating biological aging, as indicated by M2 accelerated eruption, in a sample of 1448 children followed for 2 years via an accelerated failure time (AFT) model.

Methods

Study design and participants

This cohort study utilized data from an ongoing prospective longitudinal study designed to investigate the health implications of ELA exposure. The cohort commenced on March 16, 2021, with a total of 1,558 participants aged 7–12 years who were recruited from two large elementary schools in Bengbu, Anhui Province, China. Parents reported their children's exposure to different dimensions of ELA. Simultaneously, the children completed a questionnaire on partial adversity. Follow-up oral examinations and pubertal developmental physical examinations were conducted in three waves on October 18, 2021; November 21, 2022; and May 8, 2023. The minimum follow-up interval was 6 months. The exclusion criteria included inability to complete the questionnaire; failure to attend oral and physical examinations; and having metabolic diseases (e.g., diabetes mellitus), endocrine diseases (e.g., congenital hypothyroidism), or respiratory diseases (e.g., asthma) [16–18]. The current study ultimately included 1,280 children whose data were collected via questionnaires, pubertal development, and oral examinations. The procedures for the present study were approved by the institutional review boards at Anhui Medical University. We also obtained written informed consent from the children, parents, and schoolteachers. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

Early-life adversity (ELA) exposure

This study employed a new integrated model that distinguishes ELA into three dimensions: threat, deprivation, and unpredictability [14, 19], and uses concepts from previous empirical studies to guide the selection of indicators for each dimension [19]. For detailed information

and evidence on each specific ELA indicator, please refer to the appendix (See the Appendix for details, P1-P3).

In the study, we employed a multi-informant approach to assess ELA exposure. Caregivers and children were asked about the child's exposure to ELA from birth to the present at baseline. Parent and child reports were combined using an "or" rule: each early life adversity (ELA) was considered present if reported by either the child or the parent. To ensure data completeness, we endeavored to re-contact respondents to fill in any missing or omitted items after the questionnaires were collected. Each continuous adversity factor was then converted into binary "1 = yes/0 = no" items, and a total score was calculated using the cumulative risk method. The indicators used in this study are listed below.

Threat-related ELA

Threat refers to harm or the potential for harm to the child. Twelve indicators were used to index threat-related ELA, which include: three community safety-related indicators (neighborhood friendly; unsafe community-dwelling; neighborhood violence); seven indicators related to experiencing or witnessing violence (parental verbal abuse, threats, or humiliation; teacher's public scolding; harsh physical punishment; classmate conflicts requiring parental involvement; sexual harassment or assault; peer bullying; witnessing domestic violence); and two parent health-related indicators (father smoking; parental physical disabilities).

Deprivation-related ELA

Deprivation pertains to a lack of expected inputs during a child's development. Twelve indicators were used to measure deprivation-related ELA, which include: two parent-child relationship issues (parent-child separation from father; parent-child separation from mother); two indicators related to parental depression; witnessing a drunken father or mother); two indicators of precariousness of economic situation and family resources (extreme poverty; parental unemployment); two indicators of child neglect (emotional neglect; physical neglect); two inadequate cognitive stimulation (low educational attainment of father; low educational attainment of mother); and two reactive emotional and psychological factors problems (lack of close friends; poor parental relations).

Unpredictability-related ELA

Unpredictability refers to the stochastic variation in external factors affecting morbidity and mortality. To capture unpredictability-related ELA, twelve indicators were used, including: one indicator of instability in family caregiving (parental differences in parenting); two instability in residence and related areas (frequent school transfers; frequent residential relocations); two indicators of irregularity in living schedule (irregular sleeping schedule; rarely have dinner with family); three related to changes in family composition (parents separated or divorced; having a younger brother or sister; death of an important family member); and four unexpected events (hospitalization due to illness; severe traffic accidents; close family member seriously ill; briefly lost to family).

Molar accelerated eruption

Oral examinations were conducted in school, with all children sitting in simple dental chairs, with natural sunlight used as the primary light source. Four trained and calibrated inspectors assessed the eruption status of M2 using disposable dental mirrors and probes. Radiographic assessments were not performed. The eruption status of M2 was recorded. The eruption stage of M2 was categorized using the following criteria: 0 = unerupted; 1 = partially erupted, meaning erupted but not fully occluded; and 3 = full occlusion [20]. The diagnostic criteria for assessing tooth eruption in this study was that any part of the crown had perforated the oral mucosa and was visible through it. Finally, the M2 eruption status is divided into: level 0: no, the tooth is not visible within the oral cavity; level 1: yes, the permanent tooth is clinically visible within the oral cavity.

In this study, based on an epidemiologic survey by Ekstrand et al. [21] In terms of the timing of tooth eruption, M2 eruption time < 11.3 years in girls was defined as earlier eruption, and M2 eruption time < 12.0 years in boys was defined as earlier eruption.

Covariates

The covariates identified for this study include children's baseline BMI and dental caries, gender, birth weight, and sugary drink consumption. These factors were determined using a directed acyclic graph (DAG) through the online tool DAGitty (Fig. S1). This study chose to use parental education and family poverty as exposure factors; therefore, the covariates did not repeatedly control for parental education level or perceived household SES.

Statistical analysis

The missing values in the original data (early-life adversity and demographic information) were estimated using the Multiple Imputation by Chained Equations (MICE) method in R statistical software version 4.4.3. SPSS 27.0 was used to analyze the descriptive statistics and frequency distributions of the study sample across waves 1 to 3. For continuous variables, descriptive data are presented in the form of means and standard deviations; for categorical variables, numbers and percentages are used. Subsequently, we employed univariate and multivariate accelerated failure time (AFT) models to explore the direct impact of covariates (ELA) on the time-to-event

Table 1 Characteristics of children at baseline (Wave 1) and follow-up (Waves 2–3)

Characteristics	No. of participants	Value
Age, mean (SD)		
Wave 1	1558	9.2 (1.3)
Wave 2	1298	10.1 (1.3)
Wave 3	1280	10.5 (1.3)
Girls, % (Wave 1)	654	42.0
Girls, % (Wave 3)	559	43.7
BMI, mean (SD)		
Wave 1	1558	18.1 (3.4)
Wave 2	1298	18.1 (4.3)
Wave 3	1280	18.5 (4.4)
Dental caries, mean (SD)		
Wave 1	1558	2.2 (2.4)
Wave 2	1298	2.8 (3.3)
Wave 3	1280	1.5 (2.4)
Sleep duration, mean (SD)	1558	9.7 (0.7)
Birth weight, mean (SD)	1558	4690.1 (1806.0)

outcome (M2 accelerated eruption) for the analysis of survival time data in the present study, with all models assumed to follow the Weibull distribution. Where β are the coefficients, the acceleration factor is exp (β'X), which represents the effect of the covariates (ELA) on M2 accelerated eruption. The analysis included both an unadjusted model and models that adjusted for sex, birth weight, sleep duration, baseline BMI, and dental caries.

To assess cumulative risk, each type of ELA dimension (threat, deprivation, and unpredictability) reported by all children or parents was summed to calculate a composite score for each domain and a cumulative total ELA score. Each dimension of the ELA cumulative score and the total accumulated ELA score were treated as continuous variables to assess the cumulative risk of M2 accelerated eruption in the single-dimensional and integrated-dimensional AFT models, respectively.

Next, high and low ELA exposures were identified based on the 90th percentile of the population's cumulative ELA score as a threshold, with 5 for threat-related ELA, 8 for deprivation-related ELA, 5 for unpredictability-related ELA, and 17 for total cumulative ELA. The cumulative ELA score for each dimension and the score for total cumulative adversity were used as binary variables (low ELA exposure vs. high ELA exposure) and put into the AFT model to evaluate the association between each ELA dimension and total cumulative ELA with the cumulative risk of M2 accelerated eruption.

All of the aforementioned AFT models were analyzed via STATA/MP 18.0, with all the statistical analyses conducted at a significance threshold of 0.05.

Results

General characteristics

Table 1 presents the characteristics of the cohort at the baseline and follow-up examinations. At baseline, 1,558 participants (654 boys [42.0%]; mean [*SD*] age, 9.2 [1.3] years; range, 7–12 years) were recruited for the study.

Table 2 provides the distribution of M1 eruption and different dimensions of ELA in children at Wave 1–3 follow-up. The M2 accelerated eruption rate was 13.4% (209/1,558) at baseline and increased to 34.7% (444/1,280) by the end of the 2-year follow-up period, with no significant sex difference (boys: 25.8%, girls: 26.3%).

High and low ELA exposures were identified based on the 90th percentile of the population's cumulative ELA score as a threshold, with 5 for threat-related ELA, 8 for deprivation-related ELA, 5 for unpredictability-related ELA, and 17 for total cumulative ELA. At baseline,

Table 2 Distribution of M2 eruption status at baseline and follow-up

Characteristics	Wave 1 (*n* = 1558)		*P* value	Wave 2 (*n* = 1298)		*P* value	Wave 3 (*n* = 1280)		*P* value
	Group 1	Group 2		Group 1	Group 2		Group 1	Group 2	
No. of participants	1349 (86.6)	209 (13.4)		960 (74.0)	338 (26.0)		836 (65.3)	444 (34.7)	
Sex, %			0.244						0.822
Girls	574 (42.6)	80 (38.3)		414 (43.1)	148 (43.8)	0.833	367 (43.9)	192 (43.2)	
Boys	775 (57.4)	129 (61.7)		546 (56.9)	190 (56.2)		469 (56.1)	252 (56.8)	
ELA cumulative score, mean (SD)									
Total ELA	9.4 (3.7)	10.5 (3.7)	< 0.001	9.1 (3.6)	10.2 (3.7)	< 0.001	9.0 (3.6)	10.1 (3.8)	< 0.001
Threat	2.4 (1.7)	2.9 (1.6)	< 0.001	2.3 (1.6)	2.7 (1.7)	< 0.001	2.3 (1.6)	2.6 (1.7)	< 0.001
Deprivation	4.6 (1.9)	4.8 (1.7)	0.062	4.5 (1.9)	4.7 (1.8)	0.077	4.5 (1.9)	4.7 (1.8)	0.032
Unpredictability	2.4 (1.5)	2.8 (1.7)	< 0.001	2.3 (1.5)	2.7 (1.6)	< 0.001	2.3 (1.4)	2.7 (1.5)	< 0.001
Level of adversity exposure, %									
High total ELA	176 (13)	40 (19.1)	0.018	110 (11.5)	59 (17.5)	0.005	85 (10.2)	83 (18.7)	< 0.001
High-threat	152 (11.3)	32 (15.3)	0.092	94 (9.8)	50 (14.8)	0.012	75 (9.0)	67 (15.1)	< 0.001
High-deprivation	364 (27.0)	77 (36.8)	0.003	234 (24.4)	115 (34.0)	< 0.001	198 (23.7)	148 (33.3)	< 0.001
High-unpredictability	592 (43.9)	113 (54.1)	0.006	390 (40.6)	185 (54.7)	< 0.001	324 (38.8)	241 (54.3)	< 0.001

Group 1: M2 did not accelerated eruption; Group 2: M2 accelerated eruption

Table 3 Hazard ratios for the relationship between ELA dimensions and M2 accelerated eruption

ELA	Unadjusted		Adjusted	
	HR (95%CI)	*P* value	HR (95%CI)	*P* value
Threat	1.05 (0.97, 1.14)	0.213	1.06 (0.98, 1.14)	0.153
low-threat exposure	ref		ref	
high-threat exposure	1.60 (1.12, 2.29)	0.010	1.48 (1.03, 2.13)	0.034
Deprivation	1.07 (1.00, 1.14)	0.046	1.09 (1.02, 1.16)	0.016
low-deprivation exposure	ref		ref	
high-deprivation exposure	1.33 (1.00, 1.75)	0.047	1.37 (1.03, 1.81)	0.028
Unpredictability	1.15 (1.06, 1.25)	0.001	1.14 (1.04, 1.23)	0.003
low-unpredictability exposure	ref		ref	
high-unpredictability exposure	1.75 (1.35, 2.26)	< 0.001	1.65 (1.28, 2.14)	< 0.001
Total cumulative adversity	1.05 (1.01, 1.08)	0.009	1.05 (1.02, 1.09)	0.003
low total ELA exposur	ref		ref	
high total ELA exposure	1.70 (1.22, 2.37)	0.002	1.65 (1.19, 2.30)	0.003

Note: Adjusted model: adjusted for sex, birth weight, sleep duration, baseline BMI, and dental caries

184 participants reported high-threat exposure, 441 reported high-deprivation exposure, and 705 reported high-unpredictability exposure. In addition, cumulative ELA scores for each dimension, as well as exposure levels, were significantly different for M1 accelerated eruption at the wave 3 follow-up. And the M1 accelerated eruption group (group 2) had a higher total ELA score and reported a higher proportion of high ELA exposure than the non-accelerated eruption group (group 1) (ELA cumulative score: 10.1[3.8] vs. 9.0 [3.6], $P < 0.001$; level of total ELA exposure: 18.7% vs. 10.2%, $P < 0.001$).

AFT dimensional cumulative models of the associations between cumulative ELA exposure and M2 accelerated eruption

Table 3 presents the findings of the Accelerated Failure Time (AFT) model, detailing the association between the threat, scarcity, and unpredictability dimensions and the risk of M2 accelerated eruption. In the AFT model analysis with independent tests for the ELA dimensions, each 1-unit increase in deprivation-related and unpredictability-related ELA was associated with a 7% (deprivation: HR = 1.07, 95%CI: 1.12–2.29, $P = 0.046$) and 15% (unpredictability: HR = 1.15, 95%CI: 1.06–1.25, $P = 0.001$) increase in the risk of M2 accelerated eruption, respectively. In contrast, no statistically significant association was found between threat-related ELA and M2 accelerated eruption. These findings remain robust in the adjusted model.

AFT dimensional cumulative models of the relationship between ELA exposure levels and M2 accelerated eruption

As presented in Table 3, high exposure to threat-related, deprivation-related, and unpredictability-related ELA resulted in a 60% (HR = 1.60, 95%CI: 1.12–2.29, $P = 0.010$), 33% (HR = 1.33, 95%CI: 1.00-1.75, $P = 0.047$), and 75% (HR = 1.75,95%CI: 1.35–2.26, $P < 0.001$) increase in the risk of M2 accelerated eruption, respectively. The above results remain robust in the adjusted model.

AFT integrated cumulative modeling of the relationship between total ELA exposure and M2 accelerated eruption

As seen in Table 3, in the unadjusted model, each unit increase in total cumulative ELA in children was significantly associated with a 5% increase in the risk of M2 accelerated eruption (HR = 1.05, 95%CI: 1.01–1.08, $P = 0.009$). High total ELA exposure dose resulted in a 70% increase in M2 risk (HR = 1.70, 95%CI: 1.22–2.27, $P = 0.002$). And, the results remained stable in the adjusted model.

Discussion

The findings of the present study both complement and expand upon past work, which identified exposure to early life adversities (ELA) as a potential factor contributing to the accelerated eruption of molars among children aged 7–12 years. Utilizing a prospective design, the study investigated whether the second permanent molar (M2) accelerated eruption varied across different dimensions of ELA using an accelerated failure time (AFT) modeling approach. The results revealed that ELA-accelerated biological aging might progress in a dimension-specific and dose-response manner. Deprivation-related and unpredictability-related ELA, but not threat-related ELA, were found to be correlated with M2 accelerated eruption over a 2-year follow-up period. Notably, we observed that high ELA exposure in each dimension led to an increased risk of M2 accelerated eruption.

Our study provided evidence supporting the specificity of adversity dimensions in accelerated biological development——exposure to deprivation-related and unpredictability-related ELA, but not threat-related ELA, contributed to M2 accelerated eruption. The association between deprivation-related ELA and biologically

accelerated aging aligned with some past findings [22–24], but contrasted with a cross-sectional study that reported null associations [25]. Our observation regarding unpredictability was consistent with prior work conducted by Copeland et al. [26], which revealed that unpredictability-related ELA notably accelerated aging among 381 participants from adolescence (mean age 15 years) to young adulthood (mean age 23 years). In their study, however, this correlation diminished when multiple dimensions were examined concurrently.

Our study observed no significant relationship between threat-related ELA and M2 accelerated eruption. However, when using the 90th percentile of the cumulative adversity score in the population threat dimension as a threshold, distinguishing high and low ELA exposure levels, high threat exposure was found to significantly increase the risk of M2 accelerated eruption. This suggests that the adverse effects of total exposure may be masked by different levels of exposure. It indicates that the degree of exposure may play an important role in the outcome, and only when exposure reaches a certain level will adversity significantly affect the risk of M2 accelerated eruption. Therefore, differences in exposure levels may be a key factor contributing to this result.

Methodologically, the fundamental reasons for the disparities between the outcomes of threat with earlier studies may arise from various sources, including: study design (e.g., our study vs. past studies: longitudinal vs. cross-sectional) [25]; study population (e.g., children vs. adolescents and adults) [27, 28]; heterogeneity of threat; modeling of exposure (e.g., multidimensional vs. single-dimensional or two-dimensional); and outcome indicators (e.g., molar accelerated eruption, early pubertal timing, cellular aging: telomere attrition and DNA methylation).

It is important to note that very few studies have explored the joint effects of threat, deprivation, and unpredictability in relation to their biological foundation. To our knowledge, this is the first study that has simultaneously measured the cumulative effects of threat, deprivation, and unpredictability on accelerating biological aging, as indicated by M2 eruption over a 2-year follow-up. The present longitudinal study extends the previous cross-sectional study by McDermott et al. [9] by further exploring dose-response associations between cumulative experience of different dimensions of ELA and M2 accelerated eruption during a 2-year follow-up. An important next step in this work is to determine whether accelerated maturation, as indicated by the molar eruption, mediates the risk of multiple adverse health outcomes following ELA exposure. Future work should also consider shifting to longitudinal studies with feasible psychosocial interventions to understand whether children who develop faster are more likely to benefit.

The mechanisms underlying the association between ELA and accelerated eruption of molars may involve epigenetic effects and dysregulation of the hypothalamic–pituitary–adrenal axis and its associated neuroendocrine-immune systems [29–31]. External stimuli can "get under the skin", become biologically embedded, and alter biological responses. It is critical to delineate the mechanisms by which early experiences affect health and development (i.e., how they lead to these effects).

Several limitations merit consideration. First, there is an urgent need to further refine the measure of adversity. Our study comprehensively assessed exposure to diverse types of threat-related, deprivation-related, and unpredictability-related experiences but not other aspects of ELA that could influence biological aging, such as duration, severity, or number of exposures. These factors may introduce deviations in our estimates. Second, we relied on parent-reported measures for adverse experiences, but it is crucial to recognize that these measures could introduce inherent biases. Third, although imputed complete data has been used in the analysis through multiple imputations, the omission of certain items in the questionnaire may affect the accuracy of the data. Fourth, data on molar eruption were obtained from onsite examinations, and we defined any portion of the crown breaching the oral mucosa as an eruption criterion, which is consistent with the clinical definition. However, the exact timing of tooth eruption was limited by the long follow-up interval (minimum of 6 months). Future studies should consider shorter follow-up intervals. Fifth, comparisons of other growth indicators, such as growth hormone levels, bone age, or assessment of secondary sexual characteristics, were lacking in our analysis. The results would have been more convincing if these indicators had been included. Sixth, although we have adjusted for major confounders (e.g., sex, BMI, birth weight, sleep duration, baseline BMI, and dental caries), residual confounding by unknown or unmeasured factors may still exist. Seventh, the extent to which accelerated molar eruption predicts accelerated maturation in individuals is poorly understood. Finally, this study was based on Chinese children, which might affect the generalizability of the findings to other populations.

Conclusion

In a nutshell, this prospective study is the first to reveal that the relationship between ELA and accelerated eruption of molars may potentially operate in a dimension-specific and dose-dependent manner. The data elucidated that different dimensions of ELA may lead to accelerated biological aging during childhood, emphasizing that dental milestones can play a crucial role in a comprehensive understanding of the risks associated with ELA exposure. Future work is warranted to replicate these findings and

explore in greater depth how specific dimensions and the cumulative number of ELA experiences impact various aspects of biological aging during childhood, as well as how these pathways ultimately contribute to health disparities.

Abbreviations

ELA	Early-life adversity
M2	Second permanent molar
SD	Standard deviation
CI	Confidence interval
HR	Hazard ratio

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-025-05910-w.

Supplementary Material 1

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Author contributions
X.L. contributed to conception and design, acquisition, analysis, and interpretation; drafted the manuscript; and critically revised it; X.Y. and Y.Z. contributed to acquisition, analysis, and interpretation; and drafted the manuscript. J.P. and B.Z. contributed to acquisition, analysis, and interpretation. Y.S. and X.C. contributed to conception and design; critically revised the manuscript; gave final approval; and agreed to be accountable for all aspects of work, ensuring integrity and accuracy. All authors gave their final approval and agreed to be accountable for all aspects of the work.

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Data availability
The datasets generated and analysed during the current study are not publicly available due to privacy and ethical restrictions. For those interested in this study, please make reasonable requests to obtain it from the corresponding author.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from [Anhui Medical University] (approval number: [20180082]). All participants provided informed consent before participation in the study. Participants were fully informed about the study's purpose, procedures, potential risks, and benefits. Voluntariness, confidentiality and anonymity were maintained throughout the research process.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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