



Incorporating Genomics, Resilience, and Sociability as a Pathway to Improving Academic and Public Health Outcomes Via Epigenetic Modifications

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Abstract

Background: Adverse childhood experiences (ACEs), particularly trauma, impact gene regulation through epigenetic mechanisms such as DNA methylation, linking early-life stress to long-term health risks that interact with social and environmental determinants of public health.

Objective: To investigate the relationships among genomics-informed factors, psychosocial resilience, and health-related outcomes influenced by childhood trauma, with implications for public health strategies integrating genetic and environmental perspectives.

Methods: A cross-sectional survey was conducted with 100 participants (82% female, 18% male), aged 17–28 (mean = 20.62, SD = 1.94), using a 47-item self-report questionnaire covering health behaviors, socialization, childhood experiences, stress management, and academic competence. Data analysis included reliability testing (Cronbach's $\alpha \geq 0.70$), descriptive statistics, t-tests, Pearson correlations, and linear regression via SPSS. Ethical approval and informed consent were secured.

Results: Scale means (\pm SD) and internal consistency were: "Sociability and Social Support" 3.78 ± 0.65 ($\alpha = 0.866$), "Perceived Academic Performance" 3.68 ± 0.66 ($\alpha = 0.864$), "Psychological Resilience and Childhood Effect" 3.56 ± 0.38 ($\alpha = 0.466$), "Lifestyle and Health" 3.10 ± 0.46 ($\alpha = 0.358$). No significant gender or age differences were found ($p > 0.05$). "Sociability and Social Support" correlated moderately with "Lifestyle and Health" ($r = 0.349$, $p < 0.001$) and strongly with "Academic Performance" ($r = 0.803$, $p < 0.001$). "Academic Performance" correlated weakly with "Lifestyle and Health" ($r = 0.231$, $p = 0.021$) and moderately with "Psychological Resilience and Childhood Effect" ($r = 0.309$, $p = 0.002$).

Conclusions: Integrating genomic insights with public health, this study focuses on how gene-environment interactions via epigenetics influence academic and health outcomes. Social support and resilience may buffer negative epigenomic effects of ACEs. Public health initiatives should incorporate trauma-informed, genomics-aware interventions to enhance resilience and promote equitable health across populations.

Keywords: Epigenetics; Public Health; Child Abuse/Adverse Childhood Experiences; Resilience; Community Health Social Support; Academic Performance

Abbreviations

ACEs: Adverse Childhood Experiences; DNAm: DNA Methylation; AFEs: Children's Adverse Family Experiences; PCEs: Positive Childhood Experiences; AI: Artificial Intelligence

Introduction

Epigenetic awareness has emerged as a critical lens through which public health researchers can assess the lifelong biological impact of childhood experiences, particularly trauma, on gene regulation and population health outcomes. Epigenetic studies draw attention to the importance of early-life exposures. They show that DNA methylation (DNAm), which is a key genomic mechanism, may mediate the link between adverse childhood experiences (ACEs) and long-term physiological and psychological vulnerabilities. Childhood maltreatment may mediate epigenetic mechanisms through DNAm, altering physiological responses and increasing vulnerability to psychiatric disorders and potential forensic consequences. While strong links exist between abuse-related genomic changes and mental illness, similar evidence for somatic diseases is lacking. Key findings from 36 studies show a positive correlation between childhood abuse and DNA methylation at genes controlling neuroendocrine and immune systems. The combined burden of abuse and neglect intensifies these epigenetic changes, which partly explain higher mortality and disease risk in adults with ACEs, posing major public health concerns [1]. Evidence consistently links childhood adversity to long-term health, but reproducibility suffers due to inconsistent unsupervised epigenome-wide studies. This calls for larger samples, standardized trauma definitions, and causal methods like Mendelian randomization [2]. Longitudinal data show that low socioeconomic status and stress at age 10–11 accelerate epigenetic aging. One cohort found higher parental education predicted a 1.76-year lower GrimAge and 0.03-unit slower DunedinPACE by midlife ($P = 0.002$; $P = 0.04$) [3], with GrimAge and DunedinPACE denoting specific epigenetic aging measures or clocks. GrimAge is a DNAm-based estimate of biological age linked to mortality risk [4]. DunedinPACE is a measure of the current pace of biological aging [5]. In a related study of 360 Turkish child development students, early intervention training shaped views on childhood adversity. Trained students labeled negative experiences as “toxic stress” with emotional, social, and cognitive effects, while untrained peers saw them as positive stressors [6]. These studies collectively

emphasize that epigenetic modifications are not merely individual biological anomalies but reflect broader, socially patterned genomic imprints that demand integrative public health strategies for early intervention and initiatives promoting generational health and well-being.

Social support, parental involvement, and stress management have significant implications not only for psychological well-being but also for gene expression and genomics, which in turn impact public health outcomes. Studies demonstrate that adverse social environments, including poor family functioning and low social support, correlate strongly with higher prevalence of depression and anxiety symptoms, as shown in one study, where familial and social factors influence mental health outcomes. One investigation of 2,057 Chinese medical students found that 57.5% experienced symptoms of depression and 30.8% experienced symptoms of anxiety. These mental health outcomes were significantly correlated with family functioning, social support, and coping style scores [7]. In 321 undergraduates, perceived stress, social support, and ACEs explained over 50% of the variance in mental health. Stress was the strongest predictor, with all three factors strongly linked to mental health [8]. Mindful parenting interventions improved parent–child interactions, reduced parenting stress, and enhanced cognitive emotion regulation in mothers of typically developing preschoolers. These gains lasted at least 2 months after an 8-week program, supporting its effectiveness for mothers facing parenting stress and emotional regulation challenges [9]. In a sample of 81 young adults, secure adult attachment styles were associated with higher perceived social support from friends and family and a greater likelihood of seeking social support as a coping strategy in response to stress [10]. These findings collectively emphasize the importance of social and familial environments in modulating genomic mechanisms tied to stress and mental health, reinforcing the relevance for public health initiatives to integrate social support and stress management in prevention strategies. Family socialization affects academic performance, with gene and genomics research growing in public health relevance. Authoritative parenting links to lower child maladjustment, authoritarian to higher. Perceiving the child as difficult partly mediates parenting style's impact on emotional and behavioral development [11]. Environmental and psychosocial factors interact with genetics in shaping cognitive and emotional development for academic

success. In a U.S. study of 482 heterosexual couples with children aged 3–13, parental ACEs increased children's adverse family experiences (AFEs). Fathers' ACEs, but not mothers', were linked to poorer family health. Both parents' positive childhood experiences (PCEs) predicted better family health, which related to fewer AFEs. Family health mediated links between fathers' ACEs and children's AFEs, and between both parents' PCEs and children's AFEs. Interventions targeting family health may reduce intergenerational trauma [12]. Research examined how family involvement affects care quality for older adults in home care, nursing homes, and assisted living. Using surveys and interviews, it found that active family participation improves emotional support and advocacy, especially in home care. But differing expectations can complicate care. The study emphasizes the need for policies promoting family, caregiver collaboration to improve elderly care [13]. These studies together illustrate the complex gene-environment interplay shaping academic performance, emphasizing the need for public health strategies that integrate genetic insights with psychosocial family dynamics to optimize developmental trajectories and educational outcomes.

Neurodegenerative diseases are a major public health issue, prompting research into modifiable environmental risks. Exposures like air pollution, heavy metals, pesticides, and road proximity are linked to cognitive decline. Epigenetics, especially DNAm, explains how these factors affect gene expression and brain function. A review of 14 studies found 71% (10/14) showed significant links between environmental exposures, DNAm changes, and cognitive outcomes. Several studies also identified biological pathways through which toxins affect neuronal integrity and cognition [14]. From a public health perspective, integrating genomics and epigenetics into environmental health is essential. The interplay of digital exposure, environmental stressors, and epigenetic regulation shapes health outcomes. Considering tissue-specific methylation and factors like sex, ethnicity, and socioeconomic status helps identify vulnerable populations for targeted prevention. Genomic insights enable early risk detection and personalized interventions to reduce environmental impacts on mental health. Advancing epigenetic research is vital to prevent neurodegenerative diseases and preserve cognitive health. Improved methods and larger studies on environmental exposures are urgently needed to guide public health policies.

The aim of the current study is to investigate the interrelationships among lifestyle and health factors, social support, psychological resilience, childhood experiences, and their combined effects on perceived academic performance. Using a cross-sectional survey, the study seeks to elucidate how these psychosocial and epigenetic awareness variables contribute to academic outcomes. This approach draws attention to the multifaceted genetic, genomic, environmental, social determinants shaping public health research and informing practice.

Materials and Methods

Study design

This study employed a cross-sectional quantitative survey design to investigate the interrelationships among participants' lifestyle and health, sociability and social support, psychological resilience and childhood experiences, and perceived academic performance. The structured quantitative framework allowed for systematic data collection and statistical examination of these constructs within a single time point.

Ethical approval

Ethical clearance for this study was obtained from the Biruni University Scientific Research Ethics Committee in Istanbul, under approval number 2024-BİAEK-01-07, 20.05.2024. The study was conducted in accordance with the Declaration of Helsinki and relevant institutional guidelines. All participants provided informed consent prior to participation.

Participants

A total of 100 participants were recruited for the study. The sample consisted of 82 females and 18 males. The age distribution of the participants ranged from 17 to 28 years, with a mean \pm SD age of 20.62 ± 1.94 years. Participants were selected using convenience sampling, purposive sampling method ensuring voluntary and anonymous participation. The inclusion of participants who were involved in one or more academic fields was considered as an important characteristic for inclusion in the study.

The study employed a convenience sampling approach, whereby participants were reached via online channels, including institutional email distributions and social media networks. This method supported voluntary involvement and safeguarded participant anonymity throughout data collection.

Data collection instrument

Data were collected using a structured self-administered survey developed specifically for this study. The survey consisted of 47 items organized into five thematic sections:

- General health status and epigenetic awareness (items 1–3)
- Perceptions and experiences related to socialization (items 4–11)
- Childhood experiences (items 12–20)
- Stress management and daily life (items 21–31)
- Relationship between social competence and academic performance (items 32–47)

The survey questions were formulated to capture a broad range of psychosocial and health-related factors, including epigenetic awareness, socialization behaviors, childhood emotional and material experiences, stress coping mechanisms, environmental exposures, and the influence of social competence on academic outcomes. The questionnaire included both Likert-scale and dichotomous items to quantify attitudes and behaviors relevant to the study objectives which were collected digitally.

Constructs and variables

The primary constructs investigated were:

- **Lifestyle and health:** Including health status, substance dependency, and epigenetic knowledge.
- **Sociability and social support:** Frequency and quality of social interactions and perceived social support.
- **Psychological resilience and childhood effect:** Emotional childhood memories, parental involvement, and resilience-related stress management strategies.
- **Perceptions of academic performance:** The influence of social networks and competence on academic success and motivation.

These constructs were operationalized through the survey's subscale items.

Data processing and quality control

Completed questionnaires were screened for completeness and consistency. Data were entered into IBM SPSS Statistics Version 26.0 for analysis. Internal consistency of the survey subscales was

evaluated using Cronbach's alpha coefficients, with a threshold of $\alpha \geq 0.70$ considered acceptable for reliability.

Statistical analysis

Descriptive statistics including means, standard deviations, skewness, kurtosis, minimum, and maximum values were calculated to summarize demographic characteristics and scale scores. Frequency and percentage distributions were used to describe categorical variables such as gender.

The following inferential statistics were employed:

- **Independent Samples t-test:** To examine gender differences across the four main constructs.
- **Pearson correlation coefficients:** To analyze the relationships between age and each construct, as well as inter-correlations among the four main scales.
- **Simple linear regression analyses:** To assess the predictive effects of "Lifestyle and Health," "Socialization and Social Support," and "Psychological Resilience and Childhood Influence" on "Perceptions of Academic Performance."

All tests were two-tailed, and a significance level of $p < 0.05$ was set for all analyses.

Data visualization

To enhance interpretation, the results were supported by visual representations including:

- A bar chart illustrating mean scores and associated Cronbach's alpha reliability coefficients for each scale.
- A heatmap depicting the correlation matrix among the key psychological and behavioral scales.
- These visualizations facilitated comprehensive understanding of group differences and relational patterns.

Study objectives and scope

The study aimed to explore the complex interplay of epigenetic awareness, childhood experiences, social support, stress management, and their combined influence on academic performance. Particular attention was paid to the public health relevance of gene-environment interactions and psychosocial

factors, including the roles of electronic device use and environmental toxins on mental health outcomes.

Results and Discussion

Demographic characteristics

The study sample consisted of 100 participants, of whom 82% ($n = 82$) were female and 18% ($n = 18$) were male. The age of the participants ranged from 17 to 28 years (Mean = 20.62; SD = 1.940) (Table 1).

Variable	Groups	<i>n</i>	%
Gender	Female	82	82.0
	Male	18	18.0
Variable	Min-Max	Mean	SD
Age	17-28	20.62	1.940

Table 1: Demographic information of the participants.

Descriptive statistics of the scales

Descriptive analysis showed that the highest mean score was observed in the “Sociability and Social Support” scale (mean = 3.78, SD = 0.65), followed by “Perceived Academic Performance” (mean = 3.68, SD = 0.66), “Psychological Resilience and Childhood Effect” (mean = 3.56, SD = 0.38), and “Lifestyle and Health” (mean = 3.10, SD = 0.46). Internal consistency reliability, as measured by Cronbach’s alpha, was high for the “Sociability and Social Support” ($\alpha = 0.866$) and “Perceived Academic Performance” ($\alpha = 0.864$) scales, but relatively low for “Lifestyle and Health” ($\alpha = 0.358$) and “Psychological Resilience and Childhood Effect” ($\alpha = 0.466$) (Table 2) (Figure 1).

Scale	Items (No. of Questions)	Mean ¹	SD ²	Skewness ³	SE ⁴	Kurtosis ⁵	SE ⁴	Min ⁶	Max ⁷	Cronbach’s α ⁸
Lifestyle and Health	8	3.10	0,46	0,196	0,241	-0,379	0,478	2,13	4,25	0,358
Sociability and Social Support	9	3.78	0,65	-0,393	0,241	0,614	0,478	1,56	5,00	0,866
Perceived Academic Performance	9	3.68	0,66	-0,106	0,241	0,658	0,478	1,44	5,00	0,864
Psychological Resilience and Childhood Effect	15	3.56	0,38	-0,150	0,241	-0,331	0,478	2,64	4,47	0,466

Table 2: Descriptive statistics.

¹ Mean: Average of participants’ responses for the scale.

² SD: Standard deviation, showing variability around the mean.

³ Skewness: Indicates distribution symmetry; negative values = left skew, positive = right skew.

⁴ SE: Standard error of skewness or kurtosis.

⁵ Kurtosis: Indicates the peakedness of the distribution compared to normal.

⁶ Min: Minimum observed score.

⁷ Max: Maximum observed score.

⁸ Cronbach’s α : Reliability coefficient; values $\geq .70$ are generally considered acceptable.

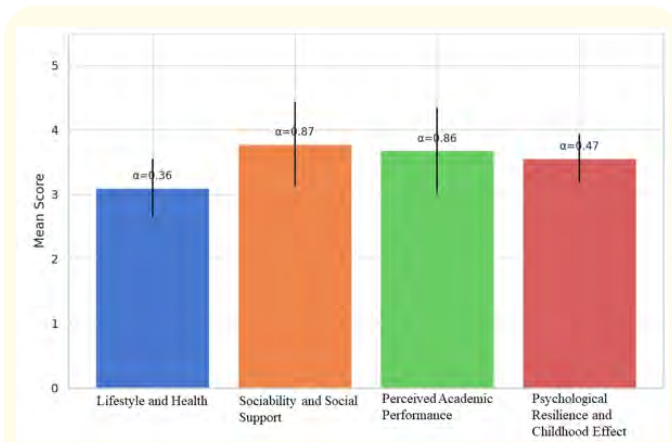


Figure 1: Descriptive statistics of the scales with reliability coefficients. A bar chart presenting the mean scores and standard deviations of the four main scales, annotated with Cronbach’s α coefficients to show internal consistency, providing a clear overview of the scales’ descriptive and reliability properties.

Gender-based comparisons

Independent samples t-tests revealed no statistically significant differences between female and male participants in any of the scale scores ($p > 0.05$ for all). Means and standard deviations by gender are presented (Table 3).

Scale	Gender	Mean	SD	t	p
Lifestyle and Health	Female	3,09	0,43	-0,330	0,742
	Male	3,13	0,57		
Sociability and Social Support	Female	3,76	0,65	-0,528	0,599
	Male	3,85	0,67		
Perceived Academic Performance	Female	3,67	0,67	-0,385	0,701
	Male	3,73	0,66		
Psychological Resilience and Childhood Effect	Female	3,56	0,38	-0,012	0,990
	Male	3,56	0,40		

Table 3: Comparison of scale scores by gender.

Predictive role of age

Pearson correlation analysis revealed no significant predictive effect of age on any of the scales ($p > 0.05$ for all), although small positive correlations were observed between age and “Sociability and Social Support” ($r = 0.117, p = 0.245$) and “Perceived Academic Performance” ($r = 0.079, p = 0.434$) (Table 4).

Scale	r	p
Lifestyle and Health	-0.016	0.877
Sociability and Social Support	0.117	0.245
Perceived Academic Performance	0.079	0.434
Psychological Resilience and Childhood Effect	-0.116	0.249

Table 4: Correlation between age and scale scores.

Correlation between scales

A correlation analysis was conducted to reveal the relationships among the scales. A moderate and statistically significant positive correlation was found between “Sociability and Social Support” and “Lifestyle and Health” ($r = 0.349, p < 0.001$). “Perceived Academic Performance” demonstrated a weak yet significant positive correlation with “Lifestyle and Health” ($r = 0.231, p = 0.021$), and a very strong positive correlation with “Sociability and Social Support” ($r = 0.803, p < 0.001$). “Psychological Resilience and Childhood Effect” was moderately and significantly correlated with both “Sociability and Social Support” ($r = 0.429, p < 0.001$) and “Perceived Academic Performance” ($r = 0.309, p = 0.002$); however, its correlation with “Lifestyle and Health” did not reach statistical significance ($r = 0.161, p = 0.110$). These findings indicate the central role of “Sociability and Social Support” in relation to both health-related behaviors and academic perceptions, and suggest a meaningful connection between “Psychological Resilience and Childhood Effect” and “Perceived Academic Performance” (Table 5).

Discussion

This discussion integrates key findings related to the multifaceted influences on academic performance, emphasizing the significant role of gene-environment interactions and psychosocial determinants within a public health framework.

Scales		Lifestyle and Health	Sociability and Social Support	Perceived Academic Performance
Sociability and Social Support	r	0,349	NA	NA
	p	0,000*	NA	NA
Perceived Academic Performance	r	0,231	0,803	NA
	p	0,021*	0,000*	NA
Psychological Resilience and Childhood Effect	r	0,161	0,429	0,309
	p	0,110	0,000*	0,002*

Table 5: Correlations between scales.

*p < 0.05 indicates statistical significance, NA: Not available.

By examining social support, psychological resilience, lifestyle factors, and demographic variables, we address how epigenetic awareness and early life experiences intersect with environmental and behavioral influences, such as electronic device use and toxin exposure, to shape mental health and cognitive outcomes. These insights respond to the study’s objective of unraveling the complex interplay between genetic and environmental factors that impact academic achievement and inform targeted public health interventions.

The role of social support and sociability in academic performance

The findings demonstrate a significant positive correlation between sociability, social support, and perceived academic performance. A very strong positive correlation was found between sociability and social support and perceived academic performance (r = 0.803, p < 0.001) (Figure 1). This indicates a strong, statistically significant positive association between these two variables. Perceived academic performance also showed a weak but significant positive correlation with lifestyle and health (r = 0.231, p = 0.021). Psychological resilience and childhood effect correlated moderately and significantly with both sociability and social support (r = 0.429, p < 0.001), as well as with perceived academic performance (r = 0.309, p = 0.002). These findings further support interconnected positive relationships among social and psychological factors and academic performance (Table 5 and Figure 2). This is consistent with prior research emphasizing the critical role of social networks in academic success. A meta-analysis was conducted revealing that moderate positive correlations between retention and academic goals, academic self-

efficacy, and academic-related skills (correlations of 0.340, 0.359, and 0.366, respectively). For cumulative grade point average, the strongest predictors were academic self-efficacy (0.496) and achievement motivation (0.303). Additional regression analyses demonstrated that the psychological skills factors contributed uniquely to predicting college outcomes beyond socioeconomic status, standardized test scores, and high school grade point average [15]. A study further explored how social support affects academic performance among 265 Chinese middle school students (mean age 13.47, SD 0.5) in Shandong Province. Using structural equation modeling, results showed that social support directly improves academic performance and also indirectly boosts it through self-efficacy and learning engagement, with self-efficacy as a key mediator. These findings emphasize the importance of supportive environments that enhance students’ confidence and engagement to promote better academic outcomes [16]. These findings corroborate the multifaceted influence of social support systems on students’ academic achievements.

Psychological resilience and the impact of adverse childhood experiences

A moderate positive and statistically significant correlation was found between psychological resilience and perceived academic performance, indicating that higher resilience is associated with better academic outcomes. The correlation coefficient (r = 0.309) falls into the moderate range and the p-value is less than 0.05, the association is both moderate (Table 5 and Figure 2). This finding aligns with existing literature suggesting that resilience mitigates the detrimental effects of ACEs on educational outcomes. Research

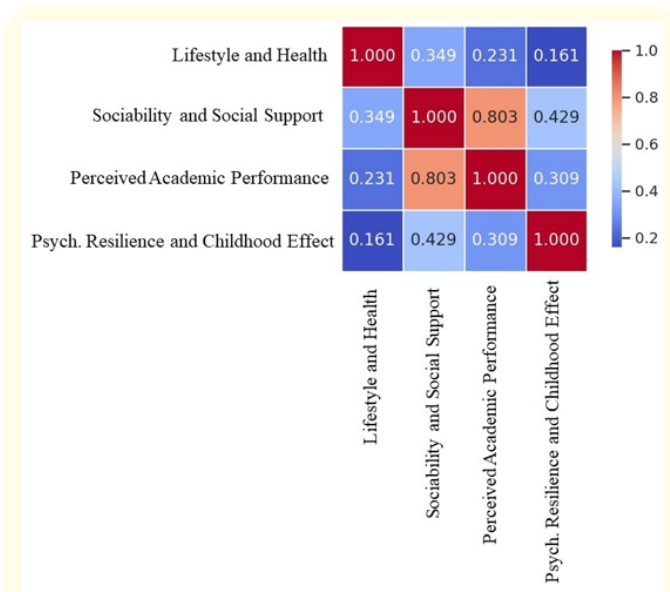


Figure 2: Correlation matrix among psychological and academic scales. A heatmap illustrating the correlation matrix among the scales. It visually emphasizes the strength and direction of associations, especially signifying the strong link between “Sociability and Social Support” and “Perceived Academic Performance”.

conducted previously among university students in Türkiye found that hope plays a partial mediating role in the relationship between ACEs and mental well-being. The study specifically revealed significant negative correlations between ACEs and both hope and mental well-being, as well as a significant positive correlation between hope and mental well-being, suggesting the protective role and potential value of hope-based interventions [17]. It has also been demonstrated that ACEs affect students’ learning by reducing their academic engagement, achievement, and school attendance. Family background and various environmental factors are additional contributors to negative mental health in adolescents, which in turn leads to poor educational outcomes [18]. Childhood maltreatment affects 10–15% of individuals in Western societies and is linked to higher risks of psychiatric disorders, earlier illness onset, greater comorbidity, and worse clinical outcomes, creating significant public health and social challenges. While the clinical effects are well known, understanding how early adverse experiences cause long-term changes in brain function remains difficult. Both animal and human studies show

that DNAm, an epigenetic mechanism, plays a key role in mediating the lasting impact of childhood maltreatment on neurobiology and increases vulnerability to psychopathology [19]. Early life stress (ELS), including childhood abuse and neglect, is a significant risk factor for later psychiatric and behavioral disorders. Both pre- and postnatal stress can have long-lasting effects on adult mental health, with the timing and type of stress being crucial. Emerging evidence shows that epigenetic mechanisms, changes in gene expression without altering DNA sequence, play a key role in how ELS becomes biologically embedded. The epigenome is sensitive to environmental influences during fetal development and after birth. One review discusses the lasting mental health impacts of ELS, accentuating shared and unique epigenetic changes depending on when the stress occurs, including stress before conception that can affect future generations. It also explores molecular mechanisms behind these epigenetic changes and how they differ based on stress timing [20].

Influence of lifestyle factors on academic achievement

The study findings provide evidence of a positive correlation between lifestyle factors and academic performance. The analysis revealed a weak yet statistically significant positive correlation between the “Lifestyle and Health” scale and “Perceived Academic Performance” ($r = 0.231, p = 0.021$), which is below the conventional significance threshold of 0.05. This indicates that as individuals’ scores on lifestyle and health improve, their perceived academic performance tends to increase as well. Although the strength of the correlation is modest, the statistical significance confirms that this relationship is unlikely to be due to chance, allowing us to confidently conclude that better lifestyle factors are associated with higher perceived academic performance in the study sample (Table 5 and Figure 2). This result is corroborated by recent literature demonstrating that physical activity, adequate nutrition, and sufficient sleep are positively associated with improved academic achievement. Research conducted with 161 medical students reported that those engaging in healthy lifestyle behaviors attained significantly higher grade point averages. High-achieving students demonstrated greater physical activity ($p = 0.012$) and better diet quality ($p = 0.043$) compared to low achievers. They also reported higher satisfaction with their mental (74% versus 29%) and physical health (54% versus 29%) and consumed more fruits, vegetables, and home-cooked meals. These findings emphasized the importance of promoting healthy behaviors to support both

academic success and well-being among medical students [21]. This is consistent with findings from the 2014 American College Health Association, which linked adherence to recommended health behaviors with improved academic outcomes. A cross-sectional study of 16,095 U.S. college students (70.3% female) examined associations between academic performance and lifestyle behaviors. Meeting public health recommendations was reported by 41.9% for moderate-to-vigorous physical activity, 32.4% for strength training, 4.6% for fruit and vegetable intake, and 23.6% for sleep. Adjusted analyses showed modest grade average increases of 0.03 points for physical activity, 0.15 points for fruit and vegetable intake, and 0.06 points for sleep, with no significant effect from strength training. Adherence to healthy lifestyle guidelines was, overall, modestly associated with better academic performance, particularly regarding physical activity, diet, and sleep [22].

Gender differences in academic performance and self-perception

The results of the current study revealed no statistically significant gender differences in psychosocial and academic variables. Independent samples t-test analyses comparing female and male participants revealed no statistically significant differences across all measured scales, with all p-values exceeding the conventional threshold of 0.05. The specifically p-values for the “Lifestyle and Health” ($p = 0.742$), “Sociability and Social Support” ($p = 0.599$), “Perceived Academic Performance” ($p = 0.701$), and “Psychological Resilience and Childhood Effect” ($p = 0.990$) scales indicate the absence of significant gender-related variation. These results demonstrate that psychosocial factors and academic perceptions measured in the study do not differ significantly between female and male participants, thereby supporting the conclusion that gender does not play a statistically significant role in these variables within the sample (Table 3). This outcome contrasts with some literature reporting differences between genders, particularly in science, technology, engineering, mathematics-related performance. A media article discusses research in which Tonei and colleagues analyzed data from approximately 3,000 children and their parents who participated in the Longitudinal Study of Australian Children. Parents rated their children’s math and reading abilities at different times, and these ratings were then compared to the children’s actual National Assessment Program Literacy and Numeracy test scores at ages

8–9. The results showed slight gender differences: girls scored about 1.7% higher in reading, while boys scored about 0.6% higher in math. Parents’ ratings of girls’ reading abilities aligned with their better scores, but in math, parents tended to overestimate boys’ skills more than their small advantage warranted [23]. Another study investigated why boys tend to rate their own math ability higher than girls, even when their actual skills are similar. Using a longitudinal twin study, the researchers examined factors influencing this gender gap in self-assessed math ability, including test scores, cognitive skills, and parental and teacher evaluations. They found that actual math ability explains only a small part of the gap. Notably, boys’ self-assessments positively correlate with their male twin’s confidence, but girls do not show this pattern with their male twins, in fact, it may be negative. Parents also tend to overestimate boys’ and underestimate girls’ math skills, contributing significantly to the gap. This indicates how parental gender stereotypes may be passed down and influence children’s self-perceptions [24]. Other research, however, suggests gender differences may diminish when controlling for contextual factors and psychosocial variables.

Lack of significant association between age and academic performance

No significant correlation was found between age and academic performance in current analysis. The Pearson correlation analysis specifically tested the relationship between age and the “Perceived Academic Performance” scale ($r = 0.079$, $p = 0.434$). The correlation is not statistically significant, as indicated by a p-value greater than 0.05. Pearson correlation analysis explicitly revealed no significant predictive effect of age on any of the scales ($p > 0.05$ for all), although small positive correlations were observed between age and “Perceived Academic Performance” ($r = 0.079$, $p = 0.434$). Age was not significantly correlated with academic performance (Table 4). This corresponds to prior research indicating that self-efficacy and mental well-being constructs are important predictors of academic grade point average, a conclusion based on another cross-sectional study conducted with 542 students [25].

Implications for interventions and educational strategies

Research outcomes reinforce the critical interplay of genetic, epigenetic, and environmental factors in shaping academic performance, with a special focus on the public health importance of integrating psychosocial and lifestyle considerations into

intervention design. Interventions aimed at enhancing social support networks, fostering psychological resilience, and promoting healthy lifestyle behaviors may positively influence gene-environment interactions affecting cognitive and mental health outcomes. Trauma-informed educational strategies addressing the impact of ACEs could further support student success, constituting the essentials to mitigate their epigenetic and psychosocial impacts, ultimately promoting more equitable academic success and long-term well-being.

Strengths, limitations, and future directions

This study presents several important strengths. The comprehensive integration of genetic, epigenetic, psychosocial, and lifestyle factors within a public health framework provides a multifaceted understanding of academic performance determinants. The inclusion of validated psychosocial scales and attention to gene-environment interactions enhances the relevance and depth of analysis, addressing a critical gap in educational and health research. The study's focus on epigenetic awareness and early life experiences additionally points to the potential for targeted public health interventions that bridge biological and social determinants of health; however, several limitations warrant consideration. The cross-sectional design restricts causal inference and limits understanding of temporal dynamics in gene-environment interplay and academic outcomes. Self-reported measures, including perceived academic performance and lifestyle behaviors, may introduce response bias and limit objective assessment. The sample's demographic characteristics may further constrain generalizability across diverse populations and educational settings. The complexity of epigenetic mechanisms and the current lack of direct biological measurements, such as genomic or epigenomic biomarkers, limit the ability to draw definitive conclusions about biological pathways underlying observed psychosocial correlations.

Future research should prioritize longitudinal, multi-omics studies incorporating direct genetic and epigenetic profiling alongside detailed psychosocial and environmental assessments to unravel causal pathways influencing cognitive and academic outcomes. This integrated approach will better inform precision public health strategies and educational policies aimed at mitigating adverse gene-environment effects. Additionally, policy-oriented research must explore scalable interventions that enhance

social support, psychological resilience, and healthy lifestyles within school and community settings, with particular attention to vulnerable populations affected by adverse childhood experiences and environmental risks. Advancing translational genomic and epigenomic research within public health frameworks offers promising avenues to develop evidence-based, equity-focused interventions that ultimately optimize educational achievement and mental well-being, informing future policy development that bridges biology, behavior, and social context.

Conclusion

We stand at the threshold of transformative possibilities toward a genomic future for public health and human potential, where the integration of genetic insights into public health enhances prevention, equity, and human well-being. This original research study supports the critical truth that global well-being depends not on isolated data, but on synthesizing gene-environment interaction, early-life experience, and the realities of our social and behavioral ecosystems. Though centered on academic performance, our findings reveal how genes, shaped by adversity or resilience, support or isolation, and activated by environment, guide health, cognition, and our shared future. This is not just a call for interdisciplinary dialogue, but a blueprint for transformation. Epigenetics shows our biological scripts are not fixed. Trauma, exposures, digital overstimulation, and behaviors shape societal outcomes, just as hope, resilience, and social ties can rewrite them. These dimensions must be embedded in public health, education, and healthcare to prioritize prevention alongside cure. As gene-based diagnostics, personalized medicine, and artificial intelligence-driven tools expand, they must be paired with a human-centered approach, recognizing that no gene functions in isolation. Public health's future is genomic, but also relational, experiential, and equitable. In the coming decades, global well-being will depend on decoding the interplay between environment, emotion, and equity. Resilience and secure psychosocial policy must be fostered; genomic insights must be translated into accessible, community-rooted interventions, unlocking human potential across generations. A future where genomic knowledge fuels justice, science serves compassion, and health becomes the foundation for all to flourish.

This study presents unique and valuable insights by integrating psychosocial, genomic, and academic factors in a Turkish youth

sample. However, its generalizability is limited by the use of convenience sampling and a non-standardized, study-specific questionnaire. Despite these limitations, it lays important groundwork for future research linking gene-environment interactions with educational and public health outcomes.

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Conflict of Interest

There is no conflict of interest

Ethical Approval

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