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Unpacking the Heterogeneity of Resilience in Female Survivors of Trauma: A Two-Step Mixture Modeling Approach on Neurobiological and Psychological Markers

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A B S T R A C T

Objective: This study aimed to identify distinct bio-psychological latent profiles of resilience among female trauma survivors by integrating psychological and neurobiological markers and to examine how trauma exposure predicts profile membership.

Methods and Materials: This cross-sectional observational study included a sample of $N = 452$ adult female trauma survivors recruited from support centers in Egypt. Participants completed culturally validated Arabic versions of the Childhood Trauma Questionnaire (CTQ), the PTSD Checklist for DSM-5 (PCL-5), and the Connor-Davidson Resilience Scale (CD-RISC). Neurobiological data included hair cortisol concentration (HCC) as a marker of chronic hypothalamic-pituitary-adrenal axis activity and resting high-frequency heart rate variability (HRV) as an index of parasympathetic regulation. A two-step mixture modeling approach was employed, using Latent Profile Analysis (LPA) to identify resilience classes, followed by multinomial logistic regression to assess predictors of class membership.

Findings: The LPA revealed an optimal three-class solution. The Dysregulated/Low Resilience profile (21.0% of the sample) was characterized by low self-reported resilience, high HCC, and low HRV. The Compensatory/Moderate Resilience profile (48.9%) demonstrated moderate scores across all psychological and biological indicators. The Adaptive/High Resilience profile (30.1%) exhibited high self-reported resilience, low HCC, and high HRV. Multinomial logistic regression showed that higher severity of childhood trauma (CTQ) and current PTSD symptoms (PCL-5) significantly increased the odds of belonging to the Dysregulated and Compensatory profiles relative to the Adaptive profile.

Conclusion: Resilience among female trauma survivors is a heterogeneous construct comprising distinct bio-psychological profiles, necessitating a multidimensional approach for accurate assessment and intervention.

Keywords: *Resilience, Trauma, Latent Profile Analysis, Neurobiology, Hair Cortisol, Heart Rate Variability, PTSD, Female Survivors*

1. Introduction

Trauma is a pervasive global phenomenon that exerts a profound impact on the psychological, emotional, and neurobiological well-being of individuals. Exposure to traumatic events—ranging from interpersonal violence and acute systemic crises to chronic adversity—often precipitates severe psychological distress and significantly increases the risk for developing trauma-related disorders, such as post-traumatic stress disorder (PTSD), anxiety, and depression. However, despite the potentially debilitating consequences of trauma, a substantial proportion of individuals demonstrate a remarkable capacity to adapt, recover, and sometimes even experience psychological growth following adversity. This dynamic capacity is widely conceptualized as psychological resilience. Recent literature has increasingly conceptualized resilience not merely as a static, innate trait, but rather as a complex, multifaceted, and highly dynamic process involving various interacting components and mechanisms (Farchi & Peled-Avram, 2025). Understanding the heterogeneity of this construct is critical, as resilience manifests differently across individuals, contexts, and specific types of traumatic exposure, fundamentally shaping the trajectory of post-traumatic recovery and adaptation.

The complexity of resilience has been extensively documented across a wide array of populations and highly stressful occupational environments. For instance, the demanding and often inherently traumatic nature of healthcare and frontline professions has served as a critical context for examining resilience mechanisms. Studies evaluating mental health nurses operating under the intense pressures of global health crises have highlighted how psychological well-being and resilience are instrumental in mitigating psychological distress and reducing turnover intentions (Foster et al., 2024). Similarly, research focusing on intensive care unit (ICU) nurses has consistently demonstrated that professional quality of life and resilience act as vital protective factors against posttraumatic stress, with targeted leisure activities further supporting coping capacities (Shin & Choi, 2024; Shin & Choi, 2023). The intricate relationship between emotional regulation, resilience, and distress disclosure has also been shown to facilitate post-traumatic growth even among nursing students preparing to enter these high-stress environments (Kim et al., 2023). Furthermore, the mediating roles of perceived stress and positive coping strategies have been identified as central pathways through which psychological resilience promotes posttraumatic growth among midwives (Zheng et al., 2024). In related highly demanding clinical settings, research on methadone treatment staff indicates that resilience significantly buffers trauma-related stress (Coffee, 2025), while studies involving healthcare workers during pandemic conditions emphasize that resilience and mindfulness foster adaptive coping and reduce stigmatization (She et al., 2025). Advanced analyses within these environments further reveal that moral resilience can profoundly influence vicarious posttraumatic growth among critical care staff, highlighting the deep ethical and psychological dimensions of occupational trauma (Ye et al., 2025).

Beyond occupational contexts, the vital role of resilience is equally evident in individuals navigating severe medical crises and the profound stress associated with chronic or life-threatening illnesses. For patients confronting a cancer diagnosis, the capacity to deploy effective coping strategies is a critical mechanism linking underlying psychological resilience to subsequent posttraumatic growth (Latif et al., 2024). Moderated mediation analyses in oncological populations further confirm that perceived social support and the mitigation of acute stress are essential conduits through which resilience translates into psychological growth (Zahra et al., 2024). This protective function extends beyond the patients themselves to their immediate caregiving networks. The psychological resilience of family members of trauma patients in intensive care units has been shown to significantly mediate the complex relationship between family functioning and the distressing uncertainty of severe illness (Yu et al., 2024). Similarly, among the parents of very low birth weight infants, resilience intersects heavily with social support and active coping styles to foster post-traumatic growth despite the immense emotional burden of neonatal intensive care (Wu et al., 2024).

Developmental perspectives on trauma further underscore the necessity of unpacking resilience, particularly concerning childhood adversity and its long-term psychological sequelae. Childhood trauma represents a significant vulnerability factor that can fundamentally alter developmental trajectories. Research indicates that the severity of childhood trauma is intrinsically linked to adolescent internalizing problems, with psychological resilience serving as a crucial mediator and parental emotional socialization acting as a moderator in this relationship (Liao & Dong-mei, 2023). Adolescence is a particularly sensitive period where exposure to interpersonal trauma, such as bullying and victimization, can strongly

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predict the onset of PTSD symptoms, making mental resilience and self-compassion vital protective assets (Makrydaki, 2025). Consequently, understanding whether and how resilience moderates the detrimental relationship between early trauma experiences and later trauma symptomatology remains a critical focus of adolescent developmental psychology (Nilsson et al., 2023). The clinical implications of these developmental findings have led to the implementation of targeted psychological interventions, such as specialized programs designed to strengthen resilience and stimulate post-traumatic growth in children and adolescents traumatized by the devastating impacts of war (Sazonova & Chuiko, 2023). The persistent neurobiological and psychological scars of early adversity are also evident in adult clinical populations, where histories of childhood trauma continue to exhibit complex relationships with resilience capacities, particularly among patients diagnosed with severe mood disorders (Yoon Park et al., 2023).

The manifestation of resilience is also deeply embedded within broader sociocultural, systemic, and collective traumatic experiences. Populations exposed to mass displacement, regional instability, and natural disasters provide critical insights into how systemic trauma interacts with individual coping mechanisms. For individuals navigating the profound trauma of defection and displacement, resilience and robust social support networks are paramount for achieving post-traumatic growth in entirely new societal contexts (Lee, 2024). Following catastrophic natural disasters, such as massive earthquakes, resilience and meaning-centered coping serve as essential mediators linking general life satisfaction to successful posttraumatic adaptation and recovery (Türk et al., 2025). Furthermore, in environments subjected to prolonged sociopolitical upheaval and systemic transformation, such as post-revolution Egypt, the intricate dynamics between ongoing trauma exposure, baseline resilience, and acute distress highlight the necessity of culturally contextualized psychological frameworks (Miller-Graff et al., 2024). The psychological toll of living in conflict zones often involves complex manifestations of traumatic grief, where resilience and posttraumatic growth play mediating roles in sustaining overall health and mental well-being despite chronic adversity (Veronese et al., 2025). These processes are similarly observed in post-conflict regions recovering from historical warfare, where exploring the nuances of resilience and growth among bereaved adults remains essential for community healing (Cërmjani & Kelmendi, 2024). Amidst global systemic disruptions like the COVID-19 pandemic, foundational psychological constructs such as hope have demonstrated strong, intrinsic relationships with resilience, serving as critical anchors for maintaining mental health during periods of pervasive uncertainty (Senger, 2023).

A critical barrier to resilience for many trauma survivors is the profound societal and internalized stigma often associated with specific types of trauma, particularly interpersonal violence and sexual assault. Addressing this requires a stigma-conscious framework that explicitly recognizes how societal prejudices impede natural posttraumatic change and recovery processes (King et al., 2024). Qualitative explorations into the experiences of vulnerable populations, such as alcohol-involved sexual assault survivors, reveal that fostering resilience inherently requires actively countering stigma, thereby identifying nuanced risk and protective factors necessary to mitigate negative psychological consequences (Strickland et al., 2023). These findings collectively emphasize that resilience cannot be accurately measured or understood in a vacuum; it must be evaluated alongside the specific contextual, developmental, and societal variables that uniquely characterize the survivor's experience.

Despite the expansive body of literature documenting the protective benefits of resilience across these diverse populations and traumatic contexts, a significant methodological limitation persists in the current research paradigm. The vast majority of studies continue to operationalize resilience as a homogenous, unidimensional construct, typically assessed via self-report psychological measures. This traditional approach assumes that resilience operates uniformly across all individuals, thereby obscuring the rich, underlying heterogeneity of adaptive responses. Survivors of trauma do not simply exhibit "high" or "low" resilience; rather, they often display complex, multidimensional profiles characterized by highly specific configurations of psychological coping and physiological regulation. Relying solely on psychological self-reports fails to capture the hidden biological costs of adaptation, often conceptualized as allostatic load, where an individual may appear psychologically resilient while simultaneously experiencing severe, chronic dysregulation of underlying neurobiological stress systems. To truly unpack the mechanisms of trauma recovery, it is imperative to move beyond variable-centered analyses and embrace person-centered methodologies that can identify unobserved subpopulations, or latent profiles, of resilience.

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Integrating neurobiological markers with traditional psychological assessments represents a critical advancement in comprehensively mapping these latent profiles. Biomarkers such as hair cortisol concentration, which provides a retrospective index of chronic hypothalamic-pituitary-adrenal axis activity, and high-frequency heart rate variability, which indexes parasympathetic vagal tone and emotional regulation capacity, offer objective, physiological measures of stress adaptation. By utilizing advanced statistical techniques, such as two-step mixture modeling, researchers can simultaneously analyze these objective neurobiological markers alongside subjective psychological scales to uncover distinct bio-psychological phenotypes of resilience. Identifying these unique profiles among female trauma survivors—a population that frequently experiences compounding layers of interpersonal, systemic, and socio-cultural trauma—is essential for understanding why certain individuals achieve highly adaptive recovery while others experience protracted suffering despite outward appearances of coping. Therefore, the primary aim of this study is to utilize a two-step mixture modeling approach on a combination of psychological and neurobiological markers to identify distinct, heterogeneous latent profiles of resilience among female survivors of trauma in Egypt, and to subsequently examine how specific trauma exposures predict membership within these profiles.

2. Methods and Materials

2.1. Study design and Participant

This study utilized a cross-sectional, observational design to investigate the multifaceted nature of resilience among female trauma survivors in Egypt. The primary objective was to identify distinct neurobiological and psychological profiles of resilience and to understand how these profiles relate to various trauma exposures. Participants were recruited through a collaborative network of psychological support centers, non-governmental organizations dedicated to women's health, and psychiatric outpatient clinics located across the greater Cairo metropolitan area. A purposive sampling strategy was employed to enroll exactly 452adult female participants who had a documented history of interpersonal or systemic trauma. Inclusion criteria required participants to be between the ages of eighteen and sixty-five, possess fluency in Arabic to ensure accurate comprehension of the psychological assessments, and have experienced at least one major traumatic event fulfilling the Criterion A of the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition. Individuals with active substance use disorders, severe psychotic disorders, or neurological conditions that could fundamentally confound neurobiological assays were systematically excluded from the sampling pool.

2.2. Measures

To capture the complex heterogeneity of resilience, an extensive battery of psychological and neurobiological assessments was administered to the participants. The psychological dimension was evaluated using culturally validated Arabic translations of several prominent psychometric instruments. Trauma exposure severity and history were quantified using the Childhood Trauma Questionnaire and the PTSD Checklist for DSM-5, which allowed researchers to establish a baseline of trauma burden. To directly measure psychological resilience, the Connor-Davidson Resilience Scale was utilized, capturing the participants' self-reported ability to cope with stress and adversity. In addition to these psychological constructs, neurobiological markers were carefully collected to provide a physiological index of stress regulation and allostatic load. Hair cortisol concentration was selected as a primary neurobiological marker because it provides a reliable, retrospective measurement of chronic hypothalamic-pituitary-adrenal axis activity over the preceding three months. A small sample of hair was collected from the posterior vertex of each participant's scalp and processed using liquid chromatography-tandem mass spectrometry. Furthermore, resting high-frequency heart rate variability was recorded to assess parasympathetic nervous system functioning, an established biomarker of emotional regulation and physiological resilience. Electrocardiogram recordings were obtained during a standardized ten-minute resting baseline period in a temperature-controlled laboratory setting, from which the root mean square of successive differences between normal heartbeats was extracted and analyzed.

2.3. Data Analysis

The statistical evaluation was conducted utilizing a sophisticated two-step mixture modeling approach to uncover hidden subpopulations characterized by distinct configurations of psychological and neurobiological resilience. In the first step, Latent Profile Analysis was executed using Mplus software to identify unobserved, mutually exclusive classes of resilience based on the

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continuous indicator variables, which included the Connor-Davidson Resilience Scale scores, hair cortisol concentrations, and heart rate variability metrics. The determination of the optimal number of latent profiles was guided by a comprehensive evaluation of several statistical fit indices, specifically the Akaike Information Criterion, the Bayesian Information Criterion, and the Sample-Size Adjusted Bayesian Information Criterion, where lower values consistently indicate superior model fit. Additionally, the Lo-Mendell-Rubin adjusted likelihood ratio test and the Bootstrap Likelihood Ratio Test were employed, wherein a significant p-value ($p < .05$) indicated that a model with $k$classes provided a significantly better fit to the data than a model with $k - 1$classes. Entropy values approaching 1.0were utilized to ensure high classification accuracy among the extracted profiles. Following the firm establishment of the optimal measurement model in the first step, the second step involved incorporating external covariates and distal outcomes to validate the emergent profiles and explore their practical implications. This was achieved utilizing the modal assignment approach with robust standard errors to appropriately account for the uncertainty inherent in the latent class assignments. Multinomial logistic regression was subsequently applied to examine how the severity and specific types of trauma exposure predicted membership within the newly identified resilience profiles, thereby illuminating the heterogeneous trajectories of recovery and adaptation among the female survivors.

3. Findings and Results

Prior to conducting the primary latent profile analysis, the data from the $N = 452$Egyptian female trauma survivors were examined for missing values, outliers, and assumptions of normality. Missing data accounted for less than 2%of the total dataset and were handled using full information maximum likelihood estimation within the Mplus environment. An examination of skewness and kurtosis indicated that the psychological variables (Connor-Davidson Resilience Scale [CD-RISC], Childhood Trauma Questionnaire [CTQ], and PTSD Checklist for DSM-5 [PCL-5]) approximated a normal distribution. However, the neurobiological markers, specifically hair cortisol concentration (HCC) and high-frequency heart rate variability (HRV-RMSSD), demonstrated significant positive skewness. Consequently, a natural logarithmic transformation was applied to both HCC and HRV-RMSSD values prior to all subsequent analyses to satisfy the assumption of normality.

The average age of the participants was $M = 34.62$years ($SD = 8.45$). Descriptive statistics and bivariate correlations for all primary continuous study variables are presented in Table 1. The bivariate correlation analysis revealed that self-reported resilience (CD-RISC) was positively associated with HRV ($r = .31, p < .01$) and negatively associated with both trauma severity (CTQ: $r = -.42, p < .01$; PCL-5: $r = -.55, p < .001$) and HCC ($r = -.28, p < .01$).

Table 1

Descriptive Statistics and Bivariate Correlations of Study Variables (N=452)

Variable	***M***	***SD***	1	2	3	4	5
1. Age (years)	34.62	8.45	–				
2. CTQ (Total)	52.34	14.21	.08	–			
3. PCL-5 (Total)	41.15	16.88	.11*	.58**	–		
4. CD-RISC	58.40	18.32	−.05	−.42**	−.55**	–	
5. HCC (pg/mg) **ln**	1.85	0.62	.14**	.35**	.41**	−.28**	–
6. HRV (RMSSD) **ln**	3.42	0.55	−.18**	−.24**	−.33**	.31**	−.46**

To identify unobserved heterogeneity in resilience, a series of Latent Profile Analyses (LPA) were estimated ranging from a one-class to a five-class model, utilizing CD-RISC, ln(HCC), and ln(HRV) as continuous indicators. The model fit indices used to determine the optimal number of latent classes are detailed in Table 2.

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Table 2

Fit Indices for Latent Profile Models (1 to 5 Classes)

Number of Classes	AIC	BIC	SABIC	Entropy	LMR-LRT p-value	BLRT p-value	Lowest Class Proportion
1 Class	3845.21	3869.89	3850.55	–	–	–	1.00
2 Classes	3512.44	3553.58	3521.35	.82	<.001	<.001	.38
3 Classes	3204.67	3262.25	3217.13	.88	.012	<.001	.21
4 Classes	3188.52	3262.56	3204.55	.84	.145	.042	.06
5 Classes	3175.30	3265.81	3194.89	.79	.320	.085	.03

As shown in Table 2, the AIC, BIC, and SABIC values decreased substantially from the one-class to the three-class model. For the three-class model, both the LMR-LRT ($p = .012$) and the BLRT ($p < .001$) were statistically significant, indicating that three classes provided a superior fit compared to two classes. When moving to the four-class model, the LMR-LRT became non-significant ($p = .145$), and the smallest class proportion dropped to 6%, suggesting potential over-extraction. Furthermore, the three-class model demonstrated the highest entropy value (.88), indicating excellent classification accuracy. Based on these statistical criteria and the theoretical interpretability of the profiles, the three-class model was retained as the optimal measurement model.

The three emergent profiles represented distinct bio-psychological configurations of resilience among the trauma survivors. Estimated marginal means for the indicator variables across the three latent profiles are presented in Table 3.

Table 3

Estimated Marginal Means and Standard Errors of Indicator Variables by Latent Profile

Indicator Variable	Class 1: Dysregulated ($\boldsymbol{n = 95, 21.0\%}$)	Class 2: Compensatory ($\boldsymbol{n = 221, 48.9\%}$)	Class 3: Adaptive ($\boldsymbol{n = 136, 30.1\%}$)
CD-RISC	34.12(2.14)	56.88(1.95)	78.05(2.08)
HCC $\boldsymbol{ln}$	2.55(0.08)	1.82(0.06)	1.41(0.07)
HRV (RMSSD) $\boldsymbol{ln}$	2.65(0.11)	3.38(0.09)	4.05(0.10)

Class 1, labeled the *Dysregulated/Low Resilience* profile ($n = 95$, 21.0%), was characterized by the lowest self-reported psychological resilience (CD-RISC $M = 34.12$), the highest levels of chronic physiological stress (HCC $\ln M = 2.55$), and the lowest parasympathetic tone (HRV $\ln M = 2.65$). Class 2, representing the majority of the sample and labeled the *Compensatory/Moderate Resilience* profile ($n = 221$, 48.9%), exhibited moderate levels across all three indicators. Class 3, designated as the *Adaptive/High Resilience* profile ($n = 136$, 30.1%), demonstrated the most optimal bio-psychological functioning, characterized by high self-reported resilience (CD-RISC $M = 78.05$), low allostatic load (HCC $\ln M = 1.41$), and robust vagal regulation (HRV $\ln M = 4.05$). Analysis of variance confirmed that the three profiles differed significantly across all three indicators (all ps $< .001$).

Following the establishment of the profiles, a multinomial logistic regression was conducted to examine the extent to which childhood trauma burden (CTQ) and current post-traumatic stress severity (PCL-5) predicted profile membership. The *Adaptive/High Resilience* class (Class 3) was designated as the reference group to determine the risk factors associated with less optimal resilience trajectories. The results of this regression analysis are detailed in Table 4.

Table 4

Multinomial Logistic Regression Predicting Latent Profile Membership

Predictor	Class 1 (Dysregulated) vs. Class 3 (Adaptive)			Class 2 (Compensatory) vs. Class 3 (Adaptive)		
	OR	95%CI	p	OR	95%CI	p
Age	1.02	[0.98,1.06]	.245	1.01	[0.97,1.04]	.582
CTQ Total	1.08	[1.04,1.13]	<.001	1.03	[1.01,1.06]	.014
PCL-5 Total	1.15	[1.09,1.21]	<.001	1.06	[1.03,1.10]	

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As shown in Table 4, adjusting for age, higher scores on the Childhood Trauma Questionnaire significantly increased the likelihood of belonging to the Dysregulated profile ($OR = 1.08,\ p < .001$) and the Compensatory profile ($OR = 1.03,\ p = .014$) relative to the Adaptive profile. Specifically, for every one-unit increase in the CTQ score, the odds of being in the Dysregulated class increased by 8%. Similarly, current trauma symptomatology was a robust predictor. Higher PCL-5 scores were significantly associated with an increased probability of membership in the Dysregulated class ($OR = 1.15,\ p < .001$) and the Compensatory class ($OR = 1.06,\ p = .002$) compared to the Adaptive class. These findings underscore that profound, compounding trauma—both distal (childhood) and proximal (current PTSD symptoms)—severely disrupts both psychological coping mechanisms and underlying neurobiological regulatory systems, drastically reducing the probability of achieving a highly adaptive resilience profile.

4. Discussion

The present study aimed to unpack the complex heterogeneity of resilience among $N = 452$female survivors of trauma in Egypt by integrating traditional psychological self-reports with objective neurobiological markers, specifically hair cortisol concentration and high-frequency heart rate variability. Utilizing a sophisticated two-step mixture modeling approach, the analysis moved beyond viewing resilience as a singular continuum and instead revealed three distinct latent profiles: the Dysregulated profile (21.0%), the Compensatory profile (48.9%), and the Adaptive profile (30.1%). Furthermore, the multinomial logistic regression demonstrated that higher burdens of distal childhood trauma and more severe proximal post-traumatic stress symptoms significantly predicted membership in the less optimal Dysregulated and Compensatory profiles relative to the Adaptive profile. These findings provide compelling evidence that trauma survivors experience highly divergent bio-psychological trajectories of recovery that cannot be accurately captured by psychological assessments alone.

The emergence of these three distinct profiles strongly supports the modern conceptualization of resilience not as a monolithic, static trait, but rather as a highly dynamic and multidimensional mechanism involving multiple interacting biological and psychological components (Farchi & Peled-Avram, 2025). The Adaptive profile, characterizing nearly one-third of the female survivors in this sample, exhibited the most optimal psychophysiological functioning. This group was marked by high self-reported psychological resilience, robust parasympathetic vagal tone, and remarkably low chronic physiological stress. This specific configuration aligns with previous research highlighting how robust resilience frameworks significantly buffer psychological distress and mitigate trauma-related symptoms across a wide variety of high-stress populations, including mental health nurses (Foster et al., 2024), methadone treatment staff (Coffee, 2025), and intensive care unit personnel (Shin & Choi, 2024). Conversely, the Dysregulated profile represented a highly vulnerable subpopulation demonstrating a systemic failure to adapt. This group exhibited a profound collapse of coping resources, evidenced by critically low psychological resilience coupled with severe neurobiological allostatic load. The presence of such a severely impacted demographic underscores the grim reality that trauma, particularly when experienced within complex, compounding sociopolitical contexts such as post-revolution Egypt, can fundamentally overwhelm both psychological and physiological regulatory systems (Miller-Graff et al., 2024).

Notably, the Compensatory profile emerged as the largest class, encompassing nearly half of the participants. These individuals demonstrated moderate levels of self-reported psychological resilience but also exhibited intermediate biological stress markers, indicating elevated systemic arousal. This configuration suggests a phenomenon where survivors are actively deploying cognitive and emotional coping strategies to maintain psychological functioning, but this adaptation incurs a hidden physiological cost. This finding resonates deeply with recent studies emphasizing the critical mediating role of active, meaning-centered, and positive coping strategies in the pathway between severe trauma exposure, life satisfaction, and post-traumatic growth (Türk et al., 2025; Zheng et al., 2024). Such active coping strategies have been identified as essential conduits for maintaining resilience even in the face of profound medical traumas, such as cancer diagnoses (Latif et al., 2024). The Compensatory profile likely reflects individuals who are in a transitional, active state of striving for post-traumatic growth; their psychological effort to overcome adversity is mirrored by a persistently elevated, yet not entirely exhausted, physiological stress response.

The predictive analysis revealed that distal childhood trauma severity was a robust risk factor, significantly

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increasing the odds of membership in the Dysregulated and Compensatory profiles. This finding is highly consistent with the broader developmental trauma literature, which posits that early adversity fundamentally disrupts the foundational maturation of emotional and neurobiological regulatory systems. Previous research has well established that childhood trauma is intricately linked to later internalizing problems, with psychological resilience often acting as a vulnerable, highly taxed mediator (Liao & Dong-mei, 2023). Furthermore, the detrimental, long-term impacts of early interpersonal victimization and bullying on subsequent adolescent post-traumatic stress underscore the critical need for robust mental resilience during sensitive developmental windows (Makrydaki, 2025). The enduring neurobiological scars of childhood trauma continuously impact adult resilience capacities and coping mechanisms, a dynamic frequently observed in adult clinical populations suffering from severe mood disorders (Yoon Park et al., 2023). Consequently, individuals with significant early trauma histories may struggle to access the intrinsic neurobiological and psychological resources necessary to attain the Adaptive profile, which heavily emphasizes the importance of early, targeted psychological interventions designed specifically to stimulate resilience and growth in traumatized youth (Nilsson et al., 2023; Sazonova & Chuiko, 2023).

In addition to the impact of distal developmental trauma, the severity of proximal post-traumatic stress symptoms was a potent predictor of latent profile membership. Participants grappling with higher current trauma symptomatology were significantly more likely to belong to the Dysregulated or Compensatory classes. This inverse relationship between acute current distress and optimal resilience functioning is extensively documented in the literature. For instance, in demanding clinical and occupational settings, higher resilience and professional quality of life are consistently associated with lower posttraumatic stress (Shin & Choi, 2023; Ye et al., 2025). Similarly, among vulnerable populations facing severe, ongoing life disruptions—such as the parents of very low birth weight infants or oncology patients—pervasive psychological distress heavily taxes innate resilience, thereby necessitating extensive external social support networks to facilitate active coping and subsequent growth (Wu et al., 2024; Zahra et al., 2024). The compounded burden of active, unmitigated trauma symptoms likely depletes the psychophysiological reserves of the female survivors in our sample, pushing their regulatory systems toward a state of chronic dysregulation.

The intersection of systemic, cultural, and interpersonal factors must also be carefully considered when interpreting the emergence of these bio-psychological resilience profiles. The sample of Egyptian female survivors in this study navigates a highly complex sociocultural landscape where interpersonal trauma is frequently compounded by broader systemic pressures and intense societal stigma. Studies examining diverse, highly traumatized populations, such as North Korean defectors and Palestinian populations living in active conflict zones, powerfully demonstrate that resilience and posttraumatic growth are profoundly reliant on social support and are deeply impacted by the chronicity of the environmental threat (Lee, 2024; Veronese et al., 2025). Furthermore, the complex grieving and recovery processes following systemic or historical traumas require a highly nuanced understanding of community-level resilience dynamics (Cërmjani & Kelmendi, 2024). For female survivors of specific, highly stigmatized interpersonal traumas, such as sexual assault, internalized shame and societal prejudice act as massive, structural barriers to resilience, necessitating culturally sensitive, stigma-conscious frameworks for psychological recovery (King et al., 2024; Strickland et al., 2023). The psychological resilience of trauma survivors, and even the vicarious resilience of their familial caregivers in critical care environments, is intimately tied to broader interpersonal functioning and overarching environmental stability (Yu et al., 2024). During periods of widespread, systemic crises, foundational psychological constructs like hope remain deeply intertwined with the human capacity to maintain mental health and resilience despite pervasive uncertainty (Senger, 2023). Similarly, healthcare workers navigating the unprecedented trauma of global pandemics required intense resilience and mindfulness to combat stigmatization and foster adaptive coping mechanisms (Kim et al., 2023; She et al., 2025). Thus, the distinct physiological and psychological profiles observed in this investigation are not merely isolated biological phenomena but are deeply embedded within, and reactive to, the survivors' broader ecological and cultural contexts.

5. Conclusion

This study provides crucial empirical evidence demonstrating the profound heterogeneity of resilience among female trauma survivors. By utilizing a sophisticated mixture modeling approach that integrates traditional psychological self-reports with objective neurobiological

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markers, we successfully identified three distinct subpopulations: the Adaptive, Compensatory, and Dysregulated profiles. The emergence of these profiles illustrates that resilience cannot be accurately captured by a single psychological metric, as many individuals—particularly those in the Compensatory group—maintain a facade of psychological coping while simultaneously bearing a significant, hidden physiological allostatic load. Furthermore, the findings highlight that heavy burdens of childhood trauma and severe ongoing post-traumatic stress symptoms act as primary barriers to achieving an optimal, adaptive state of resilience. Ultimately, this multidimensional approach underscores the necessity of evaluating both the mind and the body to truly understand the complex, divergent pathways of recovery following severe trauma.

6. Limitations and Suggestions

Despite the rigorous methodological approach, several limitations must be acknowledged when interpreting the findings of this study. First, the cross-sectional observational design precludes the ability to draw definitive causal inferences regarding the relationship between trauma exposure and the development of specific resilience profiles. It remains unclear whether profound trauma causes the biological dysregulation observed, or if pre-existing biological vulnerabilities predispose individuals to more severe psychiatric responses following a traumatic event. Second, the sample was exclusively restricted to adult female survivors within the specific sociocultural context of the greater Cairo metropolitan area. While this provides highly targeted insights, it inherently limits the generalizability of the findings to male populations, children, or survivors residing in vastly different cultural or geographic environments. Finally, the biological assessment was limited to only two markers—hair cortisol concentration and high-frequency heart rate variability. While these are robust indicators of stress regulation, they do not capture the entirety of the physiological stress response, omitting other potentially vital systems such as inflammatory cytokines, epigenetic modifications, or broader neuroendocrine networks.

Future research should prioritize longitudinal study designs to rigorously track how these distinct bio-psychological profiles of resilience evolve or fluctuate over time, particularly in response to ongoing life stressors or the initiation of psychiatric treatment. Tracking latent profile transitions would provide invaluable insights into the temporal stability of the Compensatory and Dysregulated states. Additionally, researchers should aim to replicate this two-step mixture modeling approach across diverse demographic groups, including varying genders, age cohorts, and cross-cultural populations, to determine the universality of these three specific resilience phenotypes. Further investigations would also greatly benefit from expanding the neurobiological battery to include a wider array of biomarkers, such as markers of systemic inflammation, oxidative stress, and structural or functional neuroimaging data. Incorporating these varied biological dimensions would generate an even more granular and comprehensive map of the physiological costs associated with trauma survival and psychological adaptation.

The findings from this study have profound, immediate implications for clinical practice and the delivery of trauma-informed care. Clinicians and psychiatric practitioners must recognize that relying solely on self-reported psychological assessments may result in a dangerous mischaracterization of a patient's true state of recovery. A patient may report adequate coping and psychological resilience while silently enduring severe autonomic and neuroendocrine dysregulation, placing them at high risk for future somatic and psychiatric collapse. Therefore, multi-dimensional assessment protocols that incorporate basic physiological tracking—such as resting heart rate variability—should be integrated into standard psychiatric evaluations. Furthermore, therapeutic interventions must be tailored to the specific profile of the survivor. Individuals in the Dysregulated profile may require intensive, biologically focused interventions, such as somatic experiencing, biofeedback, or pharmacological support, to stabilize the nervous system before traditional cognitive processing can be effective. Conversely, individuals in the Compensatory profile may benefit most from targeted psychotherapies aimed at reducing the hidden allostatic load of their coping strategies, helping them transition toward a more effortless, adaptive state of long-term recovery.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

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Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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