

Elastic Net Regression for Predicting Psychological Well-Being among Adolescents from Resilience, Self-Compassion, Gratitude, and Perceived Social Support

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ABSTRACT

Objective: This study aimed to examine the predictive roles of resilience, self-compassion, gratitude, and perceived social support in explaining psychological well-being among adolescents using Elastic Net Regression.

Methods and Materials: This cross-sectional predictive study was conducted among 1,284 adolescents aged 13 to 18 years from public secondary schools in Malaysia. Participants were selected through multistage cluster sampling from schools located in Selangor, Kuala Lumpur, Penang, and Johor. Data were collected using standardized self-report instruments, including the Ryff Psychological Well-Being Scale, Connor-Davidson Resilience Scale, Self-Compassion Scale-Short Form, Gratitude Questionnaire-Six Item Form, and Multidimensional Scale of Perceived Social Support. After data screening and handling of missing values through multiple imputation, descriptive statistics, correlation analysis, and Elastic Net Regression were performed. Predictor variables were standardized before modeling. The dataset was divided into training and testing subsets, and 10-fold cross-validation was applied to identify the optimal alpha and lambda values. Model performance was evaluated using R^2 , Root Mean Square Error, and Mean Absolute Error. Bootstrap resampling with 1,000 iterations was conducted to assess coefficient stability.

Findings: Elastic Net Regression showed strong predictive accuracy, explaining 69.4% of the variance in psychological well-being in the training set and 68.1% in the testing set. The optimized model produced low prediction error indices, with RMSE values of 13.21 and 13.86 and MAE values of 10.18 and 10.73 for the training and testing datasets, respectively. Resilience emerged as the strongest predictor of psychological well-being, followed by self-compassion, perceived social support, and gratitude.

Conclusion: The findings indicate that psychological well-being among adolescents is strongly predicted by a combination of personal and relational protective factors. Resilience and self-compassion were the most influential predictors, while perceived social support and gratitude also made meaningful contributions.

Keywords: Psychological well-being; Adolescents; Resilience; Self-compassion; Gratitude; Perceived social support

1. Introduction

Adolescence is widely recognized as a critical developmental period characterized by rapid biological, psychological, and social changes that profoundly influence mental health and well-being. During this stage, individuals experience heightened vulnerability to stress, emotional dysregulation, and social challenges, which may compromise psychological functioning if adequate protective factors are absent (Dorjee, 2024; Shek, 2025). The increasing prevalence of mental health concerns among adolescents worldwide has heightened the need to identify factors that can foster resilience and support positive psychological outcomes. Recent research emphasizes that adolescent well-being is multidimensional, encompassing emotional, cognitive, and social domains, and is influenced by a dynamic interplay of individual traits and environmental resources (Caskey, 2022; Vaingankar et al., 2022).

Resilience, defined as the capacity to adapt successfully to adversity and recover from stress, is one of the most consistently identified predictors of positive mental health during adolescence. Studies have shown that higher resilience is associated with reduced psychological distress, enhanced emotional regulation, and greater overall well-being (Cousino et al., 2024; Salsman & Rosenberg, 2024). Resilience can be nurtured through targeted interventions, such as skills-based programs and supportive educational environments, which enable adolescents to develop adaptive coping strategies and maintain mental equilibrium in the face of challenges (Jobin, 2025; Merlo et al., 2025). Furthermore, resilience interacts with other psychological resources, such as optimism, self-efficacy, and perceived social support, to enhance adolescents' capacity to navigate developmental stressors (Fu, 2024; Preston et al., 2021).

Self-compassion, defined as the tendency to treat oneself with kindness, acknowledge common humanity, and maintain mindfulness during periods of suffering, has emerged as another key predictor of adolescent psychological well-being (Aledoh et al., 2024; An et al., 2025). Empirical evidence indicates that self-compassion mitigates negative affect, reduces vulnerability to internalizing problems, and promotes adaptive coping behaviors (Khatib, 2023; Wekerle et al., 2022). Adolescents exhibiting higher self-compassion are more likely to experience emotional stability and less likely to engage in self-criticism, rumination, or maladaptive avoidance strategies, which in turn contributes to improved mental

health outcomes (Ginting et al., 2024; Zhao et al., 2025). Importantly, self-compassion can be cultivated through school-based interventions, mindfulness exercises, and psychoeducational programs, highlighting its potential for preventive and promotive mental health strategies (Jobin, 2025; Ünlü et al., 2025).

Gratitude, a dispositional tendency to recognize and appreciate positive experiences and interpersonal support, also plays a significant role in adolescent well-being. Research demonstrates that gratitude is associated with higher life satisfaction, reduced depressive symptoms, and enhanced social functioning (Chamizo-Nieto & Rey, 2023; Halleyda & Japar, 2023). In adolescence, gratitude may serve as a cognitive-emotional resource that promotes positive reframing of challenges, strengthens peer and family relationships, and enhances engagement in prosocial behaviors (Sorrenti et al., 2025; Zhao et al., 2025). Intervention studies have confirmed that structured gratitude training programs can yield significant improvements in subjective well-being and buffer the negative impact of stressors on adolescent mental health (Fu, 2024; Halleyda & Japar, 2023).

Perceived social support, encompassing adolescents' perceptions of emotional, informational, and instrumental support from family, peers, and significant others, has consistently been linked to positive psychological outcomes (El-Bagiz & Kinanthi, 2022; Zhao et al., 2025). Adolescents who perceive higher social support exhibit lower levels of anxiety, depression, and stress while reporting greater life satisfaction and psychological well-being (Merlo et al., 2025; Peng et al., 2024). Social support functions as both a protective buffer against stress and a promotive factor, facilitating the development of coping skills, emotional regulation, and a sense of connectedness (Cousino et al., 2024; John et al., 2024). Evidence suggests that family cohesion, peer acceptance, and school connectedness collectively enhance adolescents' resilience, self-compassion, and gratitude, underscoring the interdependent nature of these psychosocial resources (An et al., 2025; Merlo et al., 2025; Peng et al., 2024).

The integration of these individual and relational protective factors reflects a broader theoretical framework in positive psychology and developmental psychopathology, emphasizing the dynamic interactions between personal strengths and supportive environments in promoting adolescent well-being (Dorjee, 2024; Shek, 2025). Positive psychology interventions targeting resilience, self-compassion, gratitude, and social support have shown

effectiveness in diverse educational and clinical contexts, including school-based programs, digital interventions, mindfulness curricula, and lifestyle-oriented modules (Francisco et al., 2023; Linford et al., 2021; Saboor et al., 2024). For instance, mindfulness-based interventions have been demonstrated to enhance emotion regulation, reduce social media burnout, and increase psychological well-being among adolescents (Razza et al., 2025; Ünlü et al., 2025). Similarly, resilience-building programs, both in school and clinical contexts, have resulted in improved adaptive coping, positive affect, and life satisfaction (Razza et al., 2021; Salsman & Rosenberg, 2024).

Recent research also highlights the synergistic effects of these protective factors, suggesting that interventions that simultaneously address multiple dimensions—such as resilience, self-compassion, gratitude, and perceived social support—may yield stronger and more sustained improvements in adolescent mental health (Aledoh et al., 2024; An et al., 2025; Fu, 2024). Neurodevelopmental studies support this integrative approach by demonstrating that brain networks underlying emotion regulation, social cognition, and reward processing are particularly responsive to interventions that promote adaptive coping, self-compassion, and social connectedness during adolescence (Dorjee, 2024; Kim et al., 2025). Moreover, longitudinal studies indicate that adolescents who cultivate these resources early are more likely to maintain high levels of well-being, lower incidence of internalizing disorders, and stronger social functioning into adulthood (Shek, 2025; Vaingankar et al., 2022).

Despite these advances, most prior studies have relied on correlational or cross-sectional designs, limiting their capacity to identify the relative predictive contribution of resilience, self-compassion, gratitude, and perceived social support for adolescent psychological well-being. Furthermore, multicollinearity among these constructs presents methodological challenges for traditional regression approaches, necessitating the application of regularized machine learning techniques such as Elastic Net Regression to accurately estimate predictive relationships while controlling for intercorrelations (Ashmitha & Annalakshmi, 2022; Caskey, 2022). By leveraging Elastic Net, it is possible to identify the most influential predictors of well-being among adolescents while minimizing bias and overfitting, thereby providing actionable insights for educational and mental health interventions (Cousino et al., 2024; Peng et al., 2024).

In light of the growing body of evidence on adolescent mental health and the synergistic role of psychosocial protective factors, it is imperative to employ advanced predictive modeling techniques to elucidate which individual and relational resources most strongly contribute to psychological well-being. Such analyses can inform the development of targeted interventions and evidence-based policies aimed at promoting positive mental health among youth populations (Fu, 2024; John et al., 2024; Linford et al., 2021). In addition, understanding the relative influence of resilience, self-compassion, gratitude, and perceived social support may help educators, clinicians, and policymakers prioritize resource allocation and design holistic programs that enhance well-being during this formative period (Francisco et al., 2023; Merlo et al., 2025; Saboor et al., 2024).

Taken together, the current literature highlights the critical importance of examining resilience, self-compassion, gratitude, and perceived social support as key determinants of adolescent psychological well-being, emphasizing both individual and contextual dimensions. These constructs have demonstrated empirical relevance across diverse cultural, educational, and developmental contexts and are amenable to intervention strategies that promote sustained mental health outcomes (Aledoh et al., 2024; An et al., 2025; Chamizo-Nieto & Rey, 2023). Despite considerable progress, few studies have applied integrative predictive approaches that account for multicollinearity while simultaneously evaluating the unique contribution of each protective factor. Addressing this gap is essential for advancing both theoretical understanding and practical implementation of adolescent mental health promotion strategies (Shek, 2025; Sorrenti et al., 2025; Zhao et al., 2025).

The present study aims to examine the predictive roles of resilience, self-compassion, gratitude, and perceived social support on psychological well-being among adolescents using Elastic Net Regression.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a cross-sectional predictive research design to examine the extent to which resilience, self-compassion, gratitude, and perceived social support could predict psychological well-being among Malaysian adolescents using Elastic Net Regression. The study was conducted between September 2025 and January 2026 in

public secondary schools located across the states of Selangor, Kuala Lumpur, Penang, and Johor, Malaysia. A multistage cluster sampling strategy was used to ensure representation from urban and suburban educational settings. Initially, schools were randomly selected from the official lists provided by regional education authorities. Subsequently, classrooms within selected schools were chosen through random sampling procedures, and all eligible students within those classrooms were invited to participate.

The final sample consisted of 1,284 adolescents aged between 13 and 18 years ($M = 15.62$, $SD = 1.47$). Of the participants, 648 (50.5%) were female and 636 (49.5%) were male. Inclusion criteria required participants to be enrolled in a secondary educational institution, possess sufficient proficiency in English or Malay to complete the questionnaires, and provide informed assent alongside parental consent. Adolescents with severe cognitive impairments or documented psychiatric conditions that could interfere with questionnaire completion were excluded from the study.

2.2. Measures

Psychological well-being was assessed using the Psychological Well-Being Scale developed by Ryff (1989). The instrument consists of 42 items measuring six dimensions of positive psychological functioning, including autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance. Participants responded using a six-point Likert scale ranging from strongly disagree to strongly agree. Higher scores indicated greater levels of psychological well-being. Previous studies conducted among adolescent and multicultural populations have demonstrated satisfactory construct validity, convergent validity, and internal consistency reliability, with Cronbach's alpha coefficients generally exceeding .80. The scale has been widely used in youth psychological research and has shown strong psychometric properties across different cultural contexts.

Resilience was measured using the Connor–Davidson Resilience Scale (CD-RISC-25), developed by Connor and Davidson (2003). This instrument contains 25 items designed to assess an individual's capacity to adapt successfully to adversity, stress, and challenging life circumstances. Responses are rated on a five-point Likert scale ranging from 0 (not true at all) to 4 (true nearly all the

time). Total scores range from 0 to 100, with higher scores reflecting greater resilience. The CD-RISC has demonstrated strong factorial validity and excellent reliability across adolescent populations, with reported Cronbach's alpha values typically above .85. Previous studies have confirmed its applicability in diverse cultural settings, including Asian populations.

Self-compassion was assessed using the Self-Compassion Scale–Short Form (SCS-SF) developed by Raes et al. (2011), based on the original scale created by Neff (2003). The instrument includes 12 items assessing self-kindness, common humanity, mindfulness, self-judgment, isolation, and overidentification. Participants rated each statement on a five-point Likert scale ranging from almost never to almost always. Higher scores indicated greater self-compassion. The short-form scale has demonstrated strong correlations with the original version and has exhibited satisfactory psychometric properties in adolescent samples. Previous validation studies have reported acceptable construct validity and internal consistency coefficients generally ranging from .80 to .90.

Gratitude was measured using the Gratitude Questionnaire–Six Item Form (GQ-6) developed by McCullough, Emmons, and Tsang (2002). The instrument evaluates individual differences in the tendency to recognize and respond with gratitude to positive experiences and interpersonal support. Responses are provided on a seven-point Likert scale ranging from strongly disagree to strongly agree. Higher scores represent greater dispositional gratitude. The GQ-6 has demonstrated robust psychometric characteristics across adolescent and adult populations, including strong convergent validity, criterion validity, and internal consistency reliability. Previous studies have reported Cronbach's alpha coefficients typically exceeding .80.

Perceived social support was assessed using the Multidimensional Scale of Perceived Social Support (MSPSS) developed by Zimet, Dahlem, Zimet, and Farley (1988). The MSPSS contains 12 items measuring perceived support from family, friends, and significant others. Participants responded on a seven-point Likert scale ranging from very strongly disagree to very strongly agree. Higher scores indicated greater perceived social support. The MSPSS has consistently demonstrated excellent psychometric properties among adolescent populations worldwide. Previous research has confirmed its factorial validity, cross-cultural applicability, and internal

consistency reliability, with Cronbach's alpha values generally above .85 for both total and subscale scores.

2.3. Data Analysis

Data were analyzed using R statistical software version 4.3 and Python 3.12. Preliminary analyses included data screening, examination of missing values, assessment of normality, detection of outliers, and evaluation of descriptive statistics for all study variables. Missing data represented less than 3% of all observations and were handled using multiple imputation procedures. Means, standard deviations, skewness, kurtosis values, and Pearson correlation coefficients were calculated to describe the sample characteristics and relationships among variables.

The primary analytical approach involved Elastic Net Regression, a regularized machine learning technique that combines the penalties of both Least Absolute Shrinkage and Selection Operator (LASSO) regression and Ridge regression. This approach was selected because of its ability to address multicollinearity among predictors while simultaneously performing variable selection and coefficient shrinkage. Psychological well-being served as the dependent variable, whereas resilience, self-compassion, gratitude, and perceived social support were entered as predictor variables.

Prior to model estimation, all predictor variables were standardized to ensure comparability of regression coefficients. The dataset was randomly divided into training (80%) and testing (20%) subsets. Hyperparameter optimization was performed using 10-fold cross-validation within the training dataset to identify the optimal values of alpha and lambda. Model performance was evaluated using multiple indices, including Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and coefficient of determination (R^2) on both training and testing datasets. Variable importance scores and standardized regression coefficients were examined to determine the relative contribution of each predictor to psychological well-being.

To enhance model stability and generalizability, bootstrap resampling procedures with 1,000 iterations were conducted, and confidence intervals were estimated for all predictor coefficients. Statistical significance was evaluated at the .05 level, and all findings were interpreted within the framework of predictive modeling and adolescent positive psychology.

3. Findings and Results

A total of 1,284 adolescents from Malaysia were included in the final analysis. Participants were recruited from public secondary schools located in Selangor, Kuala Lumpur, Penang, and Johor. The age of participants ranged from 13 to 18 years, with a mean age of 15.62 years and a standard deviation of 1.47. In terms of gender distribution, 648 participants were female, representing 50.5% of the sample, and 636 participants were male, representing 49.5% of the sample. Regarding school level, 352 adolescents were enrolled in lower secondary education, accounting for 27.4% of the sample, while 932 adolescents were enrolled in upper secondary education, accounting for 72.6% of the sample. In relation to residential background, 794 participants lived in urban areas, representing 61.8% of the sample, and 490 participants lived in suburban areas, representing 38.2% of the sample. Data screening indicated that the dataset was appropriate for predictive analysis. Missing values were minimal and represented less than 3% of the total dataset. These missing values were handled using multiple imputation procedures before conducting the main analyses. No severe univariate or multivariate outliers were detected after screening standardized scores and Mahalanobis distance values. The assumptions required for correlation analysis were adequately met, and the presence of moderate-to-strong correlations among predictors supported the use of Elastic Net Regression as an appropriate regularized predictive approach.

Table 1

Descriptive Statistics and Correlations among Psychological Well-Being, Resilience, Self-Compassion, Gratitude, and Perceived Social Support

Variable	Mean	SD	1	2	3	4	5
1. Psychological well-being	182.74	24.16	—				
2. Resilience	68.91	12.37	.71**	—			
3. Self-compassion	39.82	8.44	.68**	.63**	—		
4. Gratitude	34.47	6.29	.61**	.54**	.57**	—	
5. Perceived social support	65.38	11.54	.65**	.58**	.55**	.60**	—

Table 1 presents the descriptive statistics and correlation coefficients for the main study variables. The mean score for psychological well-being was 182.74 with a standard deviation of 24.16, indicating that the adolescents in the sample generally reported moderate-to-high levels of psychological well-being. The mean resilience score was 68.91, suggesting that the participants demonstrated relatively favorable adaptive capacity in coping with stress and adversity. The mean score for self-compassion was 39.82, while gratitude had a mean score of 34.47 and perceived social support had a mean score of 65.38. These descriptive findings indicate that the adolescents generally reported positive psychological resources across all predictor variables. The correlation matrix showed that psychological well-being was significantly and positively associated with all four predictors. The strongest correlation was observed between psychological well-being and resilience ($r = .71, p < .01$), suggesting that adolescents with higher resilience tended to report substantially higher psychological well-being. Psychological well-being was

also strongly correlated with self-compassion ($r = .68, p < .01$), indicating that adolescents who were more accepting, kind, and emotionally balanced toward themselves reported better well-being. Perceived social support was positively associated with psychological well-being ($r = .65, p < .01$), showing that adolescents who perceived greater support from family, friends, and significant others tended to experience higher levels of positive psychological functioning. Gratitude was also significantly correlated with psychological well-being ($r = .61, p < .01$), suggesting that adolescents who were more likely to recognize and appreciate positive experiences reported better well-being. The predictors were also significantly intercorrelated, with coefficients ranging from .54 to .63. These moderate-to-strong intercorrelations indicate conceptual overlap among the protective psychological factors and further justify the use of Elastic Net Regression, which is particularly suitable when predictors are related but each may still contribute unique predictive information.

Table 2

Elastic Net Hyperparameter Optimization and Predictive Performance of the Model

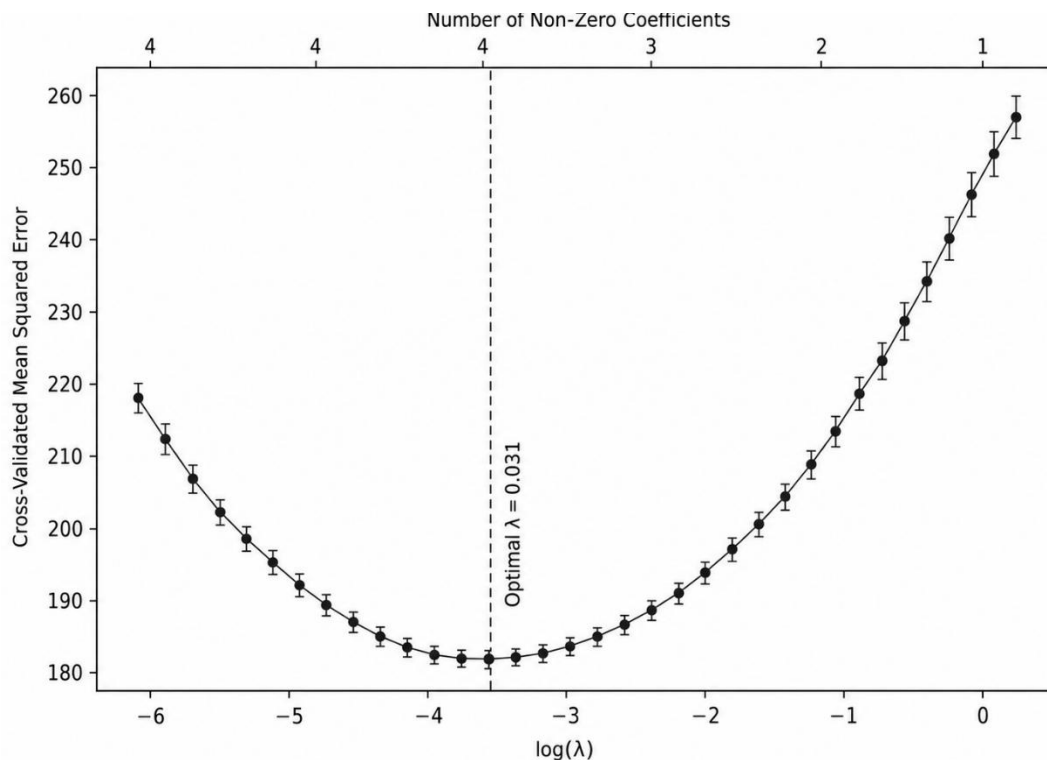
Model index	Training set	Testing set
R ²	.694	.681
Adjusted R ²	.691	.675
Root Mean Square Error	13.21	13.86
Mean Absolute Error	10.18	10.73
Mean Squared Error	174.50	192.10
Optimal alpha	0.57	—
Optimal lambda	0.031	—
Number of cross-validation folds	10	—

Table 2 presents the results of Elastic Net hyperparameter optimization and the predictive performance of the final model. The dataset was divided into a training set and a testing set, with 80% of the data used for model training and 20% retained for model evaluation. The Elastic Net model produced strong predictive accuracy in both subsets. In the training set, the model explained 69.4% of the variance in psychological well-being, as indicated by an R² value of .694. In the testing set, the model explained 68.1% of the variance, with an R² value of .681. The small difference between the training and testing R² values indicates that the model generalized well to unseen data and did not show meaningful evidence of overfitting. The adjusted R² values were also highly similar across the training and testing datasets, further supporting the stability of the model. The Root Mean Square Error was 13.21 in the training set and

13.86 in the testing set, while the Mean Absolute Error was 10.18 in the training set and 10.73 in the testing set. These values indicate that the average prediction error remained relatively low and consistent across both datasets. The 10-fold cross-validation procedure identified an optimal alpha value of 0.57 and an optimal lambda value of 0.031. The alpha value indicates that the final model used a balanced combination of LASSO and Ridge regularization, allowing the model to manage multicollinearity while preserving the predictive contribution of all relevant variables. The lambda value reflects the degree of regularization required to minimize prediction error. Overall, the findings indicate that Elastic Net Regression provided a stable, accurate, and generalizable predictive model for estimating adolescent psychological well-being from resilience, self-compassion, gratitude, and perceived social support.

Figure 1

Cross-Validation Curve for Optimal Lambda Selection in the Elastic Net Regression Model



The cross-validation curve illustrated the process through which the optimal lambda value was selected for the Elastic Net Regression model. The curve showed that prediction error decreased as regularization improved model stability and then reached its lowest point at the optimal lambda value of 0.031. After this point, further increases in regularization did not improve prediction accuracy and would have risked excessive shrinkage of the model coefficients. The pattern of the curve indicated that the selected lambda value achieved

an appropriate balance between model complexity and predictive precision. This means that the final model was sufficiently regularized to reduce coefficient instability and multicollinearity, while still retaining the meaningful contribution of resilience, self-compassion, gratitude, and perceived social support. The cross-validation results therefore supported the adequacy of the selected model and confirmed that the final Elastic Net solution represented the most efficient predictive structure for the available data.

Table 3

Elastic Net Regression Coefficients and Variable Importance for Predicting Psychological Well-Being

Predictor	Standardized coefficient β	Standard error	95% CI lower	95% CI upper	Variable importance
Resilience	.392	.028	.337	.447	100.0
Self-compassion	.318	.031	.257	.379	82.4
Perceived social support	.244	.027	.191	.297	66.7
Gratitude	.186	.025	.137	.235	52.1

Table 3 shows the standardized coefficients and variable importance values for the predictors retained in the Elastic Net Regression model. All four predictors remained in the final model, indicating that resilience, self-compassion, gratitude, and perceived social support each contributed

meaningful predictive information to adolescent psychological well-being. Resilience emerged as the strongest predictor, with a standardized coefficient of $\beta = .392$ and the highest variable importance score of 100.0. This finding indicates that resilience had the greatest relative

contribution to the prediction of psychological well-being. Adolescents who reported greater capacity to adapt to stress, recover from difficulties, and maintain effective functioning under pressure tended to report higher psychological well-being. Self-compassion was the second strongest predictor, with a standardized coefficient of $\beta = .318$ and a variable importance score of 82.4. This result suggests that adolescents who responded to personal difficulties with self-kindness, emotional balance, and acceptance were more likely to experience better psychological functioning. Perceived social support was the third strongest predictor, with a standardized coefficient of $\beta = .244$ and a variable importance score of 66.7. This indicates that adolescents who perceived higher levels of support from family, friends, and significant others reported greater psychological well-

being. Gratitude also remained a meaningful predictor, with a standardized coefficient of $\beta = .186$ and a variable importance score of 52.1. Although gratitude had the lowest relative importance among the four predictors, its coefficient was positive and its confidence interval did not include zero, confirming that it made a stable contribution to the model. The confidence intervals for all predictors were positive, indicating that each variable had a reliable positive association with psychological well-being after regularization. These findings demonstrate that psychological well-being among adolescents is best predicted by a combination of personal adaptive resources and interpersonal support, with resilience and self-compassion showing the strongest predictive effects.

Table 4

Bootstrap Validation of Elastic Net Regression Coefficients Based on 1,000 Resamples

Predictor	Original β	Mean bootstrap β	Bias	Bootstrap standard error	95% bootstrap CI lower	95% bootstrap CI upper
Resilience	.392	.389	.003	.030	.331	.448
Self-compassion	.318	.315	.003	.033	.251	.381
Perceived social support	.244	.242	.002	.029	.186	.300
Gratitude	.186	.184	.002	.027	.131	.237

Table 4 presents the results of bootstrap validation using 1,000 resamples. The purpose of this analysis was to examine the stability and reliability of the Elastic Net Regression coefficients. The bootstrap results closely replicated the original model coefficients, indicating that the predictive effects were not dependent on a single sample split or unstable estimation pattern. The original coefficient for resilience was $\beta = .392$, while the mean bootstrap coefficient was $\beta = .389$, with a very small bias value of .003. This confirms that resilience was consistently the strongest predictor of psychological well-being across repeated resampling procedures. Self-compassion also demonstrated strong stability, with an original coefficient of $\beta = .318$ and a mean bootstrap coefficient of $\beta = .315$. Perceived social

support showed a similarly stable pattern, with an original coefficient of $\beta = .244$ and a mean bootstrap coefficient of $\beta = .242$. Gratitude retained a positive and stable coefficient, with an original value of $\beta = .186$ and a mean bootstrap value of $\beta = .184$. The bootstrap confidence intervals for all four predictors remained entirely above zero, confirming that each variable made a reliable positive contribution to the prediction of psychological well-being. The small bias values and narrow confidence intervals indicate that the Elastic Net coefficients were robust and reproducible. These results strengthen the conclusion that resilience, self-compassion, perceived social support, and gratitude are stable predictors of psychological well-being among Malaysian adolescents.

Table 5

Comparison of Observed and Predicted Psychological Well-Being Scores across the Testing Dataset

Psychological well-being score group	Observed mean	Predicted mean	Mean prediction difference	RMSE	MAE
Low well-being group	143.62	146.18	2.56	14.74	11.28
Moderate well-being group	181.35	180.42	-0.93	12.91	9.84
High well-being group	218.47	215.96	-2.51	13.63	10.47
Total testing sample	182.19	181.54	-0.65	13.86	10.73

Table 5 presents the comparison between observed and predicted psychological well-being scores in the testing dataset. To provide a clearer interpretation of model performance, participants in the testing set were grouped into low, moderate, and high psychological well-being categories based on score distribution. The observed mean for the low well-being group was 143.62, while the predicted mean was 146.18, producing a mean prediction difference of 2.56. This indicates that the model slightly overestimated psychological well-being among adolescents with lower observed well-being scores. For the moderate well-being group, the observed mean was 181.35 and the predicted mean was 180.42, resulting in a very small prediction difference of -0.93. This demonstrates that the model performed especially well in predicting psychological well-being among adolescents with average levels of well-being. For the high well-being group, the observed mean was 218.47 and the predicted mean was 215.96, indicating a slight underestimation of -2.51. Across the total testing sample, the observed mean was 182.19 and the predicted mean was 181.54, with an overall prediction difference of only -0.65. The overall RMSE was 13.86 and the overall MAE was 10.73, consistent with the model performance indices reported earlier. These findings indicate that the Elastic Net Regression model demonstrated accurate prediction across different levels of psychological well-being, although it showed a minor tendency to overestimate lower scores and underestimate higher scores. This pattern is common in regularized regression models because shrinkage procedures reduce extreme predicted values in order to improve generalizability. Overall, the comparison between observed and predicted values confirms that the final model provided a reliable approximation of adolescent psychological well-being in the testing sample.

4. Discussion

The present study examined the predictive roles of resilience, self-compassion, gratitude, and perceived social support in explaining psychological well-being among adolescents using Elastic Net Regression. The findings demonstrated that the selected psychosocial predictors collectively explained a substantial proportion of variance in psychological well-being, with the model accounting for 69.4% of variance in the training set and 68.1% in the testing set. This close correspondence between training and testing performance indicates that the model was not merely fitted

to sample-specific noise but retained strong predictive accuracy when applied to unseen data. The relatively low RMSE and MAE values further confirmed that Elastic Net Regression provided a stable and generalizable prediction of psychological well-being among Malaysian adolescents. These results support the growing view that adolescent well-being is not determined by a single isolated factor but by the combined influence of internal strengths and relational resources, including adaptive coping, self-acceptance, gratitude, and social connectedness (Dorjee, 2024; Shek, 2025; Vaingankar et al., 2022).

The strongest predictor of psychological well-being in the model was resilience. This result indicates that adolescents who reported greater capacity to cope with stress, adapt to adversity, and recover from challenges also reported higher psychological well-being. The prominence of resilience in the model is theoretically consistent with positive youth development and developmental psychopathology perspectives, which position resilience as a central protective mechanism during adolescence. Adolescence is marked by academic demands, identity formation, peer evaluation, family expectations, and exposure to digital and social pressures; therefore, resilient adolescents may be better able to preserve emotional balance, maintain purpose, and sustain positive relations when faced with stress. This finding aligns with studies emphasizing resilience as a core factor in adolescent mental health promotion and well-being maintenance (Preston et al., 2021; Salsman & Rosenberg, 2024). It is also compatible with school-based and clinical intervention research showing that resilience can be strengthened through structured programs that foster coping skills, emotional awareness, self-regulation, and supportive peer connection (Cousino et al., 2024; Razza et al., 2021; Razza et al., 2025). The current result therefore suggests that resilience may operate as a broad regulatory resource that supports multiple domains of psychological well-being, including autonomy, environmental mastery, personal growth, purpose in life, self-acceptance, and positive relations.

Self-compassion emerged as the second strongest predictor of psychological well-being. This finding suggests that adolescents who respond to personal difficulties with kindness, mindfulness, and a sense of shared human imperfection tend to experience greater psychological functioning. The result is consistent with the literature indicating that self-compassion protects adolescents against excessive self-criticism, shame, rumination, isolation, and emotional overidentification (Khatib, 2023; Wekerle et al.,

2022). In the context of adolescence, self-compassion may be especially important because young people frequently experience social comparison, body image concerns, academic evaluation, and sensitivity to rejection. When adolescents can interpret mistakes and distressing experiences with self-kindness rather than harsh self-judgment, they may be more capable of preserving self-acceptance and emotional stability. This interpretation is supported by evidence linking self-compassion with happiness, mental well-being, and adaptive self-perception among adolescents (An et al., 2025; Ginting et al., 2024). It is also consistent with research suggesting that self-compassion training in schools may reduce harmful interpersonal patterns, including cyberbullying, by strengthening empathy, emotional regulation, and nonjudgmental awareness (Aledoh et al., 2024). Accordingly, the present study extends previous findings by showing that self-compassion remains a strong predictor of well-being even when resilience, gratitude, and perceived social support are considered simultaneously.

Perceived social support also made a meaningful contribution to the prediction of psychological well-being. This result highlights the central role of adolescents' perceived availability of emotional, relational, and practical support from family, friends, and significant others. The finding corresponds with prior research showing that supportive relationships reduce vulnerability to distress and enhance positive mental health outcomes among adolescents (Chi et al., 2022; Zhao et al., 2025). Perceived social support may contribute to psychological well-being through several mechanisms. First, it may buffer the negative effects of stress by providing adolescents with reassurance, advice, and emotional validation. Second, it may strengthen belongingness and connectedness, which are core components of healthy development. Third, it may indirectly enhance individual strengths such as resilience, gratitude, and self-compassion by creating a relational environment in which adolescents feel accepted and valued. This interpretation is consistent with evidence that family functioning, school connectedness, and parent-adolescent relationship quality are closely associated with adolescent well-being and self-compassion (El-Bagiz & Kinanthi, 2022; Peng et al., 2024). The finding also aligns with the expanded emphasis on connectedness as a foundational pillar of mental health and lifestyle-oriented well-being promotion (Merlo et al., 2025). Thus, perceived social support should be understood not merely as an external resource but as a developmental context that enables

adolescents to internalize safety, competence, and emotional security.

Gratitude was also retained as a significant predictor of psychological well-being, although its standardized coefficient was smaller than those of resilience, self-compassion, and perceived social support. This result indicates that adolescents who more frequently recognize positive experiences, appreciate interpersonal support, and attend to beneficial aspects of life tend to report better psychological well-being. The finding is consistent with previous studies showing that gratitude is linked to life satisfaction, reduced suicidal ideation, and improved psychological outcomes in adolescents (Chamizo-Nieto & Rey, 2023; Halleyda & Japar, 2023). Gratitude may strengthen well-being by shifting attention away from perceived deficits and toward meaningful relationships, personal resources, and positive experiences. In this way, gratitude may facilitate cognitive reappraisal, enhance positive affect, and reinforce prosocial behavior. The relatively lower coefficient of gratitude in the present model does not imply that gratitude is unimportant; rather, it suggests that part of its predictive effect may overlap with broader constructs such as resilience and perceived social support. For example, gratitude may develop through supportive relationships and may simultaneously reinforce those relationships by increasing appreciation and reciprocity. This interpretation is consistent with research identifying gratitude as a mediator between social support and adolescent mental health (Zhao et al., 2025).

The strong positive correlations among all study variables further support the assumption that adolescent psychological well-being is shaped by a network of mutually reinforcing protective factors. Resilience, self-compassion, gratitude, and perceived social support were all positively related to psychological well-being, and the predictors were also moderately to strongly intercorrelated with one another. This pattern is consistent with positive psychology models that conceptualize adolescent well-being as a multidimensional outcome arising from personal strengths, emotional regulation capacities, social resources, and meaning-oriented processes (Fu, 2024; John et al., 2024). The findings also align with evidence from positive psychology curricula and school-based well-being interventions, which suggests that adolescent mental health can be enhanced through programs that cultivate strengths, mindfulness, meaning, gratitude, and social-emotional competence (Francisco et al., 2023; Linford et al., 2021; White et al., 2022). In practical terms, this means that interventions designed to improve

adolescent well-being may be more effective when they integrate multiple components rather than focusing on a single psychological skill.

The use of Elastic Net Regression represents an important methodological contribution of this study. Because resilience, self-compassion, gratitude, and perceived social support are conceptually related and empirically correlated, conventional regression models may be affected by multicollinearity, unstable coefficients, or overestimation of predictor effects. Elastic Net Regression addresses this issue by combining LASSO and Ridge penalties, allowing the model to retain meaningful predictors while shrinking unstable coefficients. The present findings showed that all four predictors were retained, suggesting that each contributed unique predictive information to adolescent psychological well-being. This is consistent with the argument that adolescent mental health research benefits from integrative and data-driven approaches capable of examining complex relationships among protective factors (Ashmitha & Annalakshmi, 2022; Caskey, 2022). The bootstrap validation results further strengthened confidence in the model by showing that coefficient estimates remained stable across 1,000 resamples. Therefore, the results provide not only substantive evidence for the importance of resilience, self-compassion, gratitude, and social support, but also methodological evidence that regularized regression can be useful for identifying robust predictors of adolescent well-being.

The findings also support the relevance of school-based mental health promotion. Adolescents spend much of their developmental time in school environments, making schools appropriate settings for preventive and strengths-based intervention. The current results are consistent with evidence supporting mindfulness-based, yoga-based, social-emotional, and digital positive psychology interventions for improving adolescent well-being (Jobin, 2025; Kim et al., 2025; Saboor et al., 2024; Ünlü et al., 2025). The predictive importance of resilience and self-compassion suggests that interventions should help adolescents develop coping flexibility, emotional regulation, mindful awareness, and kinder self-relations. Likewise, the contribution of gratitude and perceived social support suggests that programs should include relational and appreciation-based practices, such as peer support activities, family engagement, gratitude journaling, and classroom climates that strengthen belonging. The findings are also compatible with evidence that mindfulness and positive psychology programs can improve subjective well-being and emotional adjustment

among adolescents (Primasari & Yuniarti, 2021; Razza et al., 2021). Therefore, the present study reinforces the value of comprehensive school-based approaches that combine intrapersonal and interpersonal protective factors.

5. Conclusion

In the Malaysian adolescent context, the findings have particular relevance because adolescents often navigate multiple developmental pressures, including academic competition, family expectations, digital exposure, and peer-group demands. Although the present study did not compare cultural subgroups, the results suggest that psychological well-being among adolescents in Malaysia may be strengthened through both individual psychological resources and relational support systems. This interpretation is consistent with research emphasizing that adolescent well-being is influenced by ecological systems, including family, school, peer, and community environments (El-Bagiz & Kinanthi, 2022; Sorrenti et al., 2025). It is also aligned with evidence indicating that self-compassion, gratitude, resilience, and connectedness are relevant across diverse cultural and educational settings (Halleyda & Japar, 2023; Kim et al., 2025; Zhao et al., 2025). The present results therefore add to the literature by demonstrating that these protective factors can be integrated into a predictive model with strong explanatory power among adolescents in Malaysia.

6. Limitations & Suggestions

Despite its contributions, the study has several limitations. First, the cross-sectional design prevents causal interpretation; therefore, although resilience, self-compassion, gratitude, and perceived social support predicted psychological well-being, the direction of influence cannot be definitively established. Second, all variables were measured using self-report questionnaires, which may be affected by social desirability, recall bias, and response style. Third, although the sample size was large and included adolescents from several Malaysian regions, the findings may not fully represent adolescents from rural areas, private schools, indigenous communities, or adolescents outside formal schooling. Fourth, the study focused on four positive psychological predictors and did not include other potentially important variables such as socioeconomic status, academic stress, family structure, digital media use, personality traits, physical activity, sleep quality, or clinical symptoms. Finally, although Elastic Net

Regression improved predictive stability, the model should be externally validated in independent samples before being considered fully generalizable.

Future studies should use longitudinal designs to clarify the temporal and causal relationships among resilience, self-compassion, gratitude, perceived social support, and psychological well-being. Experimental and intervention-based research would also be valuable to determine whether strengthening these predictors produces measurable improvements in adolescent well-being over time. Future research should include more diverse adolescent samples from rural, urban, public, private, and culturally distinct educational settings to examine whether the model performs equally well across demographic and cultural groups. Researchers may also expand the predictive framework by including additional psychological, family, school, lifestyle, and digital environment variables. Comparative studies using different machine learning techniques, such as Random Forest, Gradient Boosting, Support Vector Regression, and Neural Networks, may further clarify whether Elastic Net Regression provides the most interpretable and accurate prediction model for adolescent psychological well-being.

The findings suggest that adolescent mental health programs should prioritize resilience-building, self-compassion training, gratitude exercises, and social support enhancement as integrated components of school-based well-being promotion. Counselors, teachers, and school psychologists can design structured programs that teach coping skills, emotional regulation, mindful self-kindness, gratitude reflection, peer support, and help-seeking behaviors. Schools should also foster supportive classroom climates in which adolescents feel respected, connected, and psychologically safe. Family involvement is important, because perceived social support is strengthened when adolescents experience consistent encouragement and emotional availability at home. Practitioners should also use screening and early identification strategies to recognize adolescents with low resilience, low self-compassion, limited gratitude, or weak perceived support, because these students may be at greater risk for reduced psychological well-being and may benefit from targeted preventive interventions.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

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

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contributed to this article.

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