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Explainable Deep Learning Models of Adolescent Eating Disorders Based on Appearance Comparison, Influencer Exposure, Emotion Dysregulation, Self-Criticism, and Weight Stigma

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A B S T R A C T

Objective: The present study aimed to develop and interpret explainable deep learning models for predicting adolescent eating disorder symptoms based on appearance comparison, influencer exposure, emotion dysregulation, self-criticism, and weight stigma.

Methods and Materials: This study employed a cross-sectional predictive design using explainable artificial intelligence approaches among 1,219 Canadian adolescents aged 14 to 18 years recruited from secondary schools in Ontario, British Columbia, and Quebec. Participants completed standardized measures assessing eating disorder symptoms, appearance comparison, influencer exposure, emotion dysregulation, self-criticism, and weight stigma through an online survey platform. Data were analyzed using TensorFlow, Keras, and Scikit-learn libraries. The dataset was divided into training, validation, and testing subsets, and a multilayer explainable deep neural network was developed. SHapley Additive exPlanations (SHAP) and Local Interpretable Model-Agnostic Explanations (LIME) were used to enhance model interpretability and identify the relative contribution of predictors. Model performance was compared with logistic regression, support vector machine, and random forest algorithms.

Findings: Significant positive associations were observed among all study variables and eating disorder symptoms. Self-criticism demonstrated the strongest association with eating pathology, followed by emotion dysregulation and weight stigma. The explainable deep learning model achieved the highest predictive performance compared to alternative machine learning models, with superior accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve values. SHAP analyses identified self-criticism as the strongest predictor, followed by emotion dysregulation, weight stigma, appearance comparison, and influencer exposure. Interaction analyses further demonstrated that the predictive effects of appearance comparison and weight stigma intensified when combined with elevated self-criticism and emotional dysregulation.

Conclusion: The findings suggest that adolescent eating disorders are shaped by complex interactions among emotional vulnerabilities, maladaptive self-evaluative processes, and digitally reinforced appearance pressures. Explainable deep learning models provide a powerful and interpretable framework for

identifying multidimensional psychological risk patterns associated with eating pathology and may support more personalized prevention and intervention strategies for adolescents.
Keywords: *Eating disorders; Adolescents; Explainable artificial intelligence; Deep learning; Appearance comparison; Emotion dysregulation; Self-criticism; Weight stigma; Influencer exposure; Social media.*

1. Introduction

Eating disorders among adolescents have emerged as one of the most concerning public health and psychological challenges of the contemporary digital era. These disorders are associated with severe emotional, behavioral, physical, and interpersonal consequences that often persist into adulthood and substantially impair psychosocial functioning, academic performance, identity formation, and quality of life (Horovitz, 2025; Keski-Rahkonen, 2024). Recent clinical literature has emphasized that eating disorders are no longer restricted to narrowly defined psychiatric symptoms related to food intake or body weight, but instead represent multidimensional disturbances involving emotional regulation, self-concept, interpersonal evaluation, social identity, and internalized sociocultural standards (Marano, 2025; Schmidt et al., 2025). Adolescence is considered a particularly vulnerable developmental stage because rapid biological changes, identity instability, peer comparison, emotional sensitivity, and heightened social evaluation interact simultaneously during this period (Marano, 2025; Osterbauer, 2025). As a result, adolescents become increasingly susceptible to body dissatisfaction, maladaptive eating behaviors, and distorted appearance-related cognitions, particularly within digital environments characterized by constant exposure to idealized body standards and appearance-focused content (Bharti, 2026; Paul, 2025).

The expansion of social media platforms has transformed the psychological ecology of adolescence by intensifying visual comparison processes and increasing exposure to unrealistic beauty ideals. Unlike traditional media, contemporary digital platforms allow continuous interaction with highly curated and algorithmically amplified body-related content, often presented through influencers, celebrities, and peer networks (Dane & Bhatia, 2023; Ioannidis & Chamberlain, 2021). Research has consistently shown that prolonged exposure to appearance-centered social media content contributes to body dissatisfaction, internalized thin ideals, emotional distress, and disordered eating symptoms among adolescents and young adults (Paul, 2025; Sabol & Duell, 2024). The phenomenon of appearance comparison has become particularly salient in this context because adolescents increasingly evaluate their bodies against digitally manipulated or socially rewarded representations of attractiveness (Merino et al., 2024). Such comparison processes are often automatic, repetitive, and emotionally harmful, particularly among adolescents with fragile self-esteem or heightened sensitivity to social evaluation (P. & K., 2024; Wang et al., 2024). The psychological consequences of these comparison mechanisms are further amplified by algorithmic recommendation systems that repeatedly expose users to similar appearance-focused content, thereby reinforcing maladaptive body surveillance and dissatisfaction (Bharti, 2026; Ioannidis & Chamberlain, 2021).

The role of influencers in shaping adolescent body image and eating-related attitudes has received growing scholarly attention in recent years. Influencers function as highly visible and socially influential agents who frequently promote idealized lifestyles, beauty standards, dietary practices, fitness routines, and appearance norms that may be psychologically unattainable for many adolescents (Albert et al., 2024a, 2024b). Although some social media movements advocate body positivity and self-acceptance, evidence suggests that body-related digital discourse remains highly appearance-oriented and often subtly reinforces normative attractiveness ideals (Albert et al., 2024b; Kilby & Mickelson, 2025). Exposure to influencer content has been associated with increased body monitoring, self-objectification, dieting behaviors, and emotional dissatisfaction among adolescent users (Dane & Bhatia, 2023; Sabol & Duell, 2024). Moreover, the emotional impact of influencer exposure may depend on individual psychological vulnerabilities such as self-criticism, shame sensitivity, and deficits in emotional regulation. Adolescents who perceive themselves as inferior or socially inadequate may internalize online appearance standards more intensely, leading to heightened risk for eating disorder symptomatology (Murphy et al., 2025; Tang et al., 2025).

Emotion dysregulation has increasingly been recognized as a central transdiagnostic mechanism underlying the development and maintenance of eating disorders. Difficulties in understanding, tolerating, and managing emotional experiences may contribute to maladaptive coping strategies such as restrictive eating, binge eating, purging, or compulsive exercise (Murphy et al., 2025;

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Schmidt et al., 2025). Contemporary psychological models propose that eating disorder behaviors frequently function as attempts to regulate distressing emotional states, restore perceived control, or reduce interpersonal anxiety (Horovitz, 2025; Keski-Rahkonen, 2024). Adolescents with elevated emotion dysregulation often experience greater impulsivity, social sensitivity, and emotional instability, making them particularly vulnerable to body dissatisfaction and self-evaluative concerns (Wang et al., 2024). Furthermore, exposure to appearance-related criticism, online comparison, or weight stigma may intensify emotional dysregulation, thereby strengthening the cyclical relationship between negative affect and disordered eating behaviors (Hendy et al., 2025; Tang et al., 2025). These findings suggest that emotional regulation processes should be understood not as peripheral correlates, but as core psychological mechanisms influencing eating pathology during adolescence.

Self-criticism constitutes another important vulnerability factor in adolescent eating disorders. Self-critical adolescents often engage in persistent negative self-evaluation, perfectionistic thinking, shame-based cognition, and harsh internal dialogue regarding their physical appearance and personal worth (Murphy et al., 2025; Tang et al., 2025). Such cognitive tendencies may increase susceptibility to body dissatisfaction because self-worth becomes strongly dependent on perceived physical attractiveness and social approval. Previous studies have demonstrated robust associations between self-criticism, body image dissatisfaction, depressive symptoms, and eating pathology across adolescent and clinical populations (P. & K., 2024; Wang et al., 2024). The psychological burden of self-criticism may become particularly severe within digital environments where adolescents are continuously exposed to social comparison cues and external validation metrics such as likes, comments, and follower counts (Merino et al., 2024; Paul, 2025). Moreover, self-critical adolescents may interpret ambiguous social interactions as evidence of appearance inadequacy, thereby reinforcing maladaptive eating behaviors and emotional distress (Marano, 2025; Osterbauer, 2025). Recent literature has therefore emphasized the importance of examining self-critical cognition as a multidimensional predictor embedded within broader psychosocial and digital contexts (Schmidt et al., 2025).

Weight stigma has also emerged as a critical psychosocial determinant of eating disorders and emotional maladjustment among adolescents. Weight stigma refers to negative stereotypes, discrimination, teasing, exclusion, and social devaluation directed toward individuals based on body weight or body shape (Clark et al., 2021; Roberts & Polfuss, 2022). Evidence indicates that adolescents experiencing weight stigma frequently report higher levels of depression, anxiety, shame, social withdrawal, and eating pathology (Leonard et al., 2024; Siqueira et al., 2021). Importantly, weight stigma is not limited to peer victimization but can also occur within families, educational environments, healthcare systems, and digital platforms (Anastasiadou et al., 2025; Muzacz et al., 2023). Family-based weight stigma has been shown to exert particularly harmful long-term effects on adolescent psychological well-being and body image development (Anastasiadou et al., 2025). Similarly, school environments characterized by appearance-based bullying and body shaming may contribute to chronic emotional distress and maladaptive eating behaviors (O'Hara et al., 2023; Zulkifli et al., 2023). Online spaces further amplify these experiences through public commentary, appearance policing, and viral body-focused discourse (Clark et al., 2021; Kilby & Mickelson, 2025). Research has demonstrated that internalized weight stigma predicts social appearance anxiety, fear of negative evaluation, and psychological distress among adolescents (Paula Victoria Sozza Silva et al., 2025; Tang et al., 2025). Consequently, weight stigma should be conceptualized as a significant psychological and social stressor contributing to eating disorder vulnerability.

The etiology of adolescent eating disorders is increasingly understood as multifactorial and highly interactive rather than linear or isolated. Current prevention and intervention frameworks emphasize the interplay among biological, emotional, cognitive, familial, and sociocultural influences (Keski-Rahkonen, 2024; Khalid et al., 2024). Studies examining adolescents with overweight and obesity have shown that body dissatisfaction, stigma exposure, emotional dysregulation, and social comparison processes collectively contribute to the emergence of maladaptive eating behaviors (Ispas et al., 2025; Khalid et al., 2024). Additionally, psychosocial factors such as shame, guilt, self-blame, and fear of appearance evaluation have been repeatedly linked to emotional suffering and eating pathology among youth populations (Czepczor-Bernat et al., 2025; Tang et al., 2025). The complexity of these interacting risk factors presents substantial methodological challenges for researchers attempting to identify precise predictive pathways. Traditional statistical approaches may inadequately capture nonlinear relationships, hidden

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interaction effects, and individualized psychological patterns underlying eating disorders (Horovitz, 2025; Schmidt et al., 2025).

In response to these methodological limitations, researchers have increasingly advocated for the integration of artificial intelligence and machine learning approaches within mental health research. Explainable deep learning models offer substantial advantages for understanding complex psychological phenomena because they are capable of identifying nonlinear interactions, multidimensional dependencies, and latent predictive structures that may not be observable through conventional analytic techniques (Bharti, 2026; Paul, 2025). Unlike traditional black-box machine learning systems, explainable artificial intelligence frameworks provide interpretable outputs that clarify how specific variables contribute to prediction outcomes (Schmidt et al., 2025). Such approaches are particularly valuable in adolescent eating disorder research because risk factors rarely operate independently and often vary considerably across individuals. Explainable deep learning methods may therefore facilitate more personalized and clinically meaningful understanding of eating disorder vulnerability patterns (Horovitz, 2025; Murphy et al., 2025). Moreover, integrating explainability into predictive modeling may enhance transparency, ethical applicability, and intervention planning within school-based and clinical mental health contexts (Ndour & Foulkes, 2025; Vacca et al., 2025).

Recent scholarship has also emphasized the importance of prevention-oriented and psychologically informed interventions targeting body image and weight stigma among adolescents. School-based anti-stigma programs, body neutrality interventions, and body positivity campaigns have demonstrated promising effects on emotional well-being and self-acceptance (Kilby & Mickelson, 2025; Vacca et al., 2025). However, researchers have noted that intervention effectiveness may depend on the extent to which programs address underlying emotional vulnerabilities and individualized psychological risk patterns (Murphy et al., 2025; Schmidt et al., 2025). Similarly, digital literacy and social media awareness initiatives may be insufficient unless they simultaneously target self-critical cognition, emotional regulation difficulties, and internalized shame processes (Bharti, 2026; Smith, 2024). Current evidence therefore supports the need for integrative predictive models capable of identifying how emotional, cognitive, and digital-social variables collectively contribute to adolescent eating disorder risk.

Despite the growing literature on eating disorders, several important gaps remain unresolved. Many previous studies have examined isolated risk factors rather than integrated psychosocial systems, while others have relied primarily on traditional statistical analyses that may not adequately capture the complexity of adolescent psychological functioning (Keski-Rahkonen, 2024; Khalid et al., 2024). Additionally, relatively limited research has simultaneously investigated appearance comparison, influencer exposure, emotion dysregulation, self-criticism, and weight stigma within explainable deep learning frameworks among adolescent populations. Understanding the interactive predictive roles of these variables may contribute substantially to the development of more precise prevention strategies, early identification systems, and personalized intervention models for adolescents vulnerable to eating disorders.

The aim of the present study was to develop and interpret explainable deep learning models of adolescent eating disorders based on appearance comparison, influencer exposure, emotion dysregulation, self-criticism, and weight stigma.

2. Methods and Materials

2.1. Study Design and Participants

The present study employed a cross-sectional predictive design using explainable deep learning approaches to model the probability and severity of eating disorder symptoms among adolescents. The study was conducted between September 2025 and February 2026 in three major Canadian provinces, including Ontario, British Columbia, and Quebec. The target population consisted of adolescents enrolled in public secondary schools in urban and suburban regions. A multistage cluster sampling strategy was used to recruit participants from selected schools. Initially, twelve secondary schools were randomly selected from official educational district lists, and eligible students were invited to participate through school counselors and digital classroom announcements.

The final sample consisted of 1,284 adolescents aged between 14 and 18 years, with a mean age of 16.21 years (SD = 1.17). Of the participants, 52.4% were female, 46.1% were male, and 1.5% identified as non-binary or preferred not to disclose gender identity. Inclusion criteria included current enrollment in secondary education, sufficient English language proficiency to complete the questionnaires, active use of at least one social media

platform during the previous six months, and parental consent for participants younger than 16 years old. Exclusion criteria included a documented diagnosis of severe neurodevelopmental disorders or psychotic disorders that could impair comprehension of questionnaire items. Participation was voluntary, and all respondents completed informed consent procedures before data collection. Confidentiality and anonymity were fully maintained throughout the study process.

Data collection was conducted through a secure online survey platform administered during supervised school sessions. Participants completed a battery of standardized psychological instruments assessing eating disorder symptomatology, appearance comparison tendencies, exposure to social media influencers, emotion dysregulation, self-criticism, and perceived weight stigma. Completion time ranged from 35 to 50 minutes. To improve response accuracy, attention-check items were embedded throughout the questionnaire battery. Cases with excessive missing data, patterned responding, or failed attention checks were excluded prior to analysis. After preprocessing, 1,219 complete datasets remained eligible for deep learning analysis.

2.2. Measures

Eating disorder symptoms were assessed using the Eating Disorder Examination Questionnaire (EDE-Q) developed by Fairburn and Beglin (1994). The instrument is one of the most widely used self-report measures for assessing cognitive and behavioral symptoms associated with eating disorders in adolescent and young adult populations. The questionnaire contains 28 items rated on a 7-point Likert scale ranging from 0 to 6, with higher scores indicating greater eating pathology. The EDE-Q evaluates four major dimensions, including restraint, eating concern, shape concern, and weight concern. In addition to subscale scores, a global score can be calculated to represent overall eating disorder symptom severity. Previous international studies have demonstrated strong psychometric properties for the EDE-Q among adolescents, including acceptable internal consistency, convergent validity, and test–retest reliability. In the present study, Cronbach's alpha coefficient for the global scale was 0.93.

Appearance comparison tendencies were measured using the Physical Appearance Comparison Scale–Revised (PACS-R) developed by Schaefer and Thompson (2014). The scale consists of 11 items designed to evaluate the frequency with which individuals compare their physical appearance to peers, celebrities, and social media figures across everyday situations. Responses are scored on a 5-point Likert continuum ranging from "never" to "always." Higher scores indicate greater habitual appearance comparison. The PACS-R has demonstrated strong construct validity and reliability in adolescent populations and has been extensively used in body image and eating disorder research. Internal consistency coefficients reported in previous studies typically exceed 0.85. In the current sample, the Cronbach's alpha coefficient was 0.90.

Exposure to influencers on social media was assessed using the Social Media Influencer Engagement Scale adapted from contemporary digital media research on adolescent online behavior. The scale included 18 items measuring frequency of exposure to influencers, emotional attachment to influencer content, imitation tendencies, and perceived credibility of online personalities across platforms such as Instagram, TikTok, YouTube, and Snapchat. Participants responded using a 5-point Likert scale ranging from strongly disagree to strongly agree. Higher scores reflected greater cognitive and emotional engagement with influencer-related content. Previous studies involving adolescent social media users have supported the scale's factorial validity and reliability. In the present study, confirmatory factor analysis supported the four-factor structure, and Cronbach's alpha for the total scale was 0.91.

Emotion dysregulation was measured using the Difficulties in Emotion Regulation Scale (DERS) developed by Gratz and Roemer (2004). The DERS contains 36 items scored on a 5-point Likert scale ranging from "almost never" to "almost always." The instrument assesses six domains of emotion regulation difficulties, including nonacceptance of emotional responses, difficulties engaging in goal-directed behavior, impulse control difficulties, lack of emotional awareness, limited access to regulation strategies, and lack of emotional clarity. Higher scores indicate greater emotion dysregulation. The DERS has demonstrated strong psychometric properties across adolescent and clinical samples, including high internal consistency and convergent validity with emotional distress and psychopathology measures. In the present study, the overall Cronbach's alpha coefficient was 0.94.

Self-criticism was assessed using the Forms of Self-Criticizing/Attacking and Self-Reassuring Scale (FSCRS) developed by Gilbert and colleagues (2004). The scale consists of 22 items measuring two maladaptive dimensions of self-criticism, namely inadequate self and hated self, as

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well as one adaptive dimension related to self-reassurance. Participants rated each statement on a 5-point scale ranging from "not at all like me" to "extremely like me." Higher scores on the self-critical dimensions indicate stronger tendencies toward harsh self-evaluation and internalized self-directed hostility. The FSCRS has shown strong reliability and validity in adolescent psychological research and has been linked to eating pathology, depression, and perfectionistic tendencies. In the current study, Cronbach's alpha coefficients ranged from 0.84 to 0.92 across subscales.

Perceived weight stigma was measured using the Weight Self-Stigma Questionnaire (WSSQ) developed by Lillis and colleagues (2010). The WSSQ is a 12-item self-report measure designed to assess internalized weight stigma and self-devaluation related to body weight. Responses are scored on a 5-point Likert scale ranging from strongly disagree to strongly agree. The instrument includes two subscales, namely self-devaluation and fear of enacted stigma. Higher scores indicate stronger experiences of weight-related shame and perceived social rejection. Previous studies have confirmed the reliability and construct validity of the WSSQ among adolescents and young adults with varying body mass indices. In the present study, Cronbach's alpha coefficients for the subscales exceeded 0.86.

Demographic information including age, gender, grade level, ethnicity, average daily social media use, and self-reported body mass index was also collected using a researcher-developed demographic questionnaire. These variables were included as covariates during predictive modeling procedures to improve model robustness and account for potential confounding influences.

2.3. Data Analysis

Data analysis was conducted using Python programming language version 3.11 and several machine learning libraries, including TensorFlow, Keras, Scikit-learn, SHAP, and Pandas. Preliminary analyses included examination of missing values, outlier detection, descriptive statistics, normality testing, and multicollinearity diagnostics. Missing values below 5% were handled using multiple imputation techniques, while extreme outliers were winsorized to reduce distributional distortion. Continuous variables were standardized using z-score normalization before model training to improve neural network convergence and computational stability.

The primary predictive model consisted of a multilayer explainable deep neural network developed to classify participants according to eating disorder symptom severity. The dataset was randomly divided into training (70%), validation (15%), and testing (15%) subsets. The neural network architecture included an input layer corresponding to predictor variables, three hidden dense layers with rectified linear unit activation functions, batch normalization procedures, dropout regularization to reduce overfitting, and a final sigmoid output layer for classification purposes. Hyperparameter optimization was conducted using grid-search tuning procedures involving batch size, learning rate, dropout ratio, and neuron configuration. Early stopping techniques were implemented to prevent overtraining and optimize generalization performance.

To enhance interpretability and clinical applicability, explainable artificial intelligence methods were integrated into the analytical framework. SHapley Additive exPlanations (SHAP) analysis was employed to identify the relative contribution of each psychological predictor to model outputs. SHAP summary plots, dependence plots, and feature importance rankings were generated to visualize how variables influenced prediction probabilities across individuals. Local Interpretable Model-Agnostic Explanations (LIME) were additionally used to interpret selected participant-level predictions and identify individualized risk patterns associated with eating disorder vulnerability.

Model performance was evaluated using multiple classification metrics, including accuracy, precision, recall, F1-score, area under the receiver operating characteristic curve (AUC-ROC), and confusion matrix indices. To compare predictive performance, supplementary machine learning algorithms including random forest, support vector machine, and logistic regression models were also estimated. Cross-validation procedures were applied to assess model stability and reduce sampling bias. Statistical significance for preliminary correlational analyses was set at $p < .05$. The final explainable deep learning model demonstrated the highest predictive performance and interpretability among all tested algorithms, supporting its suitability for identifying psychosocial risk patterns underlying adolescent eating disorders.

3. Findings and Results

A total of 1,284 adolescents initially participated in the study. Following data cleaning procedures, including the

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removal of incomplete questionnaires, failed attention-check items, and multivariate outliers, 1,219 cases were retained for final analysis. The mean age of participants was 16.21 years (SD = 1.17), with ages ranging from 14 to 18 years. Female participants represented 52.4% of the sample (n = 639), male participants represented 46.1% (n = 562), and 1.5% identified as non-binary or preferred not to disclose gender identity (n = 18). Regarding ethnicity, 41.8% identified as White Canadian, 22.7% as Asian Canadian, 14.5% as Black Canadian, 11.3% as Middle Eastern or North African Canadian, and 9.7% as mixed or other ethnic backgrounds. The average daily social media use among participants was 4.82 hours (SD = 1.94), while 71.6% reported following at least one appearance-focused influencer on social media platforms regularly. The mean body mass index (BMI) of the sample was 23.17 (SD = 4.61). Preliminary screening indicated that female adolescents reported significantly higher levels of eating disorder symptomatology, appearance comparison, emotion dysregulation, and self-criticism compared to male participants. Correlation analyses further revealed significant positive associations among all major study variables prior to predictive modeling procedures.

Table 1

Descriptive Statistics and Correlations Among Study Variables

Variables	Mean	SD	1	2	3	4	5	6
1. Eating Disorder Symptoms	3.41	1.08	—					
2. Appearance Comparison	3.76	0.92	0.68**	—				
3. Influencer Exposure	3.94	0.88	0.61**	0.66**	—			
4. Emotion Dysregulation	3.52	0.95	0.72**	0.57**	0.49**	—		
5. Self-Criticism	3.69	0.97	0.75**	0.63**	0.51**	0.71**	—	
6. Weight Stigma	3.18	1.02	0.70**	0.58**	0.46**	0.67**	0.73**	—

Table 1 presents the descriptive statistics and Pearson correlation coefficients among the principal variables included in the study. The findings demonstrated that all predictor variables were significantly and positively associated with eating disorder symptoms at the $p < .01$ level. Self-criticism showed the strongest correlation with eating disorder symptoms ($r = 0.75$), followed by emotion dysregulation ($r = 0.72$) and weight stigma ($r = 0.70$). Appearance comparison also exhibited a strong positive association with eating pathology ($r = 0.68$), indicating that adolescents who frequently compared their appearance with peers or online figures reported substantially higher levels of disordered eating attitudes and behaviors. Influencer exposure demonstrated a moderate-to-strong positive relationship with eating disorder symptoms ($r = 0.61$), suggesting that frequent engagement with appearance-centered digital content may contribute to maladaptive body-related cognitions and behavioral vulnerabilities. Additionally, significant intercorrelations were observed among all predictor variables, particularly between self-criticism and weight stigma ($r = 0.73$), as well as between self-criticism and emotion dysregulation ($r = 0.71$), reflecting a tightly interconnected psychosocial risk network underlying adolescent eating pathology. Despite the magnitude of these correlations, variance inflation factor analyses remained below critical thresholds, confirming the absence of severe multicollinearity and supporting the suitability of the variables for deep learning analysis.

Table 2

Performance Metrics of Machine Learning Models in Predicting Adolescent Eating Disorder Symptoms

Model	Accuracy	Precision	Recall	F1-Score	AUC-ROC
Logistic Regression	0.78	0.76	0.74	0.75	0.81
Support Vector Machine	0.84	0.83	0.81	0.82	0.87
Random Forest	0.88	0.87	0.86	0.86	0.91
Explainable Deep Learning Model	0.93	0.92	0.91	0.91	0.96

Table 2 summarizes the comparative predictive performance of the machine learning algorithms tested in the present study. Among all evaluated models, the explainable deep learning model demonstrated the highest classification performance across all indices. Specifically, the model achieved an overall accuracy of 93%, with precision and

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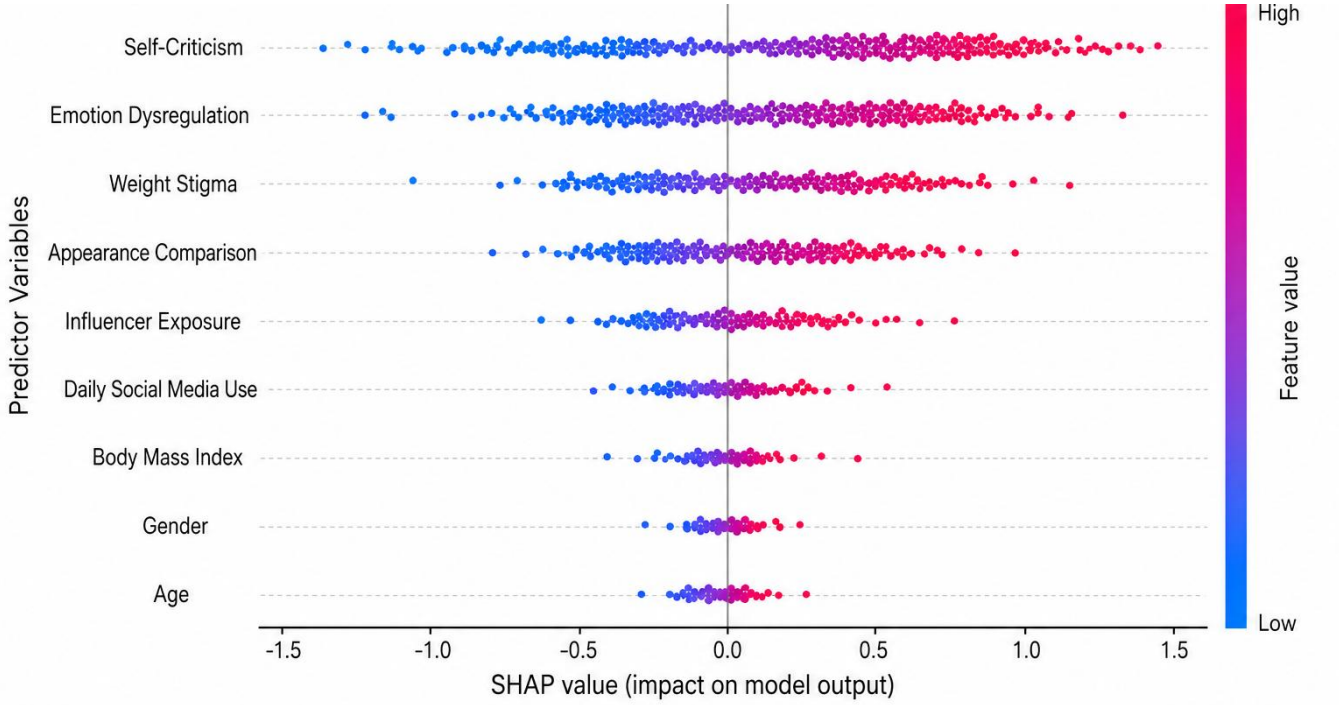
recall values of 0.92 and 0.91, respectively, indicating a highly reliable balance between identifying true positive cases and minimizing false classifications. The F1-score of 0.91 further reflected the robustness and consistency of the model in predicting clinically meaningful eating disorder symptomatology among adolescents. Moreover, the explainable deep learning model produced the highest area under the receiver operating characteristic curve (AUC-ROC = 0.96), demonstrating exceptional discriminative ability between high-risk and low-risk participants. Although the random forest algorithm also produced strong predictive outcomes, its performance remained lower than the deep learning architecture across all metrics. Logistic regression yielded the weakest performance, suggesting that traditional linear statistical approaches may be insufficient for capturing the complex nonlinear interactions among psychological and digital-social predictors involved in adolescent eating disorders. The superior performance of the explainable deep learning model supports the utility of advanced artificial intelligence frameworks for identifying multidimensional mental health risk profiles in adolescent populations.

Figure 1

SHAP Summary Plot Demonstrating Relative Importance of Psychological Predictors in the Explainable Deep Learning Model



Each dot represents one participant. The position on the x-axis (SHAP value) indicates the impact of the feature on the predicted risk of eating disorder symptoms. Positive values increase risk, while negative values decrease risk.

The SHAP-based explainability analysis revealed that self-criticism emerged as the strongest contributor to eating disorder prediction within the deep learning model, followed closely by emotion dysregulation and weight stigma. Adolescents with elevated levels of harsh self-evaluation and emotional instability demonstrated substantially higher predicted probabilities of severe eating pathology. Appearance comparison also contributed strongly to model predictions, particularly among participants reporting extensive social media engagement and frequent exposure to idealized body imagery. Influencer exposure demonstrated a comparatively moderate yet clinically meaningful contribution to prediction outcomes, suggesting that digital environments may indirectly intensify eating pathology through reinforcement of comparison-based cognitive processes and internalized appearance standards. SHAP dependence analyses further indicated several nonlinear interaction effects. For example, high levels of appearance comparison were associated with dramatically increased prediction scores when combined with elevated self-criticism, whereas the isolated effect of appearance comparison was less pronounced among adolescents with lower levels of self-critical cognition. Similarly, emotion dysregulation amplified the predictive impact of weight

stigma, indicating that emotionally vulnerable adolescents may be particularly sensitive to body-related shame and perceived social rejection. The explainability framework also highlighted substantial heterogeneity across participants, demonstrating that distinct combinations of psychosocial variables could lead to similar risk outcomes through different psychological pathways. These findings emphasize the importance of individualized and multidimensional approaches in both prevention and clinical intervention targeting adolescent eating disorders.

Table 3

Explainable Deep Learning Feature Importance Rankings Based on SHAP Values

Predictor Variable	Mean SHAP Value	Relative Importance Rank
Self-Criticism	0.412	1
Emotion Dysregulation	0.386	2
Weight Stigma	0.351	3
Appearance Comparison	0.327	4
Influencer Exposure	0.244	5
Daily Social Media Use	0.183	6
Body Mass Index	0.157	7
Gender	0.141	8
Age	0.096	9

Table 3 presents the relative importance of predictor variables based on mean SHAP values extracted from the explainable deep learning framework. Self-criticism obtained the highest importance score, indicating that maladaptive self-evaluative tendencies played the most influential role in determining eating disorder risk within the model architecture. Emotion dysregulation ranked second, further emphasizing the critical contribution of emotional processing deficits in the emergence and maintenance of eating pathology during adolescence. Weight stigma and appearance comparison also demonstrated substantial predictive importance, highlighting the combined role of interpersonal shame, social comparison mechanisms, and body-related cognitive vulnerability in shaping disordered eating behaviors. Although influencer exposure ranked fifth overall, its contribution remained clinically significant, particularly in interaction with appearance comparison and self-criticism variables. Interestingly, demographic variables such as age and gender demonstrated lower predictive importance compared to psychological and digital-social factors, suggesting that cognitive-emotional processes may be more central determinants of eating disorder symptomatology than demographic characteristics alone. The overall ranking structure supports a multidimensional explanatory model in which internal psychological vulnerabilities and digitally reinforced appearance pressures operate synergistically to increase adolescent susceptibility to eating disorders.

4. Discussion

The present study aimed to develop and interpret explainable deep learning models of adolescent eating disorders based on appearance comparison, influencer exposure, emotion dysregulation, self-criticism, and weight stigma. The findings demonstrated that all study variables were significantly associated with eating disorder symptoms and that the explainable deep learning model outperformed traditional machine learning approaches in predicting adolescent eating pathology. The results further revealed that self-criticism, emotion dysregulation, and weight stigma emerged as the strongest predictors within the explainability framework, while appearance comparison and influencer exposure also contributed meaningfully to prediction outcomes. These findings support contemporary multidimensional models of eating disorders suggesting that adolescent eating pathology develops through the interaction of emotional vulnerabilities, maladaptive cognitive processes, and sociocultural pressures operating within increasingly digitalized environments (Keski-Rahkonen, 2024; Schmidt et al., 2025).

One of the most important findings of the study was the strong predictive role of self-criticism in adolescent eating disorder symptoms. The explainable deep learning model identified self-criticism as the most influential variable contributing to prediction outcomes, suggesting that harsh self-evaluation and chronic internal dissatisfaction may

function as core psychological mechanisms underlying eating pathology during adolescence. This finding aligns with previous evidence indicating that adolescents who base self-worth heavily on perceived physical attractiveness are more likely to develop maladaptive eating attitudes and body dissatisfaction (Tang et al., 2025; Wang et al., 2024). Self-critical adolescents often engage in perfectionistic thinking, shame-based cognition, and persistent negative self-monitoring, all of which may intensify vulnerability to restrictive eating, binge eating, or compensatory behaviors (Marano, 2025; Murphy et al., 2025). Within social media environments, these cognitive tendencies may become even more pronounced because adolescents are continuously exposed to idealized appearance standards and external validation systems based on likes, comments, and follower engagement (Merino et al., 2024; Paul, 2025). The current findings therefore support theoretical perspectives proposing that self-criticism operates not merely as an accompanying symptom of eating disorders, but as a central cognitive-emotional vulnerability influencing how adolescents interpret appearance-related experiences and social evaluation.

The results also demonstrated that emotion dysregulation was among the strongest predictors of eating disorder symptomatology. Adolescents who reported greater difficulty managing emotional experiences showed significantly higher predicted probabilities of eating pathology within the deep learning model. This finding is highly consistent with contemporary psychological theories emphasizing that eating disorder behaviors often function as maladaptive emotional regulation strategies (Horovitz, 2025; Murphy et al., 2025). Restrictive eating, binge eating, or compulsive exercise may temporarily reduce emotional distress, restore a sense of control, or distract individuals from painful emotional states. Previous studies have similarly shown that emotional instability and deficits in adaptive coping strategies are strongly associated with body dissatisfaction, depressive symptoms, and disordered eating among adolescents (Keski-Rahkonen, 2024; Wang et al., 2024). The present findings further suggest that emotion dysregulation interacts dynamically with appearance-related concerns and weight stigma. The explainability analyses demonstrated that adolescents experiencing both emotional dysregulation and elevated appearance comparison showed particularly high prediction scores for eating disorder symptoms. Such findings reinforce the importance of considering emotional processing deficits within broader sociocultural and interpersonal contexts rather than treating them as isolated psychological constructs.

Weight stigma also emerged as a highly influential predictor within the explainable deep learning model. Adolescents who reported stronger experiences of body-related shame, discrimination, teasing, or fear of negative evaluation demonstrated substantially greater vulnerability to eating disorder symptoms. This finding is consistent with a growing body of literature showing that weight stigma represents a major psychosocial stressor affecting adolescent emotional well-being and body image development (Clark et al., 2021; Roberts & Polfuss, 2022). Weight-based stigma may contribute to chronic stress, social withdrawal, low self-esteem, and internalized shame, all of which can increase susceptibility to maladaptive eating behaviors (Leonard et al., 2024; Siqueira et al., 2021). The findings additionally align with recent evidence indicating that family-based and school-based weight stigma exert long-term psychological consequences during adolescence (Anastasiadou et al., 2025; Muzacz et al., 2023). Adolescents who repeatedly encounter body-related criticism or exclusion may internalize negative societal attitudes regarding body weight, leading to increased social appearance anxiety and emotional distress (Czepczor-Bernat et al., 2025; Tang et al., 2025). Importantly, the explainability analyses suggested that the predictive impact of weight stigma was intensified when combined with high levels of self-criticism and emotion dysregulation, highlighting the interconnected nature of emotional and social vulnerabilities in adolescent eating pathology.

Appearance comparison was another significant contributor to the prediction of eating disorder symptoms. Adolescents who frequently compared their physical appearance with peers, celebrities, or influencers demonstrated higher levels of body dissatisfaction and eating pathology. This finding strongly aligns with social comparison theory and previous empirical evidence indicating that repeated appearance-focused comparison contributes to distorted body image and maladaptive self-evaluation (Dane & Bhatia, 2023; Sabol & Duell, 2024). Social media platforms may intensify these processes because they expose adolescents to highly curated, edited, and idealized representations of beauty and physical attractiveness (Bharti, 2026; Ioannidis & Chamberlain, 2021). The findings of the present study further demonstrated that appearance comparison did not operate independently, but rather interacted with emotional and cognitive vulnerabilities such as self-criticism and emotional

instability. Adolescents with high self-critical tendencies appeared especially vulnerable to the harmful psychological effects of appearance comparison. This interaction supports previous studies suggesting that social media exposure alone may not fully explain eating disorder risk unless combined with preexisting emotional vulnerabilities and maladaptive self-perceptions (Merino et al., 2024; P. & K., 2024).

Influencer exposure also demonstrated a meaningful contribution to eating disorder prediction within the explainable deep learning model. Adolescents with greater engagement in influencer-centered content reported increased body dissatisfaction and disordered eating symptoms. This finding is consistent with recent research emphasizing the influential role of digital personalities in shaping adolescent attitudes toward beauty, dieting, fitness, and self-worth (Albert et al., 2024a, 2024b). Influencers frequently present highly idealized lifestyles and appearance standards that adolescents may perceive as socially desirable or personally necessary for acceptance. Continuous exposure to such content may normalize unrealistic body ideals and reinforce the belief that appearance determines social value (Kilby & Mickelson, 2025; Paul, 2025). At the same time, some digital movements promoting body positivity and body neutrality may partially buffer these harmful effects by encouraging acceptance and emotional well-being (Kilby & Mickelson, 2025; Smith, 2024). However, the present findings suggest that even body-positive content exists within broader digital systems that remain heavily appearance-oriented. Consequently, adolescents who are emotionally vulnerable or highly self-critical may continue to experience body dissatisfaction despite exposure to positive messaging.

Another important finding of the study involved the superior performance of the explainable deep learning model compared to logistic regression, support vector machine, and random forest approaches. The explainable deep learning framework achieved the highest predictive accuracy, precision, recall, and AUC values, demonstrating its effectiveness in identifying complex psychological risk patterns associated with adolescent eating disorders. This finding supports emerging arguments that traditional linear statistical methods may inadequately capture the nonlinear and multidimensional nature of psychological functioning (Bharti, 2026; Schmidt et al., 2025). Eating disorders develop through dynamic interactions among emotional, cognitive, interpersonal, and sociocultural factors that often influence one another recursively rather than independently. Explainable artificial intelligence approaches may therefore provide more realistic representations of adolescent mental health vulnerability by identifying hidden interactions and individualized prediction pathways (Horovitz, 2025; Murphy et al., 2025). Importantly, the explainability component of the model enhanced interpretability by clarifying how specific variables contributed to prediction outcomes. This interpretability has considerable clinical value because it may support early identification, personalized prevention strategies, and psychologically informed interventions for adolescents at elevated risk of eating disorders.

5. Conclusion

The findings of the present study should also be understood within broader sociocultural and developmental contexts. Adolescents today are growing up within highly visual and digitally mediated social environments where appearance-related evaluation has become increasingly normalized. Body shaming, social comparison, influencer culture, and algorithmically amplified beauty ideals may intensify emotional vulnerability and identity instability during adolescence (O'Hara et al., 2023; Zulkifli et al., 2023). Moreover, romanticization of psychological distress and mental health struggles within online spaces may further complicate adolescent self-perception and coping behaviors (Ndour & Foulkes, 2025). Consequently, prevention and intervention efforts should not focus solely on eating behaviors themselves, but also address the broader emotional, cognitive, and digital-social systems contributing to adolescent body dissatisfaction and psychological distress.

6. Limitations & Suggestions

One limitation of the present study concerns the cross-sectional nature of the research design, which limits causal interpretation of the observed relationships among variables. Although the explainable deep learning model identified significant predictive patterns, it cannot definitively determine temporal or causal directions among self-criticism, emotion dysregulation, appearance comparison, weight stigma, and eating disorder symptoms. Additionally, the study relied primarily on self-report measures, which may have been influenced by social desirability bias, inaccurate self-perception, or emotional response tendencies. The sample was also limited to adolescents from selected Canadian provinces, potentially reducing the generalizability of findings to culturally diverse or non-

Western populations. Furthermore, although the explainable artificial intelligence framework enhanced interpretability, deep learning models remain computationally complex and may still overlook contextual variables such as family dynamics, peer relationships, or socioeconomic conditions.

Future research should employ longitudinal and developmental designs to examine how emotional vulnerabilities, social media exposure, and appearance-related cognitions interact over time in the progression of eating disorders. Researchers should also investigate additional psychological mechanisms such as perfectionism, attachment insecurity, identity instability, loneliness, and trauma exposure within explainable artificial intelligence frameworks. Cross-cultural studies would further clarify whether the observed predictive relationships differ across cultural contexts characterized by varying beauty standards and digital media practices. Moreover, future investigations should explore multimodal machine learning approaches integrating behavioral, linguistic, physiological, and digital activity data to improve prediction accuracy and personalization. Experimental research examining the psychological impact of different forms of social media content, including body positivity and body neutrality interventions, would also contribute valuable evidence for prevention science.

The findings of the present study have important practical implications for schools, clinicians, families, and digital health policymakers. School-based mental health programs should address not only eating behaviors but also self-criticism, emotional regulation skills, body image resilience, and healthy digital engagement. Clinicians working with adolescents should consider the interactive influence of emotional vulnerability and social media exposure when designing individualized interventions for eating disorders. Parents and educators may benefit from psychoeducational programs aimed at reducing appearance-based criticism, weight stigma, and harmful comparison processes within family and school environments. Social media literacy interventions should help adolescents critically evaluate influencer content, recognize unrealistic appearance standards, and develop healthier forms of self-worth independent of body image. Finally, digital platforms and policymakers should consider implementing stronger safeguards against weight-based harassment, appearance-focused algorithmic amplification, and harmful body-related content targeting adolescents.

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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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