

## Machine Learning–Based Prediction of Emotional Eating Patterns in Adolescents Using Psychological and Lifestyle Variables

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### ABSTRACT

**Objective:** This study aimed to develop and evaluate explainable machine learning models to predict emotional eating patterns among adolescents by integrating psychological distress indicators and lifestyle-related variables.

**Methods and Materials:** A cross-sectional, school-based study was conducted among adolescents aged 13–18 years in Poland. Participants completed validated self-report measures assessing emotional eating, perceived stress, depressive and anxiety symptoms, emotion regulation difficulties, impulsivity, self-esteem, sleep quality and duration, physical activity, screen time, and dietary habits, alongside sociodemographic information. Data were preprocessed using standardization, imputation, and encoding procedures. Multiple supervised machine learning algorithms, including regularized logistic regression, random forest, gradient boosting, and extreme gradient boosting, were trained and evaluated using nested cross-validation. Model performance was assessed using area under the receiver operating characteristic curve, accuracy, sensitivity, specificity, and F1-score. Explainable artificial intelligence techniques based on SHAP values were applied to interpret predictor contributions.

**Findings:** Ensemble-based machine learning models significantly outperformed linear models in predicting emotional eating, with extreme gradient boosting demonstrating the highest discriminative performance. Psychological variables, particularly perceived stress, emotion regulation difficulties, and depressive symptoms, showed the strongest positive associations with emotional eating risk, while poor sleep quality and higher impulsivity further increased predicted vulnerability. Protective effects were observed for higher self-esteem and greater physical activity. Explainability analyses revealed consistent directional effects across predictors and identified nonlinear interactions between psychological distress and lifestyle factors. Subgroup analyses indicated higher predictive accuracy among female adolescents compared to males.

**Conclusion:** Explainable machine learning models provide robust and interpretable tools for identifying adolescents at risk of emotional eating.

**Keywords:** Emotional eating; Adolescents; Machine learning; Psychological distress; Lifestyle factors; Explainable artificial intelligence

## 1. Introduction

Emotional eating has emerged as a critical behavioral and psychological phenomenon at the intersection of mental health, lifestyle, and nutrition science, particularly during adolescence, a developmental period marked by heightened emotional reactivity, identity formation, and vulnerability to maladaptive coping strategies. Emotional eating is commonly defined as the tendency to consume food in response to negative emotional states such as stress, anxiety, sadness, or boredom rather than physiological hunger cues, and it has been increasingly recognized as a transdiagnostic behavior associated with a wide range of psychological and physical health outcomes (Shriver et al., 2020; Wozniak & Huang, 2024). Over the past several decades, the global burden of obesity and diet-related non-communicable diseases has prompted intensified scholarly attention to the psychological determinants of eating behaviors, with emotional eating occupying a central role in contemporary models of obesity, food addiction, and disordered eating (Chew et al., 2025; Zhou et al., 2025). Bibliometric analyses demonstrate a sharp rise in publications linking emotional processes, eating behaviors, and metabolic health, reflecting a paradigm shift from purely nutritional explanations toward integrated biopsychosocial frameworks (Zhou et al., 2025).

Adolescence represents a particularly sensitive window for the development and consolidation of emotional eating patterns. Neurodevelopmental changes in reward sensitivity, emotion regulation systems, and executive functioning interact with expanding social demands and academic pressures, rendering adolescents especially susceptible to emotionally driven eating behaviors (Heshmati et al., 2022; Joseph et al., 2023). Empirical evidence consistently indicates that emotional eating is prevalent among adolescents across diverse cultural contexts, with notable associations with depressive symptoms, anxiety, stress exposure, and impaired emotion regulation capacities (Kidwell et al., 2024; Sánchez-Charcopa et al., 2025). Large-scale population studies conducted in Europe, Asia, and the Americas reveal that emotional eating is not only widespread but also socially patterned, varying by sex, socioeconomic status, and lifestyle characteristics such as sleep quality and physical activity (Calizaya-Milla et al., 2025; Ljubičić et al., 2023; Wardani et al., 2024).

Psychological distress has been repeatedly identified as a core driver of emotional eating in both adolescent and adult populations. Stress, whether arising from academic

demands, family dynamics, traumatic events, or broader societal disruptions, has shown a robust positive association with emotionally driven food consumption (Shah et al., 2023; Silva et al., 2025). Studies conducted during periods of collective stress, such as the COVID-19 pandemic or natural disasters, further underscore the sensitivity of eating behaviors to emotional and environmental stressors (Skolmowska et al., 2023; Toğuç & Hökelek, 2025). Depression and anxiety have likewise been implicated as key correlates of emotional eating, with evidence suggesting bidirectional relationships in which negative affect both precipitates and is reinforced by maladaptive eating patterns (Akkuş et al., 2024; Metin et al., 2024). These findings are consistent with affect regulation models proposing that food consumption serves as a short-term strategy for mood modulation, particularly in individuals with limited adaptive coping resources (Elran-Barak et al., 2021; Rossi, 2025).

Beyond individual psychopathology, emotional eating is embedded within broader psychosocial and lifestyle contexts. Family environment and parenting styles have been shown to shape children's emotional coping strategies and eating behaviors from early life onward, with permissive, authoritarian, or emotionally neglectful parenting patterns associated with higher emotional eating tendencies (Ay, 2021; González-Olmo et al., 2022). Lifestyle factors such as sleep duration, sleep quality, physical inactivity, and excessive screen time further interact with emotional states to influence eating behavior, particularly during adolescence when circadian rhythms are already biologically delayed (Akkuş et al., 2024; Sun et al., 2023). Nutritional patterns, including frequent consumption of ultra-processed foods, irregular breakfast intake, and high saturated fat consumption, have also been linked to emotional eating, creating a feedback loop between emotional dysregulation and poor dietary quality (Buja et al., 2022; Calizaya-Milla et al., 2025).

Importantly, emotional eating has been associated with adverse health outcomes extending beyond weight gain alone. Research indicates links with food addiction symptoms, body image distortion, reduced health-related quality of life, and increased cardiometabolic risk, underscoring its clinical and public health relevance (Akdeniz et al., 2024; Ijaz & Rehman, 2023; Şerban et al., 2025). Studies among adolescents and young adults demonstrate that emotional eating may serve as an early behavioral marker for later eating disorders or chronic weight-related conditions, highlighting the need for early identification and prevention (Mentzelou et al., 2025;

Mutiek et al., 2021). Moreover, emotional eating does not occur in isolation but often coexists with other maladaptive behaviors such as binge eating, impulsivity, and sedentary lifestyles, suggesting the presence of complex behavioral clusters rather than single risk factors (Marwood et al., 2025; Rossi, 2025).

Despite the growing body of literature, much of the existing research on adolescent emotional eating relies on traditional statistical approaches that assume linear relationships and examine predictors in isolation. While these methods have yielded valuable insights, they may be insufficient to capture the complex, nonlinear, and interactive nature of psychological and lifestyle determinants underlying emotional eating behaviors (Wozniak & Huang, 2024). Emotional eating is shaped by multiple interdependent variables, including emotional states, personality traits, behavioral habits, and sociodemographic factors, which may interact in dynamic and context-specific ways (Joseph et al., 2023; Kidwell et al., 2024). This complexity necessitates analytical approaches capable of modeling high-dimensional data and uncovering latent patterns that are not readily observable through conventional regression-based techniques.

Machine learning methods offer a powerful alternative for advancing the understanding and prediction of emotional eating in adolescents. By leveraging algorithms capable of handling nonlinear associations, complex interactions, and large numbers of predictors, machine learning enables more accurate risk stratification and individualized prediction compared to traditional models (Wu et al., 2023; Zhou et al., 2025). Recent applications of machine learning in nutritional psychology and behavioral health have demonstrated superior predictive performance in identifying at-risk individuals and uncovering novel predictor hierarchies, particularly when integrating psychological and lifestyle variables (Sánchez-Charcopa et al., 2025; Tan et al., 2025). However, the use of machine learning in adolescent emotional eating research remains limited, and few studies have systematically applied explainable machine learning techniques to elucidate the relative importance and directional influence of predictors.

Explainability is a critical consideration in the application of machine learning to psychological and clinical domains. While complex ensemble models often achieve high predictive accuracy, their “black-box” nature can limit interpretability and practical utility. Recent advances in explainable artificial intelligence, such as SHAP-based approaches, allow researchers to quantify the contribution of

individual variables to model predictions, thereby bridging the gap between predictive performance and theoretical interpretability (Rossi, 2025; Wozniak & Huang, 2024). Such approaches are particularly valuable in adolescent mental health research, where transparent identification of modifiable risk factors is essential for informing prevention strategies, school-based interventions, and public health policies (Jerzyk et al., 2024; Mentzelou et al., 2025).

The Polish context provides a compelling setting for examining emotional eating through a machine learning lens. Prior studies conducted among Polish adolescents and consumers have documented meaningful associations between stress exposure, emotional states, and food-related behaviors, suggesting culturally specific patterns alongside universal psychological mechanisms (Jerzyk et al., 2024; Skolmowska et al., 2023). However, no prior research has integrated a broad spectrum of psychological distress indicators and lifestyle behaviors into a unified machine learning framework to predict emotional eating risk among adolescents in Poland. Addressing this gap is particularly relevant given increasing concerns about adolescent mental health, sedentary lifestyles, and dietary transitions in Central and Eastern Europe (Ljubičić et al., 2023; Zhou et al., 2025).

In light of the multifactorial nature of emotional eating, the demonstrated limitations of traditional analytic approaches, and the growing availability of rich psychosocial data, there is a clear need for advanced predictive models that can simultaneously account for psychological vulnerabilities and lifestyle factors while remaining interpretable and clinically meaningful (Cuyan-Zumaeta et al., 2025; Heshmati et al., 2022). Integrating machine learning with established psychological theory holds promise for improving early detection of adolescents at heightened risk for emotional eating and for informing targeted, evidence-based interventions that address both emotional regulation and health-related behaviors (Elran-Barak et al., 2021; Pickett et al., 2020).

The aim of this study was to develop and evaluate explainable machine learning models to predict emotional eating patterns in Polish adolescents using an integrated set of psychological and lifestyle variables.

## 2. Methods and Materials

### 2.1. Study Design and Participants

This study employed a cross-sectional, school-based design aimed at developing and validating machine learning models to predict emotional eating patterns among

adolescents using a comprehensive set of psychological and lifestyle variables. The target population consisted of adolescents aged 13 to 18 years enrolled in lower and upper secondary schools across urban and semi-urban regions of Poland. A multistage cluster sampling strategy was used to enhance representativeness. In the first stage, public secondary schools were randomly selected from official regional education registries. In the second stage, intact classrooms within each selected school were randomly chosen, and all students in those classrooms were invited to participate. Inclusion criteria comprised being within the specified age range, current enrollment in the selected schools, and sufficient proficiency in Polish to comprehend the study instruments. Adolescents with diagnosed eating disorders, severe chronic medical conditions affecting appetite or metabolism, or current psychiatric treatment for major mood or psychotic disorders were excluded to avoid clinical confounding. Prior to data collection, written informed consent was obtained from parents or legal guardians, and assent was obtained from all participating adolescents.

## 2.2. Measures

Data were collected using a structured, self-administered questionnaire battery administered during regular school hours under the supervision of trained research assistants and school counselors. Emotional eating, which served as the primary outcome variable, was assessed using a validated adolescent-adapted emotional eating scale measuring the tendency to consume food in response to negative emotional states such as stress, sadness, anger, and boredom. Psychological predictor variables included perceived stress, depressive symptoms, anxiety symptoms, emotion regulation difficulties, self-esteem, and impulsivity, each measured using standardized psychometric instruments with established reliability and validity in adolescent populations and previously translated and validated for use in Polish samples. Lifestyle-related predictors encompassed sleep duration and sleep quality, physical activity frequency and intensity, daily screen time, social media use, and dietary habits such as breakfast consumption regularity and intake of ultra-processed foods. Anthropometric information, including self-reported height and weight, was collected to compute body mass index adjusted for age and sex. Additional sociodemographic variables, including age, sex, parental education, and perceived family socioeconomic status, were included as contextual covariates. To minimize

common method bias, participants were assured of confidentiality, instructed that there were no right or wrong answers, and encouraged to respond honestly based on their typical behaviors and feelings over the previous three months.

## 2.3. Data Analysis

Data analysis followed a rigorous multi-stage machine learning pipeline designed to maximize predictive accuracy while preserving interpretability. Initial preprocessing included inspection for missing values, outlier detection, and plausibility checks. Missing data were handled using multiple imputation with chained equations when the proportion of missingness was low and met the assumption of missing at random. Continuous variables were standardized to a common scale, while categorical variables were encoded using appropriate techniques such as one-hot encoding. The dataset was then randomly partitioned into training and testing subsets using an 80/20 split, with stratification based on emotional eating severity to preserve outcome distribution. Several supervised machine learning algorithms were trained and compared, including regularized logistic regression, random forest, gradient boosting machines, and extreme gradient boosting, selected for their ability to capture complex nonlinear relationships and interactions among psychological and lifestyle variables. Hyperparameter optimization was performed within the training set using nested cross-validation to prevent information leakage and overfitting. Model performance was evaluated on the independent test set using multiple metrics, including area under the receiver operating characteristic curve, accuracy, sensitivity, specificity, and F1-score. To enhance clinical and psychological interpretability, explainable machine learning techniques were applied, including feature importance rankings and SHAP values, to identify the most influential predictors of emotional eating risk. All analyses were conducted using Python-based machine learning libraries, and statistical significance of model performance differences was assessed using resampling-based methods. This integrative analytical approach allowed for both high predictive performance and meaningful insight into the psychological and lifestyle mechanisms underlying emotional eating in adolescents.

## 3. Findings and Results

The findings section is organized to first describe the characteristics of the study sample and key study variables,

followed by detailed reporting of machine learning model performance, predictor importance, and explainability analyses. Table 1 presents the descriptive statistics of

demographic, psychological, and lifestyle variables for the total sample, providing an empirical foundation for subsequent predictive modeling results.

**Table 1**

*Descriptive Characteristics of the Study Sample (N = 812)*

Variable	Mean (SD) / n (%)
Age (years)	15.6 (1.4)
Sex (female)	426 (52.5%)
Body Mass Index (BMI z-score)	0.42 (1.01)
Emotional Eating Score	2.91 (0.74)
Perceived Stress	18.3 (5.6)
Depressive Symptoms	14.7 (6.2)
Anxiety Symptoms	16.1 (5.9)
Emotion Regulation Difficulties	72.4 (15.8)
Self-Esteem	21.9 (4.7)
Impulsivity	31.2 (7.4)
Sleep Duration (hours/night)	7.1 (1.2)
Poor Sleep Quality	318 (39.2%)
Physical Activity ( $\geq 3$ days/week)	356 (43.8%)
Daily Screen Time (hours)	4.6 (1.9)
Daily Social Media Use (hours)	3.2 (1.6)
Skips Breakfast $\geq 3$ days/week	287 (35.3%)
High Ultra-Processed Food Intake	334 (41.1%)
Middle-to-Low Perceived SES	301 (37.1%)

As shown in Table 1, the sample consisted of a balanced distribution of male and female adolescents with a mean age in mid-adolescence. Emotional eating scores demonstrated substantial variability, supporting their suitability for predictive modeling. Psychological distress indicators, particularly perceived stress, anxiety, and emotion

regulation difficulties, showed moderate-to-high mean levels, while lifestyle characteristics reflected widespread sleep insufficiency, high screen exposure, and irregular dietary habits. These patterns suggest a multifactorial risk environment for emotional eating behaviors in Polish adolescents.

**Table 2**

*Predictive Performance of Machine Learning Models for Emotional Eating Classification*

Model	AUC	Accuracy	Sensitivity	Specificity	F1-Score
Regularized Logistic Regression	0.74	0.71	0.69	0.73	0.70
Random Forest	0.81	0.78	0.80	0.76	0.78
Gradient Boosting Machine	0.84	0.81	0.83	0.79	0.81
Extreme Gradient Boosting (XGBoost)	0.87	0.84	0.86	0.82	0.84

Table 2 indicates that ensemble-based models substantially outperformed the regularized logistic regression approach. The extreme gradient boosting model achieved the highest discriminative power, with an area under the curve of 0.87 and balanced sensitivity and

specificity. These findings indicate that nonlinear interactions among psychological and lifestyle variables play a critical role in predicting emotional eating patterns, which are more effectively captured by advanced ensemble algorithms.

**Table 3**

*Top Ten Predictors of Emotional Eating Identified by the Best-Performing Model*

Rank	Predictor Variable	Relative Importance
1	Perceived Stress	0.18
2	Emotion Regulation Difficulties	0.16
3	Depressive Symptoms	0.13
4	Sleep Quality	0.11
5	Impulsivity	0.10
6	Anxiety Symptoms	0.09
7	Daily Screen Time	0.08
8	Self-Esteem	0.06
9	Breakfast Skipping	0.05
10	Physical Activity Frequency	0.04

As presented in Table 3, psychological variables dominated the predictive hierarchy, with perceived stress and emotion regulation difficulties emerging as the most influential predictors of emotional eating. Lifestyle factors such as sleep quality and screen time also demonstrated

meaningful contributions, whereas sociodemographic variables showed comparatively weaker predictive value. This pattern underscores the central role of emotional and self-regulatory processes in adolescent eating behaviors.

**Table 4**

*Direction and Strength of Associations Based on SHAP Value Analysis*

Predictor	Direction of Effect	Interpretive Summary
High Perceived Stress	Positive	Higher stress increased emotional eating risk
Poor Emotion Regulation	Positive	Greater dysregulation predicted higher risk
Depressive Symptoms	Positive	Elevated symptoms associated with increased eating
Poor Sleep Quality	Positive	Sleep problems amplified emotional eating
High Impulsivity	Positive	Impulsive traits increased vulnerability
High Self-Esteem	Negative	Protective against emotional eating
Regular Physical Activity	Negative	Reduced probability of emotional eating
Lower Screen Time	Negative	Associated with lower risk

Table 4 provides a nuanced interpretation of predictor effects derived from SHAP values. Higher levels of stress, emotional dysregulation, depressive symptoms, and poor sleep quality consistently shifted model predictions toward

greater emotional eating risk. In contrast, protective factors such as higher self-esteem and regular physical activity exerted negative effects on predicted risk, highlighting potential targets for prevention and intervention.

**Table 5**

*Subgroup Differences in Model Performance by Sex*

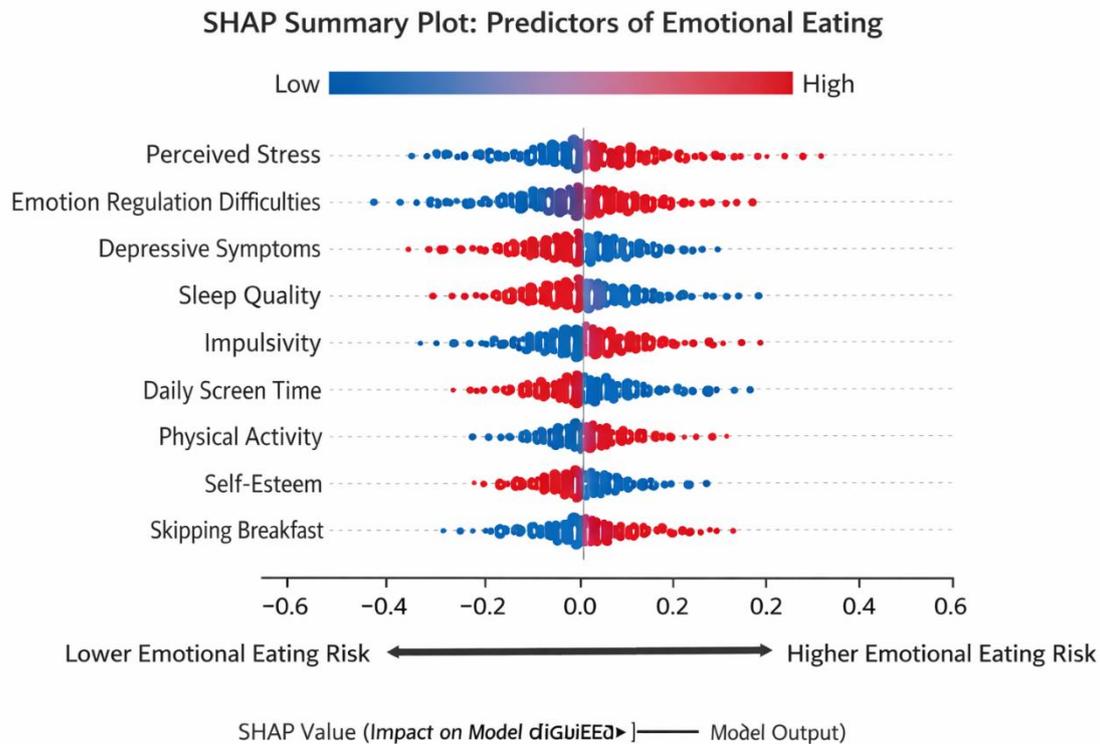
Sex	AUC	Accuracy	Sensitivity	Specificity
Female Adolescents	0.89	0.86	0.88	0.84
Male Adolescents	0.82	0.79	0.80	0.78

Results in Table 5 demonstrate that the predictive model performed more strongly among female adolescents, with higher discrimination and classification accuracy compared to males. This suggests that emotional eating in females may

be more closely linked to the psychological and lifestyle variables included in the model, whereas additional unmeasured factors may play a role in males.

Figure 1

SHAP Summary Plot Illustrating the Global Importance and Direction of Psychological and Lifestyle Predictors of Emotional Eating



Overall, the findings indicate that machine learning models can accurately identify adolescents at risk for emotional eating by integrating psychological vulnerability markers with lifestyle behaviors. The dominance of stress-related and emotion regulation variables, alongside modifiable lifestyle factors such as sleep and physical activity, provides a robust empirical basis for targeted preventive strategies and personalized interventions in adolescent populations.

#### 4. Discussion and Conclusion

The present study sought to advance understanding of adolescent emotional eating by applying explainable machine learning models to an integrated set of psychological and lifestyle variables in a large sample of Polish adolescents. The findings demonstrated that ensemble-based machine learning models, particularly extreme gradient boosting, achieved strong predictive performance, confirming that emotional eating is best conceptualized as a multifactorial behavior shaped by complex, nonlinear interactions among emotional, cognitive, and behavioral factors. Consistent with prior epidemiological and psychosocial research, perceived stress, emotion regulation difficulties, depressive symptoms, sleep

quality, and impulsivity emerged as the most influential predictors, underscoring the centrality of emotional distress and self-regulatory processes in adolescent eating behavior (Heshmati et al., 2022; Kidwell et al., 2024; Shriver et al., 2020). These results align with affect regulation theories suggesting that food consumption serves as an accessible coping mechanism in the face of emotional overload, particularly during developmental periods characterized by heightened emotional sensitivity and still-maturing executive control systems (Rossi, 2025; Wozniak & Huang, 2024).

Perceived stress emerged as the strongest predictor of emotional eating in the machine learning models, a finding that is highly consistent with a broad international literature documenting the role of stress in dysregulated eating behaviors. Studies among adolescents in Asia, Europe, and the Americas have consistently shown that academic pressure, social stressors, and family-related stress increase the likelihood of eating in response to negative affect rather than hunger (Sánchez-Charcopa et al., 2025; Shah et al., 2023; Wardani et al., 2024). The prominence of stress in the present models mirrors findings from both adolescent and adult samples, including pandemic-related research demonstrating that heightened stress exposure amplifies emotional eating tendencies across populations (Silva et al.,

2025; Skolmowska et al., 2023). The machine learning results extend this evidence by illustrating that stress does not merely exert an additive effect but interacts with other vulnerabilities, such as sleep disturbances and impulsivity, to substantially elevate emotional eating risk.

Emotion regulation difficulties ranked as the second most influential predictor, reinforcing the conceptualization of emotional eating as a maladaptive strategy for managing overwhelming affective states. Prior research has repeatedly shown that adolescents who struggle to identify, tolerate, or modulate emotions are more likely to rely on external regulatory behaviors, including food consumption (Heshmati et al., 2022; Shriver et al., 2020). Empirical studies have linked poor emotion regulation to emotional eating across diverse cultural contexts, including European populations similar to the present sample (Ljubičić et al., 2023; Mentzelou et al., 2025). The current findings are also consistent with evidence indicating that emotion dysregulation mediates the relationship between stress and emotional eating, suggesting that stress may increase eating vulnerability primarily among adolescents lacking adaptive regulatory skills (Akkuş et al., 2024; Tan et al., 2025). By quantifying the relative importance of emotion regulation difficulties within a predictive framework, this study provides further support for interventions that target emotional awareness and regulation capacities as a means of reducing emotional eating behaviors.

Depressive symptoms and anxiety-related indicators also demonstrated substantial predictive value, corroborating a well-established association between internalizing psychopathology and emotional eating. Numerous studies have documented positive associations between depressive symptoms and emotionally driven eating in adolescents, young adults, and clinical populations (Joseph et al., 2023; Kidwell et al., 2024; Metin et al., 2024). Depression may contribute to emotional eating through mechanisms such as anhedonia, low self-worth, and diminished motivation for health-promoting behaviors, thereby increasing reliance on food for short-term mood relief (Carandang et al., 2023; Wu et al., 2023). Anxiety, particularly when combined with heightened stress sensitivity, has similarly been shown to predict emotional eating, especially in evaluative or high-pressure contexts such as examinations or social comparison environments (Shah et al., 2023; Sun et al., 2023). The machine learning findings suggest that depressive and anxiety-related symptoms function as core components within a broader psychological vulnerability network rather than isolated risk factors.

Lifestyle variables, particularly sleep quality and screen time, also contributed meaningfully to emotional eating prediction, highlighting the importance of daily behavioral contexts in shaping eating responses. Poor sleep quality has been repeatedly linked to emotional eating through both physiological and psychological pathways, including impaired emotion regulation, increased reward sensitivity, and heightened stress reactivity (Akkuş et al., 2024; Calizaya-Milla et al., 2025). Research conducted during periods of widespread sleep disruption, such as the COVID-19 pandemic, further supports the role of sleep as a critical moderator of emotional eating behaviors among adolescents (Skolmowska et al., 2023). Similarly, excessive screen time and social media use have been associated with emotional eating through mechanisms involving negative social comparison, exposure to food cues, and reduced opportunities for physical activity (Joseph et al., 2023; Sun et al., 2023). The present findings extend this literature by demonstrating that these lifestyle behaviors retain predictive importance even when psychological distress variables are simultaneously considered.

Self-esteem and physical activity emerged as protective factors within the explainable machine learning framework, exerting negative effects on emotional eating risk. Higher self-esteem may buffer adolescents against emotional eating by fostering more adaptive coping strategies and reducing vulnerability to stress-induced affective disturbances (Rossi, 2025; Şerban et al., 2025). Physical activity, in turn, has been shown to improve mood regulation, reduce stress, and enhance self-regulatory capacity, thereby indirectly decreasing reliance on food for emotional relief (Buja et al., 2022; Elran-Barak et al., 2021). These findings align with prior research suggesting that emotional eating is embedded within broader lifestyle patterns, and that health-promoting behaviors may serve as resilience factors even in the presence of psychological distress (Cuyan-Zumaeta et al., 2025; Ijaz & Rehman, 2023).

Notably, the machine learning models demonstrated stronger predictive performance among female adolescents compared to males, a pattern consistent with previous research indicating higher prevalence and stronger psychosocial correlates of emotional eating in females. Studies across multiple countries have shown that girls are more likely to report emotional eating and to exhibit stronger associations with stress, depression, and body image concerns (Kidwell et al., 2024; Shriver et al., 2020; Skolmowska et al., 2023). Sociocultural norms surrounding emotional expression and body ideals may partly explain

these differences, as females may be more prone to internalizing distress and using food as a coping mechanism (Mentzel et al., 2025; Pickett et al., 2020). The observed sex differences underscore the importance of considering gender-sensitive approaches in both research and intervention design.

From a methodological perspective, the superiority of ensemble-based machine learning models over traditional linear approaches reinforces the value of advanced analytical techniques for studying complex health behaviors. Emotional eating is influenced by interdependent psychological and lifestyle factors that interact in nonlinear ways, and machine learning models are uniquely suited to capture these dynamics (Wu et al., 2023; Zhou et al., 2025). Importantly, the use of explainable machine learning techniques allowed for transparent interpretation of model outputs, bridging the gap between predictive accuracy and theoretical understanding. This approach aligns with recent calls for interpretable artificial intelligence in psychological and public health research, particularly when findings are intended to inform prevention and intervention strategies (Rossi, 2025; Wozniak & Huang, 2024).

## 5. Limitations & Suggestions

Regarding limitations, this study employed a cross-sectional design, which precludes causal inference and limits conclusions about the temporal directionality of associations between psychological distress, lifestyle behaviors, and emotional eating. All data were based on self-report measures, which may be subject to recall bias or social desirability effects, particularly for sensitive behaviors related to eating and mental health. Additionally, although the sample was relatively large and diverse, it was limited to adolescents attending school in specific regions of Poland, which may constrain generalizability to other cultural or socioeconomic contexts. Finally, while machine learning models demonstrated strong performance, they are inherently dependent on the quality and scope of input variables, and unmeasured factors such as genetic predisposition or family eating norms may also contribute to emotional eating risk.

With respect to future research, longitudinal studies are needed to examine the developmental trajectories of emotional eating and to determine how psychological and lifestyle predictors interact over time. Incorporating ecological momentary assessment or wearable technology could provide more fine-grained data on emotional states,

sleep patterns, and eating behaviors, thereby enhancing predictive accuracy. Future studies should also explore cross-cultural comparisons using harmonized machine learning frameworks to identify universal versus context-specific predictors of emotional eating. Additionally, integrating biological markers, such as stress hormones or metabolic indicators, may further enrich predictive models and deepen understanding of underlying mechanisms.

In terms of practical implications, the findings highlight the importance of early screening for emotional eating risk in school and community settings using multidimensional assessment approaches. Interventions aimed at improving emotion regulation skills, stress management, sleep hygiene, and physical activity may be particularly effective in reducing emotional eating among adolescents. The use of explainable machine learning tools could support personalized prevention strategies by identifying individual risk profiles and tailoring interventions accordingly. Moreover, collaboration between educators, mental health professionals, and public health practitioners is essential to address emotional eating as a multifaceted behavior embedded within adolescents' emotional and lifestyle environments.

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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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