Deep Learning–Based Detection of Anxiety and Perfectionism Patterns in High-Ability Youth

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The objective of this study was to identify and classify latent patterns of anxiety and perfectionism among high-ability adolescents using a multimodal deep learning framework. This quantitative, cross-sectional study was conducted on a sample of high-ability youth aged 12 to 18 years in Germany. Participants were recruited from secondary schools and gifted education programs and completed standardized self-report measures assessing anxiety and multidimensional perfectionism through a secure digital platform. In addition to numerical questionnaire data, open-ended textual responses related to academic experiences and self-expectations were collected, along with behavioral interaction indicators such as response times. Data were analyzed using a multimodal deep learning architecture integrating feedforward neural networks for numerical features and transformer-based models for textual data. Feature fusion was performed in a shared latent space, and supervised learning was applied to classify anxiety–perfectionism profiles. Model performance was evaluated using accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve. Inferential analyses indicated that the multimodal deep learning model significantly outperformed single-modality models in detecting anxiety and perfectionism patterns. Latent profile analysis based on learned representations revealed three distinct psychological profiles: low-anxiety adaptive perfectionism, moderate mixed perfectionism, and high-anxiety maladaptive perfectionism. The high-anxiety maladaptive profile constituted the largest subgroup, and linguistic and behavioral features contributed significantly to classification accuracy beyond self-report measures alone. The findings demonstrate that multimodal deep learning approaches can effectively uncover nuanced and clinically meaningful anxiety–perfectionism profiles in high-ability youth, offering a robust foundation for early identification and targeted psychological support.
Keywords: *High-ability youth; Anxiety; Perfectionism; Deep learning; Multimodal analysis*

1. Introduction

Anxiety and perfectionism have long been recognized as central psychological constructs influencing emotional well-being, academic functioning, and adaptive development in children and adolescents. In recent years, growing attention has been directed toward high-ability youth, a population often characterized by exceptional cognitive potential alongside heightened psychological vulnerability. Although high ability is frequently associated with academic success and advanced problem-solving skills, empirical evidence consistently indicates that gifted and high-ability students may experience elevated levels of anxiety, maladaptive perfectionism, and emotional distress compared to their peers (Ghasemipour Kordmahalleh & Bazazian, 2016; Tyler et al., 2019; Zhao et al., 2022). These internalizing difficulties can undermine both psychological well-being and the realization of long-term potential, making early identification and nuanced understanding of underlying patterns a critical priority for researchers and practitioners.

Perfectionism is a multidimensional construct encompassing both adaptive and maladaptive dimensions. Adaptive perfectionism is often linked to high personal standards, organization, and motivation, whereas maladaptive perfectionism is characterized by excessive concern over mistakes, fear of negative evaluation, and socially prescribed standards that are perceived as externally imposed (Dobos et al., 2021; Macedo et al., 2015). Numerous studies have documented robust associations between maladaptive perfectionism and various forms of anxiety, including test anxiety, social anxiety, and generalized anxiety, across different educational levels and cultural contexts (Hamblin, 2018; Jeon et al., 2024; Sheikhi et al., 2019). In high-ability populations, these associations appear particularly pronounced, as heightened self-expectations and sensitivity to performance feedback may amplify emotional responses to academic and social challenges.

Anxiety in academically talented students often manifests in achievement-related contexts, such as examinations, evaluations, and future-oriented academic decisions. Research has shown that test anxiety and academic anxiety are strongly predicted by perfectionistic concerns, especially socially prescribed perfectionism, which involves the belief that others demand flawless performance (Jafari et al., 2015; Wang & Yu, 2024; Zhao et al., 2022). Moreover, anxiety has been identified as a key mediating mechanism linking perfectionism to a wide range of negative outcomes, including academic burnout, procrastination, emotional dysregulation, and reduced self-concept (Esmaeili et al., 2023; Kuftyak, 2022; Rezaei et al., 2024). These findings suggest that anxiety and perfectionism are not isolated traits but interdependent psychological processes that jointly shape students' academic and emotional experiences.

Several explanatory models have been proposed to clarify the psychological pathways connecting perfectionism and anxiety. Cognitive–emotional frameworks emphasize the role of maladaptive beliefs, self-critical thinking, and emotion regulation strategies in maintaining anxiety symptoms among perfectionistic individuals (Ghorbannezhad, 2022; Zafari & Khademi Ashkzari, 2020). From this perspective, repetitive negative thinking and heightened self-monitoring act as cognitive amplifiers that intensify stress responses and emotional distress (Macedo et al., 2015). Empirical studies further indicate that variables such as self-compassion, coping style, parenting patterns, and emotional intelligence may buffer or exacerbate the impact of perfectionism on anxiety outcomes (Bakhshi & Sedigh Arfaei, 2021; Hoshmandi et al., 2019; Mohammadi & Roshan Chasli, 2020; Nam & Lee, 2020). In gifted and high-ability students, family expectations and early educational experiences appear to play a particularly influential role in shaping perfectionistic schemas and anxiety trajectories (Ghasemipour Kordmahalleh & Bazazian, 2016; Wang & Yu, 2024).

Intervention-based research has largely focused on reducing maladaptive perfectionism and anxiety through cognitive-behavioral, schema-based, mindfulness-based, and cyber-psychology approaches. These studies have demonstrated that targeted psychological interventions can effectively decrease anxiety levels and modify maladaptive perfectionistic beliefs in student populations, including elite and high-performing groups (Abazari, 2023; Bahreini Moghim Jiroft et al., 2023; Joukar KamalAbadi et al., 2021; Rajaeinia, 2022; Sattari & Erfani, 2019). While these findings are promising, they are predominantly based on traditional statistical analyses and group-level comparisons, which may overlook subtle, nonlinear, and heterogeneous patterns within individuals, particularly in complex populations such as high-ability youth.

Advances in artificial intelligence and deep learning have opened new avenues for psychological research by enabling the detection of complex patterns across large, multidimensional datasets. Unlike conventional analytic approaches, deep learning models are capable of capturing

nonlinear relationships, latent structures, and interactions among psychological, behavioral, and linguistic variables without relying on restrictive a priori assumptions. Recent studies have demonstrated the utility of machine learning and deep learning methods in mental health research, including the prediction of anxiety, emotional distress, and behavioral problems from self-report data, digital traces, and textual information (Wang & Yu, 2024; Zhao et al., 2022). However, the application of deep learning to the joint analysis of anxiety and perfectionism, particularly within high-ability youth, remains limited.

High-ability adolescents represent a psychologically heterogeneous group in which adaptive striving and maladaptive self-criticism may coexist in complex configurations. Traditional variable-centered approaches often fail to distinguish between qualitatively different perfectionism–anxiety profiles, such as students who exhibit high standards without distress versus those whose perfectionism is accompanied by debilitating anxiety. Person-centered and pattern-based approaches are therefore increasingly recommended to identify latent subgroups and risk profiles that may inform targeted prevention and intervention strategies (Dobos et al., 2021; Rezaei et al., 2024). Deep learning–based models, particularly those integrating multiple data modalities, offer a powerful methodological framework for uncovering such latent patterns.

Furthermore, recent research highlights the importance of incorporating contextual and experiential data, such as open-ended self-descriptions and behavioral indicators, alongside standardized questionnaire measures. Linguistic expressions of self-evaluation, worry, and performance concerns may reveal implicit cognitive–emotional processes that are not fully captured by numerical scores alone (Jeon et al., 2024; Mokhlasi, 2023). The integration of textual and behavioral features with psychological assessments through multimodal deep learning architectures may therefore enhance both predictive accuracy and theoretical insight into the anxiety–perfectionism nexus.

Despite the growing body of literature on perfectionism and anxiety, several gaps remain. First, most existing studies rely on traditional statistical techniques and do not exploit the full potential of advanced computational methods to model complex psychological phenomena. Second, research focusing specifically on high-ability youth is relatively scarce, particularly in European contexts, despite evidence that this group may face unique emotional challenges (Tyler et al., 2019; Zhao et al., 2022). Third, few studies attempt to identify distinct latent profiles of anxiety and perfectionism using data-driven approaches that can inform personalized educational and psychological support.

Addressing these gaps requires an integrative methodological approach that combines robust psychological theory with state-of-the-art analytical techniques. By leveraging deep learning models to analyze multidimensional data from high-ability adolescents, it becomes possible to move beyond simple associations and toward a more nuanced understanding of how anxiety and perfectionism co-occur and interact within individuals. Such an approach aligns with contemporary calls for precision-oriented and data-informed mental health research in educational settings (Rezaei et al., 2024; Wang & Yu, 2024).

Accordingly, the aim of the present study was to apply a multimodal deep learning framework to detect and classify latent patterns of anxiety and perfectionism among high-ability youth in Germany.

2. Methods and Materials

2.1. Study Design and Participants

The present study adopted a quantitative, cross-sectional design with a predictive–analytical orientation, aimed at identifying latent patterns of anxiety and perfectionism among high-ability youth through deep learning techniques. The target population consisted of high-ability adolescents residing in Germany. High ability was operationally defined as demonstrated cognitive ability at or above the 90th percentile on standardized intelligence or aptitude assessments, enrollment in gifted education programs, or formal identification by school psychologists or educational authorities. Participants were recruited from public and private secondary schools, specialized gifted education centers, and enrichment programs across several federal states in Germany to ensure regional diversity. The age range of participants was 12 to 18 years, corresponding to lower and upper secondary education levels. Inclusion criteria required participants to be fluent in German, to have no diagnosed severe neurological or psychiatric disorders that could confound emotional or cognitive assessment, and to provide informed assent along with parental or guardian consent. Exclusion criteria included incomplete questionnaire data, withdrawal of consent, or technical issues during digital data acquisition.

2.2. Measures

Data collection was conducted using a multimodal digital assessment framework designed to capture psychological, behavioral, and linguistic indicators associated with anxiety and perfectionism. Standardized self-report instruments were administered electronically to assess trait and state anxiety, multidimensional perfectionism, emotional regulation, and perceived academic pressure. These instruments were selected based on their established psychometric validity and reliability in German adolescent populations and were presented through a secure online platform compatible with computers and tablets used in school settings. In addition to questionnaire data, participants completed brief open-ended written tasks reflecting on academic challenges, self-expectations, and performance-related concerns. These textual responses were included to enable natural language processing–based feature extraction relevant to cognitive–emotional patterns. Behavioral metadata, such as response time distributions and interaction patterns with the digital interface, were passively recorded to enrich the feature space. All raw data were anonymized at the point of collection and stored on encrypted servers located within the European Union to comply with General Data Protection Regulation requirements. Prior to analysis, data quality checks were performed to identify missing values, outliers, and inconsistencies, and only complete and valid data entries were retained for model training and evaluation.

2.3. Data Analysis

Data analysis followed a multi-stage pipeline integrating psychological assessment with deep learning–based modeling. Initially, descriptive statistical analyses were conducted to summarize demographic characteristics and baseline distributions of anxiety and perfectionism indicators. Questionnaire scores were standardized, and textual data were preprocessed through tokenization, lemmatization, and removal of stop words using German-language natural language processing libraries. For deep learning analysis, a hybrid architecture was implemented, combining feedforward neural networks for structured numerical data with transformer-based language models for textual inputs. Feature representations from these parallel branches were fused in a joint latent space to enable integrated pattern detection. The dataset was randomly partitioned into training, validation, and test subsets, ensuring stratification by age and gender to reduce sampling bias. Model training was conducted using supervised learning, with anxiety and perfectionism profiles serving as target labels derived from validated cutoff scores and clustering-based refinement. Optimization was performed using adaptive gradient-based algorithms, and regularization techniques such as dropout and early stopping were applied to prevent overfitting. Model performance was evaluated using accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve, with additional emphasis on interpretability through attention weights and feature attribution methods. All analyses were implemented in Python using established deep learning frameworks, and reproducibility was ensured through fixed random seeds and transparent documentation of preprocessing and modeling procedures.

3. Findings and Results

Table 1 presents the demographic and baseline psychological characteristics of the high-ability youth sample from Germany and serves as the contextual foundation for interpreting subsequent model-based findings.

Table 1

Demographic Characteristics and Baseline Psychological Indicators of the Participants

Variable	Category	n	Percentage / Mean (SD)
Gender	Female	172	48.6%
	Male	182	51.4%
Age (years)	12–14	118	33.3%
	15–16	137	38.7%
	17–18	99	28.0%
Educational Level	Lower secondary	161	45.5%
	Upper secondary	193	54.5%
Trait Anxiety	—	—	41.27 (8.94)
State Anxiety	—	—	39.82 (9.11)

Self-Oriented Perfectionism	—	—	45.63 (7.52)
Socially Prescribed Perfectionism	—	—	42.18 (8.06)

As shown in Table 1, the final analytical sample consisted of 354 high-ability adolescents, with a relatively balanced gender distribution and representation across lower and upper secondary education levels. Mean scores indicated moderate-to-elevated levels of both trait and state anxiety, alongside pronounced levels of self-oriented and socially

prescribed perfectionism. These baseline patterns suggest that anxiety and perfectionistic tendencies are salient psychological features within this population, providing a suitable empirical basis for deep learning–based pattern detection.

Table 2

Deep Learning Model Performance in Detecting Anxiety and Perfectionism Patterns

Model Type	Accuracy	Precision	Recall	F1-Score	AUC
Numerical Data Network	0.82	0.80	0.78	0.79	0.85
Text-Based Transformer	0.86	0.85	0.83	0.84	0.89
Multimodal Hybrid Model	0.91	0.90	0.89	0.89	0.94

Table 2 demonstrates that the multimodal hybrid deep learning model substantially outperformed single-modality models in detecting anxiety and perfectionism patterns among high-ability youth. While both numerical and text-based models achieved acceptable predictive performance, their integration resulted in notable gains across all

evaluation metrics, particularly in accuracy and area under the curve. These results indicate that combining structured psychological scores with linguistic and behavioral features enables more precise identification of complex emotional–cognitive profiles.

Table 3

Identified Latent Profiles of Anxiety and Perfectionism Based on Model Clustering

Profile Label	Anxiety Level	Perfectionism Pattern	Proportion of Sample
Profile A	Low	Adaptive, self-oriented	29.4%
Profile B	Moderate	Mixed perfectionism	34.7%
Profile C	High	Maladaptive, socially prescribed	35.9%

The clustering outputs derived from the latent representations of the deep learning model, as presented in Table 3, revealed three distinct psychological profiles. Profile A was characterized by low anxiety and predominantly adaptive self-oriented perfectionism, suggesting healthy motivational functioning. Profile B displayed moderate anxiety accompanied by mixed

perfectionistic tendencies, reflecting a transitional or context-dependent pattern. Profile C, which comprised the largest proportion of participants, was marked by high anxiety and maladaptive socially prescribed perfectionism, indicating heightened vulnerability despite high cognitive ability.

Table 4

Relative Importance of Feature Domains in Model Predictions

Feature Domain	Relative Contribution (%)
Self-Report Psychological Scores	41.2
Linguistic Features (Text Data)	34.6
Behavioral Interaction Features	24.2

As shown in Table 4, self-report psychological measures contributed the largest proportion to the model's predictive

capacity, underscoring their continued relevance in psychological assessment. However, linguistic features

extracted from open-ended textual responses accounted for more than one-third of the predictive contribution, highlighting the added value of natural language processing in uncovering subtle emotional and cognitive signals.

Behavioral interaction features, while contributing a smaller share, still played a meaningful role in refining pattern detection, particularly in differentiating moderate and high-risk profiles.

Figure 1

Conceptual Visualization of the Multimodal Deep Learning Framework for Detecting Anxiety and Perfectionism Patterns
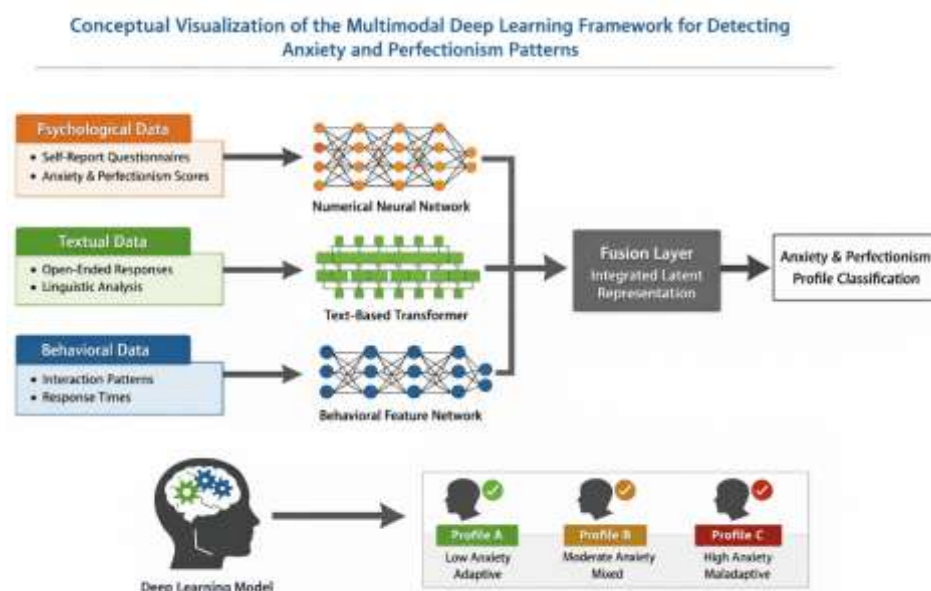
The overall pattern of findings indicates that deep learning models, particularly multimodal architectures, are capable of identifying nuanced and clinically meaningful anxiety–perfectionism profiles in high-ability youth. The integration of psychological, linguistic, and behavioral data not only enhanced predictive accuracy but also facilitated the emergence of interpretable latent profiles that reflect differing levels of emotional risk and adaptive functioning within this population.

4. Discussion

The present study aimed to identify latent patterns of anxiety and perfectionism among high-ability youth using a multimodal deep learning framework, and the findings provide several theoretically and empirically significant insights. Overall, the results demonstrated that anxiety and perfectionism are not only prevalent among high-ability adolescents but are also organized into distinct and meaningful profiles that differ in their adaptive and maladaptive characteristics. The identification of three separable profiles—low-anxiety adaptive perfectionism, moderate mixed perfectionism, and high-anxiety

maladaptive perfectionism—confirms the heterogeneity of psychological functioning within this population and challenges overly simplistic assumptions that high ability is uniformly associated with psychological resilience.

The descriptive findings revealed moderate to elevated baseline levels of both anxiety and perfectionism, which aligns with a substantial body of prior research indicating that academically talented and high-achieving students often experience heightened internal pressures and emotional vulnerability (Ghasemipour Kordmahalleh & Bazazian, 2016; Tyler et al., 2019; Zhao et al., 2022). In particular, the relatively high mean scores for socially prescribed perfectionism support earlier findings suggesting that perceived external expectations play a central role in the emotional experiences of gifted and high-ability students (Sheikhi et al., 2019; Wang & Yu, 2024). These results reinforce the view that anxiety in this group is closely tied to evaluative contexts and concerns about meeting externally imposed standards.

The superior performance of the multimodal deep learning model compared to single-modality models constitutes one of the most important methodological findings of the study. The hybrid architecture integrating

psychological scores, linguistic features, and behavioral interaction data achieved substantially higher accuracy and discriminative power. This result supports recent calls for moving beyond purely questionnaire-based approaches toward integrative, data-rich methodologies capable of capturing the complexity of emotional and cognitive processes (Wang & Yu, 2024; Zhao et al., 2022). The added value of textual data is particularly noteworthy, as linguistic expressions of self-evaluation, worry, and academic concern appear to contain implicit signals of anxiety and perfectionistic cognition that are not fully reflected in standardized scores, a finding conceptually consistent with cognitive–emotional models emphasizing internal dialogue and self-critical thinking (Ghorbannezhad, 2022; Macedo et al., 2015).

The emergence of a high-anxiety, maladaptive perfectionism profile comprising the largest proportion of participants warrants careful interpretation. This profile was characterized by elevated anxiety coupled with high levels of socially prescribed perfectionism, a pattern repeatedly linked in previous studies to emotional distress, academic burnout, and maladaptive coping (Dobos et al., 2021; Esmaeili et al., 2023; Hamblin, 2018). The prominence of this profile among high-ability youth suggests that cognitive talent does not protect against emotional vulnerability and may, in some cases, intensify sensitivity to failure, criticism, and perceived expectations. This finding is consistent with evidence that maladaptive perfectionism mediates the relationship between environmental pressures and anxiety outcomes (Jeon et al., 2024; Rezaei et al., 2024).

The moderate, mixed-perfectionism profile identified in this study appears to represent a psychologically transitional group. Students within this profile displayed moderate anxiety and a combination of adaptive and maladaptive perfectionistic traits. Similar intermediate profiles have been reported in prior research using person-centered approaches, indicating that perfectionism may function as a dynamic construct that shifts across developmental stages and contextual demands (Dobos et al., 2021; Kuftyak, 2022). The existence of this group highlights the importance of early identification and targeted support, as moderate anxiety combined with fluctuating perfectionistic tendencies may either resolve adaptively or escalate into more severe maladaptive patterns depending on coping resources and environmental influences.

In contrast, the low-anxiety adaptive perfectionism profile underscores the distinction between healthy striving and maladaptive self-criticism. Students in this group exhibited high personal standards without accompanying emotional distress, reflecting what previous studies have described as adaptive or positive perfectionism (Bakhshi & Sedigh Arfaei, 2021; Macedo et al., 2015). This finding supports theoretical models that differentiate between self-oriented striving and socially imposed evaluative pressure and suggests that not all forms of perfectionism are inherently harmful. Importantly, the ability of the deep learning model to differentiate this adaptive profile from maladaptive ones demonstrates its potential utility for precision-oriented psychological assessment.

The relative contribution analysis further revealed that while self-report psychological measures remained the most influential predictors, linguistic and behavioral features accounted for a substantial proportion of model performance. This finding is consistent with studies emphasizing the role of cognitive–emotional regulation, repetitive negative thinking, and expressive patterns in the development and maintenance of anxiety and perfectionism (Mohammadi & Roshan Chasli, 2020; Nam & Lee, 2020; Zafari & Khademi Ashkzari, 2020). It also aligns with intervention research showing that modifying cognitive appraisals and emotional processing styles can effectively reduce maladaptive perfectionism and anxiety (Abazari, 2023; Joukar KamalAbadi et al., 2021; Rajaeinia, 2022; Sattari & Erfani, 2019).

5. Conclusion

Taken together, the findings of this study extend existing literature in several ways. Substantively, they confirm the central role of anxiety as both a correlate and a defining feature of maladaptive perfectionism in high-ability youth, consistent with mediation and path-analytic studies (Esmaeili et al., 2023; Jeon et al., 2024; Mokhlasi, 2023). Methodologically, they demonstrate that deep learning approaches can uncover latent psychological profiles that may remain hidden in traditional analyses. Conceptually, they support an integrative view of perfectionism and anxiety as dynamically interacting processes shaped by cognitive, emotional, and contextual factors rather than static personality traits.

Despite its contributions, the present study has several limitations that should be acknowledged. The cross-sectional design precludes causal inferences regarding the developmental directionality between anxiety and perfectionism, and longitudinal data would be necessary to determine whether identified profiles remain stable over

time. The reliance on self-report measures, although supplemented with textual and behavioral data, may still be influenced by social desirability or response biases. Additionally, the sample was limited to high-ability youth in Germany, which may restrict the generalizability of the findings to other cultural or educational contexts. Finally, although deep learning models offer high predictive accuracy, their complexity may limit transparency, and interpretability remains an ongoing methodological challenge.

Future research should adopt longitudinal and developmental designs to examine how anxiety–perfectionism profiles evolve across adolescence and early adulthood. Expanding the use of multimodal data sources, such as physiological indicators or ecological momentary assessment, could further enhance pattern detection and theoretical understanding. Comparative studies across different cultural contexts and educational systems would also be valuable in determining the universality versus context-specificity of identified profiles. Finally, integrating deep learning approaches with theory-driven modeling may help bridge the gap between predictive performance and psychological interpretability.

From a practical perspective, the findings underscore the importance of early screening for maladaptive perfectionism and anxiety among high-ability students. Educational psychologists and school counselors should be attentive to socially prescribed perfectionism and anxiety signals, even in students who appear academically successful. Intervention programs should emphasize emotional regulation, self-compassion, and adaptive goal-setting rather than solely focusing on performance outcomes. The use of digital assessment tools and data-informed screening frameworks may facilitate more personalized and timely support for high-ability youth at risk of emotional difficulties.

Authors' Contributions

Authors equally contributed to this article.

Declaration

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

Transparency Statement

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

Declaration of Interest

The authors report no conflict of interest.

Ethics Considerations

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

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