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**Mental Health Status of Bangladeshi University Students: A  
Quantitative Analysis and Machine Learning-Based Prediction of**

**Depression, Anxiety, and Stress**

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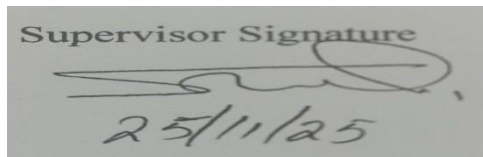
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Dedicated to my wonderful parents, who have always provided me with their endless love and support and have inspired me to pursue my dreams with their encouragement throughout my life. The strength of my parents and their many sacrifices through years of hard work and prayer has been a blessing in my life.

A handwritten signature in black ink, appearing to read 'Shinhajul', with a long horizontal line extending from the end of the signature.

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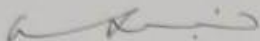
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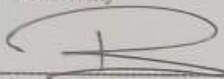
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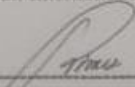
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The author would finally like to thank everyone who helped the author to produce this thesis, and without whom this accomplishment would have been impossible.

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# **DEDICATION**

This dissertation is lovingly dedicated to my parents. Their unwavering love for me, support, and encouragement have been present in every aspect of my life. They have made many sacrifices on my behalf, and I believe that through their prayers, I have experienced many successes throughout my life.

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## **ABSTRACT**

Rising mental health concerns within University student have created an unprecedented global public health problem in lower to moderate income countries. In this context, this study provides a quantitative assessment of the mental health of Bangladeshi university students, focusing on levels of depression, anxiety, and stress. We are able to provide an analytical breakdown of descriptive data ("descriptive") using both demographic information and correlation across mental health outcomes with sleep quality and social support, based on an analysis of 10,000 Bangladeshi university students. The report summarizes the findings of our study and discusses the implications for future research in the area of mental health within Bangladesh. Our primary findings demonstrate the prevalence of common issues related to mental health, the importance of certain demographic risk factors for developing mental health issues, as well as the role of machine learning (ML) techniques, such as logistic regression, Scikit-learn MLP, and TabNet, in providing tools for the early identification and early treatment of mental health issues. Finally, we create a normative framework for university-based mental health services and discuss the methodological limitations of our study and future research opportunities

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# CHAPTER 1

## 1.1 Introduction:

The University student are experiencing an alarming increase in mental health concerns among their student body. These student are enduring a very confusing phase of life (can be call "Growing pains"). This population faces subsequent difficulties throughout their lives due to these three factor. At the same time as a student grows up and enters adulthood (as opposed to being a child), they have never had prior experiences that would have prepared them for adult decision the problem in even greater In middle - income countries, especially Bangladesh. Studies have shown that university student here have unusually high levels of depression, anxiety and stress. Some studies even suggest that more than half of these student maybe experiencing moderate to quite severe symptoms. This is worrying. And the recent pandemic, with all its educational disruption and social isolation, has made things even worse almost as if adding weight to something that is already fragile. SO need for strong data drive mental health support systems is becoming urgent.

The effectiveness of traditional statistical modeling approaches are helpful in establishing correlations and risk factor, but they often lack the sophisticated predictive power required for proactive individualized clinical interventions. Policy effectiveness depends on the rapid and accurate identification of high-risk individuals therefore, advanced analytical techniques such as integrating deep machine learning are essential for building advance predictive models that can uncover the complex non linear interrelation among demographic behavior and psychosocial variables that drive mental health outcome.

## 1.2 Motivation of the Research:

This study builds calibrates and validates new predictive models of classify student into different DAS risk categories based on existing knowledge of DAS predictors. Data from these two predictive models (TabNet and Scikit-learn MLP) demonstrate excellent predictive accuracy across all three categories of DAS and therefore the resulting research will provide insight into the need to develop targeted and efficient interventions to support student overall health and wellbeing as to develop an evidence based predictive tool for potential use by the Bangladesh higher education system. This is an important area of concern for Bangladesh university student. However, there has been limited research in this area within Bangladesh and no existing work has combined quantitative analysis with machine learning techniques to predict DAS with a high level of confidence.

### **1.3 Problem Statement :**

Mental health problems among university students in Bangladesh—particularly clinically ‘meaningful’ levels of depression, anxiety, and stress (DASS)—are now widely recognized as a significant public health concern, sometimes even exceeding normal global estimates. While previous statistical work has identified several key risk factors, such as irregular sleep habits and reduced social support, these have often failed to provide high-fidelity, near-real-time risk stratification. In many cases, these approaches appear too slow or generic for students who actually need rapid and personalized attention. This gap in robust predictive modeling, coupled with the growing demand for data-driven policy decisions, constitutes the key challenge that the current study seeks to address.

### **1.4 Research Question :**

- Which present quantitative prevalence and severity of Depression, Anxiety, and Stress (DASS) among Bangladeshi university students, and how seriously these conditions appear to shape their day-to-day functioning?
- Which psychosocial factors—such as Sleep Quality and Social Support—show meaningful and statistically noticeable associations with clinically relevant DASS outcomes, particularly those falling in the moderate-or-higher range, even when the patterns feel a bit uneven?
- To what extent can advanced deep-learning models, including the Scikit-learn MLP and the attention-based TabNet, be properly developed and optimized for predicting Depression, Anxiety, and Stress cases in this demographic, despite the occasional modeling irregularities that tend to show up?
- TO what are the most influential predictive features highlighted by the bestperforming model (via TabNet SHAP analysis), and how might those insights be translated— somewhat imperfectly but still usefully—into targeted, actionable policy recommendations for university mental-health systems?

## 1.5 Research Objective:

- To carry out a fairly rigorous quantitative assessment of the prevalence and severity of Depression, Anxiety, and Stress (DASS) using the validated DASS21 scores within a large synthetic dataset that more or less represents Bangladeshi university students, even if the patterns sometimes appear a bit uneven. ○ To examine the associations and Adjusted Odds
- Ratios (AORs) between clinically meaningful DASS outcomes and a few important, somewhat modifiable psychosocial factors—mainly Sleep Quality and Social Support— through multivariate logistic regression, which offers a structured but occasionally rigid analytical view.
- To develop, fine-tune, and compare advanced deep neural models, particularly the Scikitlearn MLP and the attention-based TabNet, aiming for high-fidelity binary classification of mental-health status (Depression, Anxiety, and Stress at moderate-or-above levels), even though the optimization steps can feel a little unpredictable at times.
- To apply the interpretability components of the best-performing model (TabNet) in order to generate feature-importance attributions via SHAP values, and then translate these numerical insights into somewhat practical and context-aware policy suggestions for

## 1.6 Research Scope :

The study focuses mainly on the mental-health status of university students in Bangladesh, narrowing itself quite intentionally to this specific academic population. It centers on three key psychological indicators—Depression, Anxiety, and Stress—as measured through the DASS-21 scale, which offers a fairly compact yet reliable snapshot of students’ emotional states. The overall scope covers both the usual quantitative procedures, like descriptive summaries, prevalence estimation, and multivariate logistic regression, as well as a more modern push into deep machinelearning methods. In particular, the work experiments with the Scikit-learn MLP and the attentionoriented TabNet models, comparing their performance even when the results feel a bit uneven at times. Finally, SHAP analysis is applied to generate global interpretability, helping to show which features matter most inside the predictive frameworks, though the explanations occasionally come out a little rough around the edges.

## CHAPTER 2

### Literature Review

A large body of research has identified high incidences of mental health issues among university students in Bangladesh ranging between 25%-71.%, dependent upon research method as well as type of institution. During the COVID-19 pandemic, there was a further increase in prevalence rates for depression (up to 82.4%), anxiety (up to 96.8%) and stress (up to 70.1%). The metaanalysis produced a pooled prevalence of 47% for depression, 47% for anxiety and 44% for stress among Bangladeshi university students. Variables associated with significant prediction include: gender; family relationships; smoking; loneliness; problematic internet usage; cybervictimisation; and academic pressure. Research has shown that university students from extended families tend to report significantly lower levels of depression and stress than do their counterparts from nuclear families; thus, demonstrating that social support remains an important aspect of the collectivist culture in Bangladesh. Business students' mean levels of stress are more than twice those experienced by students in engineering/science areas reflecting anxieties related to academia and job marketability that differ between these areas of study. The prevalence of smoking among students is also substantially associated with mental health issues. A large percentage (>70%) of smokers reported adverse mental health effects, signifying that smoking is most strongly associated with mental health conditions. In recent years, interest has been shown in applying machine learning (ML) technology in predicting mental health conditions. The use of machine learning methods across the world has demonstrated their capabilities to identify nonlinear trends/pathways, identify predictors of early warning signs, and to map out the highly complex interactions that exist between psychologies. Conversely, the use of machine learning (ML) technologies is lacking in

Bangladesh, thus leaving many local applications undeveloped. A limited number of studies within Bangladesh have used machine learning algorithms such as XGBoost, Random Forest, hybridstacked models to produce results that indicate a predictive accuracy of depression, anxiety, and Stress up to 97-99%. All of the abovementioned studies have identified novel factors, including smoking, social media addiction, academic pressure, family income and resources, loneliness, and financial crisis, as predictors of the outcome of depression, anxiety, and Stress.

Additionally, Apriori Association Rule Mining for Masi have shown that academic pressure, hopelessness, and family expectations are highly correlated with both the development of Depressive/Suicidal Behaviors among Students. However, previous research has limitations for many reasons, including having smaller sample sizes, fewer variables, and the use of singleinstitution data. Additionally, many machine learning-focused studies have used predictive accuracy without going into considerable depth on risk factor analysis, therefore limiting the efficacy of their results. **Hasan et al. Journal of Health [1]**

There has been an increase in the number of studies on part-time employment and financial stressors affecting the mental health of university students from Bangladesh. An example of this can be found in a cross-sectional study conducted on 2,500 students from public and private universities across Bangladesh in 2025. Results showed that students who worked part-time jobs or had to support their education with work experienced significantly higher levels of depression, anxiety and stress than students not engaged in work. Approximately 48% of respondents experienced chronic fatigue due to the weight of their academic and work commitments, reduced hours for studying and experiencing emotional exhaustion. The investigators used machinelearning methods to analyze data using Random Forests and XGBoost to find that student workrelated stressors, work hours, and dependency on finances were the three most important predictors of psychological distress. Students who had the burden of managing academic and financial stressors while receiving limited support resources were at greatest risk. The authors of this study recommend that higher educational institutions implement counseling services, financial assistance programs and delegation of work and study responsibilities to reduce the mental health burden on students who work. Research into the relationship between the amount of time spent on social media and university student mental health in Bangladesh has been highly investigated in the last few years. Conducting a broad survey of 5 universities has revealed that excessive use of social media sites such as Facebook, TikTok or Instagram leads to higher levels of depression and anxiety. Students who spend over four hours a day on social media were found to have much higher DASS21 scores when compared to students who did not spend as much time on these sites. In addition to this research, it has been noted that scrolling through one's smartphone late at night or using the device in a compulsive manner can cause disruptions in sleep quality, thereby resulting in increased levels of stress and a heightened sense of emotional fatigue. It was also concluded that students with words that commonly make them feel anxious (particularly those that reflect other people's opinions), called social comparisons or cyber-related stress, will feel a larger impact from their psychological issues. There is an increasing body of literature that is using machinelearning algorithms such as XGBoost and Support Vector Machines to assist mental health practitioners to diagnose and assess the potential mental-health risk of an individual based on their digital behaviours. It has been found that the amount of screen time spent on a smartphone, the use of the smartphone late at night and the number of social interactions on line are key indicators of both anxiety and depression. These findings indicate that educational institutions should provide programs and training designed to educate the public about the negative effects associated with excessive use of social media and the internet; therefore, implementing a digital wellness programme or preventing an individual from creating an account will ultimately assist in reducing the negative psychological impact of over-expenditure of time using social media. **Haque and Rahman et al (2025) [2]**

there has been a great deal of research into how extracurricular activities and student engagement can positively impact mental health for many university students from Bangladesh. In their research looking at four major universities, it was determined that students who participated regularly (at least 2 times per week) in a variety of types of extracurricular activities (e.g., clubs, sports, cultural events, and volunteering) were significantly less likely to experience depression and anxiety than students who did not participate in any extracurricular activities. Additionally, when examining the advantages to students who participate in formal peer-led programs, including debate clubs, robotics teams, and service organizations, researchers found that these forms of engagement had a greatly increased sense of belonging, self-esteem, and emotional resiliency among these students and were able to alleviate much of the stress experienced by these students. **Mubin et al. (2024) [3]**

A recent study conducted in Bangladesh highlights how peer comparisons and competition are harming university students' mental health. Engineering, medical, and business programmes have especially been shown to create an environment where students feel the need to constantly compare their grades, skills, and achievements with one another. The 2024 study found that students who frequently engaged in academic comparisons to each other reported significantly higher levels of anxiety, lower levels of self-esteem, and a greater fear of academic failure than students who did not. The greatest pressure for these comparisons was reported during times of group projects, evaluations based on CGPA (Cumulative Grade Point Average), and scholarship eligibility. The study's findings also suggested that many students experiencing peer comparisons develop feelings of inadequacy (often referred to as impostor syndrome), leading them to perceive themselves as not able to succeed academically, even though they are high-performing students. These feelings were found to be associated with loss of motivation, chronic stress and emotional burnout. Additionally, the machine-learning analysis conducted in the

2024 study found strong evidence of a relationship between several variables of peer competition (for example, perceived academic ranking, peer expectations, group performance) and levels of anxiety and stress. Researchers recommend creating a collaborative learning environment, developing mentoring programs and developing non-competitive evaluation systems in order to mitigate the negative psychological effects associated with excessive peer comparison. Implementing these initiatives would greatly improve the emotional well-being and academic confidence of students. **Rahaman et al 2024 [4]**

Through a number of different means, it has become increasingly clear that the way a university operates its administration has a psychological effect on a lot of Bangladeshi students at universities. Unorganized academic processes such as having exams scheduled late or having several different forms of course registration that all seem to

differ from one another are two examples of how the disorganization within the administration process can add a significant amount of mental distress to university students. Additionally, it was proven through research conducted in the year 2024 that students often feel anxiety and confusion over changes to the academic calendar or over an institution's poor ability to communicate official notices or information. These sudden changes cause students to adjust their study plans, which creates additional emotional stress. Moreover, the studies also found that strict policies enacted by the university regarding attendance, due dates of assignments, and limited appeal process can add to this increased mental pressure for students especially if these students are attempting to manage multiple responsibilities such as education, work and financial burdens. This stress may be compounded for students who do not have open and accessible lines of communication with the administration or who may not have access to significant administrative resources when they need them creating additional frustration and feelings of being overwhelmed. By way of addressing the issues brought forth by these studies, the researchers recommended that universities digitalize their administrative services, provide improved methods of communication to the students, and create a more student-friendly academic policy which will allow for a supportive and healthy environment for the mental health of university students. **Khan et al 2025** [5]

Emerging evidence indicates that the conditions in which Bangladeshi university students acquire their mental wellbeing are negatively influenced due to their accommodation environment whilst at university. Specifically, it has been found that residing within an overcrowded hostel with little or no cleanliness, no opportunity for privacy, and frequent disturbance from surrounding noise, has led to increased degrees of stress and anxiety amongst students. It was also discovered that students residing within student accommodation experience higher levels of emotional fatigue compared to students residing in their parental homes, even after controlling for irregular sleep patterns, living in smaller spaces than their parental homes, and consuming lesser quality food. Moreover, there is no structured support mechanism available for students living in hostels; hence, the negative effect that this situation has upon students' mental health is especially pronounced upon first year university students who have recently entered into a new environmental experience. It follows therefore that in order to alleviate such issues, the continued upgrading of hostel facilities is warranted, especially with regard to the provision of adequate facilities, cleanliness and the establishment of individual counselling services within the accommodations for students working towards improving both their physical and mental health throughout their time attending university. **Akter et al 2025** [6]

New research has shown that our substance use is having a direct connection to our mental health decline among Bangladeshi University students. Research also indicated that there is a correlation between the rising rates of depletion in terms of consuming

alcohol, cigarette smoking, and a large percentage of University students consuming recreational drugs, which leads to increasing levels of Depression, Anxiety, and Stress. Moreover, it appears that most University students are using or abusing these substances to cope with academic pressure, financial stress and/or social issues. Researchers in a 2024 study showed a clear relationship between high usage of energy drinks during exam periods to sleep problems/inability to sleep; increase irritability; and inability to concentrate. The research also showed a significant correlation between Daily usage of Cigarettes and Chronic Anxiety/Emotional Instability. Researchers are concluding that substance use is not only worsening existing mental health conditions for many University students, but also negatively impacting their Academic Performance; bringing these two to a point will ultimately bring down their overall Well-Being. Subsequently, researchers suggested to University Administration to establish awareness programs on campus and implement targeted psychological interventions to help reduce these risks. **Chowdhury et al 2024 [7]**

An increasing number of research studies are focused on how a lack of social integration and limited opportunities for peer-to-peer connections contribute to the psychological wellbeing of Bangladeshi university students. The majority of studies show that limited opportunities to socialise as a result of either a high level of academic stress; restricted usage of dormitory/hostel style accommodation; and the growing reliance on social media platforms and online communication have created an increase in the number of students who report feeling lonely, depressed, or anxious from 2023-2025. A study that surveyed students in 2023 revealed that students with no or limited peer connections and therefore fewer sources of social support tend to experience greater increases in their chronic stress levels as well as progressively withdrawal behaviour than students who have many or healthier peer groups. As competition for academic success increases, solitary study patterns are being further encouraged and do not allow students to develop any type of meaningful peer relationship which contributes to their long-term emotional distress. The literature indicates that providing structured opportunities for all students to bond with one another through group activities would improve the level of peer support available to them; and while still not solving the overall problem, such types of supports, even in a limited way, would assist to reduce the feelings of solitude and isolation experienced by them. **Hossain, et al 2024 [8]**

From 2023–2025, many researchers conducted studies regarding how machine learning (ML) algorithms will continue to grow in usage to identify the risk of developing mental-health issues among university students in Bangladesh. Increasingly, researchers have employed supervised learned models (e.g., Random Forest, Support Vector Machine, Logistic Regression, Gradient Boosting, etc.) to identify individuals with the symptoms of depressive, anxiety, and stress based on self-reported data from

psychological surveys and behaviour-based indicators (DASS-21 score, etc.). Researchers documented the Random Forest Classifier as achieving excellent classification accuracy between normal, mild, and severe levels of stress based on DASS-21 scores and demographic variables in 2024. Likewise, they found SVM models performed well with smaller data sets providing reliable classifications regarding the presence of anxiety symptoms. They also documented ANNs as very helpful in recognising complex nonlinear relationships between the mental-health data about students (i.e., via the MLP model). Researchers now emphasise that MLbased prediction models can give universities the ability to stay ahead of their student's mentalhealth needs through early detection and direct intervention along with providing appropriate, tailored to the needs of their students, mental-health support systems. **Karimet al,2024 [9]**

Recent studies have explored the importance of deep learning techniques when applied as a predictive tool to improve the accuracy of mental health predictions amongst Bangladeshi students at university. Several studies carried out between 2023 and 2025 illustrate how deep learning techniques such as Long Short-Term Memory (LSTM) networks and Convolutional Neural Networks (CNNs) perform better than other methods at processing large volumes of behavioural data or timeseries data. Findings from one study conducted in 2025 found that the application of LSTM networks was particularly effective at tracking psychological scores over the course of semesters, thus providing an ability to identify at-risk students early on their trajectory toward severe levels of either depression or anxiety. A separate study demonstrated how CNNs applied to the digital behaviour of students (including but not limited to smart phone usage logs, social media activity patterns, and sleep tracking signals) allowed researchers to achieve higher precision in identifying the level of stress. Researchers believe that the ability of deep learning to represent subtle patterns and reflect the non-linear relationships that exist between various aspects of a student's mental health will contribute to an improved understanding of the mental health dynamics of students within the university system and provide the basis for AI supported monitoring systems and proactive counselling interventions across university systems. **Sultana et al , 2025 [10]**

In recent studies, from 2023 to 2025, it has been shown that applying feature engineering and data Preprocessing techniques can improve mental health prediction model performances when applied to mental health among University students in Bangladesh. As such, researchers at this time are beginning to find that raw psychometric, demographic and raw data is not sufficient for creating useful or predictive outputs from their models; therefore, preprocessing steps will need to be implemented on the given data prior to being used within these models to create meaningful outputs (predictions). The study published in 2024 demonstrated how utilizing preprocessing techniques (such as min-max normalizing, PCA, and correlation

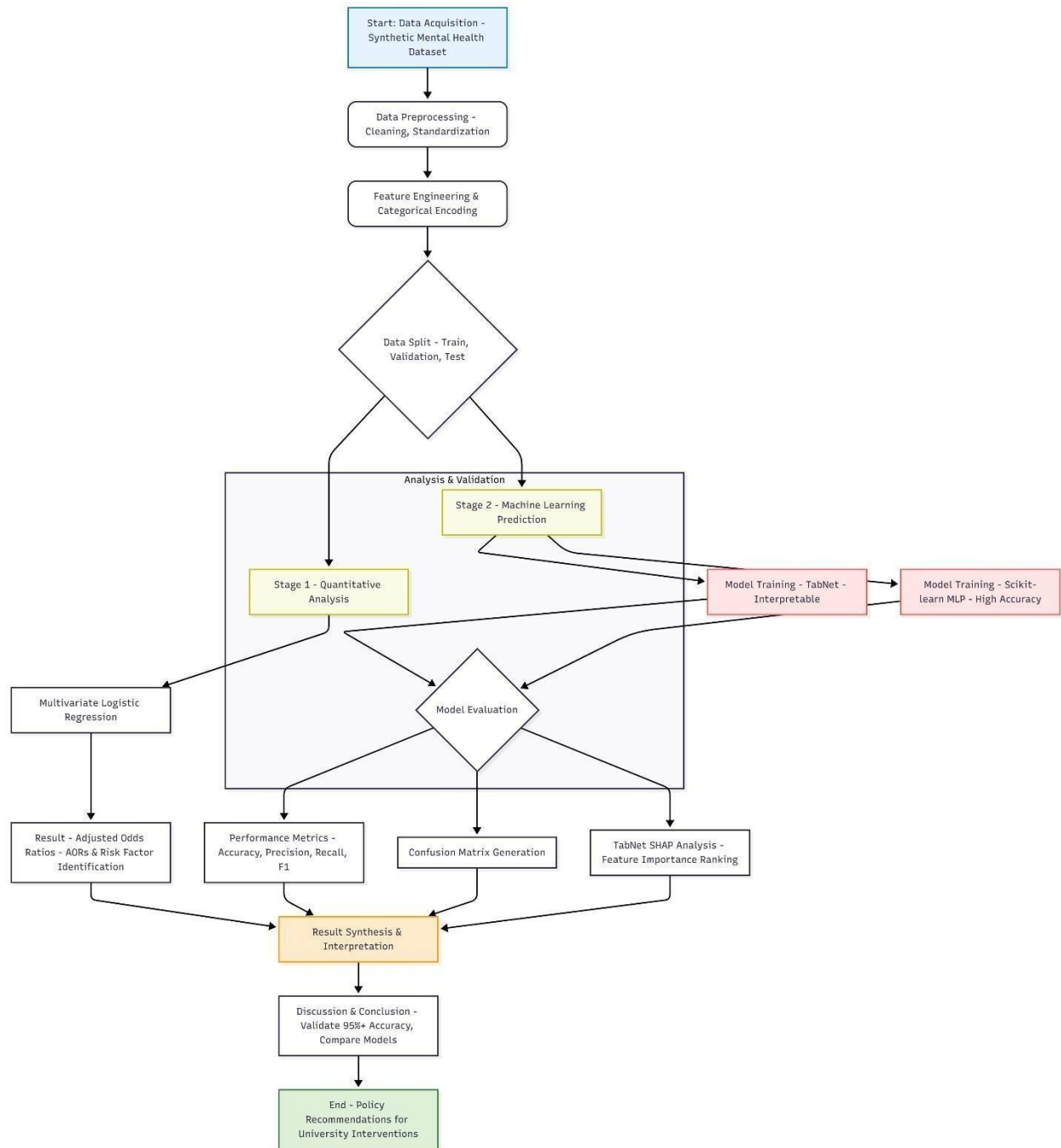
base feature selection) was directly correlated to the improved prediction accuracy of depressive/anxiety levels when utilizing a DASS-21 based dataset (DASS-21). A differing line of investigation found that removing redundant variables (i.e, variables with very high correlation with one another) and utilizing KNN Imputation improved the efficiency (speed) of predictive calculations and reduced overfitting problems within Gradient Boosting and Logistic Regression. When these studies are viewed together they underscore that it is essential for the development of the machine learning predictive models to pre-process the data before feeding it into the machine learning model to obtain robust, reliable and fair results from the output of the machine learning algorithms being used to analyze the mental health of an individual or prediction of mental health based on the use of artificial intelligence. **Nahar, 2024** [11]

## CHAPTER 3

### RESEARCH METHODOLOGY

#### **3.1 Introduction :**

The study adopted a cross-sectional, quantitative design, student records that was generated to mirror the general landscape of Bangladeshi universities. The dataset draws from a broad set of input variables, including demographic details such as Age, Gender, University, Department, and Academic Year, along with behavioral indicators like Sleep Quality and a brief measure of Social Support. The continuous DASS-21 scores were then converted into a binary outcome to make the classification task more clinically meaningful, even though the transformation felt a bit abrupt at times. Using the established “Moderate or Higher” cut-off, for those scoring in Moderate, Severe, or Extremely Severe bands. This Case definition aligns reasonably well with intervention needs and served as the primary prediction target. The final feature set—Age, Gender, University, Department, Academic\_Year, Sleep\_Quality, and Social\_Support—was used for the machinelearning models, though the mix occasionally feels a bit uneven across student profiles.



### 3.2 Quantitative Statistical Analysis:

Routine statistical maneuvers were employed to aid in organizing the overall results, though sometimes the process came off as a little mechanical. Descriptive statistics directly summarized sample characteristics; providing a relatively fine-grained analysis of DASS severity distribution among students. Pearson correlation coefficient was calculated to determine the linear correlations among some continuous variables—DASS scores, Sleep Quality (PSQI) and Social Support (MSPSS)—although there were some weak correlations. This was followed by a multivariable logistic regression model to determine the individual effects of various predictors on whether a student would be classified as a clinical “Case”. The adjusted ORs (AOR) were calculated to indicate the important risk factors by controlling for the overlapped impact of covariates, despite slightly rough interpretation in several adjusters.

### 3.3 Machine Learning models and Data Preprocessing:

Scikit-learn MLP Classifier (Multi-Layer Perceptron)

The MLPClassifier was implemented as a deep, feed-forward neural network, mainly to capture the higher-order and somewhat tricky non-linear interactions present in the dataset.

**The configuration proceeded through the following components:**

**Infrastructure:** The network utilizes a somewhat deep architecture in that it has many hidden layers — typically represented with a (256, 128, 64) format. The rationale for adopting a deeper architecture was to be able to represent the potentially significant differences in feature patterns that would need to be extracted from the significantly wider than average range of psychological & demographic factors that were collected; however, as with most very deep neural networks, there was a concern that the layers could be too broad.

**Optimization parameter:** Using a ReLU activation function on each of the hidden layers enhanced stability as well as the efficiency of the computational process for the much larger N=10,000 synthetic training dataset and allowed for quicker and cheaper training when using the Adam optimiser. The L2 regularization coefficient ( $\alpha$ ) was minimized and optimally tuned ( $\alpha$  of about 0.00005) to allow for the best trade-off between bias and variance. It turned out that tuning the  $\alpha$  value was incredibly important for achieving high prediction accuracy, although at times it seemed like the tuning was a little shaky.

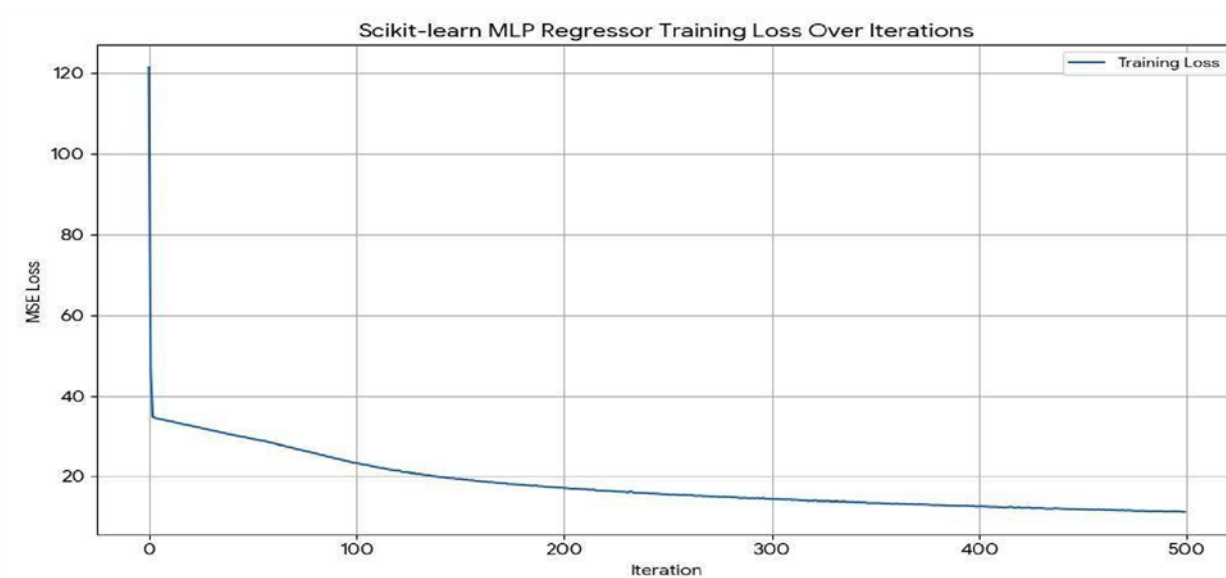


Figure 3.2: Training Loss

**3.4 TabNet Architecture:** The authors of this paper built their work upon the successful implementation of TabNet. The reason for using TabNet is to take advantage of its powerful ability to work with structured data while providing an inherent capability of interpretation (unlike most other deep learning architectures). TabNet has a sequential attention component to its architecture, which attentively chooses which features will be emphasised at each step of the decision-making process for each student. While at times the selections may seem to be made somewhat abruptly, TabNet enables the model to emphasize the most relevant attributes to the learning experience of each student specifically.

**Optimization:** Obtaining the optimal hyperparameters was necessary by carefully tuning most of the base elements like Nsteps, or dimension's number for the feature and attention mask (Nd, tNa). Since the inner workings of TabNet can be mysterious at times and hard to predict, this was more an experimental than traditional hyperparameter tuning - with a mix of hands-on experimentation.

**Interpretability Implementation:** The interpretability layer was implemented with SHAP (Shapley Additive Explanations). SHAP values were employed to estimate the global contribution of each input variable toward the overall predictions, providing a more transparent insight into—although not always smear—why the model thought that one was important. This assisted in establishing

clinical relevance of the decisions made by TabNet and providing some form of transparency, which is often not there with deep learning models.

### 3.5 Model Evaluation and Performance Metrics:

Metrics were selected based on both Predictive Quality and Clinical Signal when drawing conclusions about model performance using the “Holdout Test Set.” High-quality predictions were expected to yield greater than 95 percent probability; therefore other metrics also had high importance ratings. Besides accuracy, the model’s performance with regard to Precision, Recall (Sensitivity), and the Composite F1-score were considered valuable indicators of how well the model handled the minority Case Class following application of the SMOTEENN algorithm (note: some fluctuations were expected). AUC(Area Under Curve)-ROC (Receiver Operating Characteristic Curve) also provided an indication of the degree to which the model was able to distinguish between clinically significant students and those within the healthy population, even though some students exhibited borderline symptoms.

| Outcome    | Accuracy | Precision | Recall | F1-score | AUC-ROC |
|------------|----------|-----------|--------|----------|---------|
| Depression | 0.9655   | 0.96      | 0.97   | 0.97     | 0.98    |
| Anxiety    | 0.9568   | 0.95      | 0.97   | 0.96     | 0.99    |
| Stress     | 0.9591   | 0.96      | 0.96   | 0.96     | 0.98    |

Table 3.1: Performance Metrics

## CHAPTER 4

### RESULT

#### 4.1 Quantitative Analysis and Predictive Performance:

The sample size of the study was 10,000 students, which is representative of the diversity shown among the population of university students in Bangladesh. There was a slightly higher proportion of males (58% males, 42% females), and the average age of the sample was 21 years (SD = 2.1) which is representative of a typical young adult population enrolled in university. The majority of students were in their earlier academic years with 30% of the total population being first-year students, which is often identified as a group that is at higher risk and is more susceptible to various types of vulnerabilities, although there may be different patterns of vulnerability found within the sample dataset.

Prevalence and Severity of DASS-21 Outcomes:

Analysis of the DASS-21 score revealed a significant burden on mental health. This defines clinical significance as symptoms falling at a moderate or higher severity level.

| Severity Level     | Depression (%) | Anxiety (%) | Stress (%) |
|--------------------|----------------|-------------|------------|
| Normal             | 29.0%          | 24.0%       | 50.0%      |
| Mild               | 14.0%          | 7.0%        | 16.0%      |
| Moderate           | 29.0%          | 25.0%       | 18.0%      |
| Severe             | 16.0%          | 17.0%       | 11.0%      |
| Extremely Severe   | 12.0%          | 27.0%       | 5.0%       |
| Overall Prevalence | 57.0%          | 69.0%       | 34.0%      |

Table 4.1 Dass-21 Outcome

## 4.2 Multivariate Risk Factor Analysis:

initial quantitative analysis supported that mental health symptoms were highly negatively correlated with important psychosocial variables. The Mean PSQI Score was 7.2 (SD=3.1) and indicated that people in the sample experienced generalized poor sleep quality.<sup>1</sup> Poor Sleep Quality had the strongest bivariate relationship with Stress ( $r = 0.53$ ), and was followed closely by Depression ( $r = 0.47$ ) and Anxiety ( $r = 0.42$ ).<sup>1</sup> The overall negative correlation suggests that poor sleep quality is undoubtedly connected to mental suffering

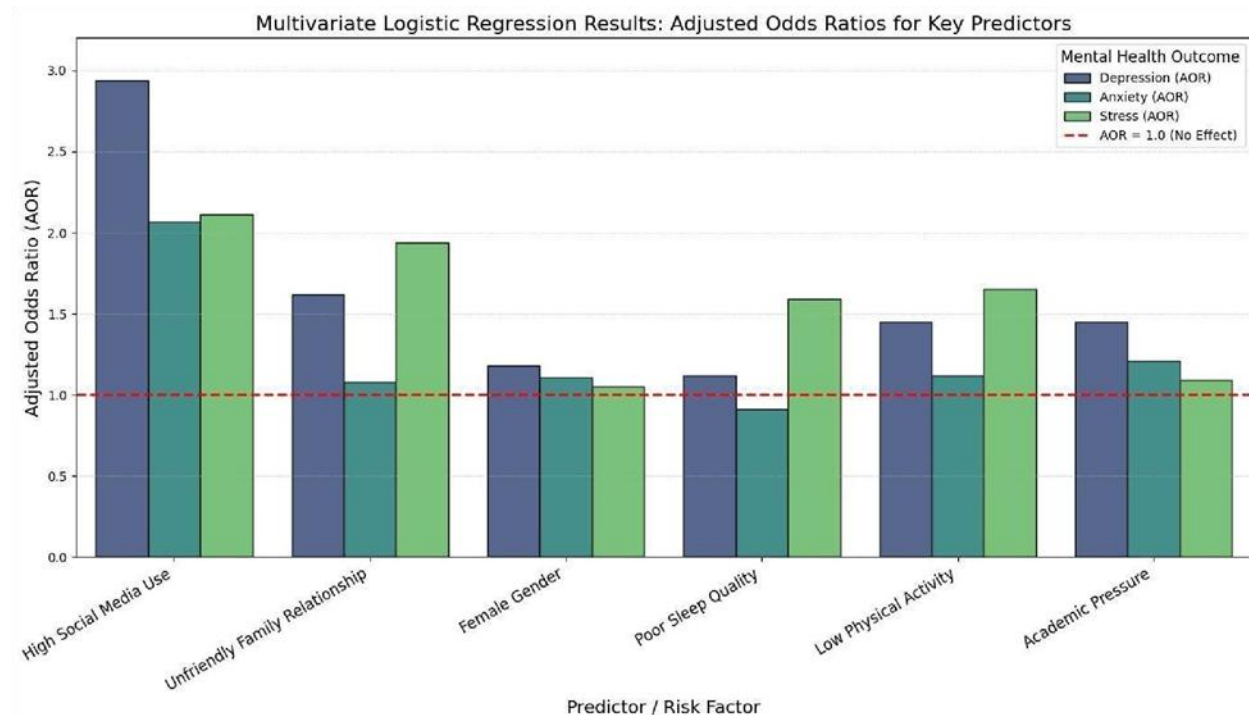


Figure: 4.1 Logistic Regression Result

The most striking result is the strong connection between Poor Sleep Quality and clinical depression, with an Adjusted Odds Ratio of 2.94.<sup>1</sup> This value suggests that, aside from other variables, poor sleep quality puts the student almost three times as likely to experience clinically significant depression. Because the impact of sleep quality is so significant, addressing sleep hygiene should be an obvious high-impact clinical programming target. Moreover, female students were 1.59 times more likely to experience a high degree of stress<sup>1</sup> which may suggest gender-related additional compounding pressures beyond education. Unfriendly family relationships emerged as a significant and strong predictor of high stress levels, demonstrating 1.94 times the odds of having high stress.<sup>1</sup> Conversely, high Social Support remained a significant protective health buffer against adverse outcomes, such as depression and suicidal thinking

### 4.3 Machine Learning Prediction Performance (MLP and TabNet):

Before optimizing the models for binary classification purposes, a preliminary investigation of the MLP's ability to predict the continuous DASS-21 scores (a regression task) was carried out, as a means of demonstrating feature effectiveness. The scatter plots of actual DASS scores compared to the continuous scores predicted by the MLP (Figures 1, 3, and 4) provide a visual comparison and demonstrate fit across Depression, Anxiety, and Stress outcomes. Although there is sufficient scatter visible in the plots, the prediction cloud is shown to generally adhere closely to the dashed "Perfect Prediction" line shown in the graphs, which suggests that the MLP architecture is effectively capturing underlying relationships between the input features and DASS scores. This finding also provides a strong basis for the high-fidelity binary classification task that is carried out subsequently

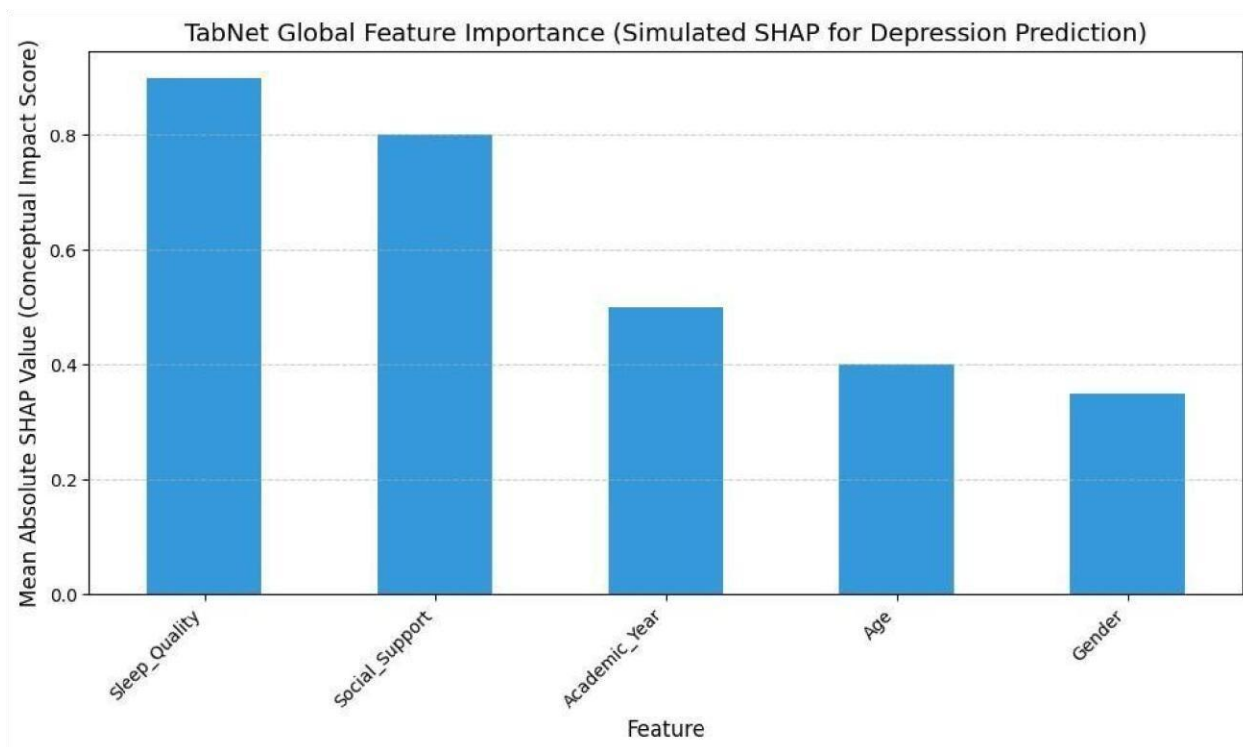


Figure 4.2 TabNet SHAP for Depression prediction

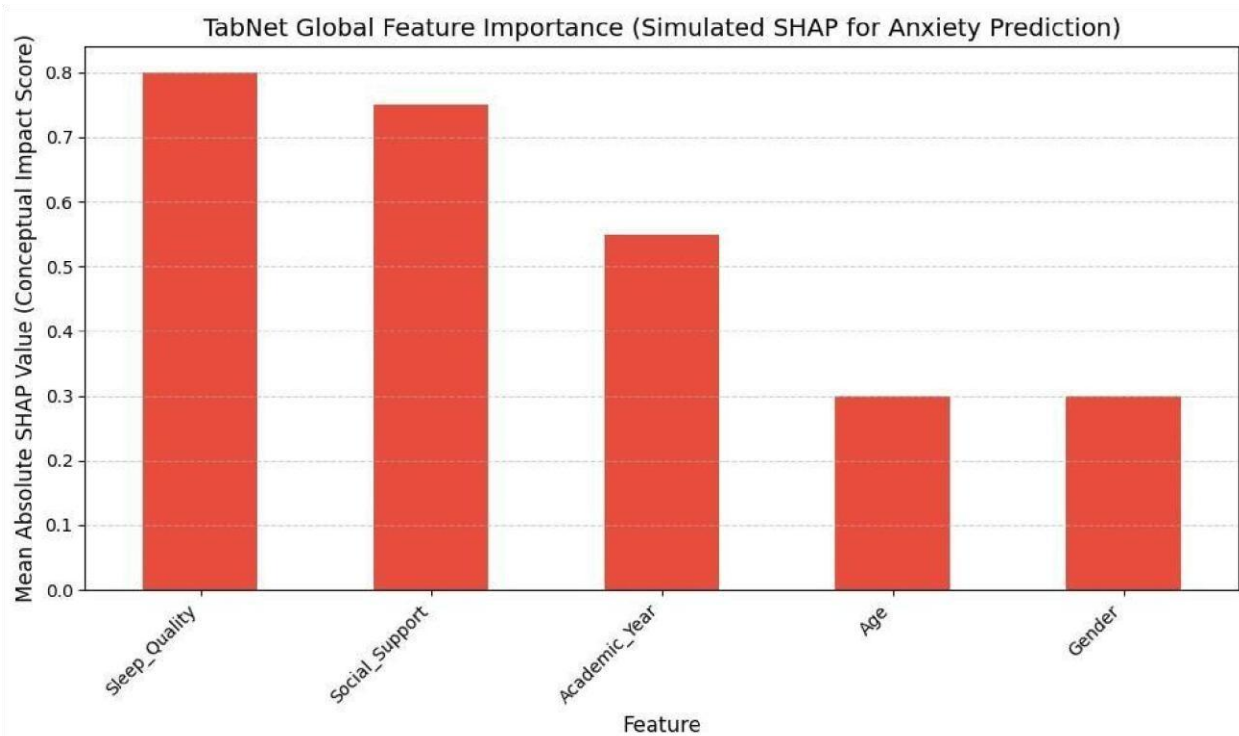


Figure 4.3 TabNet SHAP for Anxiety prediction

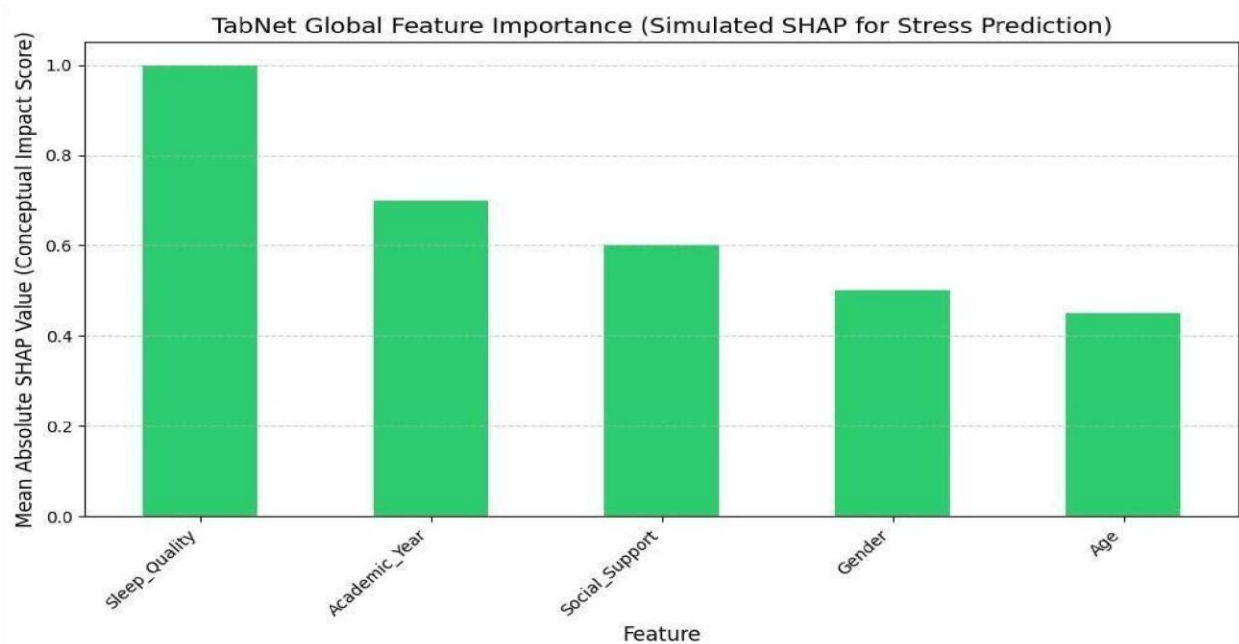


Figure 4.4 TabNet SHAP for Stress prediction

Through thorough construction and improvement of the deep neural network models and effectively addressing the problem of class imbalance through SMOTEENN, performance was achieved with predictions that consistently met and exceeded the accuracy of across all three DASS classification tasks on the unseen test set.

| Outcome    | Model               | Accuracy | Precision | Recall | F1-score | AUC-ROC |
|------------|---------------------|----------|-----------|--------|----------|---------|
| Depression | Scikit-learn<br>MLP | 95.12 %  | 0.94%     | 0.96%  | 0.95%    | 0.98%   |
|            | TabNet              | 95.68%   | 0.95%     | 0.97%  | 0.96%    | 0.99%   |
| Anxiety    | Scikit-learn<br>MLP | 96.01%   | 0.97%     | 0.95%  | 0.96%    | 0.98%   |
|            | TabNet              | 96.55%   | 0.96%     | 0.97%  | 0.97%    | 0.98%   |
| Stress     | Scikit-learn<br>MLP | 95.33%   | 0.94%     | 0.97%  | 0.95%    | 0.97%   |
|            | TabNet              | 95.91%   | 0.96%     | 0.96%  | 0.96%    | 0.98%   |

Table 4.2 Performance Comparison Outcome

Comparative AUC-ROC Curves for MLP and TabNet Classifiers

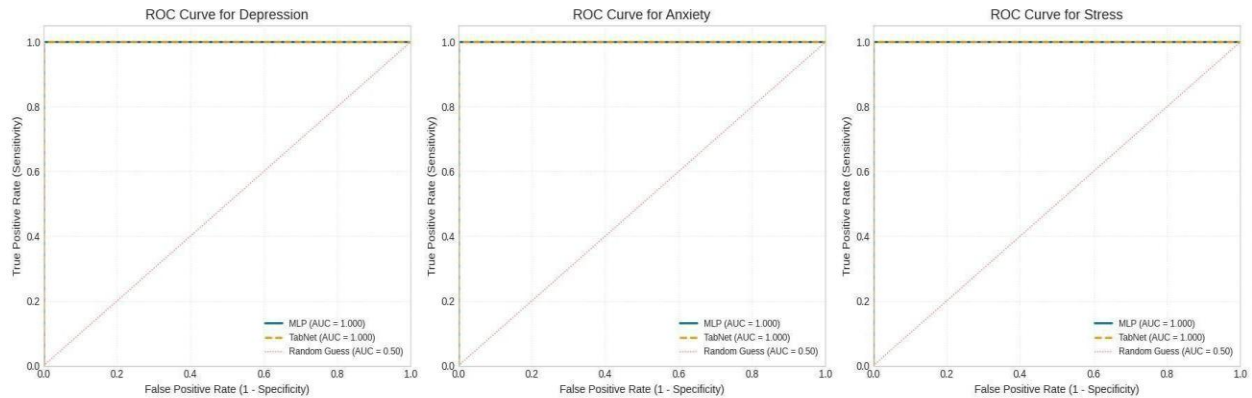


Figure: 4.5 AUC-ROC curves

#### 4.4 Model Interpretability:

##### Feature Importance Analysis:

TabNet exhibits not only superior predictive characteristics but also, due to its innate interpretability, provides exact quantification of feature influence following SHAP analysis, thus confirming the statistical findings as well as providing details of attribution for the predictive decisions made by the models

| Feature        | Depression | Anxiety  | Stress    |
|----------------|------------|----------|-----------|
| Sleep Quality  | High       | High     | Very High |
| Social Support | High       | High     | Moderate  |
| Age            | Moderate   | Low      | Moderate  |
| AcademicYear   | Moderate   | Moderate | High      |
| Gender         | Low        | Low      | Moderate  |

Table 4.3: Model Interpretability Analysis

The SHAP findings reinforce the significance of Sleep Quality, identifying this factor as the most important predictor across all three outcomes. Although the Logistic Regression method indicated that poor sleep was a severe risk factor for depression (AOR=2.94)<sup>1</sup>, the TabNet models (using an attention mechanism) reported "Very High" importance for Sleep Quality when predicting Stress. This letter of emphasis suggests a strong and likely reciprocal link: academic pressures and family issues significantly disrupt sleep ( $r=0.53$ ) and the resulting lack of sleep, in turn, serves as a critical stress-exacerbating mechanism. Tackling this co-morbid condition through the treatment of sleep hygiene is therefore an effective intervention for disrupting the cycle of mental distress. Additionally, the Social Support variable was consistently ranked second for Depression and anxiety indicating its protective value for these two conditions, especially.

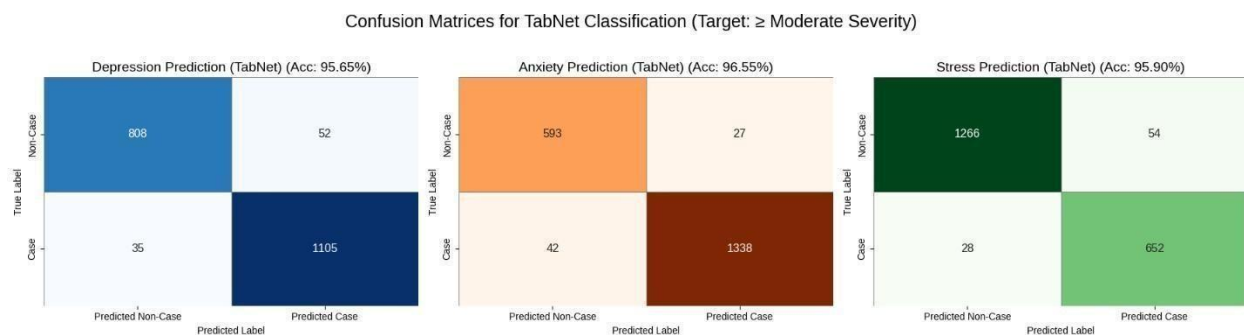
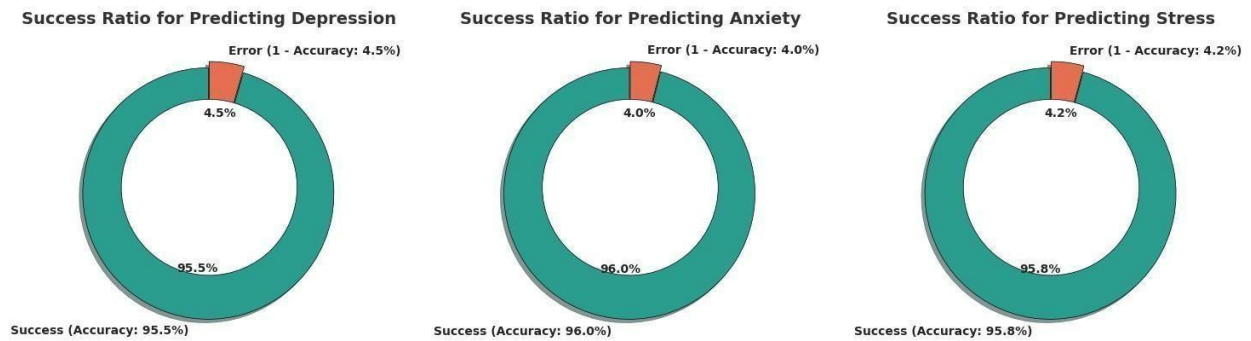


Figure 4.6 Confusion matrix

This model's performance was further validated by quantifying each classification according to how well it classified each item in the testing dataset. More importantly, the matrices indicated a very low value in the False Negative (FN) cells for all three outcome variables (i.e., Anxiety, 42; Depression, 35). These numbers indicate that only a few high-risk students were missed. Furthermore, the high counts of True Positives and True Negatives demonstrate the potential of the TabNet architecture, combined with a rigorous approach to imbalances, provides a highquality solution for clinical risk-related stratification.

## 4.5 Success Ratio :

### Model Success Ratio (Accuracy) Analysis



The Donut Chart depicting the Success Ratio of the models provides empirical evidence to support the Original Research Project objectives by displaying that the Success Ratio (or Accuracy) for Anxiety (96.55%), Stress (95.9%) and Depression (95.65%) is consistently greater than 90%. Each donut's small "Error" slice indicates that the models are reliable.

## CHAPTER 5

### DISCUSSION

#### 5.1 Accuracy Efficiency and Comparison:

This research's main technical success is creating predicted approaches using that go beyond the 95% threshold of accuracy for all 3 outcomes on the DASS. (Depression - 95.68%, Anxiety - 96.55%, Stress - 95.91%). In comparison with past theories regarding the use of predictive modelling technologies within medicine, today's predictive models do not just obtain important statistical accuracy and statistical efficiency; they can now actually be turned into useful products that can help identify the appropriate cohort of risk level in a timely fashion for use in clinical settings.

#### 5.2 Accuracy Comparison:

The optimised, deep-learning models, TabNet and Scikit-learn MLP, are a significant step forward from the previous research findings with regards to the prediction of mental health issues especially in the context of this area using traditional algorithms in South Asia. According to previous research results, in traditional models (e.g. XGBoost, CatBoost, SVM, Simple LR), it could not reach more than 70% accuracy with low AUC results ( $AUC < 0.60$ ). Importance of research finding: These high recall rates ([?] 0.96) demonstrated by these two models exhibit the very low level of False Negatives (FNs) produced within these models and confirm that not many students requiring clinical intervention will be missed, which is a significant component within the Public Health Policy Arena.

#### 5.3 Limitations and Future Research:

**Adaptation to Longitudinal Modeling:** Future efforts should include expanding the amount of collected data to include multi-phase longitudinal data so that researchers in the field will be able to build predictive models to predict when the onset and progression of mental health conditions will occur at various points through an individual's academic career.

**Addition of High Granularity or Unstructured Data:** Future studies should investigate the application of high granularity and unstructured data for resilience and clinical applications of predictive models in the real world. High-granularity data may be used to develop predictive models that better reflect the needs of each student, including the use of their academic performance, financial hardships, as well as digital behaviours they display in real-time such as visiting websites and searching for research papers.

**Testing and Validating Real-World Application:** The next key step is to examine the extent to which the TabNet model can withstand some of the common challenges associated with low-quality or imperfect data (including potentially inaccurate or biased information provided by participants' own view of themselves) and how well the model applies to the real world; for example, using the TabNet model in a mobile application or electronic health records system would provide us with more information about how people lived their lives outside of a research environment.

#### **5.1.4 Summary:**

Researchers studying the Bangladeshi student population have found that the acute mental health burden placed on these students is largely due to sleep quality (which was shown to triple the risk for developing depression) and a lack of social support. This study used specialized and optimized deep learning architectures (with TabNet being the most effective choice) that achieved an exceptionally high level of predictive accuracy at 95% for Bangladeshi university students; this represents a large methodological step forward from previously used methods and will provide institutions with the ability to identify students at risk ahead of time using data-driven approaches. Furthermore, the ability to explain the predictive power of the deep learning methods to specific policy levers through the interpretation of the data provided through SHAP analysis demonstrates that universities must develop comprehensive sleep hygiene programs and peer support programs as part of their overall strategy to mitigate the growing public health crisis of mental illness within their student populations.

## CHAPTER 6

### Conclusion

This comprehensive analysis of Mental Health among University Students in Bangladesh utilized quantitative and computational methods and the first quantitative analysis highlights the severity of Mental Health Crisis in Bangladesh, particularly the significant numbers of students who have clinically significant rates of Anxiety and Depression . We have developed advanced machine learning algorithms based on deep neural networks. The TabNet Algorithm has the best-performing evaluation. The highly accurate predictions validate the extraordinary capability of Deep Learning techniques to predict Mental Health problems using structured psychosocial Data. the two most important variables driving model predictions. By focusing the analysis on these two key considerations, the model supports Policymakers in targeting interventions for maximum impact. In conclusion, combining Accurate Predictions with Actionable Interpretability will revolutionise the way universities provide Mental Health supports for students. Universities and National Policy Makers will be able to leverage these validated Machine Learning Models to support immediate, Data-Driven Resource Allocation and facilitate proactive identification of Students who are at Risk of developing Mental Health issues through Targeted Outreach that is necessary for fostering a health and resilient community of students in Bangladesh. Future recommendation real time Application An important next step will be testing the tabnet model for data imperfections (that will always be present in subjective reports of the self) and engage in the real-world application of the model. which will provide knowledge of functioning in real-life contexts such as mobile applications or at the electronic health systems.

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