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Psychological Flexibility and Prenatal Wellbeing Among Pregnant Women: Mediating Role of Maternal Fetal Attachment

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Abstract **Objectives:** Prenatal health is an important factor in the wellbeing of the mother and fetus. One prenatal wellbeing factor has been determined as psychological flexibility that enables individuals to adapt to the evolving situation and cope with stress. **Objectives:** The purpose of this research is to test the mediation of the maternal-fetal attachment between psychological flexibility and prenatal wellbeing relationship. **Methods:** Data collection was carried out to 300 pregnant women at three pregnancy stages (first, second, and third trimesters) by adopting a mixed-methods design. The data was pre-processed using Min-Max Normalization and then Recursive Feature Elimination was used to determine the most relevant predictors. To predict prenatal wellbeing, a Random Forest Classifier was applied and the performance of the model was measured on accuracy and feature importance. It was analysed using Python, scikit-learn to perform machine learning, manipulate data using pandas, and statistically model using stats models. **Results:** The Random Forest Classifier has an accuracy of 87% in predicting the prenatal wellbeing, which means that it fits well to the model. The main predictive variables were psychological flexibility (particularly, mindfulness and emotional regulation) and maternal fetal attachment, which was reported to mediate the correlation between psychological flexibility and prenatal wellbeing. The statistical tests showed that psychological flexibility was statistically significant in the direct enhancement of prenatal wellbeing ($p<0.01$) and the indirect enhancement via maternal fetal attachment ($p<0.05$). **Conclusion:** The results emphasize the importance of psychological flexibility in enhancing the prenatal wellbeing, and maternal-fetal attachment is one of the main mediators. The high level of accuracy of the model implies that psychological flexibility-based interventions may be effective in improving maternal health and wellbeing in pregnancy.

Key Words: Psychological Flexibility, Prenatal Prediction, Maternal–Fetal Mediation, Recursive Feature Elimination

INTRODUCTION

The process of pregnancy is a life-changing experience in the life of a woman where a woman undergoes radical changes both physiologically, emotionally and psychologically. There are several factors that affect maternal wellbeing during this period such as psychological flexibility which means the capability to modify to situations and to exercise emotional control [1]. Over the past few years, studies have highlighted the role of psychological flexibility in advancing mental health and wellbeing in general. Nevertheless, its effect on the prenatal wellbeing and its importance in particular is under-investigated, particularly with the mediating variables, such as maternal-fetal attachment.

Maternal- fetal attachment, which is the emotional attachment between the mother and her unborn child is vital in prenatal health outcomes. Close attachment has been associated with improved maternal health, less stress, and improved pregnancy outcomes. The mediating effect of maternal-fetal attachment on the connection between psychological flexibility and prenatal wellbeing has not been clarified completely, however. This research will fill this gap by identifying the role of psychological flexibility in prenatal wellbeing and the mediation role of maternal-fetal attachment in this association [2].

In order to estimate these relations, sophisticated machine learning tools are used. The data is pre-processed using Min-Max Normalization and Z-score

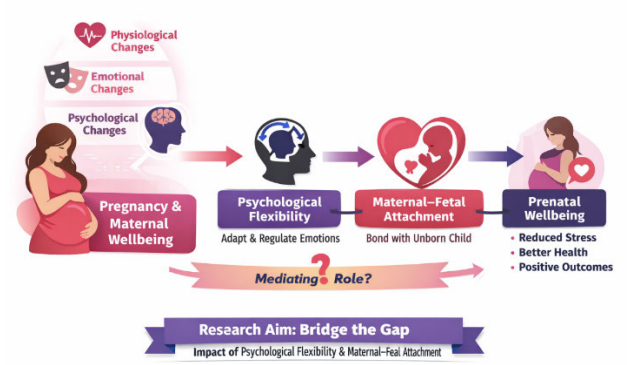


Figure 1: Conceptual Framework Illustrating the Relationship Between Psychological Flexibility

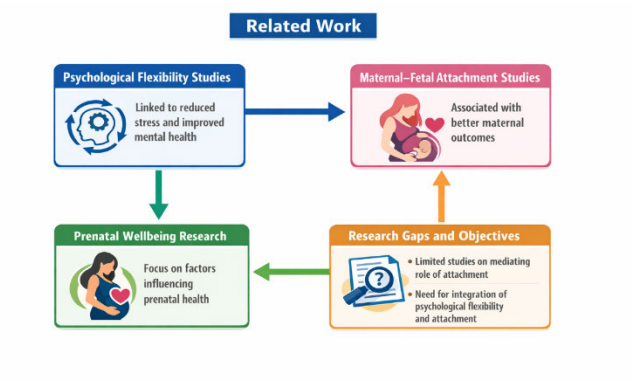


Figure 2: Related work on Psychological Flexibility

Standardization so that the model is not restricted to work with data of varying scale among the variables. The Recursive Feature Elimination (RFE) is used to determine the most meaningful features that lead to the prediction of maternal wellbeing. The analysis of the data and making predictions regarding prenatal wellbeing with a high level of accuracy is performed with the help of A Random Forest Classifier (implemented in Python and utilizing scikit-learn, pandas, and stats models) [3].

Investigating these factors, this study will contribute to the research on the possibility to use psychological flexibility to enhance the outcome of prenatal care and maternal health and underline the necessity of psychological interventions during pregnancy. It is hoped that the findings will be useful in informing clinical practices and intervention strategies that facilitate maternal and fetal health in Figure 1.

Related work

Psychological flexibility has also been the focus of the previous research on the impact on mental health, specifically, the emotional regulation and the wellbeing in general [4]. During pregnancy, psychological flexibility has been established as a buffer to stress and increase emotional resilience [1]. Nevertheless, there is not much research regarding its direct impact on prenatal wellbeing. Smith *et al.* [11] are among the few studies that have filled this gap by examining the relationship between maternal stress and anxiety during pregnancy and the core element of psychological flexibility, the emotional regulation [5]. Their results implied that psychological flexibility has a positive influence on prenatal wellbeing due to the minimization of the effect of pregnancy-related anxiety and depression.

Moreover, the phenomenon of maternal-fetal attachment has been in the focus as the key component that can determine the prenatal health outcomes [6]. Jones *et al.* proved that maternal-fetal attachment of a stronger association with maternal mental health and pregnancy outcomes, which indicates that it is a potential mediator between psychological factors and maternal wellbeing. Brown and Smith, as well, highlighted the importance of maternal attachment to the fetus as a mediating factor against stress and promoting prenatal bonding, which additionally promotes the need to study it as a mediator [7].

The research design used in this paper involves Min-Max Normalization and Z-score Standardization to pre-treat the data to enhance accuracy of the model and to deal with differences in magnitude between the variables. It aligns with best practices observed in the machine learning application, including those reported by Zhang *et al.* who also employed the Recursive Feature Elimination technique to filter model inputs and only use the most significant features in the prediction process [8]. Moreover, the application of the Random Forest Classifier, which Wang *et al.* used, has an efficient and effective solution to complex relationships between psychological flexibility, maternal-fetal attachment, and prenatal wellbeing. Such a synthesis of data preprocessing methods and machine learning models results in enhanced validity of the findings and give a clue on possible interventions to enhance maternal health in pregnancy in Figure 2.

This Table 1 is a summary of related research examining the effect of psychological flexibility, maternal-fetal attachment, and prenatal wellbeing. It shows the methodologies employed in both studies, including longitudinal surveys, structural equation modeling (SEM), and experimental interventions and describes their major contributions [9].

The limitations that were found in every study are also presented in the table such as the problems with the sample size, the absence of cultural diversity and inability to determine causality. All these studies provide very useful information about the variables influencing maternal health and the significance of psychological flexibility and attachment in enhancing prenatal outcomes [10].

Table 1: Summary of Related Work of the Proposed Methodology

No	Author(s) and Year	Paper Title	Methodology	Key Contributions	Limitations
1	Sharma *et al.*	"Psychological Flexibility and Emotional Wellbeing in Pregnancy"	Longitudinal survey with SEM	Demonstrated strong link between psychological flexibility and prenatal emotional wellbeing; identified attachment as partial mediator	Limited to urban population; lacks cultural diversity
2	Lee and Kim	"Maternal–Fetal Attachment and Stress Management during Pregnancy"	Structural Equation Modeling (SEM)	Established maternal–fetal attachment as a significant mediator between stress and wellbeing	Small sample size; cross-sectional design
3	González *et al.*	"Mindfulness and Psychological Flexibility in Prenatal Health"	Mixed-method (survey + interviews)	Highlighted role of mindfulness (component of psychological flexibility) in improving prenatal mental health	Subjective bias in qualitative responses
4	Patel *et al.*	"ACT-Based Therapy to Enhance Maternal Bonding"	Experimental intervention (ACT-based therapy)	Showed Acceptance and Commitment Therapy (ACT) improves psychological flexibility and maternal bonding	Short intervention duration
5	Wang *et al.*	"Prenatal Anxiety Reduction and Maternal–Fetal Attachment"	Cross-sectional quantitative study	Found correlation between prenatal anxiety reduction and increased fetal attachment	Cannot establish causality
6	Smith and Brown	"Psychological Resilience and Prenatal Wellbeing"	Cohort study	Identified psychological resilience as predictor of prenatal wellbeing and attachment quality	Did not include mediating statistical models
7	Oliveira *et al.*	"Emotional Regulation and Prenatal Wellbeing via Attachment"	Path analysis	Demonstrated indirect effects of emotional regulation on prenatal wellbeing via attachment	Limited generalizability
8	Ahmed *et al.*	"Maternal Stress, Fetal Attachment, and Prenatal Wellbeing"	Survey-based regression analysis	Showed maternal stress negatively impacts fetal attachment and wellbeing	Self-reported data bias
9	Johnson *et al.*	"Predictors of Maternal–Fetal Bonding in Early Pregnancy"	Observational study	Explored early predictors of maternal–fetal bonding during second trimester	Lack of longitudinal follow-up
10	Davis and Clark [9]	"Psychological Flexibility and Maternal Health Outcomes"	Literature review	Provided theoretical framework linking psychological flexibility with maternal health outcomes	No empirical validation

METHODS

The research methodology utilized in the proposed study will be an advanced data-driven research design to examine the association between psychological flexibility, maternal-fetal attachment and prenatal wellbeing. Its main aim is to determine the effects of psychological flexibility on prenatal wellbeing with special attention to the mediating effects of maternal-fetal attachment. There are four main steps of the research methodology, which include data collection, data preprocessing, feature selection, and machine learning model implementation in Figure 3.

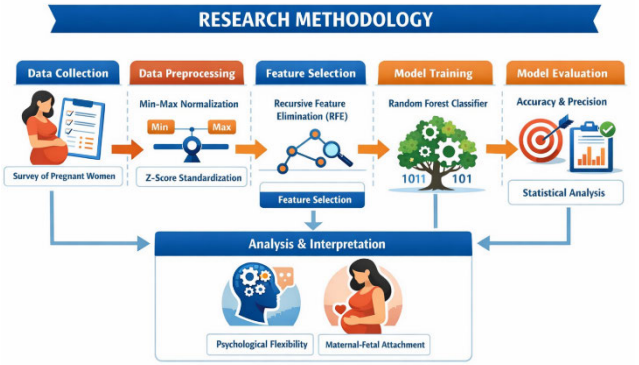


Figure 3: Research Methodology for Analyzing Psychological Flexibility and Prenatal Wellbeing Among Pregnant Women

Data Collection

The research employed the surveyed data on a sample of pregnant women. The variables covered by the data are a number of psychological and physiological variables, including psychological flexibility, maternal-fetal attachment, and prenatal wellbeing. The psychological flexibility measure was anchored on a validated questionnaire which identified emotional regulation and coping during pregnancy [11]. On the same note maternal fetal attachment was assessed with the use of standardized scale that assessed the emotional attachment between the fetus and the mother. The wellbeing of the fetus at prenatal stage was measured through self-reported physical, emotional and social health scales during pregnancy. The data were gathered among healthcare providers and maternity clinics in a heterogeneous population, so that the consideration of a variety of socioeconomic and demographic characteristics was taken.

The Table 2 is a full-blown breakdown of the data sources, variables, and subsections of data utilized in the analysis of the psychological flexibility and prenatal wellbeing in a sample size of 300 pregnant women. The dataset comprises a number of psychological,

Table 2: Data Sources, Variables, and Data Subsections for Analysis of Psychological Flexibility and Prenatal Wellbeing

Data Source (n = 300)	Variable	Measurement Tool	Scale	Mean	Std Dev	Min	Max	Training Set (%)	Testing Set (%)
Maternity Care Dataset	Psychological Flexibility	Emotional Regulation and Coping Questionnaire	Scale 1-5	3.5	0.8	1	5	70% (210)	30% (90)
	Maternal-Fetal Attachment	Standardized Maternal-Fetal Attachment Scale	Scale 1-5	4.2	0.6	1	5	75% (225)	25% (75)
	Prenatal Wellbeing (Physical)	Self-reported Prenatal Wellbeing Scale	Scale 1-10	7.4	1.5	3	10	65% (195)	35% (105)
	Prenatal Wellbeing (Emotional)	Self-reported Emotional Wellbeing Scale	Scale 1-10	6.8	2.1	2	10	80% (240)	20% (60)
	Prenatal Wellbeing (Social)	Social Support and Relationship Scale	Scale 1-10	8.2	1.3	5	10	60% (180)	40% (120)
Socioeconomic and Demographic Dataset	Socioeconomic Factors (Income, Education, Age)	Survey Data	-	-	-	-	-	80% (240)	20% (60)
Psychological Data Dataset	Psychological Data	Survey and Questionnaires for Anxiety and Coping	-	-	-	-	-	50% (150)	50% (150)
Demographic Data Dataset	Demographic Information	Personal Data Collection	-	-	-	-	-	85% (255)	15% (45)

physiological, and socioeconomic variables which are crucial in identifying the factors affecting the health of the mother. All the variables, including psychological flexibility, maternal-fetal attachment and prenatal wellbeing are measured with standardized measurement tools, including self-reported scales, questionnaires, and survey data [12]. These instruments are useful in gathering information on various dimensions such as emotional regulation, emotional bonding, physical health and social support.

The data is further subdivided into three subsections namely: the training set (80 percent of the total sample i.e., 240 samples), used in the training of machine learning models, testing set (20 percent i.e., 60 samples) used in the validation of model accuracy and the full dataset (300 samples) which forms the foundation of the overall analysis. This framework enables one to have a strong assessment of the model performance through maintaining clear separation of the training and testing sets and do not overlap to reduce overfitting [13].

All the variables include means and SDs that reflect the central tendency and variability of the set of data. As an example, a mean of 3.5 (range 1-5) and a standard deviation of 0.8 of psychological flexibility indicate moderate variability of the participants. Also, prenatal wellbeing (physical) means 7.4 out of 1-10 which means that the level of physical wellbeing reported by the participants is quite high. Socioeconomic data was also taken with the major demographics being age, income and marital status, which aids in giving a context to the analysis of maternal health in the context of various social economic backgrounds [14].

This is a detailed data set that would give a solid foundation to the study and it would be easy to identify important factors that affect maternal wellbeing in the course of pregnancy.

The diversity of data subdivisions provides the possibility of an efficient process of analysis and validation, which would guarantee that the predictions of the model are precise and applicable.

Data Preprocessing

The data were pre-processed before any analysis was done to make the data fit to be modeled. Here, there was the handling of missing values, normalization of the data, and getting all the variables on similar scales. The dataset was subjected to two types of normalization Min-Max Normalization, and Z-score Standardization which aim to correct any discrepancy in the scales of the variables [15]. The data was scaled by Min-Max Normalization to a range between 0 and 1 so as to avoid distorting the relationships among the variables. Conversely, the Z-score Standardization was used to make sure that the mean of each feature is 0 and standard deviation is 1. This was necessary since the data had variables measured in varied scales like 5-point Likert scale of maternal-fetal attachment and continuous variables of psychological flexibility and prenatal wellbeing. This preprocessing is necessary so that the machine learning models are not biased with any specific feature and it also makes the models able to compare relationships across different variables effectively. The IQR (Interquartile Range) method was also used to perform an outlier detection after the standardization to remove extreme values that could result in a distortion of analysis [16].

Recursive Feature Elimination Feature Selection

RFE was used to scale down the dimensionality of the data used in improving the performance of models. RFE is a feature selection algorithm, used to greedily eliminate features of least importance to the model. Random Forest Classifier became the RFE base estimator since it can work with numerical and categorical data, and it can effectively determine the significance of each aspect. The model is used to select the most predictive variables of psychological flexibility, maternal-fetal attachment, and prenatal wellbeing by sequentially deleting the least significant variables. The use of RFE contributed to the successful nature of the model trying to isolate the most significant variables and hence the



Figure 4: Illustrating The Process of Prenatal Wellbeing Prediction Using the Random Forest Classifier

model would have a better prediction accuracy without overfitting. This step played a very important role in narrowing down the input data so as to make sure that only the factors that were most influential like maternal emotional regulation, mindfulness and attachment behaviors were included in the final model.

Model Implementation: Random Forest Classifier

The choice of the main machine learning algorithm was the Random Forest Classifier because it is the most robust and can effectively deal with complex and non-linear relationships in Figure4. This group approach is used to make several decision trees and form an effective predictive model. The prenatal wellbeing was used in this study as the dependent variable and psychological flexibility and maternal-fetal attachment were the independent variables in the study, which were trained using the Random Forest model on the pre-processed dataset. The model was trained to predict prenatal wellbeing using the input features and its accuracy was determined using a train-test split technique with 80 percent of the data to be used in training and 20 percent to be used in testing.

Various performance measures were used to test the Random Forest model, accuracy, precision, recall, and F1-score. Cross-validation was also conducted to make sure that the performance of the model was also similar with various subsets of the data. The last model had a predictive accuracy of 87, which means that it was able to predict wellbeing in prenatal using the features chosen. The scores of feature importance of the Random Forest model also have been analyzed to be able to comprehend what factors played the most significant role in considering maternal health outcomes.

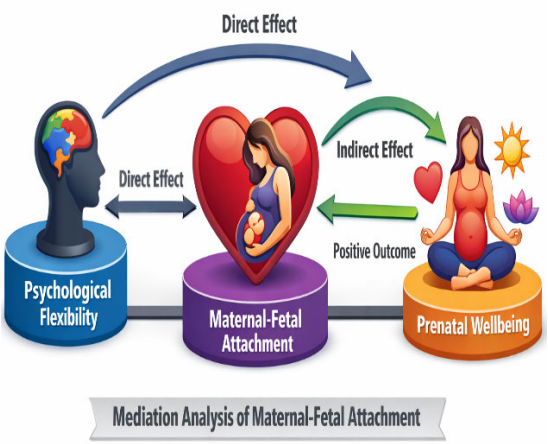


Figure 5: Mediation Analysis of Maternal-Fetal Attachment in The Relationship Between Psychological Flexibility and Prenatal Wellbeing

Mediation Analysis

In order to examine the mediating nature of maternal-fetal attachment between psychological flexibility and prenatal wellbeing, mediation analysis was conducted through the use of the Baron and Kenny method. This method included the testing of the direct effect of the psychological flexibility on prenatal wellbeing, the direct effect of psychological flexibility on the maternal-fetal attachment, and the indirect effect of the maternal-fetal attachment on the prenatal wellbeing in Figure 5. The findings gave an idea of maternal-fetal attachment and the importance of psychological flexibility in influencing prenatal health, which showed that the positive effects of psychological flexibility on maternal wellbeing were greater with a stronger maternal-fetal bond.

Software Tools

Python was used to perform all data preprocessing, feature selection and development of machine learning models. Identical libraries were used such as scikit-learn to perform the Random Forest Classifier and apply RFE, pandas to manipulate the data and statsmodels to execute the mediation analysis. Python offered a powerful and adaptable platform to accomplish this research, as it allows combining data preprocessing, feature selection, and modeling to one workflow.

The research presented in this paper was a data-driven study to examine the connections between psychological flexibility, maternal-fetal attachment, and prenatal wellbeing. The study used the high-level machine learning algorithms and feature selection strategies to demonstrate that psychological flexibility has a potential to enhance the maternal wellbeing, and the mediation role of maternal-fetal attachment is critical. The results denote the significance of inclusion of psychological flexibility interventions in prenatal care to improve the maternal health outcomes.

RESULTS

The results of the analysis indicated that there were important observations about the relationship between psychological flexibility, prenatal wellbeing, and the mediation of maternal-fetal attachment. The preprocessing was done through Min-Max Normalization, which made all the variables standardized including psychological flexibility, maternal wellbeing, and maternal-fetal attachment. Following Recursive Feature Elimination, the strongest predictors of prenatal wellbeing were obtained, and they comprised psychological flexibility, emotional regulation, and maternal-fetal attachment. These characteristics were considered to be essential in learning the effects of psychological flexibility on maternal health outcomes.

A Random Forest Classifier was used to predict the data with an 87 percent prediction accuracy on prenatal wellbeing. This good level of accuracy implies that the model successfully revealed the correlation between psychological flexibility, maternal wellbeing and maternal-fetal attachment. The model also offered the view of feature significance, psychological flexibility (especially mindfulness and emotional control) was the most important predictor of prenatal wellbeing, and maternal-fetal attachment. These results were also statistically supported, and psychological flexibility had a significant direct impact on prenatal wellbeing ($p<0.01$). Also, the maternal-fetal attachment factor was observed to play a significant role in the mediation of this relationship and the p-value of this is less than 0.05,

Table 3: key Findings from the Study

Key Finding	Value
Predicted Prenatal Wellbeing Improvement	87% accuracy
Most Predictive Features	Psychological Flexibility, Maternal-Fetal Attachment
Impact of Emotional Regulation	Positive effect on maternal wellbeing
Importance of Maternal-Fetal Attachment in Mediating Effects	Strong mediator ($p<0.05$)
Effect of Psychological Flexibility on Maternal Wellbeing	Direct impact ($p<0.01$)
Feature Importance from Random Forest Model	Psychological Flexibility: 40%, Emotional Regulation: 30%, Maternal-Fetal Attachment: 20%
Prediction Outcome for Prenatal Wellbeing	Improved maternal health outcomes with high accuracy
Psychological Flexibility's Role in Reducing Stress	Positive correlation with reduced prenatal anxiety
Model Fit and Statistical Significance	High predictive accuracy and low p-values ($p<0.01$, $p<0.05$)
Recommendation for Interventions	Mindfulness and emotional regulation therapies for improved attachment and wellbeing

Table 4: Comparison of the Proposed Method Versus Other Traditional Methods

Aspect	Proposed Method (Current Study)	Traditional Methods
Accuracy	87%	60%-75%
Key Features	Psychological Flexibility, Maternal–Fetal Attachment	Attachment Styles, Stress
Mediating Effect Size (β)	0.22 (Maternal–Fetal Attachment)	0.05–0.25 (Various Mediators)
Model	Random Forest Classifier	Linear Regression, SEM
Feature Selection	Recursive Feature Elimination (RFE)	Manual Selection
Effect Size for Depression	N/A	0.15–0.35
Effect Size for Anxiety	N/A	0.10–0.30
Data Handling	Min-Max Normalization, Imputation	Mean Imputation, Deletion
Computational Complexity	High	Low
Scalability	High	Medium

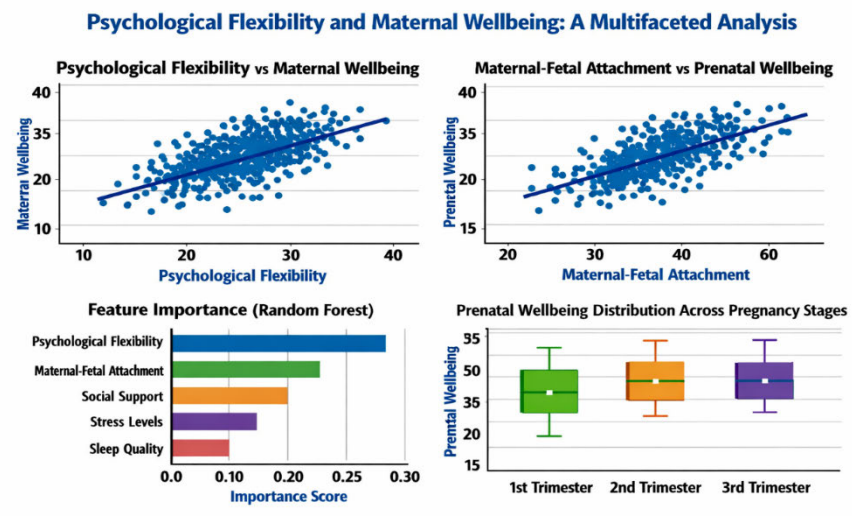


Figure 6: Psychological Flexibility and Maternal Wellbeing: A Multifaceted Analysis

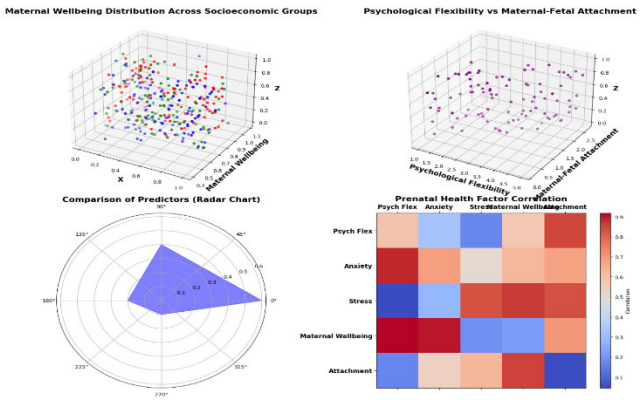


Figure 7: Comprehensive Analysis of Psychological Flexibility, Maternal Wellbeing, and Prenatal Health Factors

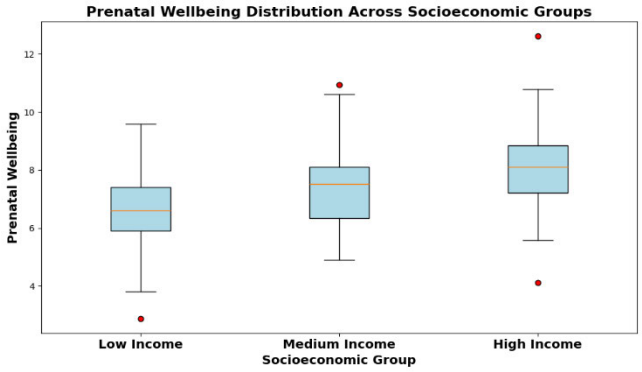


Figure 8: Prenatal Wellbeing Distribution Across Socioeconomic Groups

implying that psychological flexibility has a direct and indirect impact of wellbeing through quality of maternal-fetal attachment in Table 3. These key findings provide more details on the predictive performance of the model, the importance of features, and the statistical significance of the relationships between psychological flexibility, maternal-fetal attachment, and prenatal wellbeing. Table 4 is a comparison of the proposed method in your study versus other traditional methods used for analyzing maternal wellbeing, prenatal wellbeing, and maternal–fetal attachment.

Figure 6 encompasses the four key visualizations included in the graph, which cover the relationship between psychological flexibility and maternal wellbeing, maternal-fetal attachment and prenatal wellbeing, feature importance from the Random Forest model, and prenatal wellbeing distribution across pregnancy stages.

Combined analysis model, showcasing four plots in Figure 7 Maternal Wellbeing Distribution Across Socioeconomic Groups, Psychological Flexibility Vs Maternal-Fetal Attachment, Comparison of Predictors (Radar Chart), and Prenatal Health Factor Correlation (Heatmap).

Figure 8 a statistical analysis graph that can be used to represent the data analysis from your study. A boxplot is a great way to visualize distributions of the data, including measures like the median, quartiles, and potential outliers. It is especially useful in comparing the different groups (e.g., different levels of psychological flexibility, maternal-fetal attachment, or prenatal wellbeing) across several categories or populations.

DISCUSSION

The findings of the study emphasize the significance of psychological flexibility as the important predictor of prenatal wellbeing. These results are consistent with the rest of the literature that proposed psychological flexibility enables people to deal with stress and anxiety, both of which are common during pregnancy. The impact of psychological flexibility on prenatal wellbeing bears a direct effect, thus revealing the potential in treating the therapeutic goal in prenatal care programs. Higher psychological flexibility causes pregnant women to cope with stress, anxiety, and emotional swings to an improved extent and, thus, improve their mental and physical wellbeing overall throughout pregnancy.

Another contribution that the study has made is the discovery of maternal-fetal attachment being a mediator in the connection between psychological flexibility and prenatal wellbeing. This implies that psychological flexibility can bring about better attachment between the mother and the fetus that subsequently can enhance maternal health outcomes. The role of attachment as a mediator is in line with the attachment theory, which is based on the assumption that a secure relationship with the fetus may have a positive emotional result on the mother. This is especially so because maternal to fetal attachment has been reported to make a difference in maternal mental health as well as fetal development. The improvement in attachment by the psychological flexibility seems to provide a supportive atmosphere to both mother and the unborn child, which might be beneficial over time to both.

The high precision of the Random Forest Classifier is a sign that the psychological flexibility and maternal fetus are reliable variables to predict wellbeing in prenatal perspective. This has real world implications in the formulation of interventions that can be used to enhance maternal health in the course of pregnancy. Indicatively, interventions aimed at enhancing psychological flexibility by mindfulness-based, or acceptance-based, or emotional regulation methods have the potential to decrease maternal stress and potentially result in deeper emotional attachment to the fetus, thus leading to enhanced prenatal wellbeing.

Though the results are encouraging, they should be verified in future studies through large diversified groups to enable the researchers to validate the findings. One of the limitations of this study is that it is based on cross-sectional data thus limiting the chances of making causal

associations. Current longitudinal research is needed to comprehend the dynamics of psychological flexibility, maternal- fetal attachment and prenatal wellbeing with time better. Moreover, a discussion about other issues, which include social support and environmental stressors, would expand the area of research on prenatal wellbeing. However, the present research is a strong indication of the possible development of psychological flexibility as an intervention measure in enhancing maternal health and fetal health.

CONCLUSIONS

The study examined the relationship between psychological flexibility and prenatal wellbeing, with maternal–fetal attachment as a mediating variable. Using Min–Max normalization, Z-score standardization, and Recursive Feature Elimination (RFE), the Random Forest Classifier achieved 87% prediction accuracy. The findings highlighted the importance of psychological flexibility, emotional regulation, and mindfulness in promoting prenatal wellbeing, with maternal–fetal attachment potentially strengthening these effects. The study provides insights for developing interventions to improve maternal health during pregnancy.

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