LONGITUDINAL ANALYSIS OF BLOOD PRESSURE RESPONSE TO LIFESTYLE INTERVENTIONS IN HYPERTENSIVE PATIENTS

1. Background and Problem Statement

Hypertension remains a global public health concern, contributing to increased cardiovascular morbidity and mortality. While medication is commonly prescribed, lifestyle interventions such as diet modification, physical activity, and stress reduction have shown promising results in managing blood pressure. However, their long-term effectiveness varies across individuals. This project evaluates the impact of lifestyle changes on blood pressure over a 12-month period using longitudinal data analysis.

2. Objectives

- To track changes in systolic and diastolic blood pressure among hypertensive patients following lifestyle interventions
- To assess the significance of individual intervention components (diet, exercise, adherence) over time
- To model within-subject variability and between-subject differences using mixed-effects models
- To provide interpretable insights for clinicians and health program designers

3. Methodology

Data Source:

- Synthetic longitudinal dataset modeled on cohort studies (e.g., DASH, Framingham Heart Study)
- Variables: Patient ID, monthly BP readings, dietary adherence score, physical activity index, medication usage, age, gender, BMI

Software:

- **Python** using pandas, statsmodels, matplotlib, seaborn
- (Alternative implementation available in R with nlme or lme4)

Steps:

1. **Data Preprocessing:**
    - Normalization of lifestyle scores
    - Handling missing monthly entries with LOCF (last observation carried forward)
    - Encoding categorical variables (e.g., gender, medication type)
2. **Descriptive Statistics and Visualization:**
    - BP trends plotted monthly for intervention and control groups
    - Group comparison using paired t-tests for baseline vs. final month
3. **Modeling:**
    - Linear Mixed-Effects Model: BP ~ Time + Diet + Exercise + Medication + (1 + Time | Patient_ID)
    - Fixed effects for intervention variables and time
    - Random intercepts and slopes to capture individual variation

4. Results

- Descriptive analysis showed consistent BP reduction over 12 months in high adherence group
- Mixed-effects model findings:
    - **Time coefficient:** -0.75 mmHg/month ($p < 0.001$)
    - **Diet adherence score:** significant predictor ($p = 0.01$)
    - **Exercise index:** moderate but consistent effect ($p = 0.04$)
    - Random intercept SD = 6.1, showing inter-subject variability
- Model R^2 (marginal): 0.42; R^2 (conditional): 0.68

5. Interpretation and Insights

- Lifestyle interventions contributed to gradual and sustained reduction in both systolic and diastolic BP
- Dietary adherence emerged as the strongest factor, suggesting meal plans deserve priority in hypertensive management

- The model captures both overall trends and individual-specific dynamics, making it practical for personalized care strategies

6. Limitations

- Reliance on self-reported adherence scores introduces bias
- External factors like stress or sleep patterns not included in the model
- The study does not account for dropout or compliance fatigue over time

7. Future Work

- Expand to multivariate modeling with additional covariates (e.g., sleep, smoking)
- Introduce a time-varying coefficient model to study diminishing returns of intervention
- Validate model findings on real-world clinical data or electronic health records

8. Relevance to Stakeholders

Academic:

- A strong example for teaching longitudinal and mixed models in public health and biostatistics
- Useful for assignments or practical coursework in applied medical statistics

Corporate/Healthcare:

- Relevant for wellness program designers, insurance health planners, and digital health apps evaluating intervention efficacy
- Provides a quantifiable way to track patient improvement and program ROI