**Objective**

The primary objective of this study is to determine if the average growth rates of weight-for-age Z-scores differ by sex in Nepalese children aged 1 to 60 months. To achieve this, the Nepal Anthropometry Study (NAS) dataset is analyzed. The weight-for-age Z-scores are computed using sex-specific World Health Organization (WHO) standards for children from birth to 5 years of age. These Z-scores represent the difference in standard deviations between a child's weight and the average weight for a normative population of children of the same age and gender.

**Data**

The dataset used for this analysis is the complete Nepal Anthropometry Study (NAS) dataset. The dataset was preprocessed to include only children aged 1 to 60 months and to exclude any missing values. The variables used for the analysis:

*id*: Unique identifier for each child. *age*: Age of the child in months.

*zscores*: Weight-for-age Z-scores. *female*: Recoded sex variable (0 for Male, 1 for Female).

*fuvisit*: Follow-up visit number.

**Methods**

Weighted Least Squares Model

To analyze the growth rates of weight-for-age Z-scores in Nepalese children, I first used an ordinary least squares model. Specifically, I used natural splines to model the nonlinear relationship between age and weight-for-age Z-scores, and I included an interaction term with sex to assess whether the growth rates differ by gender. The mean model was specified as:

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where *ns(age, df = 3)* represents the natural spline of age with 3 degrees of freedom, and *female* is a binary variable indicating the sex of the child.

After performing model checking, such as visualizing the distribution of the residuals, I proposed a weighted least squares model. This model accounts for the variability in the data by allowing the variance of the residuals to depend on the age of the child.

Correlation and Variance Assumptions

To account for the correlation between repeated measurements on the same child, I used a correlation structure that reflects the temporal dependence of the data. We considered two correlation structures: an autoregressive (AR(1)) model and a Toeplitz model. The AR(1) model assumes that the correlation between measurements decreases exponentially as the time interval between them increases. The Toeplitz model allows the correlation between measurements to depend on the specific time intervals. I also allowed the variance of the residuals to depend on age, which was modeled using a variance function that captures the heteroscedasticity observed in the data.

Sensitivity Analyses

Several sensitivity analyses were conducted to ensure the robustness of the findings. The GLS models with AR(1) and Toeplitz correlation structures were compared based on AIC values to assess the impact of different correlation assumptions on the model estimates. Additionally, I used robust standard errors to account for potential violations of the model assumptions, such as heteroscedasticity. I also performed a bootstrap analysis to estimate the variability of the model parameters and to provide a more reliable assessment of the significance of the interaction terms.

**Results**

The sample consisted of 743 children, with a balanced distribution of males (384) and females (359). The weighted least squares (WLS) model with a AR(1) correlation structure and age-dependent variance gives a better fit while accounting for the heteroscedasticity in the data, as indicated by the lowest AIC values (1137.4).

The result of this model shows no significance in the interaction terms under significance level of 0.05. Specifically, the p-values are:

*ns(age, df = 3)1*: 0.1117; *ns(age, df = 3)2*: 0.6739; *ns(age, df = 3)3*: 0.1064.  
The Wald test for the interaction terms between age and sex also indicated that the average growth rates did not significantly differ by sex under significance level of 0.05. The Wald statistic was 4.038 with 3 degrees of freedom, and the p-value was 0.2574.

Sensitivity analyses using robust and bootstrap variance estimates provided stronger evidence against the null hypothesis. The robust Wald test yielded a statistic of 5.387 with a p-value of 0.1455, and the bootstrap Wald test resulted in a statistic of 5.509 with a p-value of 0.1381. These results suggest that the variability in the data may be higher than initially estimated, but the overall conclusion remains that there is no strong evidence to support a difference in growth rates between males and females.

**Discussion**

In this analysis, I used a Generalized Least Squares (GLS) model with an AR(1) correlation structure and age-dependent variance to analyze the growth rates of Nepalese children. The result suggested no significant difference in growth rates by sex.

One thing that stands out in the sensitivity analysis was that robust and bootstrap variance estimates provided evidence that the model might be slightly mis-specified, particularly for the interaction term *ns(age, df = 3)3:femaleFemale*, having a robust p-value of 0.055 and a bootstrap p-value of 0.0545, which make it a significant term at the 0.1 significance level.

Thus, an additional sensitivity analysis could be conducted by exploring the impact of different correlation structures on the model fit and the significance of the interaction terms. For example, compound symmetry correlation that assumes that the correlation between any two observations is constant.