Jimma University

College of Natural Science

Department of Statistics

Statistical Analysis of Correlates of Nutritional Status of Adolescents Using Univariate and Multivariate Linear Regression: the case of Jimma zone, south west Ethiopia

By:

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Abstract

This study is an attempt to study the determinants of nutritional status of adolescents in Jimma zone using data from longitudinal family survey of youth. The survey collected information from a total of 2084 adolescents aged from 13 to 17 years in Jimma zone.

Depending on the objectives of the study descriptive, Univariate and multivariate linear regression and multivariate linear regression statistical techniques were used for data analysis using socio-economic, demographic and health variable as explanatory variables and measures of nutritional status with underweight and stunting as response variables.

The results of the analysis showed place of residence, sex of adolescent and working in a job were the most important determinants of adolescents nutritional status in Jimma zone.

Acronyms

BAZ – BMI for Age Z-score

BMI – Body mass Index

BSc – Bachelor of Science

CED - Chronic Energy Deficiencies

DF - Degree of Freedom

DHS – Demographic and Health Survey

EDHS – Ethiopia Demographic and Health survey

HAZ – Height for Age Z-score

JU – Jimma University

MSc – Masters of Science

NCHS - National Center for Health Statistics

NGO – Non Governmental Organization

OLS – Ordinary Least Square

PSNP - Productive Safety Net Programme

RR – Ridge Regression

SNNPR - Southern Nations, Nationalities and Peoples Region

SES - Socio-Economic Status

VIF – Variance Inflation Factor

WHO – World Health Organization

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1. INTRODUCTION

1.1 Background of the study

The world population is believed to have reached over 6.6 billion [8]. Adolescence is a particularly unique period in life because it is a time of intense physical, psychosocial, and cognitive development. Increased nutritional needs at this juncture relate to the fact that adolescents gain up to 50% of their adult weight, more than 20% of their adult height, and 50% of their adult skeletal mass during this period and dramatic bone remodeling occur and soft tissues, organs, and even red blood cell mass increase in size. (46) This situation is further complicated when adolescents are often exposed to infections and parasites that can compromise nutritional status.

Nutrition during adolescence plays an important role in the individual's life. Malnutrition in adolescence encompasses under nutrition as well as over nutrition (3). Under nutrition implies being underweight for one's age, too short for one's age (stunted), or deficient in vitamins and minerals (6). Long-term under nutrition is an important cause of stunting or short height-for-age (7).

According to the study by the Ethiopian Ministry of Economic Development and Cooperation, 50 percent of the Ethiopian population are living below the food poverty line and cannot meet their daily minimum nutritional requirement of 2200 calories (31). According to the 2009 special report of the Crop and Food Security Assessment Mission to Ethiopia (13), 7.5 million persons are still chronically food insecure and were under the productive safety net programme (PSNP); an additional 4.9 million people are facing acute food insecurity, as of January to June 2009. A study in the Southern Nations, Nationalities and Peoples Region (SNNPR) of Ethiopia(51) showed that women from low economic status households were the most affected by malnutrition and also showed that the higher the level of education, the lower the proportion of undernourished women.

The nutritional status of adolescents can be assessed using one of the statistical methods known as multiple regression analysis. Thus, the objective of this study was to determine the nutritional status of adolescents using the application of Linear Regression.

1.2 Statement of the Problem

Surprisingly, information regarding the nutritional status of adolescents from the developing world is lacking. Part of the reason for the lack of information has been the difficulty of interpreting anthropometric data in these age groups (10). While a great deal of research has been conducted on child and adult malnutrition in developing countries, there are only a handful of studies on adolescent malnutrition in developing countries- there is indicates that younger adolescents tend to be more undernourished than older adolescents, and, contrary to expectations that boys are almost twice as undernourished as girls. In addition, these few studies suggest that there are more undernourished adolescents in Sub-Saharan Africa, and a higher prevalence in rural than in urban areas illustrate the potential for government-driven solutions(33).

In Ethiopia, undernourishment among preschool aged children has been well documented (17), but studies on factors affecting the nutritional status of adolescents have not been studied in detail (57). The available studies focused on factors affecting pregnancy outcomes rather than on problems associated with normal growth and development of adolescents (5, 6). A recent study on the nutritional status of adolescent girls from rural communities of Tigray, Northern Ethiopia (38) has helped to close the research gap in the area, although it is still focused only on adolescent girls, on small geographic area and small populations.

Most of the researches done on nutritional status of adolescents are using logistic regression which is one of the statistical models applied for categorical data. The accuracy of linear models for modeling bounded variables (categorical data) is not as good as for other unbounded variables (continuous variables) obtained in the same experiment, and the resulting linear model also predicts poorly at values close to 0 and 1. An insurmountable limitation of the linear approach is that the model can predict percentages outside the probability range, i.e., values of, 0 or 1.

The nutritional status of adolescents is measured using anthropometric measurements such as height and weight which are continuous variables. These anthropometric measurements are converted to z-scores which are not categorical variables. These z-scores are continuous variables and for a continuous data linear regression is appropriate than logistic regression. Most statistical software packages can do logistic regression with no more effort than linear regression. However, it is not as easy and straightforward to interpret the coefficients and test for goodness of fit of logistic models. There is no R^2 associated with a logistic model, since a residual in the commonly accepted sense does not exist. In linear regression, R^2 can be easily obtained and is often used to evaluate the goodness of fit of models.

Therefore it is appropriate to use linear regression in determining the nutritional status of adolescents.

1.3 Significance of the Study

In many developing countries, nutrition initiatives have focused on children and women, resulting in adolescents often been neglected (5).Previous studies from developing countries have indicated that younger adolescents are at greater risk of being undernourished than their older counterparts, with the risk increasing in adolescents living in rural than in urban areas (5).

Previous studies have identified the nutritional status of adolescents in other parts of the country (38) but there are no research reports on nutritional status of adolescents from Jimma zone using linear regression model.

The finding of this study can provide policy makers and NGOs with relevant information for future planning and interventions of appropriate strategies to promote and maintain nutritional status of Ethiopian adolescents. The finding of this study may also be used by program implementers as an input towards supporting and promoting nutritional status among the study population with their ultimate goal of reducing malnourished and obesity.

This study is expected to play important role in identifying the malnutrition level of the study area and identifying the appropriate model. Therefore, the need to apply linear Regression in determining the nutritional status of adolescents will be very important.

1.4 Objectives of the Study

General objective

- The general objective of this study was to determine the various possible factors and their contribution for malnutrition among Adolescents in Jimma Zone, South West Ethiopia.

Specific Objectives

- To identify the most important socio-economic, demographic and health determinants of nutritional status among adolescents of Jimma zone,
- To determine the magnitude of adolescent malnutrition,
- To identify the relationship between the types of nutritional status (underweight and stunting) related to various possible factors with respect of adolescents.

1.5. Limitations of the Study

Although many factors affect malnutrition as indicated by different studies in different countries by including different social, economic, political, cultural, demographic, physiological, biological, reproductive health rights, family planning policies/programs etc, this study is undertaken to explore a few of the socio-economic, demographic and health determinants and differentials of nutritional status in Jimma zone and since the study is cross-sectional it can not show cause and effect relationship between different factors with outcome variables.

Also the study was conducted based on the available data (secondary data) from Jimma Longitudinal Family Survey of Youth for adolescents of ages 13-17 years and a secondary data, which might have incomplete.

The study was not supported by laboratory investigation and the available research on adolescent malnutrition is limited in the Ethiopian setting so that we are unable to compare the findings of this study with other studies.

2. LITERATURE REVIEW

2.1 Concepts and Definitions

Direct nutritional assessment of a community depends on biochemical tests, clinical examination and anthropometric measurements. Biochemical tests need laboratory facilities and are usually costly, time consuming and the results are difficult to interpret, so they need to be performed in well equipped health facility. To use clinical signs for nutritional assessment is inexpensive, fast and does not require highly qualified staff, but it is subjective and, clinical signs may not appear at an early stage of malnutrition (25).

Anthropometry is the most commonly used direct method for the assessment of nutritional status. The frequently employed anthropometric measurements are weight and height. They are economical to carry out, objective, easily understandable, gives result which can be numerically graded and provides information on different degrees of malnutrition. Therefore, most studies on nutritional status are performed using anthropometric measurements (25). They have been used as indices of nutritional status of an individual and the community. (54)

Classification of nutritional status was made according to the public health criteria recommended by a World Health Organization (WHO) expert committee. A low height-for-age Z-score (HAZ or height SDS) (<-2SD) (42) indicates stunting (stunted growth), and reflects a process of failure to reach linear growth potential as a result of suboptimal health and/or nutritional conditions.

The use of weight alone to assess nutritional status should be limited to monitoring purposes because it is confounded by height. The body mass index (BMI) is widely accepted as one of the best indicators of nutritional status in adults (24).The body mass index (BMI) is calculated from weight and height measurements using the formula BMI = weight (in kg) divided by height (in m-2). The BMI was first introduced by Quetlet in order to eliminate the confounding effects of height on weight. In normal adults, the ratio of the weight to the square of height is roughly constant, and a person with a low BMI is underweight for their height (43). BMI may be appropriate for population-level assessments of chronic under nutrition. In 1988, researchers proposed the use of BMI to define and diagnose chronic under nutrition (24). This classification provides a useful framework for the analysis of height and weight data from chronically undernourished adult populations.

2.2 Determinant Factors of Adolescent Malnutrition

Various studies in different/same countries may find different results over the importance of the determinant factors behind adolescents' nutrition. Estimates may differ depending on various factors including the nature of the data and estimating methodology.

Factors that are contributing to malnutrition may differ among regions, communities and over time. Identifying the underlying causes of health malnutrition in a particular locality is important to solve the nutritional status of adolescents.

Various studies on nutrition have been undertaken and conclusions were reached by different scholars in the past regarding predictors of nutritional status. The detailed literature review presented below focuses on the socioeconomic and demographic of adolescents' nutritional status.

2.2.1 Demographic Characteristics

Most studies report that demographic characteristics such as age and sex are important determinants of nutritional status. A study done by Elena (12) showed that BMI variability in girls' series differs significantly in comparison with the one in boys' series. Analysis of Z-score values for the main body sizes among adolescents (studied in 2004) illustrates the effects of malnutrition in the girls' series through a physical growth significantly lower in comparison with the boys' series.

Also a study done in Tigray (38) using the Stepwise multiple regression analysis showed age to be the strongest predictor of stunting ($r^2 = 0.88$, $p<0.01$) and thinness ($r^2 = 0.33$, *p-value* <0.01) and under nutrition was prevalent among adolescent girls from the study communities. Both z scores (height-for-age and BMI-for-age) of the study girls were below -1Z scores of the NCHS/WHO reference population. The deviation of the height-for-age and BMI-for-age z scores of the study girls from that of the reference population was greater at 13 and 14 years of age, respectively.

The results of the correlation analysis in a study done in Nigeria (40) showed that the prevalence of underweight and overweight was significantly higher in boys at mid adolescents (24.2% and 9.3% respectively at *p-value* <0.02) while the prevalence of underweight was significantly higher in girls who lived with extended family members (11.9%, *p-value* <0.05).

DHS surveys conducted in Burkina Faso, Ghana, Malawi, Namibia, Niger, Senegal, and Zambia show a greater proportion of mothers age 15-19 that exhibit chronic energy deficiencies (CED). A local study in Ethiopia also showed that women in the youngest age group (15-19) are most affected by under nutrition (51).

In a study done in Ambo (Ethiopia) (33) where the data was analyzed by gender, the proportion of underweight males was significantly higher (29.8%) than that of females in the same weight category (24.6%) (t=3.16; df=416; *p-value*<0.05). In contrast, the proportion of males (66.4%) in the normal weight category was significantly lower than that of females (70.5%) in the same weight category (t=5.31; df=423; *p-value* <0.05). The proportion of overweight females and males was 4.9% and 3.8%, respectively, but were not statistically different from each other (t=1.12; df=423; *p-value* >0.05).

2.2.2 Socioeconomic Characteristics

Socioeconomic characteristics such as household income, paternal and maternal socioeconomic characteristics (fathers` education, mothers' education and their household status)**,** household size, etc are important in adolescent nutrition outcomes.

In a study done in Iran (11), no association between family size and BMI status was found (*p-value* >0.05). There was a significant association between mothers' educational level and BMI status of adolescents (*p-value* =0.001). There was no association between parents' job and BMI status of the adolescents. No association between household economic status and BMI status was found. To identify the factors that had the strongest influence on manifestation of malnutrition, logistic regression analyses were undertaken.

In a study done in Turkey (42) all anthropometric indices showed significant differences according to SES. Height SDS values in adolescents of low SES groups were significantly lower compared to those in adolescents of high SES (*p-value<0.001*). BMI in adolescents of middle SES was found to be significantly higher than this in adolescents of other groups (*p-value<0.001*). The frequency of stunting was significantly different between the socioeconomic groups (*p-value=0.012*). Frequency of stunting was also not significantly different between male and female adolescents (*p-value=0.354*). Although frequency of being underweight in male adolescents tended to be higher than in female adolescents, the difference was not significant (p=0.063). The study found that frequency of being overweight and obese tended to be higher in female adolescents, but no significant differences were observed between the two sexes (*p-value=0.331*).

A study of most of the DHS surveys conducted in developing countries (29) and a study in the Southern Nations, Nationalities and Peoples Region (SNNPR) of Ethiopia (51) showed that women from low economic status households were the most affected by malnutrition.
Women who receive even a minimal education are generally more aware than those who have no education of how to utilize available resources for the improvement of their own nutritional status and that of their families. Education may enable women to make independent decisions, to be accepted by other household members, and to have greater access to household resources that are important to nutritional status (1). A comparative study on maternal malnutrition in ten sub-Saharan African countries (29) and a study in the SNNPR of Ethiopia (51) showed that the higher the level of education, the lower the proportion of undernourished women and Also rural women are more likely to suffer from chronic energy deficiency than women in urban areas. These higher rates of rural malnutrition were also reported by local studies in Ethiopia (58).

Marital status of women is associated with household headship and other social & economic status of the women that affects their nutritional status. Nutritional and social securities could be endangered by a negative change in marital status. A study on the SNNPR Region of Ethiopia showed that women's malnutrition is significantly associated with marital status indicating that compared to married women malnutrition is higher among unmarried rural and divorced/separated urban women compared to married ones (51).

According a study done in Ethiopia (56) the proportion of women suffering from chronic energy deficiency (CED) malnutrition was significantly higher in rural areas than in urban areas. Women's educational level was also found to be negatively associated with malnutrition in women. The prevalence of malnutrition in women was also higher among the unemployed than women who were employed. Demographic variables such as parity and marital status of the women were also found to be significantly associated with women's nutritional status. Logistic regression analysis identified the most important explanatory variables of nutritional status in urban women. In this model, region of residence, household economic status, employment status and marital status of women were found to be determinants of women nutritional status.

3. DATA AND METHODOLOGY

3.1 Data

Data for this study were obtained from a longitudinal family survey of youth among adolescents in Jimma zone southwest Ethiopia. A census was done to generate the list of all households which gave a sampling frame for random selection of 3,700 households from the total of 5,795 households in the list. A two-stage sampling plan was used to select the target sample of adolescents. Households were classified into urban (Jimma City), semi-urban (Serbo, Dedo and Yebbu Towns) and six rural communities in the vicinity of the small towns. At the first stage, households were randomly sampled with the sample size in each kebele determined by the relative proportion of the study population in the kebele and the overall target sample size. In the second stage, one adolescent (a boy or a girl) was randomly selected from each household using a Kish Table. Using this sampling strategy a total of 1059 boys and 1025 girls were interviewed in round one.

3.2 Variables included in the study

As demonstrated in the literature review, socio-economic, demographic and health characteristics were considered as the most important determinants of adolescent nutritional status.

3.2.1 Dependent (Response) variables

Height-for-age, weight-for-height and BMI for age Z-scores which give the information about stunting, wasting and underweight are used as measure of health outcomes, respectively. In this study, height and weight measurements of adolescents, taking age into consideration, were converted into Z-scores based on the National Center for Health Statistics (NCHS) reference population recommended by the World Health Organization (WHO). Thus, those below -2 standard deviations of the NCHS median reference for height-for-age, BMI-for-age and weight-for-height were defined as stunted, underweighted, and wasted, respectively. All the three indicators were used to describe the level of adolescent malnutrition problem. But wasting (weight-for-age) represents a short-term indicator useful only to monitor short-term changes in nutritional status. Therefore, an in-depth analysis was performed on stunting and underweight.

3.2.2 Independent (Explanatory) variables

Predictor variables to be studied as determinants of nutritional status of adolescents were grouped in to socio-economic, demographic and health factors.

a. Socio-Economic Characteristics

As proxy indicators of socioeconomic characteristics, the following factors were included: Place of residence, marital status, have a child, highest grade completed, type of school completed, religion, have a job, household income, household size, mother’s education and father’s education.

b. Demographic Characteristics

Demographic characteristics include age of the adolescent and sex of the adolescent.

c. Health, Nutrition and Food Security Characteristics

There are certain health characteristics that may increase or decrease the risk of malnutrition and health problem among adolescents. Fever, Cough, Breathing, Diarrhea, Vomiting, unable to drink or eat, Ulcer, Depression, sleep under insecticide treated mosquito bed net(ITN),currently smoke tobacco(smoking), number of cigarettes smoked (howsmoking), does member of the household smoker(hhsmoker),in the last 3 months how many days do you worry about run of food(fworry),in the last 3 months how many days have you reduce the number of meals eaten in a day(freduce), in the last 3 months how many days have you had to spend the whole day without eating(fspend),in the last 3 months how many days have you had to ask for food or money to buy food(fask) and Food insecurity(insec) were important health and nutrition factors included in this study.

3.3 Study Area and Period

The study was conducted in Oromia Regional State in Jimma zone, whose capital is Jimma town, located 350kms south west from Addis Ababa. The zone has an estimated total population of 2,486,155, of whom 1,250,527 are men and 1,235,628 women; urban inhabitants number 137,668 or 11.31% of the population, a further 858 or 0.03% are pastoralists. As estimated from the project 1994 Central Statistical Authority data approximately 20% of the adolescent people are between the ages of 13-17 years (4). With an estimated area of 15,568.58 square kilometers, this zone has an estimated density of 159.69 people per square kilometer. A total of 521,506 households were counted in this Zone, which results in an average of 4.77 persons to a household, and 500,374 housing units (50). The study period was from September 2005 to April 2006.

3.4 Study Designs and Sampling Method

The study design was a cross-sectional study which involves only quantitative method. The quantitative method was used to apply linear Regression in determining nutritional status of adolescents in the study area.

The study was based on data from 2084 adolescents enrolled in the first round of the 5-year longitudinal study of adolescents in the Jimma zone in southwest Ethiopia. The study area was stratified into urban (Jimma City), semi-urban (small towns), and 6 rural communities ("kebeles") adjacent to the towns and represents a range of ecological and developmental contexts. A census was conducted to generate a list of all households in each site that produced a sampling frame of 5,795 households. A 2-stage sampling plan was used to select a sample of 2100 adolescents of age. As a first stage, 3,700 households comprising at least 1 male or 1 female adolescent were randomly selected from the list.

The sample size for each study site was allocated on the basis of probability proportional to size. In the second stage, 1 adolescent aged 13 to 17 years (boy or girl) was randomly selected from each household in the sample using a Kish table. This age group was selected for follow-up to capture life events that happened as boys and girls transitioned to adulthood. This sampling plan produced a representative sample of households and adolescent boys and girls.

Source and Study Population

The source of population for the study was all adolescents of age group 13-17 years in Jimma zone for the study. The study population was sample adolescents of age group 13-17 years in Jimma zone.

Inclusion and Exclusion criteria

Inclusion criteria

- Up to two adolescents of ages 13-17 years were interviewed from each sampled household.
- In households where there were more than one adolescent; one adolescent of each sex was randomly selected and interviewed.
- Included household heads and spouses of the head aged 13-17, children of the head residing in the household and any other adolescent identified by the household head or spouse of the head as a member of the household.

Exclusion criteria

- In the cases where there was no adolescent in the household, the next randomly selected household was visited.
- Adolescents who were resident in the household, but who were not considered members of the household, such as visitors, renters, or those who were not physically and mentally capable of completing the interview (for example, deaf or mentally disabled) were excluded.

3.5 Methodology

Multiple regression was used to determine the relationship between anthropometric measurements (dependent variables) and independent variables. Assessing the extent to which anthropometric measurements are associated with the independent variables, the level of malnutrition of the adolescents in Jimma was compared with WHO standards of 2007 using multiple regression Analysis. If serious multicollinearity exists Ridge Regression Model would be compared with the result obtained using multiple linear model. Data on the nutritional status of adolescents would be analyzed using statistical package SAS 9.2.

3.5.1. Introduction to Linear Regression

Regression analysis is the statistical method for predicting values of one or more response (dependent) variables from a collection of predictor (independent) variable values. It can also be used for assessing the effects of the predictor variables on the responses. This model is then generalized to handle the prediction of several dependent variables. (26)

Regression analysis is a body of knowledge dealing with the formulation of mathematical models that depict relationships among variables and the use of these modeled relationships for the purpose of prediction and statistical inference on the regression curve. Multiple regression is a method used to model the relationship between a dependent variable and two or more independent variables. We will consider parametric regression models and we will assume a relationship that is linear in the parameters or regression coefficients. Multiple linear regression is mainly used

- To check whether there is a relationship between a dependent or response variable and more than one independent variable, called predictors or regressors.
- To predict a continuous dependent variable from a number of independent variables.

The independent variables used in multiple linear regression can be either continuous or dichotomous. Independent variables with more than two levels can also be used in multiple linear regression analysis, but they first must be converted into variables that have only two levels. This is called dummy coding.

The multiple linear regression model expresses the value of a response variable as a linear function of two or more predictor variable and an error term. The multiple linear regression model has the following general form

$$y_i = \mu(x_{i1},...,x_{i,p-1}) + \varepsilon_i \qquad i=1, . . . , n$$

Where

- $x_{i1},...,x_{i,p-1}$ are the particular (deterministic) values of the (p-1) regressors
- y_i is the corresponding continuous response random variable.
- μ(.) the unknown mean response function
- $\varepsilon_1,...,\varepsilon_n$ independent (unobservable) random error terms with E(ε_i)=0

To estimate μ(.) we can use methods from nonparametric regression estimation theory or we can be more specific and assume a parametric functional form. We shall consider the linear model

$$\mu(x_1,...,x_{p-1}) = \beta_o + \sum_{j=1}^{p-1} \beta_j X_j$$

This assumption simplifies the problem, since we only have to estimate a finite number of parameters, the regression parameters $\beta_o,...,\beta_{p-1}$. In other words, we define the general linear regression model as $y_i = \beta_o + \beta_1 x_{i1} + ... + \beta_{p-1} x_{i,p-1} + \varepsilon_i$. Thus, we have the equations

$$\begin{cases} y_1 = \beta_o + \beta_1 x_{11} + ... + \beta_{p-1} x_{1,p-1} + \varepsilon_1 \\ . \\ . \\ . \\ y_i = \beta_o + \beta_1 x_{i1} + ... + \beta_{p-1} x_{i,p-1} + \varepsilon_i \\ . \\ . \\ . \\ y_n = \beta_o + \beta_1 x_{n1} + ... + \beta_{p-1} x_{n,p-1} + \varepsilon_n \end{cases}$$

This can be written in matrix forms as follows

$$\underset{(n\times 1)}{Y} = \underset{(n\times p)}{X}\ \underset{(p\times 1)}{\beta} + \underset{(n\times 1)}{\varepsilon}$$

Where

- X is the design matrix, also called the regression matrix
- Y is vector of responses
- β is a vector of parameters
- ε is a vector of independent random variables with expectation E(ε)=0 and variance covariance matrix $\sigma^2(\varepsilon)=\sigma^2 I$ (34)

Assumptions for Linear Regression Analysis

The least squares fitting procedure described can be used for data analysis as a purely descriptive technique. However, the procedure has strong theoretical justification if a few assumptions are made about how the data are generated. The independent variables play the role of experimental or treatment variables. The error term captures the inherent noise of the process including the effects of all omitted variables. In an experiment, randomization of the treatments (independent variables) ensures that the omitted factors (the disturbances) are uncorrelated with the treatments. This greatly simplifies inference. Non-experimental researchers, however, must substitute assumptions for experimental controls. The validity of non experimental results therefore depends critically upon the accuracy of the assumptions. One set of assumptions, known as the Gauss-Markov assumptions, are sufficient to guarantee that ordinary regression estimates will have good properties. These assumptions are: (34)

- The errors have an expected value of zero. This means that on average the errors balance out.
- The independent variables are non-random. In an experiment, the value of the independent variable would be fixed by the experimenter and repeated samples could be drawn with the independent variables fixed at the same value in each sample.
- The independent variables are linearly independent. That is, no independent variable can be expressed as a (non-zero) linear combination of the remaining independent variables. The failure of this assumption, known as multicollinearity, clearly makes it infeasible to

separate the effects of the supposedly independent variables. If the independent variables are linearly dependent, then there is singularity in independent variables.

- The disturbances are homoscedastic. This means that the variance of the disturbance is the same for each observation.
- The disturbances are not autocorrelated. This means that disturbances associated with different observations are uncorrelated.

3.5.2. Multivariate Regression Model

In this study as we have two dependent variables it is appropriate to employ multivariate linear regression analysis.

Generally, if we have a set of m responses $Y_1, Y_2, \ldots, Y_m$ and a single set of predictor variables $X_1, X_2, \ldots, X_r$. Each response is assumed to follow its own regression model, so that

$$Y_j = \beta_{0j} + \beta_{1j} X_1 + \ldots + \beta_{rj} X_r + \varepsilon_j$$
$$j = 1, 2, \ldots, m$$

The error term $\varepsilon = [\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_m]'$ *has* $E(\varepsilon) = 0$ *and* $\text{var}(\varepsilon) = \Sigma.$ Thus, the error terms associated with different responses may be correlated.

The observation in multivariate regression model is

$$Y_{ji} = \beta_{0j} + \beta_{1j} X_{i1} + \ldots + \beta_{rj} X_{ir} + \varepsilon_{ij}$$
$$i = 1, \ldots, n$$
$$j = 1, \ldots, m$$

In matrix form becomes

$$\underset{(nxm)}{Y} = \underset{(nx(r+1))}{X} \underset{((r+1)xm)}{\beta} + \underset{(nxm)}{\varepsilon}$$

With

$$1)\ E(\varepsilon_{(i)}) = 0;\ and$$
$$2)\ \Sigma = \sigma_{ik} I \qquad i, k = 1, 2, \ldots, m$$

The m observations on the jth trial have covariance matrix $\Sigma = [\sigma_{ik}]$, but observations from different trials are uncorrelated. Here β and σ_{ik} are unknown parameters; the design matrix X has jth row $[X_{j0}, X_{j1}, \ldots, X_{jr}]$ (26).

3.5.3 Method of Estimation

One of the objectives of Regression analysis is to develop an equation that will allow the investigator to predict the response for given values of the predictor variables. Thus to fit the above multivariate model, we will use the method of least squares which selects the estimated regression coefficients so as to minimize the sum of squares of the differences.

Given the outcomes Y and the values of the predictor variables X with full column rank, the Least-square estimates are

$$\hat{\beta}_i = \left(X^t X\right)^{-1} X^t Y$$

Using $\hat{\beta}$, we can form the matrices of

Predicted values: $\hat{Y} = X\hat{\beta} = X\left(X^t X\right)^{-1} X^t Y$

Residuals: $\hat{\varepsilon} = Y - \hat{Y} = \left(I - X\left(X^t X\right)^{-1} X^t\right) Y$ (34)

3.5.4 Model Building

Model building problems and the selection of the regression model where such topics as misspecification of predictor variables, *selection criteria* like Mallows C_p, $PRESS_P$, AIC_P, BIC_P, and *selection methods* such as stepwise, forward, backward selection procedures are considered. By the use of these selection methods, the possible "best" model will be determined among the alternative predictor variables. If we have, say P predictor variables, we will be able to have a total of 2^{p-1} possible candidate models with p-1 predictor variables from which the best one could be selected. And such problems, related with the method of identifying such group of regressors, are known as variable selection problems (34).

Selection Criteria:

Model selection is the best method of choosing the best sub-model among the set of all possible sub-models for a given data set. To select a sub-model, we will use one of the following selection criteria: Mallows C_p, R^2 criteria, MSE_P, $PRESS_P$ criteria, F-ratio, C_p criteria, AIC_p criteria and BIC_p selection criteria. Here we will use one of the *selection criteria* which is the Akaike`s information criteria (AIC). An information criterion is a measure of goodness of fit or uncertainty for the range of values of the data. In the context of multiple linear regression, information criteria measures the difference between a given model and the "true" underlying model. Akaike (1973) introduced the concept of information criteria as a tool for optimal model selection. Akaike`s information criteria (AIC) is a function of the number of observations n, the SSE and the number of parameters p. AIC is based on the maximum likelihood estimates of the model parameters. In the maximum likelihood, the idea is to estimate parameters so that, under the model, the probability of the observed data would be as large as possible. The likelihood is this probability, and will always be between 0 and 1. It is common to consider likelihoods on a log scale. Logarithms of numbers between 0 and 1 are negative, so log-likelihoods are negative numbers. In a regression setting, the estimates of the β_i based on the least squares and the maximum likelihood estimates are identical. The difference comes from estimating the common variance σ^2 of the normal distribution for the errors around the true means. We use the best unbiased estimator of $\sigma^2, \hat{\sigma}^2 = \frac{SSE}{n-p}$ where there are p parameters for the means (p different β_i) and SSE is the residual sum of squares. This estimate does not tend to be too large or too small on average. The maximum likelihood estimate, on the other hand, is $\frac{SSE}{n}$. This estimate has a slight negative bais, but also has a smaller variance. The correct formula for the AIC for the model with parameters $\beta_o \ldots \beta_{p-1}$ and σ^2 is

$$AIC = n + n\log 2\pi + n\log\left(\frac{SSE}{n}\right) + 2(p+1)$$

And in some literature

$$AIC = n\log\left(\frac{SSE}{n}\right) + 2p$$

When comparing AIC between two models, however, it makes no difference which formula you use because the differences will be the same regardless of which choice we make. The first term in the last two equations is a measure of the model lack of fit while the second term is a penalty term for additional parameters in the model. Therefore, as the number of parameters p included in the model increases, the lack of fit term decreases while the penalty term increases.

Conversely, as variables are dropped from the model the lack of fit term increases while the penalty term decreases. The model with smallest AIC is deemed the "best" model since it minimizes the difference from the given model to the "true" model. (34)

Stepwise Regression Methods:

Once the possible candidates of predictor variables have been identified while building a regression model, a decision should be made on the choice of the variables to be involved in the final regression model. One of the statistical procedures that are used for such selection mechanism is stepwise method which adds/deletes regressors one at a time. To understand how this selection method works, let us look at the successive steps. (34)

3.5.5 Model Diagnosis

Partial Regression Plots:

Partial regression plots, also known as added-variable plots or adjusted variable plot, are plots that play important role in providing graphical information regarding the marginal use of a regressor x_k given other regressor variables are involved in the model. Such plots are important since they provide information on the relative impact of a specific regressor on the response conditional on the other regressors included in the model. The procedure for plotting the partial regression plots is as follows:

- First, we need to regress Y on all predictor variables where x_k is removed from the model. Then the corresponding residuals, say e_y, will be computed using the fitted model.
- We regress x_k on all the remaining regressors except x_k itself. Again the corresponding residuals, say e_x, will be computed.
- Finally, a plot of e_y against e_x, where the residual with respect to the predictor variable displayed along the x-axis will be plotted.

Then the interpretation of the plots will be made just by inspecting the pattern in the plots. Accordingly, if a horizontal band across an x-axis is observed, it means that x_k has no additional information that can help to improve the model that already contains the remaining predictor variable. On the other hand, the pattern of a linear band with a non-zero slope gives an indication for the predictor variable x_k to add it in the model because it may help to give additional value in predicting the response variable Y. (34)

Outlying Responses:

Outliers generally, are extreme observations which are far away from the rest of the observations in a given data set. This in turn yields large residuals which can seriously affect the fitted least squares regression function. Then it will be necessary to identify such typical observations and make necessary evaluation either to retain or eliminate them from the model. The detection of such outliers is based on different types of residuals. To define appropriate residuals, we need the hat matrix (the projection matrix).

$$H = P = X(X^t X)^{-1} X^t$$

since $\hat{\beta} = (X^t X)^{-1} X^t y$ we have that

$$\hat{y} = X\hat{\beta} = X(X^t X)^{-1} X^t y = HY$$

And that $$e = y - \hat{y} = (I-H)y \quad (34)$$

Outlying Regressors:

The hat matrix we have seen in the previous section also plays an important role in identifying outlying x observations. Specifically, its diagonal elements indicate whether there are outlying cases with respect to the values of the predictor variable or not. The diagonal element h_{ii} of the hat matrix is a measure of the distance between the values of the predictor variable for the *i-the* case and the means of values for all n cases. Hence, a large value of the diagonal element h_{ii} indicates that the *i-th* case is distant from the center of all observations of variable. And this diagonal element, h_{ii}, is known as the leverage of the *i-th* case. With introduction about outlying observations, let`s see how this can be explained mathematically.

To identify outlying x observations we need the Mahalanobis distance. Let $\tilde{x}_{i1} = x_{i1} - \overline{x_{.1}}$, etc with

$$X_c = \begin{pmatrix} \tilde{x}_{11} & \ldots & \tilde{x}_{1,p-1} \\ \ldots & & \ldots \\ \tilde{x}_{n1} & \ldots & \tilde{x}_{n,p-1} \end{pmatrix}$$

And $C = \frac{1}{n-1} X_c^t X_c$ the "covariance matrix" (as a descriptive measure) of the vectors

$(x_{i1},...,x_{i,p-1})^t$, the Mahalanobis distance, measuring the distance between $\begin{pmatrix} x_{i1} \\ . \\ . \\ . \\ x_{i,p-1} \end{pmatrix}$ and $\begin{pmatrix} x_{.1} \\ . \\ . \\ . \\ x_{.,p-1} \end{pmatrix}$ in a way that takes into account the covariance structure, is defined as

$$MD_i^2 == (n-1)\left[h_{ii} - \frac{1}{n}\right] \qquad (34)$$

Identifying Influential Cases

Sometimes a few elements of a data set exert disproportionate influence model coefficients, that is, parameter elements might depend more on these few influential cases than on the other cases large in number. These influential observations might be shown up for nothing important so that they should be eliminated, or there might be a reasonable justification for their existence in the model. However, once the identification of outlying observations has taken place, the next step is to check whether or not these outlying observations have impact on the estimated model. In making such evaluations, we consider cases to be influential if their removal causes a major change on the fitted regression model.

Influence on all fitted values (Cook`s distance measure)

We start from the viewpoint "global impact" on the p regression coefficients.

Note that

$$\frac{(\hat{\beta}-\beta)^t X^t X(\hat{\beta}-\beta)}{pMSE} \sim F(p,n-p)$$

So if we set

$$\frac{(\hat{\beta}-\beta)^t X^t X(\hat{\beta}-\beta)}{pMSE} = F(1-\alpha; p,n-p)$$

We determine the boundary of (1-α)*100% confidence region. Now define

$$D_i = \frac{(\hat{\beta}-\hat{\beta}_i)^t X^t X(\hat{\beta}-\hat{\beta}_i)}{pMSE}$$

We can say that $\hat{\beta}$ is in a small neighborhood of $\hat{\beta}_i$;

If $D_i > F(0.5; p, n-p)$ (i.e., α=0.5), we consider $\hat{\beta}$ and $\hat{\beta}_{(i)}$ to be far apart. The reason to select the 0.5 percentile is that

E(F(p ,n-p)) = $\dfrac{n-p}{n-p-2} \approx median = F(0.5; p, n-p)$

Since $\dfrac{n-p}{n-p-2} \approx 1$ we obtain by this 0.5 choice the simple guideline that the i^th observation is influential if $D_i > 1$.

The alternative expressions for D_i are:

$$D_i = \frac{\sum_{j=1}^{n} (\hat{y}_j - \hat{y}_{j(i)})^2}{pMSE}$$

$$D_i = \frac{(\hat{y} - \hat{y}_{(i)})(\hat{y} - \hat{y}_{(i)})}{pMSE}$$

$$D_i = \frac{e_i^2}{pMSE} \frac{h_{ii}}{(1-h_{ii})^2}$$

Then the Cook`s distance measure, $D_i$, a summary measure related to DFFITS, measures the change in the estimate that results from deleting each observation. Essentially, Cook`s distance measure is an aggregate influence measure showing the effect of the i^{th} observation on all n fitted values. It can be seen that Cook`s distance measure is similar to DFFITS measure, which considers the influence of the $i^{th}$ observation on the fitted value $\hat{y}_i$ except that in the case of Cook`s distance measure, the influences are combined to form an aggregate effect. (34)

Diagnostics for Multicollinearity:

For orthogonal (or uncorrelated) regressors, there is no problem with multicollinearity. However, for most datasets, there exists some correlation between the regressors and hence the multicollinearity problem show up. That is, there are situations where regressors have certain relationships among themselves. And when such kind of correlations between regressors occurs, we say that there exists a problem of multicollinearity. As a consequence of multicollinearity, the following problems can be mentioned.

1. Adding or deleting regressors significantly change the magnitude of regression coefficients,
2. Extra sum of squares depends upon which other regressors are already in the model,
3. Estimated standard deviations of regression coefficients become large, and
4. Estimated regression coefficient may not be statistically meaningful even though there is a definite relation between this regressor and the response.

Then there are several techniques that are used to detect multicollinearity problems. However, the formal method of detecting multicollinearity problem, is variance inflation factor (VIF). This statistic measures how much the variance of an estimated coefficient is inflated due to collinearity. (34)

4. RESULTS AND DISCUSSION

4.1 RESULTS

This topic presents the statistical data analysis with detail discussion including descriptive analysis of the characteristics of inputs and output for nutritional status of adolescents. The descriptive analysis here is to summarize the overall records of each of the variables incorporated in the research before a full examination of the models proposed in the previous topics using regression methods. The statistical package used for data analysis was SAS 9.2.

4.1.1 DESCRIPTIVE

In this study, it was observed that the measure of nutritional status of adolescents varies with demographic, socio-economic, nutrition and health characteristics. The total number of adolescents covered in the present study was 2084. Among these, 746(35.8%), 589(28.3%) and 749 (35.9%) reside in urban, semi-urban and rural areas, respectively. In terms of gender, about 50.8 percent of the adolescents were males. In the adolescents' nutritional status using anthropometric outcomes, the first step is usually to look at the distribution of the z-scores. The cut-off point to define abnormal anthropometry with Z- scores was -2 standard deviations.

4.1.1.1 Major demographic, socioeconomic, nutrition and health characteristics with underweight (BMI for Age z-scores)

The major socioeconomic, demographic, nutrition, health background characteristics of the respondents and adolescents with underweight are presented in Table 1. Out of 2084 adolescents covered in this study 374 (19.17 percent) were found to be underweight. Here out of the total 2084 observations 133 were missing values.

Table 1: Distribution of socioeconomic, demographic and health related characteristics for BMI for Age z-score.

Covariates		BMI for age Z – score		
		under weight		Total number of adolescents
		number of under weight adolescents	Percent	
place of Residence	Urban	123	16.55	743
	Semi-urban	86	15.78	545
	Rural	165	24.89	663
Sex of the adolescent	Female	102	10.84	941
	Male	272	26.93	1010
Age of the adolescent	13	103	24.18	426
	14	99	22.05	449
	15	82	18.30	448
	16	51	14.17	360
	17	39	14.55	268
Highest grade	No education	29	28.43	102
	Primary	321	19.36	1658
	Secondary	24	12.57	191
Current job	No	281	20.10	1398
	Yes	93	16.82	553
Fever	No	56	19.72	284
	Yes	318	19.08	1667
Diarrhea	No	324	19.10	1696
	Yes	50	19.61	255
Unable to drink	No	161	16.68	965
	Yes	213	21.60	986
Depression	No	297	19.42	1529
	Yes	77	18.25	422
How many days did you worry that you would run out of food or not have enough money to buy food?	Never	309	19.05	1622
	1 to 7 days	57	20.36	280
	8 to 21 days	6	24.00	25
	More than 21 days	2	8.33	24
How many days you had to reduce the number of meals eaten in a day because of shortages of food or money?	Never	310	19.47	1592
	1 to 7 days	59	18.85	313
	8 to 21 days	3	10.71	28
	More than 21 days	2	11.11	18

The proportion of underweight adolescence, as can be seen in Table 1, differs by type of place of residence: rural, urban and semi-urban. Accordingly, higher numbers of underweight adolescents (20.89 percent) reside in rural areas, and relatively small numbers of underweight adolescent (15.78 percent) reside in Semi-urban centers.

The proportion of underweight adolescence, as can be seen in Table 1, differs by sex. Accordingly, higher numbers of underweight adolescents (26.93 percent) were males, and relatively small numbers of underweight adolescents (10.84 percent) were females.

With regards to adolescents age, the highest proportion of underweight adolescent were observed among those whose age was 13 years (24.18 percent) as opposed to the smallest percentage (14.17 percent) of underweight adolescent which was observed among those whose age was 16 years. And highest numbers of underweight adolescents (19.22 percent) had no child and relatively small number of underweight adolescents (10 percent) had child.

Table 1 shows, the nutritional status of adolescents vary by their educational status. The highest prevalence of underweight (28.43 percent) was from adolescents who have no education and relatively small number of underweight (12.57 percent) was from adolescents having secondary education. Regarding adolescents' employment status, the highest prevalence of underweight (20.10 percent) was from adolescents who have no job and relatively small number of underweight (16.82 percent) was from adolescents having a job.

Regarding health and health seeking behavior of the underweight adolescents, 19.08%, 19.61%, 21.60% and 18.25% had fever, diarrhea, unable to eat or drink, and depression, respectively.

Table 1 show that the nutritional status of adolescents varies by food status. The highest prevalence of adolescent underweight (24 percent) worry about shortage of enough money to buy food was observed from eight to twenty one day and relatively small numbers of underweight adolescents (8.33 percent) worry more than 21 days in the last three months. Also the highest proportion of adolescent underweight (19.47 percent) never worry about reducing the number of meals eaten in a day because of shortage of food or money and relatively small numbers of underweight adolescents (10.71 percent) worry more than 21 days in the last three months.

4.1.1.2 Major demographic, socioeconomic, nutrition and health characteristics with stunting (Height for Age z-scores)

The major socioeconomic, demographic, nutrition, health and background characteristics of the respondents and adolescents with stunting are presented in Table 2 below. The total number of adolescents who were measured for anthropometric measurements of height for age was 2084. Among these, 313 (16 percent) were found to be stunted whereas 1643 (84 percent) were not. Here out of the total 2084 observations 128 are missing values.

Table 2: Distribution of socioeconomic, demographic, nutrition and health related characteristics for height for age z-score

Covariates		Height for age Z-score		
		Stunting		Total number of adolescents
		number of under weight adolescents	percent	
Place of Residence	Urban	88	11.84	743
	Semi-urban	90	16.48	546
	Rural	135	20.24	667
Sex of adolescent	Female	103	10.93	942
	Male	210	20.71	1014
Age of adolescent	13	96	22.43	428
	14	90	20.00	450
	15	65	14.48	449
	16	41	11.36	361
	17	21	7.84	268
What is the highest grade you have completed?	No education	28	27.18	103
	Primary	274	16.49	1662
	Secondary	11	5.76	191
What type of school is/was this last/current school?	Government	291	15.56	1870
	Private	4	23.53	17
	Community	0	0.00	4
	Other	18	27.69	65
What is your religion?	Muslim	191	16.32	1170
	Orthodox	104	15.66	664
	Protestant	16	14.16	113
	Catholic	0	0.00	3
	Traditional	0	0.00	1
	None	1	50.00	2
	Other	1	33.33	3
Are you currently working in a job?	No	234	16.73	1399
	Yes	79	14.18	557
Abdominal pain?	No	192	14.41	1332
	Yes	121	19.39	624
Genital discharge or ulcer?	No	310	16.01	1936
	Yes	3	15.00	20
How many days have you had spend the whole day without eating, because of shortages of food or money?	Never	294	15.83	1857
	1 to 7 days	14	17.50	80
	8 to 21 days	3	37.50	8
	More than 21 days	2	18.18	11

The proportion of stunted adolescence, as can be seen in Table 2, differs by place of residence: rural, urban and semi-urban. Accordingly, higher numbers of stunted adolescents (20.24 percent) reside in rural areas, and relatively small numbers of stunted adolescent (11.84 percent) reside in urban centers.

The proportion of stunted adolescence, as can be seen in Table 2, differs by sex. Accordingly, higher numbers of stunted adolescents (20.71 percent) were males, and relatively small numbers of stunted adolescents (10.93 percent) were females. With regards to adolescents' age, the highest proportion of stunted adolescent were observed among those whose age is 13 years (22.43 percent) as opposed to the smallest percentage (7.84 percent) of underweight adolescents which was observed among those whose age was 17 years.

Likewise, as Table 2 shows, the nutritional status of adolescents varies by educational status. The highest prevalence of stunted adolescent (27.18 percent) was from adolescents who had no education and relatively small number of stunted adolescents (5.76 percent) had secondary education. And highest prevalence of stunted adolescent (27.69 percent) was from other type of schools and small prevalence of stunted adolescent was in private. There was no stunted adolescent from community/NGO.

Regarding adolescents' employment status, those who had no job showed higher prevalence adolescents stunted (16.73 percent) than those had a job (14.18 percent). Regarding health and health seeking behavior of the stunted adolescents, 19.39% and 15% had abdominal pain and genital discharge or ulcer, respectively.

Table 2 shows that, the nutritional status of adolescents vary by food status. The highest prevalence of adolescent stunted (37.50 percent) had spend the whole day without eating, because of shortages of food or money from eight to twenty one day and relatively small numbers of stunted adolescents (15.83 percent) had never spend the whole day without eating, because of shortages of food or money in the last three months.

4.1.2. INFERENTIAL STATISTICS

In this study, multiple linear regression analysis with stepwise variable selection and AIC criteria procedure was employed to select basic demographic, socio-economic; nutrition and health determinants of nutritional status of adolescents in terms of BMI for Age z-scores and height for age z-score. The models (BMI for age z-score and height for age z-score) were diagnosed and a multivariate multiple linear regression analysis was employed using the statistical package SAS 9.2.

4.1.2.1 Determinant of Nutrition Status of Adolescents: Univariate Linear Regression Analysis

Once the possible candidates of predictor variables have been identified while building a regression model, a decision should be made on the choice of the variables to be involved in the final regression model. One of the statistical procedures used for selection mechanism is to use the AIC criteria, which is stepwise method that adds/deletes regressors one at a time.

Multiple linear regression analysis is used to examine the effect of each independent variable in the model on nutritional status of adolescents while controlling for the other independent variables. Thus, two different models were fitted in this study to see the basic determinants of nutritional status among adolescents aged 13-17 years in Jimma zone. The first model was fitted to identify the basic demographic, socio-economic, nutrition and health determinants of nutritional status of adolescents in terms of short and long-run measures (underweight) at Jimma zone. Similarly, the second model was fitted to identify the determinants of nutritional status of adolescents in terms of long-run measures (stunting) at Jimma zone.

Goodness of Fit Test

Goodness of fit of the fitted multiple linear regression models was assessed using Akaike`s information (AIC) based on Fishers-test (F-test) and Adjusted-R^2. Accordingly, the AIC based F-test provided F-value of 21.87 (p-value<0.0001) and 7.38 (p<0.0001) for BMI for age z-score and height for age z-score, respectively.

Model Diagnostics

The fitted model was checked for linearity, for possible presence of outliers and influential values, for homoscedasticity and normality of the residuals; and also checked for possible presence of strong multicollinearity. The diagnostic test results for detection of outliers and influential values, test of homoscedasticity and normality; and diagnosis for multicollinearity are presented in Appendix A.

Detecting Non-linearity

The OLS regression model is linear in the parameters, meaning that the relationship between the dependent variable and the independent variables is linear. From Appendix A of partial regression residual plots of the study showed the relationship between the dependent variables (BMI for age z-score and height for age z-score) and the independent variables all had linear relationship and therefore the OLS regression model was linear in the parameters.

Diagnostic Test of Normality and Homoscedasticity:

A residual is the difference between the observed and model-predicted values of the dependent variable. The residual for a given product is the observed value of the error term for that product. A histogram or Q-Q plot of the residuals will help us to check the assumption of normality of the error term.

Test for normality using Shapiro-Wilk (w=0.971542, p-value= <0.0001), Kolmogorov-Smirnov (D= 0.040508, p-value= <0.0100), Cramer-von Mises (W-sq= 0.896973, p-value= <0.0050) and Anderson-Darling (A-sq= 5.707514, p-value= <0.0050) for BMI for age z-score and Shapiro-Wilk (w= 0.990097, p-value= <0.0001), Kolmogorov-Smirnov (D= 0.028878, p-value= <0.0100), Cramer-von Mises (W-sq= 0.324276, p-value= <0.0050) and Anderson-Darling (A-sq= 2.331047, p-value= <0.0050) for height for age z-score showed that all were statistically significant which indicates that normality assumption holds. And the shape of the histogram of the BMI for age z-score and Height for age z-score should also approximately follow the shape of the normal curve. These histograms were acceptably close to the normal curve. The Q-Q plotted residuals of the BMI for Age z-score and Height for Age z-score should also follow the 45-degree line. Neither the histograms nor the Q-Q plots indicate that the normality assumption was violated.

The plots of residuals of the BMI for Age z-score and Height for Age z-score by the predicted values show that the variance of the error term was constant across cases and independent of the variables in the model. The test for homoscedasticity and normality as presented in Appendix A We can say that our model was adequate.

Diagnostics for Outliers and Influential Values:

There are some outliers and influential observations as shown in the plot of leverages and plot of cooks distance in Appendix A. In perspective to BMI for age z-score and height for Age z-score there were some outliers and influential observations as shown in the plot of leverages and plot of cooks distance in Appendix A. To check their influence the suspected subjects were removed one at a time and the model was refitted. There were no large change in the model estimates and hence these observations were not as such influential outliers and then retained in the final model.

Diagnostics for Multicollinearity

In this study the correlation coefficients between predictors were very small as presented in Appendix B. This means that the predictors were not statistically correlated. Tolerance is the percentage of the variance in a given predictor that cannot be explained by the other predictors. When the tolerances are close to 0 or less than 0.1, there is high multicollinearity and the standard error of the regression coefficients will be inflated. But in this study the tolerances for BMI for age z-scores and for height for age z-scores were close to one and therefore there were no high multicollinearity.

A variance inflation factor (VIF) greater than 10 is usually considered problematic and here for BMI for age z-scores and height for age z-scores, there were no variables that its variance inflation factor greater than ten (10), the Collinearity diagnostics confirm that there were no serious problem with multicollinearity.

Table 3: Collinearity diagnostics for BMI for age z-score

Parameter Estimates								
Variables	Parameter Estimate	Standard Error	t-value	P-value	Tolerance	Variance Inflation	Eigenvalue	Condition Index
Intercept	-1.95	0.3392	-5.75	<.0001	.	0.0000	9.9963	1.0000
Place	-0.08	0.0347	-2.41	0.0159	0.7089	1.4106	0.9996	3.1623
Sex	-0.74	0.0504	-14.73	<.0001	0.9669	1.0342	0.9284	3.2813
Age	0.09	0.0197	4.40	<.0001	0.8840	1.1313	0.7548	3.6391
Have child	0.42	0.3474	1.20	0.2303	0.9967	1.0033	0.6830	3.8256
Highest grade	0.06	0.0712	0.86	0.3878	0.8170	1.2240	0.4715	4.6047
Current job	0.21	0.0563	3.80	0.0002	0.9521	1.0503	0.4106	4.9341
Fever	0.12	0.0725	1.63	0.1043	0.9381	1.0660	0.2267	6.6402
Diarrhea	0.08	0.0751	1.08	0.2812	0.9574	1.0445	0.1890	7.2729
Unable drink	-0.11	0.0534	-2.03	0.0423	0.8619	1.1602	0.1428	8.3674
Depression	0.12	0.0637	1.85	0.0646	0.8912	1.1221	0.0920	10.4252
Fworry	-0.21	0.0813	-2.57	0.0104	0.3527	2.8352	0.0581	13.1140
Freduce	0.13	0.0833	1.52	0.1292	0.3486	2.8686	0.0292	18.4889
HHincome	0.07	0.0444	1.66	0.0980	0.8581	1.1654	0.0145	26.2328
HHsize	-0.01	0.0077	-1.66	0.0963	0.8849	1.1301	0.0035	53.5809

Table 4: **Collinearity diagnostics for Height for Age Z-score**

Parameter Estimates								
Variable	Parameter Estimate	Standard Error	t-value	P-value	Tolerance	Variance Inflation	Eigenvalue	Condition Index
Intercept	-1.10	0.3522	-3.11	0.0019	.	0	9.37286	1
Place	-0.08	0.0357	-2.22	0.0265	0.672	1.4881	0.99988	3.0617
Sex	-0.16	0.05045	-3.19	0.0014	0.96928	1.03169	0.70173	3.65469
Age	0.03	0.01987	1.51	0.1308	0.86948	1.15011	0.64434	3.814
Highest grade	0.19	0.08167	2.28	0.0226	0.6228	1.60566	0.45358	4.54581
Type school	-0.09	0.05247	-1.71	0.0881	0.73768	1.35561	0.2818	5.76716
Religion	-0.08	0.03979	-1.97	0.0495	0.84352	1.18551	0.18308	7.15511
Current job	0.19	0.05642	3.38	0.0007	0.94989	1.05276	0.11712	8.94599
Abdominal pain	-0.14	0.05373	-2.53	0.0114	0.98208	1.01825	0.10232	9.57116
Ulcer	0.33	0.24806	1.33	0.182	0.98908	1.01104	0.07893	10.89688
Fspend	-0.23	0.07855	-2.9	0.0037	0.96418	1.03715	0.05039	13.63799
HHincome	0.09	0.04435	1.95	0.0518	0.86545	1.15546	0.0105	29.87433
HHsize	-0.02	0.00771	-2.7	0.0069	0.87815	1.13876	0.00347	51.96702

4.1.2.1.1 Determinants of nutritional status of Adolescents in terms of BMI for Age z-scores (Underweight) at Jimma zone.

Multiple linear regression analysis with stepwise variable selection and AIC criteria procedure was employed to select the most important determinants of nutritional status of adolescents in terms of BMI for Age z-scores**.** The outcome shows that Place of residence, sex of adolescent, age of adolescent, current job, unable to drink or eat and the number of times adolescents worried about availability of food in the last 3 months were found to be important predictors of nutritional status in terms of underweight.

Table 5: **Multiple Regression Model results of BMI for Age z-score (underweight) at Jimma zone**

Parameter	Parameter Estimate	Standard Error	t – Value	P-VALUE	95% Confidence Limits	
Intercept	-2.1413	0.5653	-3.7900	0.0002	-2.6164	-1.2861
Place of Residence	-0.0837	0.0347	-2.4100	0.0159*	-0.1518	-0.0157
Urban	0.1809	0.0697	2.6000	0.0095		
Semi-urban	0.2189	0.0694	3.1500	0.0016		
Rural (Ref)	0.0000	.	.	.		
Sex of the adolescent	-0.7425	0.0504	-14.7300	<.0001*	-0.8413	-0.6436
Female	0.7462	0.0504	14.8100	<.0001		
Male (Ref)	0.0000	.	.	.		
Age of the adolescent	0.0892	0.0201	4.4400	<.0001*	0.0480	0.1251
Have you ever had a child?	0.4168	0.3474	1.2000	0.2303	-0.2644	1.0981
No	-0.4206	0.3467	-1.2100	0.2252		
Yes (Ref)	0.0000	.	.	.		
What is the highest grade you have completed?	0.0615	0.0712	0.8600	0.3878	-0.0781	0.2011
No education	-0.1140	0.1460	-0.7800	0.4352		
Primary	-0.0410	0.0926	-0.4400	0.6581		
Secondary (Ref)	0.0000	.	.	.		
Are you currently working in a job?	0.2139	0.0563	3.8000	0.0002*	0.1034	0.3243
No	-0.2024	0.0567	-3.5700	0.0004		
Yes (Ref)	0.0000	.	.	.		
Fever?	0.1178	0.0725	1.6300	0.1043	-0.0244	0.2600
No	-0.1143	0.0726	-1.5800	0.1154		
Yes (Ref)	0.0000	.	.	.		
Diarrhea	0.0809	0.0751	1.0800	0.2812	-0.0663	0.2282
No	-0.0859	0.0750	-1.1500	0.2521		
Yes (Ref)	0.0000	.	.	.		
unable drink to eat or drink	-0.1084	0.0534	-2.0300	0.0423*	-0.2131	-0.0038
No	0.1189	0.0533	2.2300	0.0259		
Yes (Ref)	0.0000	.	.	.		
Depression	0.1178	0.0637	1.8500	0.0646	-0.0072	0.2428
No	-0.1330	0.0639	-2.0800	0.0375		
Yes (Ref)	0.0000	.	.	.		
How many days did you worry that you would run out of food or not have enough money to buy food?	-0.2086	0.0813	-2.5700	0.0104*	-0.3681	-0.0491
Never	0.2444	0.3143	0.7800	0.4369		
1 to 7 days	0.0082	0.3133	0.0300	0.9790		
8 to 21 days	-0.6124	0.3499	-1.7500	0.0803		
More than 21 days (Ref)	0.0000	.	.	.		
How many days you had to reduce the number of meals eaten in a day because of shortages of food or money?	0.1264	0.0832	1.5200	0.1292	-0.0369	0.2896
Never	-0.1959	0.3518	-0.5600	0.5778		
1 to 7 days	-0.1335	0.3507	-0.3800	0.7034		
8 to 21 days	0.4902	0.3660	1.3400	0.1806		
More than 21 days (Ref)	0.0000	.	.	.		
House hold income	0.0581	0.0446	1.3000	0.1925	-0.0136	0.1606
House hold size	-0.0093	0.0078	-1.2000	0.2303	-0.0278	0.0023

* *Significant (p<0.05) and Ref. = Reference category*

The model indicated that the mean BMI for Age z-score for adolescents who dwell in the urban and semi-urban were 0.1809 and 0.2189 units more than the mean for adolescents in rural, respectively, the mean BMI for Age z-score for female adolescent were 0.7462 units more than the mean of male adolescents and mean of adolescents those have no child were 0.4206 units less than the mean of adolescents that have child.

The model shows that the mean of BMI for Age z-score for adolescents who were not job 0.2024 units less than the mean of adolescents who were job.

The model show that the mean of BMI for Age z-score for adolescents who had unable to eat or drink in the last times they were sick were 0.1189 units more than the mean for adolescents who had not.

The model also show that the mean of BMI for Age z-score for adolescents who were never worry and who worry one to seven days worry that they would run out of food or not have enough money to buy food were 0.2444 and 0.0082 units more than the mean of adolescents worry more than 21 days. Also the mean of BMI for Age z-score for adolescents who were worry that they would run out of food or not have enough money to buy food from eight to twenty one days were 0.6124 units less than the mean of adolescents who worry more than 21 days.

4.1.2.1.2 Determinants of nutrition status of adolescents in terms of Height for Age z-scores (Stunting) at Jimma zone.

Multiple linear regression analysis with stepwise variable selection procedure was also employed to select the most important determinants of nutritional status of adolescents in terms of long-run measures (stunting). The result showed that Place of residence, sex of the adolescent, Highest grade completed, Have current job, Religion, Abdominal pain, the numer of days adolescents had to spend the whole day without eating in the last 3 months and Household size were found to be important predictors of nutritional status in terms of stunting.

Table 6: **Multiple Regression Model results of Height for Age z-score (stunting) at Jimma zone**

Parameter	Estimate	Standard Error	t - Value	P-value	95% Confidence Limits	
Intercept	-2.2971	0.7751	-2.9600	0.0031	-1.7871	-0.4057
Place of Residence	-0.0792	0.0357	-2.2200	0.0265*	-0.1493	-0.0092
Urban	0.1751	0.0736	2.3800	0.0175		
Semi-urban	0.0614	0.0723	0.8500	0.3954		
Rural	0.0000	.	.	.		
Sex of adolescent	-0.1609	0.0505	-3.1900	0.0014*	-0.2599	-0.0620
Female	0.1604	0.0505	3.1800	0.0015		
Male	0.0000	.	.	.		
Age of adolescent	0.0338	0.0201	1.6800	0.0929	-0.0089	0.0690
What is the highest grade you have completed?	0.1864	0.0817	2.2800	0.0226*	0.0262	0.3466
No education	-0.4542	0.2026	-2.2400	0.0251		
Primary	-0.1341	0.0930	-1.4400	0.1496		
Secondary	0.0000	.	.	.		
What type of school is/was this last/current school?	-0.0895	0.0525	-1.7100	0.0881	-0.1924	0.0134
Government	0.1887	0.2248	0.8400	0.4012		
Private	-0.0966	0.3501	-0.2800	0.7827		
Community	1.2358	0.5958	2.0700	0.0382		
Other	0.0000	.	.	.		
What is your religion?	-0.0782	0.0398	-1.9700	0.0495*	-0.1562	-0.0002
Muslim	0.6938	0.4929	1.4100	0.1594		
Orthodox	0.5524	0.4937	1.1200	0.2634		
Protestant	0.6936	0.5026	1.3800	0.1677		
Catholic	0.0835	0.8050	0.1000	0.9174		
None	0.3455	1.2054	0.2900	0.7744		
Other	0.0000	.	.	.		
Are you currently working in a job?	0.1910	0.0564	3.3800	0.0007*	0.0803	0.3016
No	-0.1952	0.0568	-3.4400	0.0006		
Yes	0.0000	.	.	.		
Abdominal pain?	-0.1362	0.0537	-2.5300	0.0114*	-0.2415	-0.0308
No	0.1335	0.0538	2.4800	0.0132		
Yes	0.0000	.	.	.		
Genital discharge or ulcer?	0.3311	0.2481	1.3300	0.1820	-0.1553	0.8176
No	-0.3273	0.2491	-1.3100	0.1890		
Yes	0.0000	.	.	.		
How many days have you had spend the whole day without eating, because of shortages of food or money?	-0.2282	0.0786	-2.9000	0.0037*	-0.3822	-0.0741
Never	0.4113	0.3336	1.2300	0.2177		
1 to 7 days	0.1448	0.3540	0.4100	0.6825		
8 to 21 days	-0.3758	0.5109	-0.7400	0.4620		
More than 21 days	0.0000	.	.	.		
House hold income	0.0792	0.0448	1.7700	0.0773	-0.0007	0.1733
House hold size	-0.0226	0.0079	-2.8700	0.0041*	-0.0360	-0.0057

* *Significant (p<0.05) and Ref. = Reference category*

The model indicated that the mean Height for Age z-score for adolescents who dwell in the urban and semi-urban were 0.1751 and 0.0614 units more than the mean for adolescents in rural, respectively and the mean Height for Age z-score for female adolescent were 0.1604 units more than the mean of male adolescents.

The model shows that the mean of Height for Age z-score for adolescents who have no education and primary education were 0.4542 and 0.1341 units less than the mean of adolescents who were secondary education. And the mean of Height for Age z-score for adolescents who have no job were 0.1952 units less than the mean of adolescents who were job.

The result show that the mean of Height for Age z-score for adolescents who had abdominal pain in the last times they were sick were 0.1335 units more than the mean for adolescents who had not.

The model also show that the mean of Height for Age z-score for adolescents who were never and from one to seven days had spend the whole day without eating, because of shortages of food or money were 0.4113 and 0.1448 units more than the mean of adolescents spend the whole day without eating, because of shortages of food or money more than 21 days and the model also show that the mean of Height for Age z-score for adolescents who were from eight to twenty one days had spend the whole day without eating, because of shortages of food or money were 0.3758 units less than the mean of adolescents spend the whole day without eating, because of shortages of food or money more than 21 days.

4.1.2.2 Determinant of nutritional status of adolescents: Multivariate Linear Regression Analysis

We use multivariate analysis for comparisons and for joint analysis of the effects of socio-economic, demographic and health variables on the measures of nutritional status (stunting and underweight) of adolescents and to estimate any residual correlation between stunting and underweight.

When we look at the Univariate results for BMI for age z-score and Height for age z-score, we see that the overall model was statistically significant, but not all the predictor variables are statistically significant. Multivariate tests tell us that the set of predictors accounts for a statistically significant portion of the variance in the BMI for age z-score and Height for age z-score.

Table 7: Tests of all coefficients of the independent variables are the same

Multivariate Statistics and Exact F Statistics					
Statistic	Value	F Value	Num DF	Den DF	P-value
Wilks' Lambda	0.9489	3.11	31	1791	<.0001
Pillai's Trace	0.0511	3.11	31	1791	<.0001
Hotelling-Lawley Trace	0.0538	3.11	31	1791	<.0001
Roy's Greatest Root	0.0538	3.11	31	1791	<.0001

Table 7 shows that the test of whether the coefficients of all the independent variables are the same. The four multivariate test statistics (Wilks' Lambda, Pillai's Trace, Hotelling-Lawley Trace and Roy's Greatest Root) were all highly significant, giving strong evidence that the coefficients of all the independent variables were not the same across dependent variables, BMI for age z-score and height for age z-score.

Table 8: Tests of all coefficients of the independent variables are zero

Multivariate Statistics and F Approximations

Statistic	Value	F Value	Num DF	Den DF	P-value
Wilks' Lambda	0.8219	5.95	62	3580	<.0001
Pillai's Trace	0.1825	5.8	62	3582	<.0001
Hotelling-Lawley Trace	0.2113	6.1	62	3364.2	<.0001
Roy's Greatest Root	0.1814	10.48	31	1791	<.0001

And table 8 shows that the tests of whether all the coefficients of all the independent variables are zero, the four multivariate test statistics were highly significant, indicating that the null hypothesis that the coefficients of all independent variables are not significantly different from zero is rejected.

Table 9: **multivariate model for underweight and stunting at Jimma zone**

Covariate	Estimate		Standard Error		t -value		P-value		95% Confidence Limits	
	Under weight	Stuntin g	Under weight	Stuntin g	Under weight	Stunting	Unde r weigh t	Stunti ng	Under weight	Stunting

Intercept	-0.737	-1.465	1.090	1.108	-0.680	-1.320	0.499	0.186	-3.883	-0.986	-2.567	0.366
Place of Residence	-0.082	-0.093	0.040	0.040	-2.060	-2.300	0.039*	0.022*	-0.161	-0.004	-0.172	-0.014
Urban	0.196	0.228	0.083	0.084	2.370	2.700	0.018	0.007				
Semi-urban	0.256	0.073	0.079	0.080	3.260	0.910	0.001	0.362				
Rural	0.000	0.000	.	.	.	.	.	.				
Sex of the adolescent	-0.740	-0.176	0.053	0.054	-13.960	-3.270	<.0001*	0.001*	-0.844	-0.636	-0.281	-0.070
Female	0.733	0.172	0.053	0.054	13.810	3.190	<.0001	0.002				
Male	0.000	0.000	.	.	.	.	.	.				
Age of the adolescent	0.081	0.034	0.021	0.021	3.900	1.610	0.000*	0.109	0.040	0.122	-0.008	0.075
age 13	-0.248	-0.155	0.096	0.097	-2.590	-1.600	0.010	0.110				
age 14	-0.107	-0.063	0.094	0.095	-1.140	-0.660	0.254	0.509				
age 15	0.080	-0.017	0.092	0.094	0.860	-0.180	0.388	0.857				
age 16	0.084	-0.067	0.094	0.096	0.890	-0.700	0.374	0.484				
age 17	0.000	0.000	.	.	.	.	.	.				
What is the highest grade you have completed?	0.162	0.173	0.087	0.088	1.870	1.970	0.062	0.049*	-0.008	0.331	0.001	0.345
No education	-0.411	-0.449	0.211	0.215	-1.950	-2.090	0.052	0.037				
Primary	-0.191	-0.146	0.100	0.102	-1.910	-1.440	0.057	0.150				
Secondary	0.000	0.000	.	.	.	.	.	.				
Are you currently working in a job?	0.220	0.190	0.059	0.060	3.720	3.170	0.000*	0.002*	0.1041	0.337	0.072	0.308
No	-0.202	-0.199	0.060	0.061	-3.380	-3.260	0.001	0.001				
Yes	0.000	0.000	.	.	.	.	.	.				
Unable to eat or drink?	-0.140	0.023	0.061	0.062	-2.300	0.380	0.022*	0.704	-0.259	-0.021	-0.097	0.144
No	0.148	-0.023	0.061	0.062	2.430	-0.370	0.015	0.708				
Yes	0.000	0.000	.	.	.	.	.	.				
Abdominal pain?	-0.003	-0.148	0.061	0.061	-0.050	-2.410	0.964	0.016*	-0.122	0.116	-0.269	-0.028
No	0.018	0.143	0.061	0.062	0.300	2.320	0.764	0.021				
Yes	0.000	0.000	.	.	.	.	.	.				
Depression?	0.137	-0.010	0.068	0.069	2.020	-0.150	0.044*	0.880	0.004	0.269	-0.145	0.124
No	-0.153	0.002	0.068	0.069	-2.240	0.030	0.025	0.978				
Yes	0.000	0.000	.	.	.	.	.	.				
Do you usually sleep under an insecticide treated mosquito bed net?	-0.081	-0.059	0.081	0.082	-1.000	-0.720	0.317	0.474	-0.239	0.078	-0.219	0.102
No	0.064	0.074	0.081	0.083	0.790	0.890	0.430	0.374				
Yes	0.000	0.000	.	.	.	.	.	.				
How many days did you worry that you would run out of food or not have enough money to buy food?	-0.196	-0.020	0.092	0.093	-2.130	-0.210	0.033*	0.832	-0.377	-0.015	-0.203	0.163
Never	0.432	-0.138	0.341	0.347	1.270	-0.400	0.205	0.691				
1 to 7 days	0.127	-0.217	0.328	0.333	0.390	-0.650	0.698	0.516				
8 to 21 days	-0.540	-0.412	0.368	0.374	-1.470	-1.100	0.142	0.270				

More than 21 days	0.000	0.000	.	.	.	.	.	.				
How many days have you had spend the whole day without eating, because of shortages of food or money?	0.078	-0.282	0.117	0.119	0.660	-2.370	0.507	0.018*	-0.152	0.308	-0.515	-0.049
Never	0.180	0.383	0.536	0.545	0.330	0.700	0.738	0.483				
1 to 7 days	0.089	-0.001	0.540	0.549	0.160	0.000	0.869	0.999				
8 to 21 days	0.791	-0.396	0.588	0.598	1.350	-0.660	0.178	0.507				
More than 21 days	0.000	0.000	.	.	.	.	.	.				
House hold size	-0.007	-0.021	0.008	0.009	-0.800	-2.500	0.422	0.013*	-0.029	0.003	-0.036	-0.004

Table 9 shows the joint analysis of the effects of socio-economic, demographic and health characteristics on the measures of nutritional status of adolescents (stunting and underweight).

As shown in table 9 place of residence, sex of adolescents and working in a job were jointly statistically significant explanatory variables on both stunting and underweight. Age of adolescent, unable to eat or drink and depression were significant only in terms of underweight and highest grade completed, abdominal pain, How many days have you had spend the whole day without eating because of shortages of food or money (fspend) and Household size were significant only in terms of stunting.

As can be seen in table 9, on average, female adolescents were less vulnerable to malnutrition than male adolescents in terms of both stunting and underweight. Likewise, on average adolescents who have no job were highly vulnerable to health problem and malnutrition than adolescents who have in terms of underweight and stunting.

Table 9 also shows on average adolescents who have no education and primary education were highly vulnerable to malnutrition than adolescents who have secondary education in terms of stunting.

Table 9 shows on average adolescents who were never, one to seven days and eight to twenty one days spend the whole day without eating, because of shortages of food or money were less vulnerable to malnutrition and health problems than adolescents who were more than twenty one days spend the whole day without eating, because of shortages of food or money in terms of underweight and adolescents who were never spend the whole day without eating, because of shortages of food or money were less vulnerable to malnutrition and health problems than adolescents who were more than twenty one days spend the whole day without eating, because of shortages of food or money in terms of stunting. Also on average adolescents who were one to seven days and eight to twenty one days worry that they would spend the whole day without eating, because of shortages of food or money were highly vulnerable to malnutrition and health problems than adolescents who were more than twenty one day spend the whole day without eating, because of shortages of food or money in terms of stunting. However it was statistically insignificant in terms of underweight.

4.2 DISCUSSION

This study was also intended to identify the determinants of the nutritional status of adolescents based on the longitudinal family survey of youth data. Accordingly, separate multiple linear regression techniques on stunting and underweight were employed. In addition to this multivariate linear regression techniques jointly on stunting and underweight were employed. The results obtained are discussed as follows.

The findings of the study show that the risk of malnutrition problem was significantly less, on average, for adolescents who lived in urban and semi urban areas than adolescents who lived in rural areas in Jimma zone in terms of both underweight and stunting. The observed urban-rural difference in nutritional status could be an indication of low access and use of health services in the rural areas as compared with urban areas (5, 33, 56, 58). In general, people living in cities have better health and lower death rates than rural residents, even though the urban poor often live in unsanitary and crowded conditions. Compared with rural residents, urban residents have better access to medical services and are more easily reached by immunization and educational campaign.

The findings of this study also show that there was a significant difference in the risk of nutritional status in adolescents by their sex in terms of underweight and stunting. The risk of malnutrition problem was, on average, significantly higher for adolescent males than adolescent females in terms of underweight and stunting. This finding is consistent with other studies (55).This may be because of the fact that biological, behavioral, and socio-cultural mechanisms have been proposed for the gender differences in morbidity and mortality. Biologically, female subjects have an advantage for better health and longer survival because of the role of sex hormones in modulating lipid levels and increasing immune response. In addition, the difference in morbidity and mortality between boys and girls is further related to individual lifestyle, the use of health care, and health and illness behaviors and practices. For example, adolescent boys are more likely to smoke and have higher propensities of taking greater risks that expose them to injury.

Educational status was an important socio-economic variable that affects nutritional status of adolescents in this zone in terms of stunting. The risk of malnutrition problem was significantly high, on average, for adolescents who have no education and primary than adolescents who have secondary education in Jimma zone in terms of stunting. This finding seemed to be consistent with other studies (29). They indicated that adolescents who receive even a minimal education are generally more aware than those who have no education of how to utilize available resources for the improvement of their own nutritional status and that of their families. Education may enable to make independent decisions, to be accepted by other household members, and to have greater access to household resources that are important to nutritional status (1).

Working in a job was also an important socio-economic variable that affects nutritional status of adolescents in this zone in terms of underweight and stunting. The risk of malnutrition problem was significantly high, on average, for adolescents who have no job than adolescents who have job in Jimma zone in terms of underweight and stunting. This finding is consistent with other studies (56). They indicated that unemployment is a significant factor for chronic energy deficiency in these adolescents as compared with employed adolescents.

The findings of this study show that adolescents who were unable to eat or drink last time before date of survey were significantly vulnerable to malnutrition than those who have not in terms of underweight. The findings of this study also show that adolescents who have abdominal pain last time before date of survey were significantly vulnerable to malnutrition than those who have not in terms of stunting.

In this study there was no association between household size and underweight, also there was no association between household income for both underweight and stunting; this is consistent with other studies (11,42), but there was association between household size and stunting.

The finding of the study show for models BMI for Age z-score (underweight) and Height for Age z-score (stunting), the models were statistically significant. The relationship between the dependent variables (BMI for age z-score and height for age z-score) and the independent variables all had linear relationship. Test for normality and homoscedasticity for BMI for age z-score and height for age z-score showed that normality assumption holds and the models were no heteroscedastic and we can say that models were adequate.

5 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The study revealed that socio-economic, demographic and health variables have significant effect on the nutritional status of adolescents in Jimma zone. Place of residence, sex of adolescent and working in a job were the most important determinants of adolescents nutritional status in Jimma zone.

It is observed that adolescents living in rural parts of the zone were at higher risk of health problem and malnutrition. The result also suggested that uneducated adolescents were more vulnerable to health problem/malnutrition in Jimma zone.

The findings of this study show that adolescents who had abdominal pain and unable to eat or drink last time before the date of survey were significantly vulnerable to malnutrition than those who had not.

Adolescents who had not job were significantly vulnerable to malnutrition and health problem than those who had a job.

5.2 RECOMMENDATION

Based on the findings and conclusions the following recommendations are made:

- It is useful to strengthen health care and food security programs in rural areas to directly address food insecurity and malnutrition problems of the poor and vulnerable communities in rural parts of the zone.
- It is useful to improve adolescents’ access to education in all areas in order to enhance their income earning capacity and also enhancing the quality of care and attention by improving their education level.

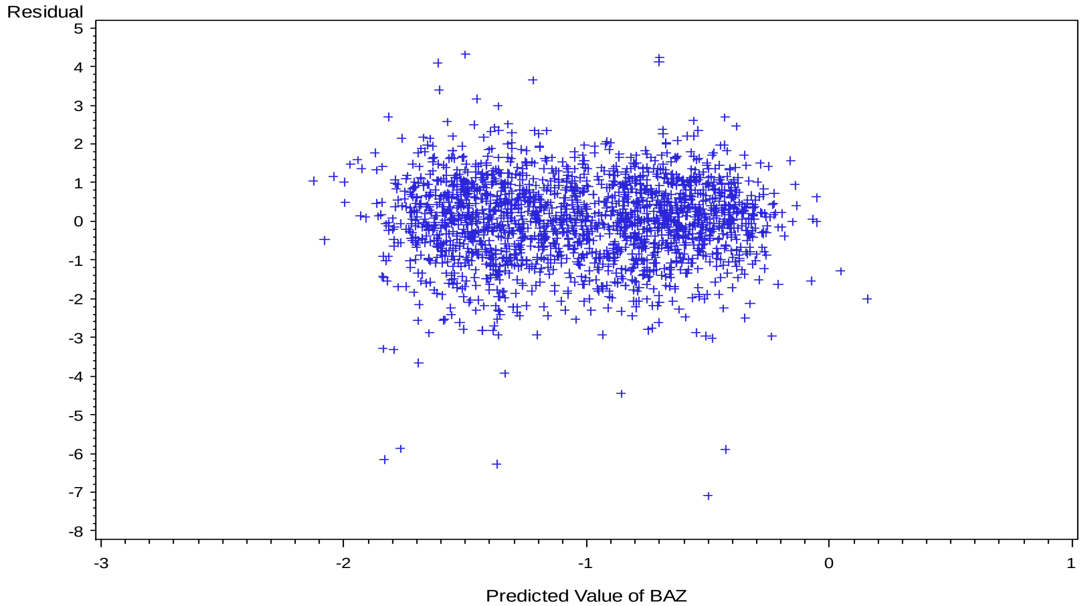
- Efforts should be made in improving environmental sanitation and personal hygiene to prevent exposure to abdominal pain.
- Efforts should be made to minimize unemployed adolescents to improve the malnutrition level.
- Finally we strongly recommend further studies to be conducted on adolescent malnutrition which is supported by laboratory investigation.

APPENDIXES

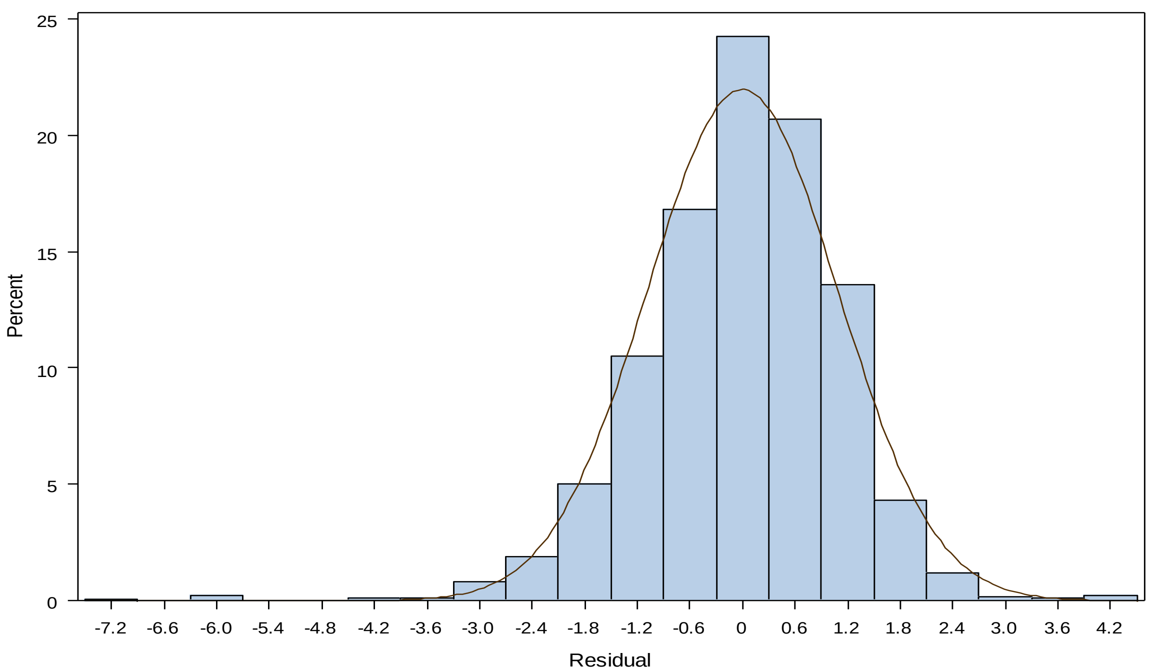
Appendix A: Results of diagnostic Checking

Dependent Variable: BMI for Age Z-score

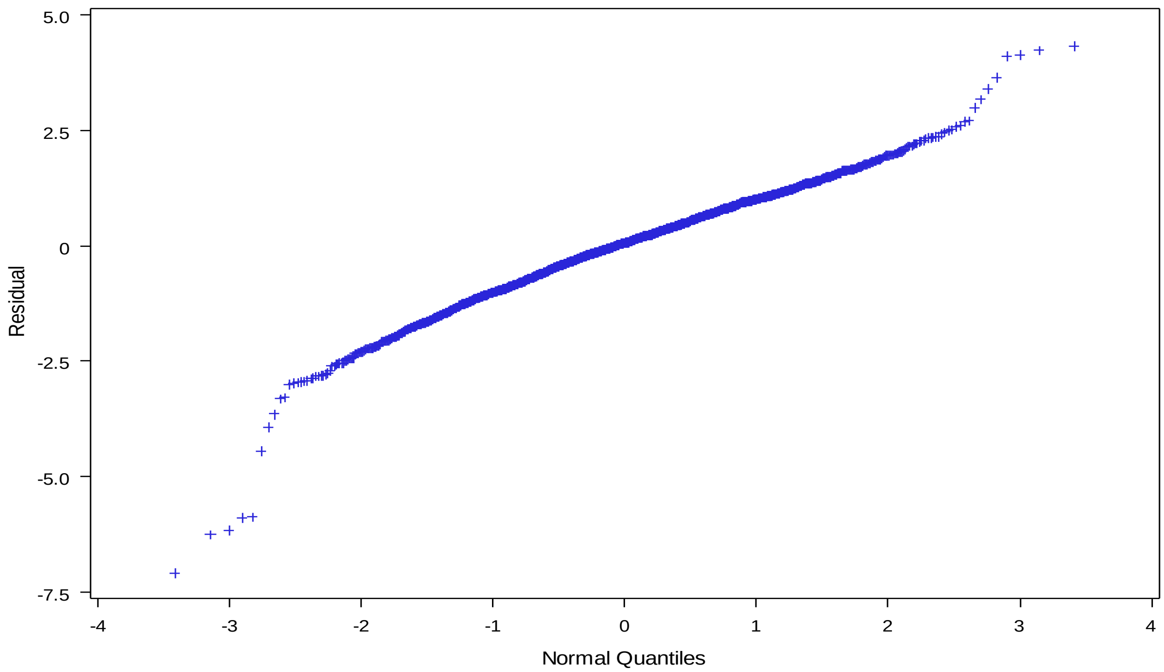
homoescedasticity and independence of residuals for BAZ

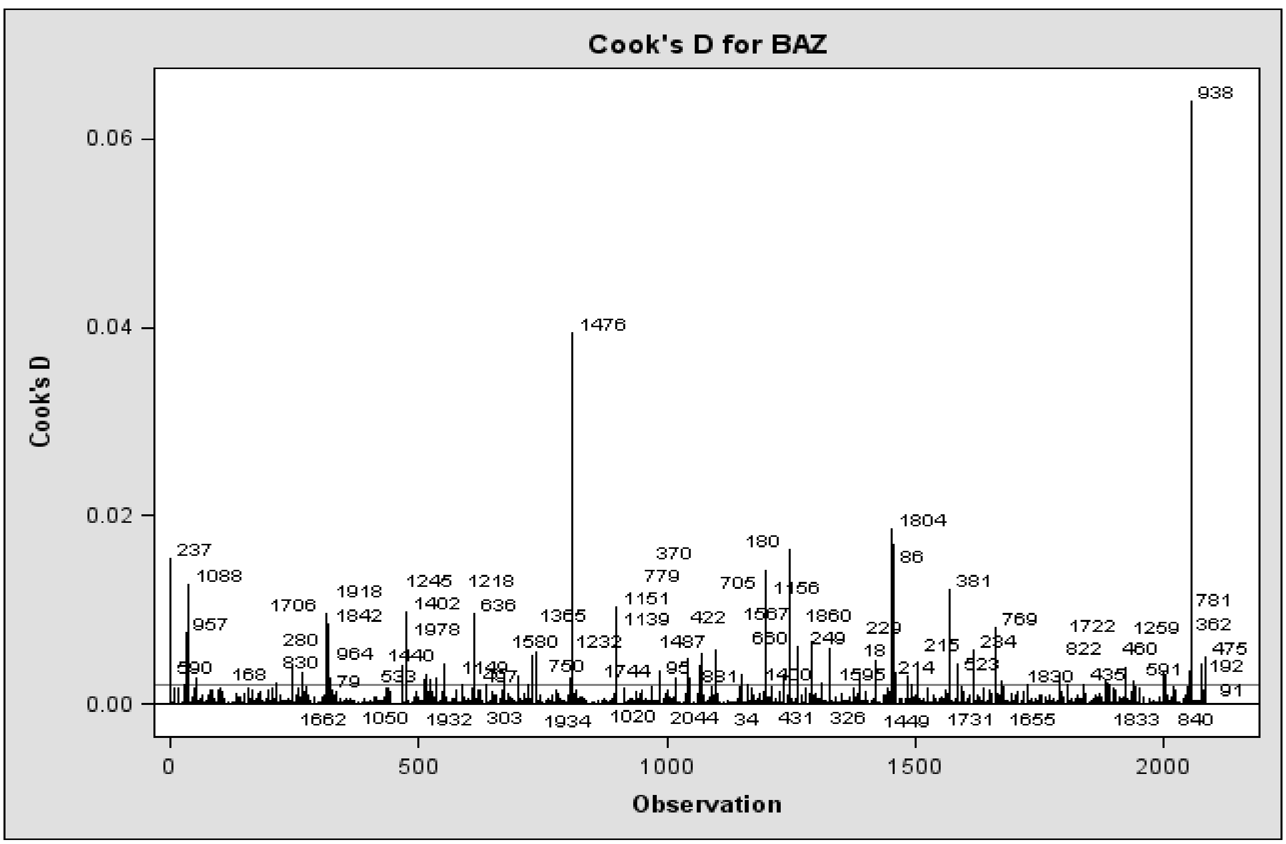


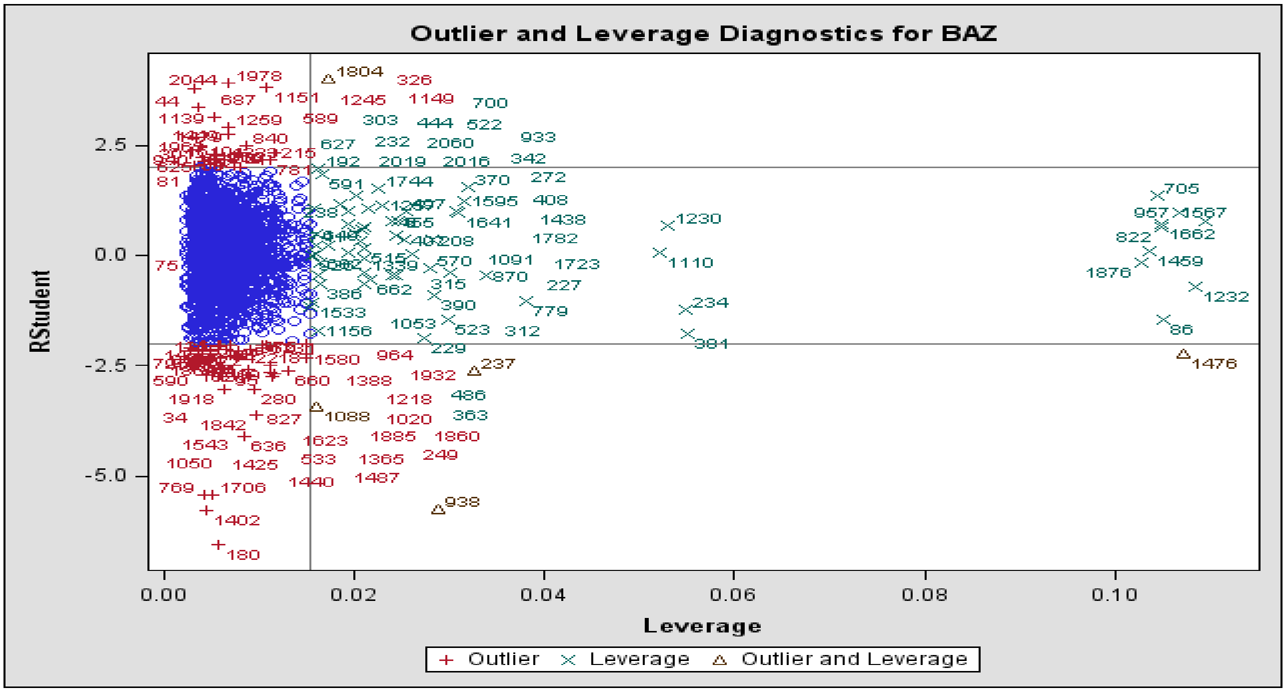
Check the mean and normality of residuals for BAZ

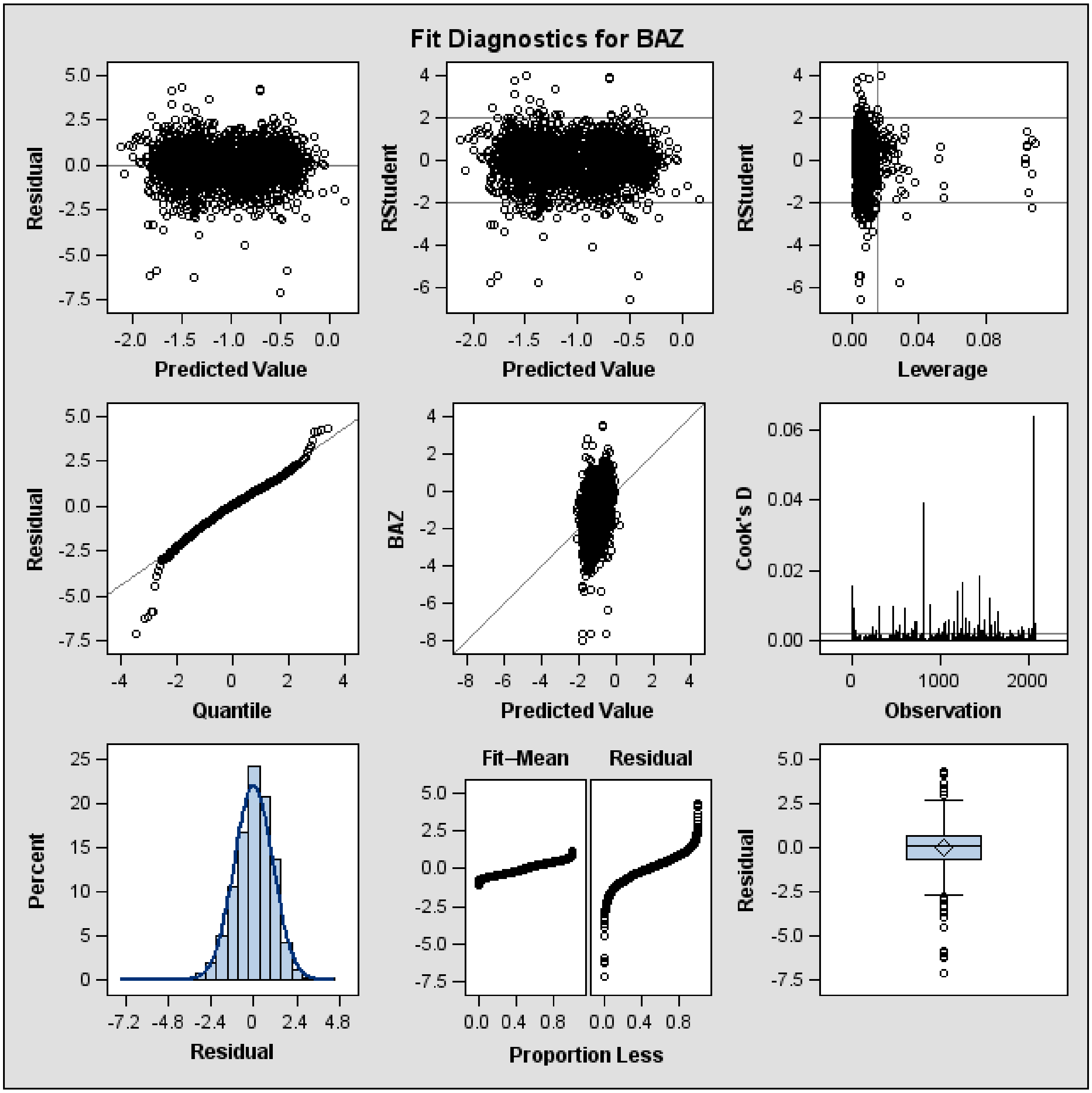


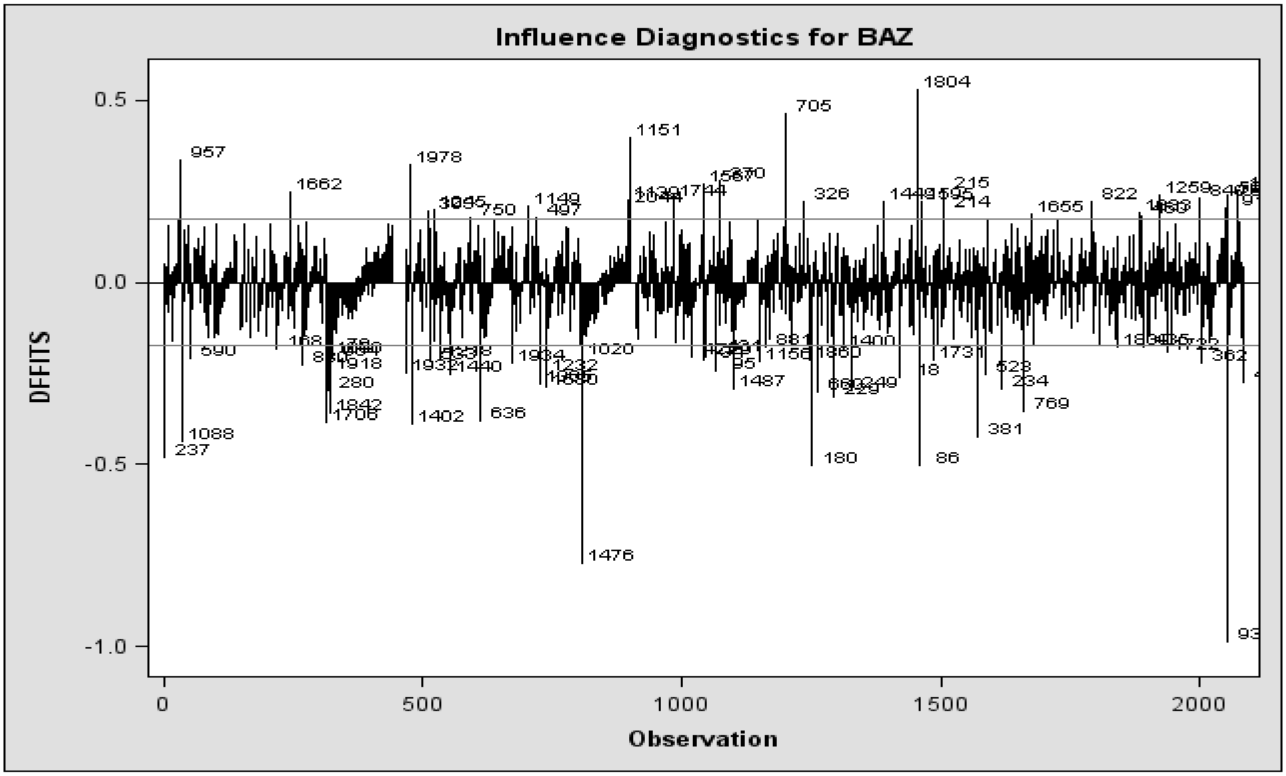
Check the mean and normality of residuals for BAZ

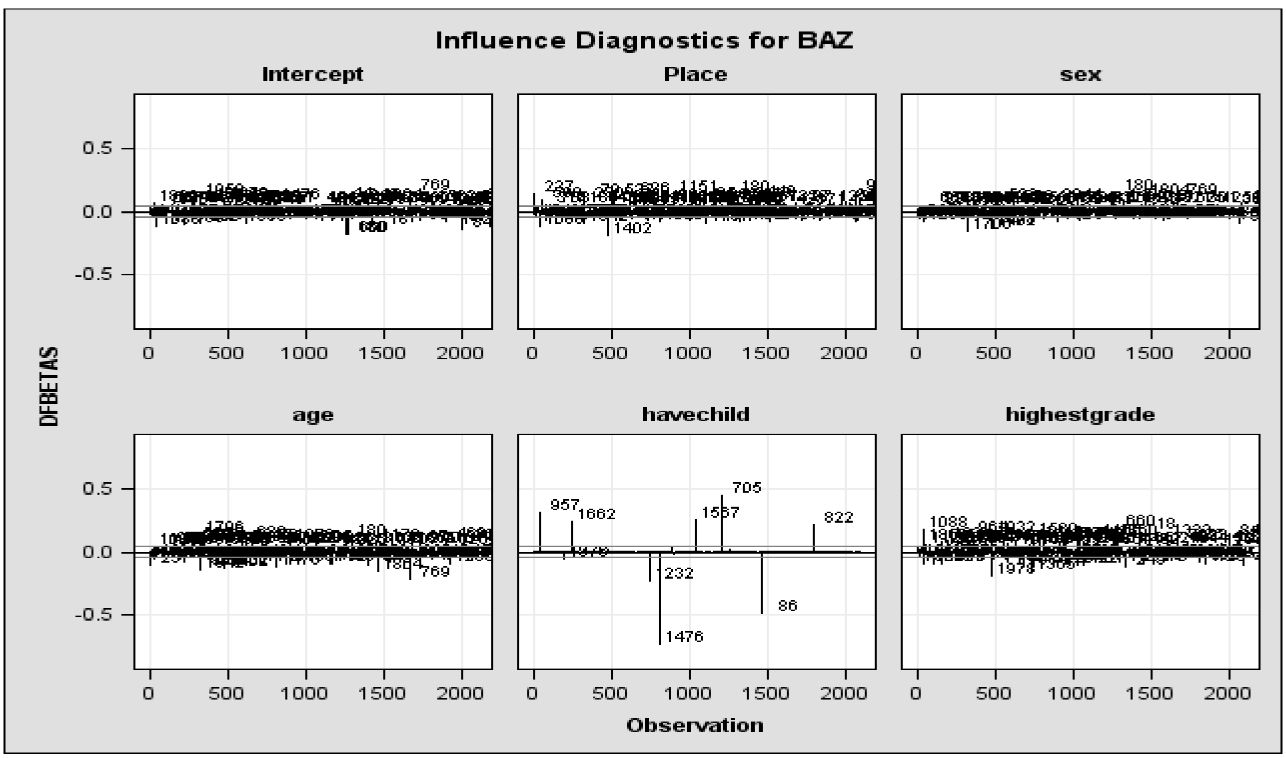


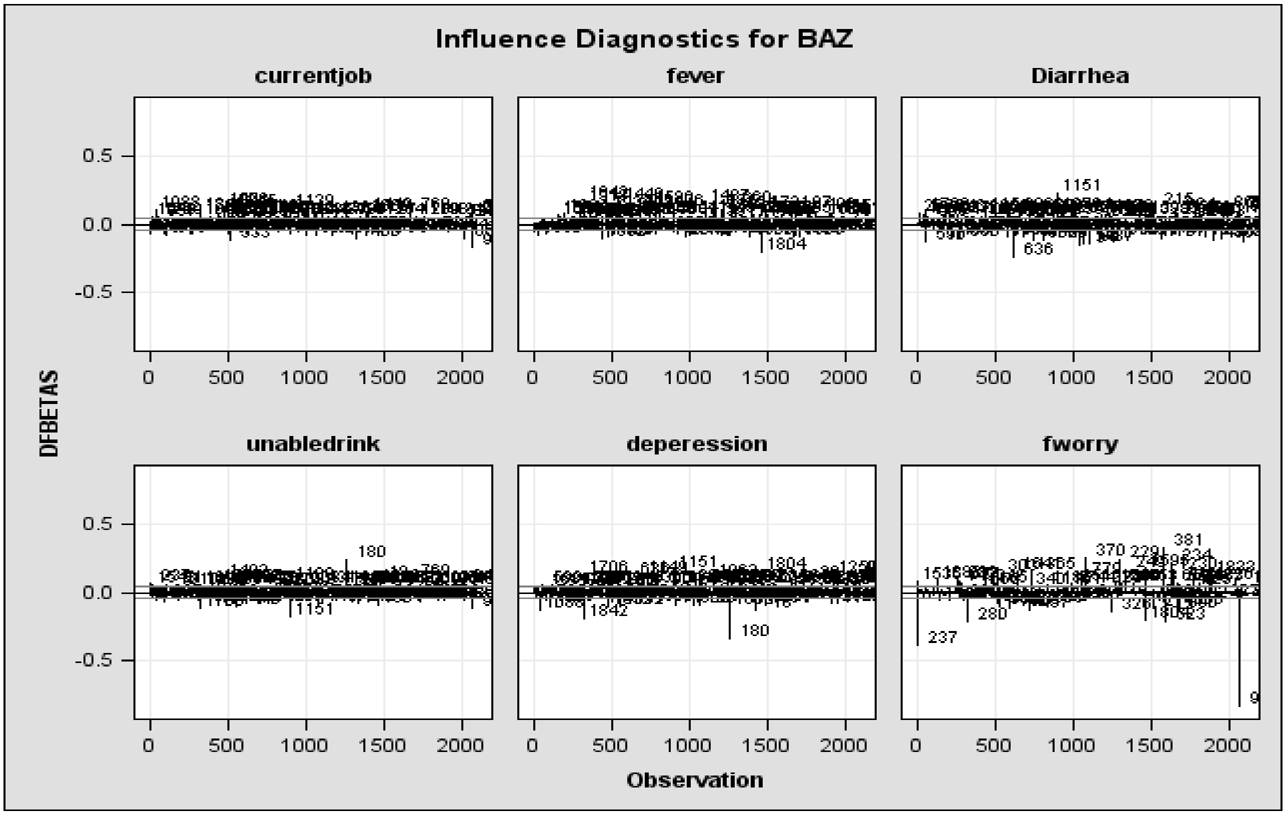


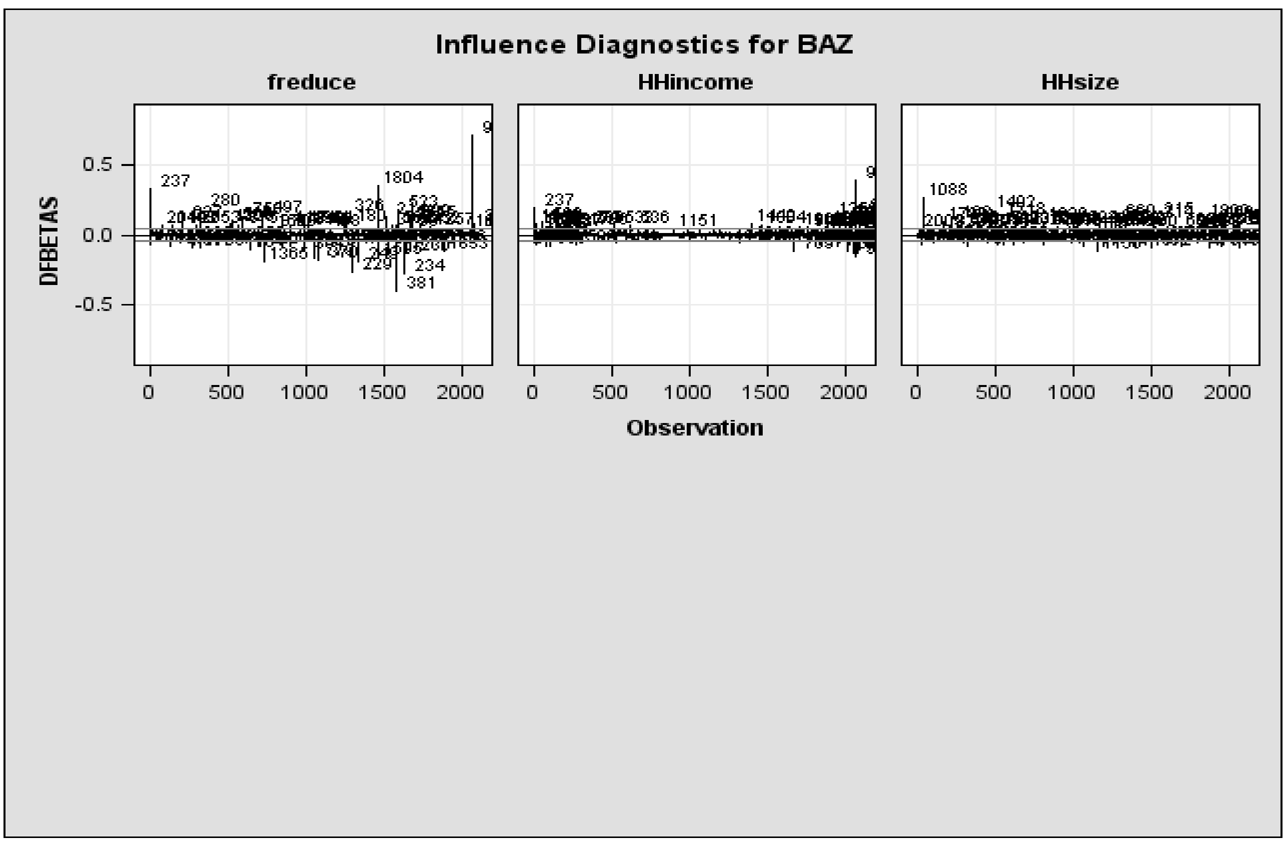

Outlier and Leverage Diagnostics for BAZ
RStudent
2.5
0.0
-2.5
-5.0
0.00
0.02
0.04
0.06
0.08
0.10
Leverage
Outlier
Leverage
Outlier and Leverage

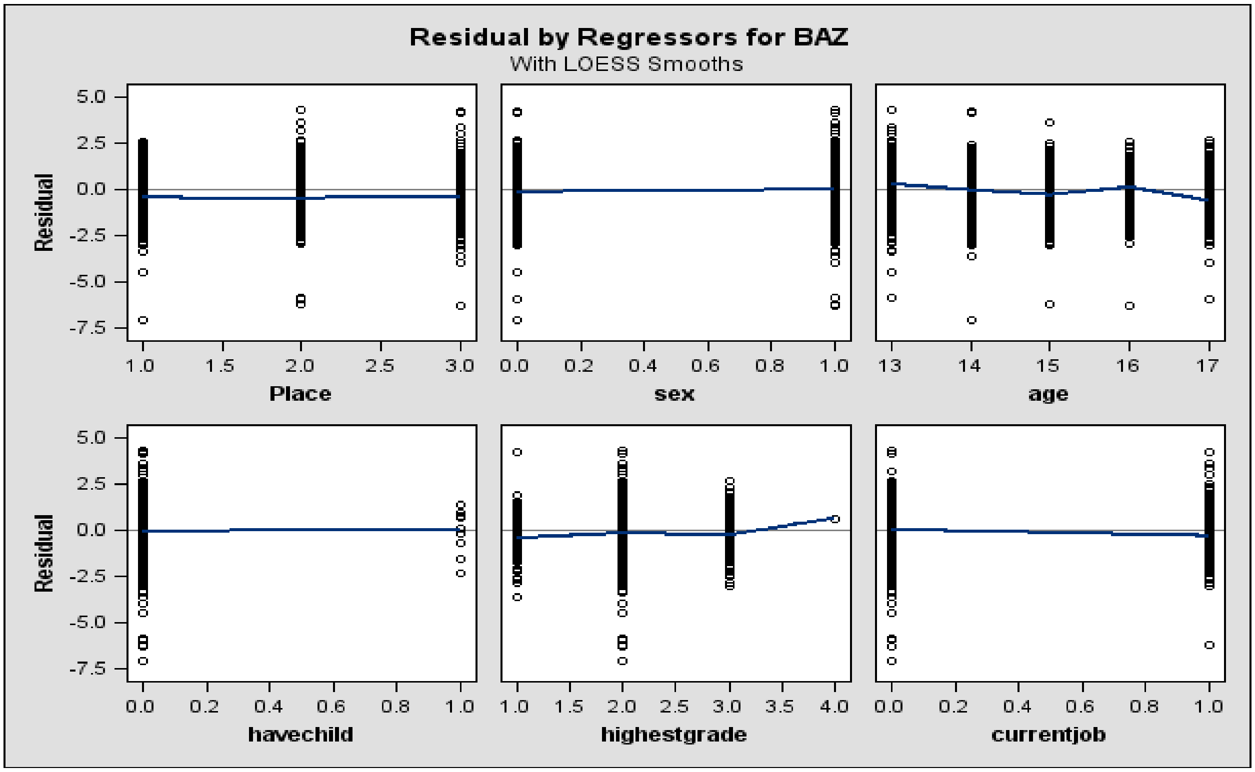

Fit Diagnostics for BAZ
Residual
Predicted Value
RStudent
Predicted Value
RStudent
Leverage
Residual
Quantile
BAZ
Predicted Value
Cook's D
Observation
Percent
Residual
Fit–Mean
Residual
Proportion Less
Residual

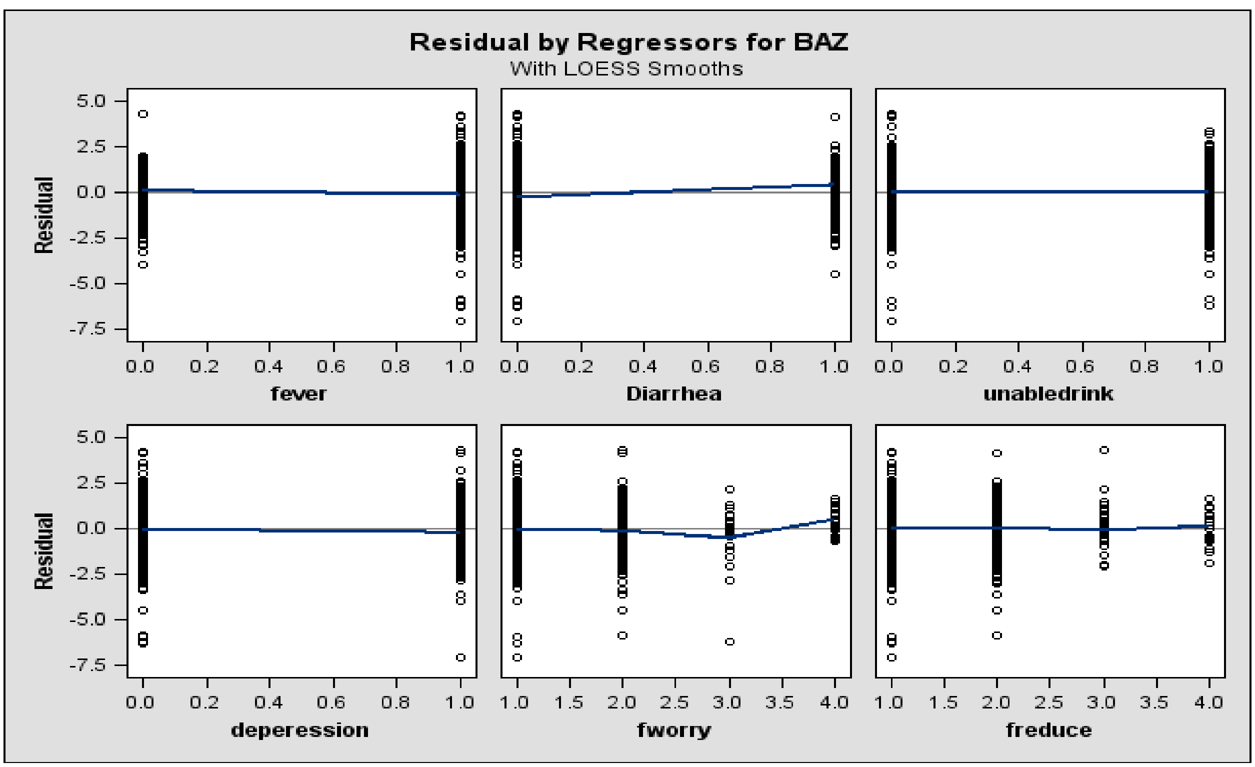

Influence Diagnostics for BAZ
DFFITS
Observation
0.5
0.0
-0.5
-1.0
0
500
1000
1500
2000
1804
705
1151
957
1978
1662
1476
180
86
381
769
237
1088
1402
636

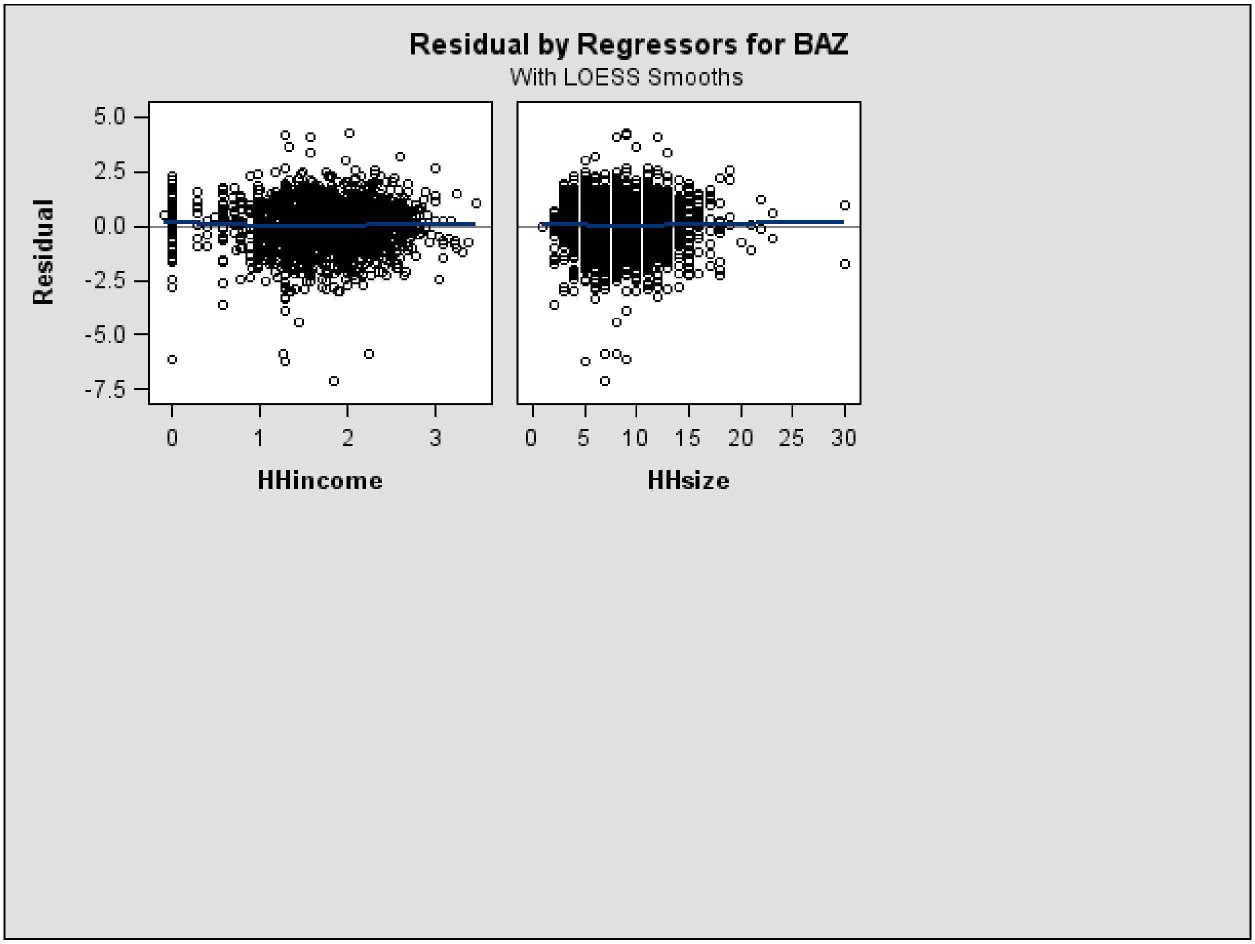

Influence Diagnostics for BAZ
Intercept
Place
sex
age
havechild
highestgrade
DFBETAS
Observation
0.5
0.0
-0.5
0
500
1000
1500
2000
705
957
1662
1587
822
1232
86
1476
1402
769


Influence Diagnostics for BAZ
currentjob
fever
Diarrhea
unabledrink
deperession
fworry
DFBETAS
Observation
0.5
0.0
-0.5
0
500
1000
1500
2000

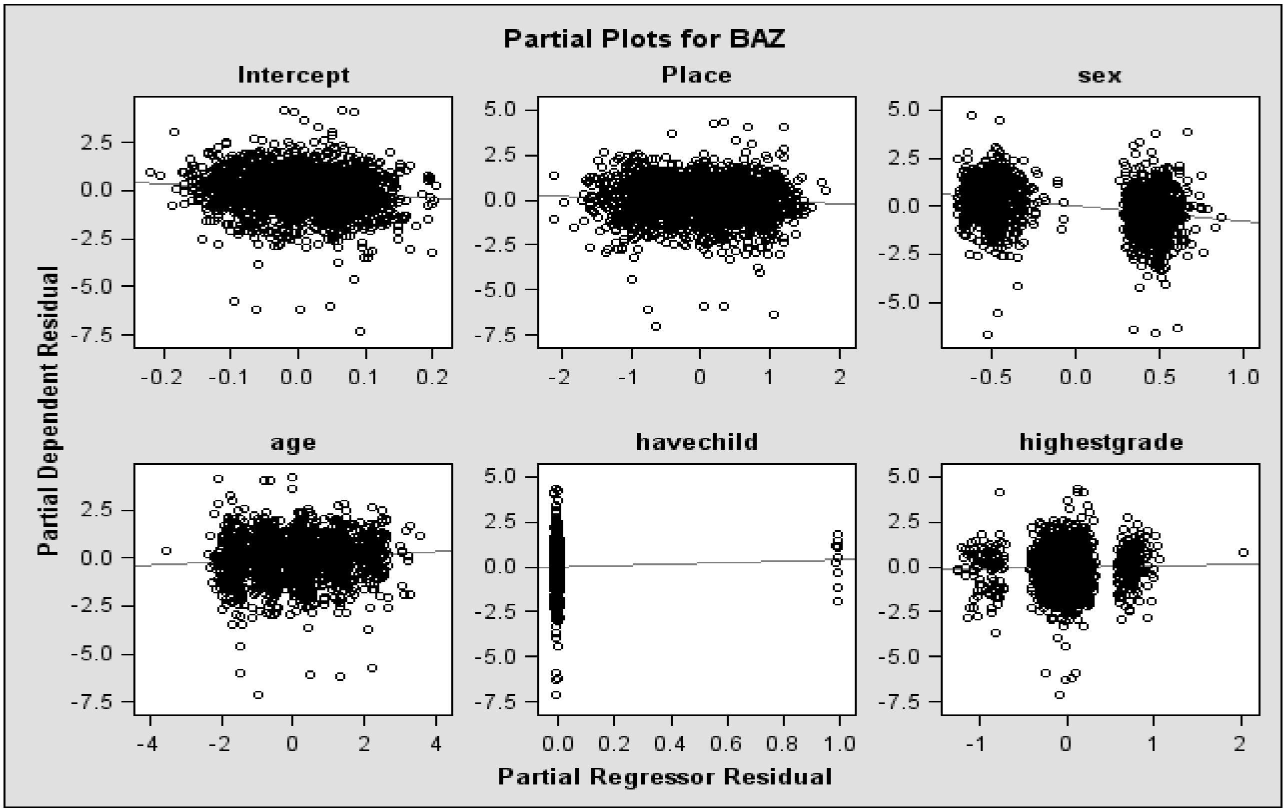

Influence Diagnostics for BAZ
freduce
HHincome
HHsize
DFBETAS
Observation
0.5
0.0
-0.5
0
500
1000
1500
2000

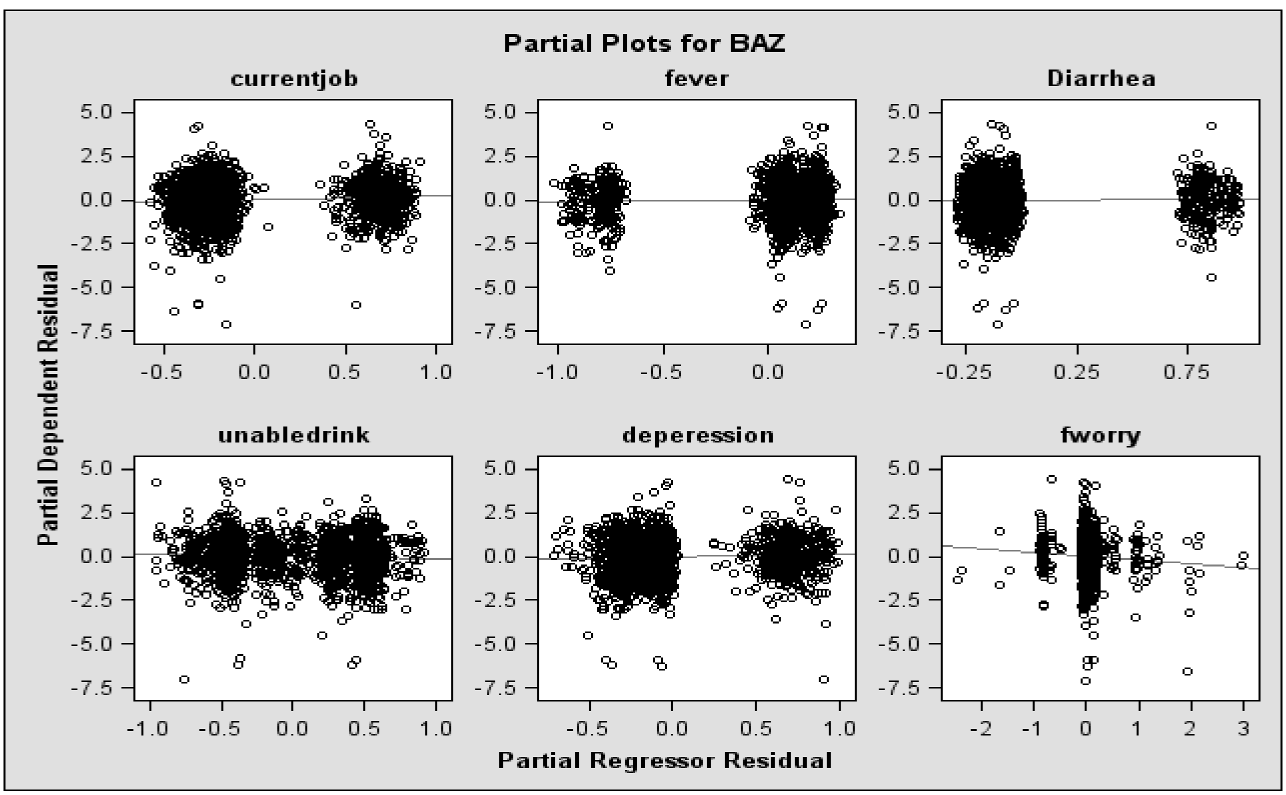

Residual by Regressors for BAZ
With LOESS Smooths
Residual
Place
sex
age
havechild
highestgrade
currentjob

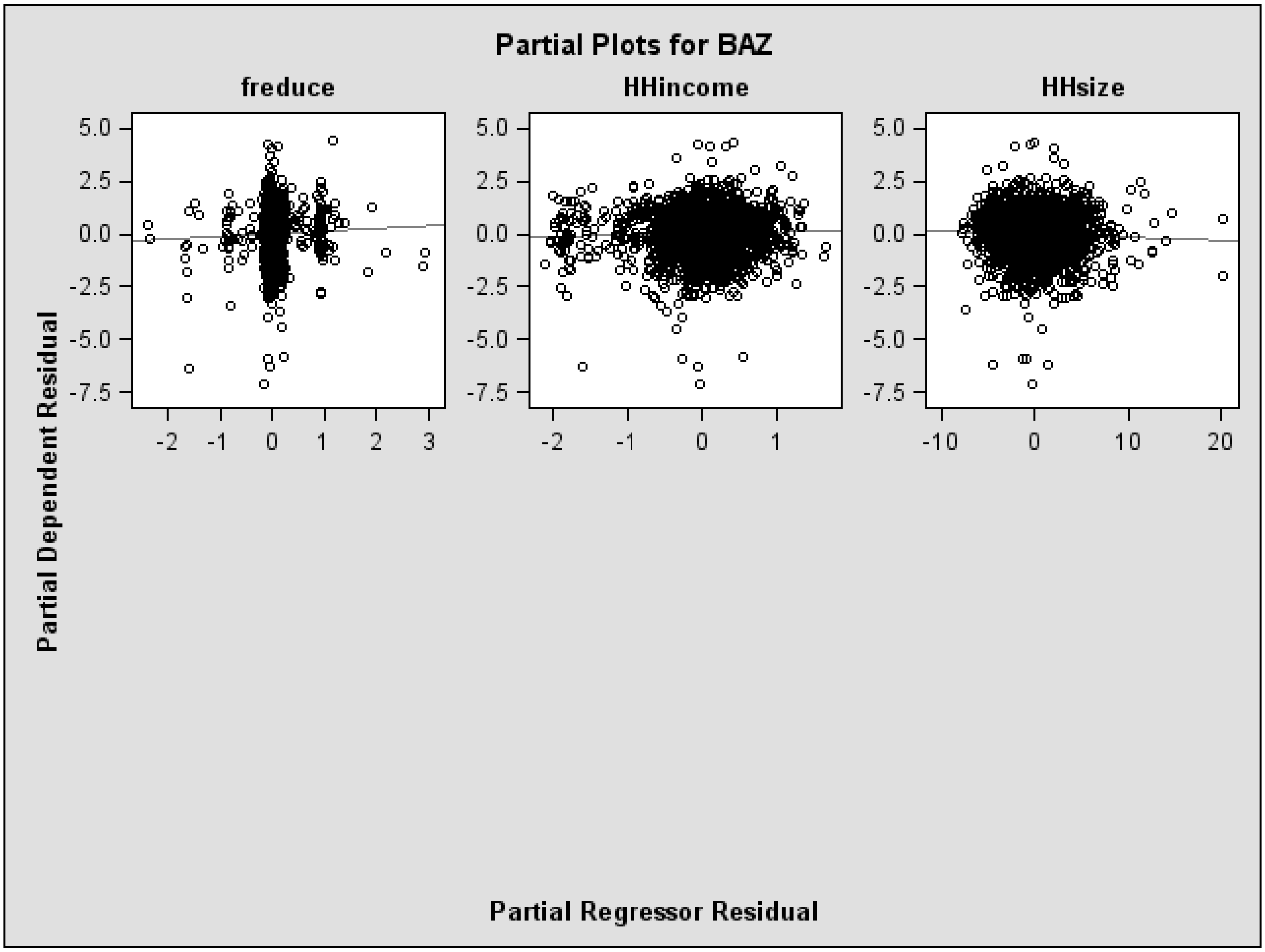

Residual by Regressors for BAZ
With LOESS Smooths
Residual
fever
Diarrhea
unabledrink
deperession
fworry
freduce


Residual by Regressors for BAZ
With LOESS Smooths
Residual
5.0
2.5
0.0
-2.5
-5.0
-7.5
0
1
2
3
HHincome
0
5
10
15
20
25
30
HHsize

Partial Regression Residual Plot

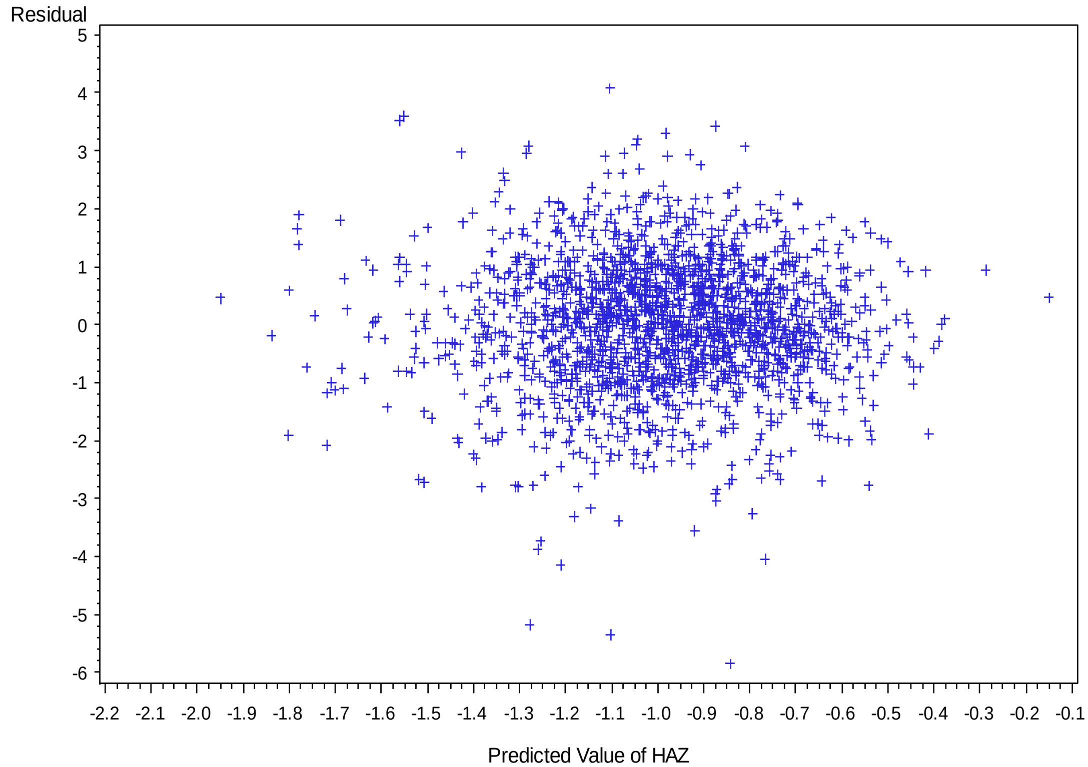


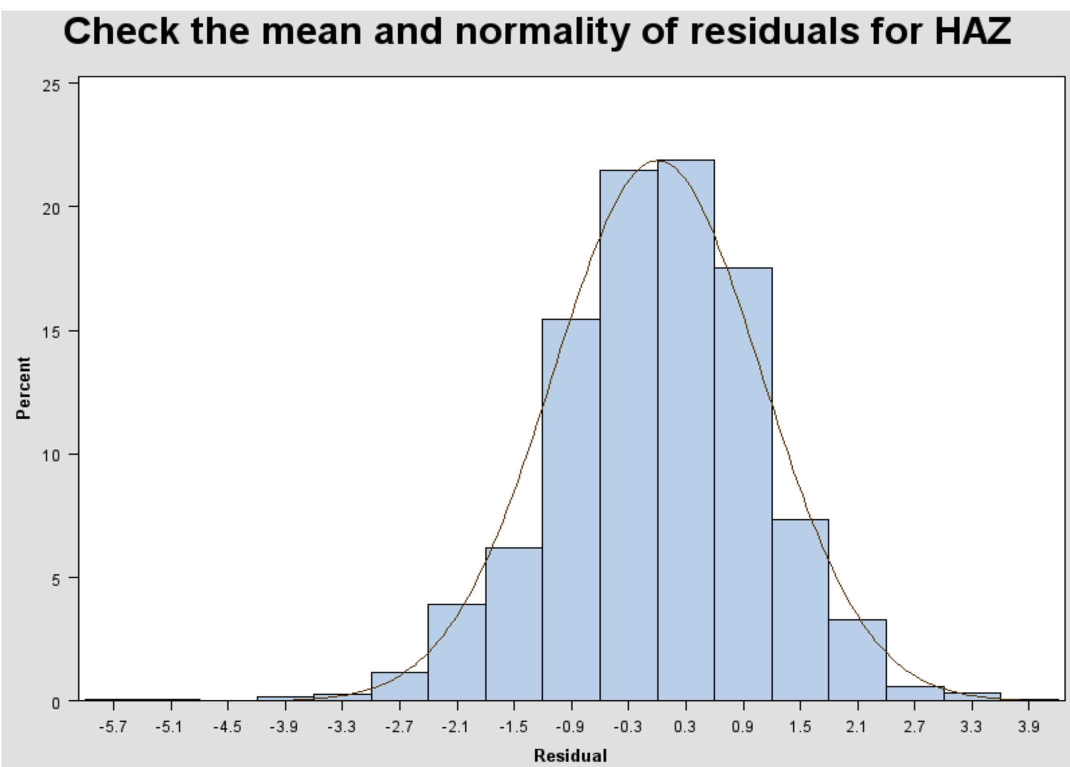


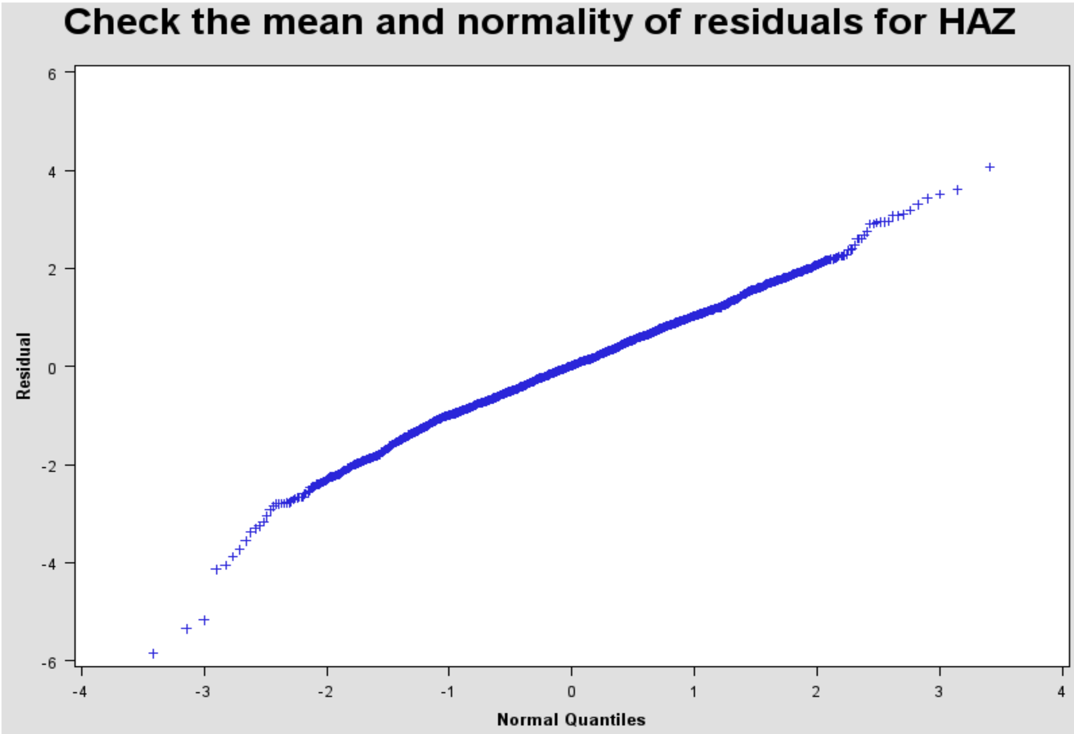

Partial Plots for BAZ
freduce
HHincome
HHsize
5.0
2.5
0.0
-2.5
-5.0
-7.5
-2
-1
0
1
2
3
-10
10
20
Partial Dependent Residual
Partial Regressor Residual

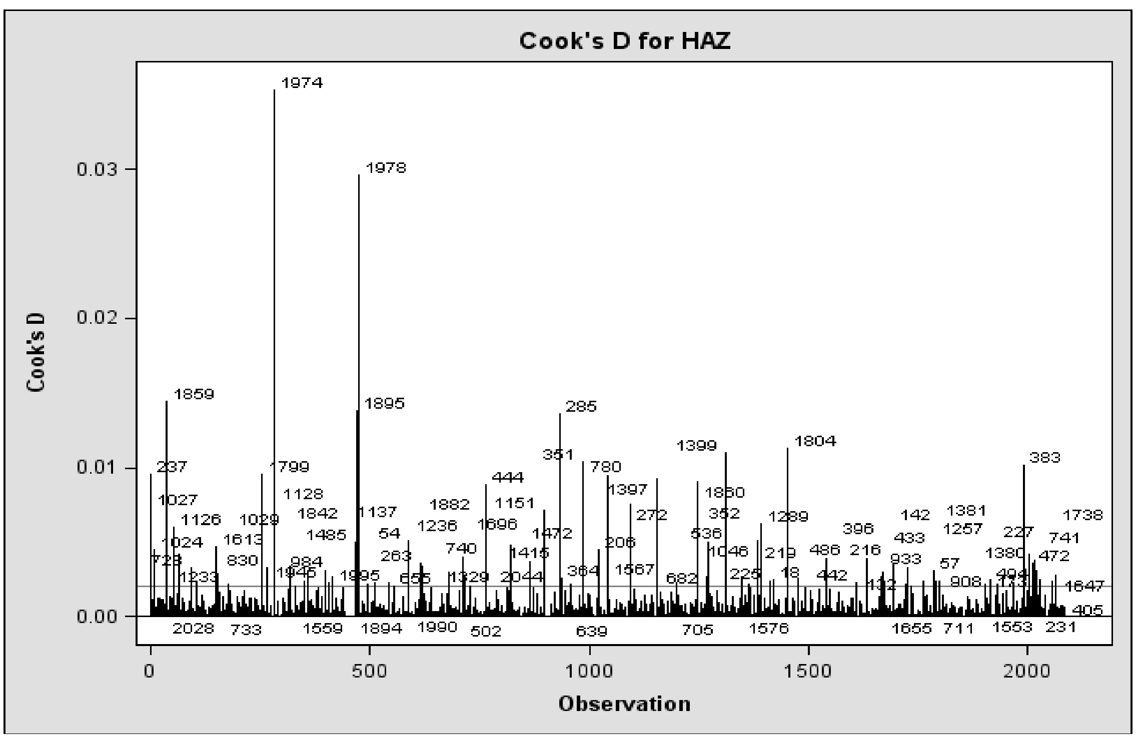
Dependent Variable: Height for Age Z-score

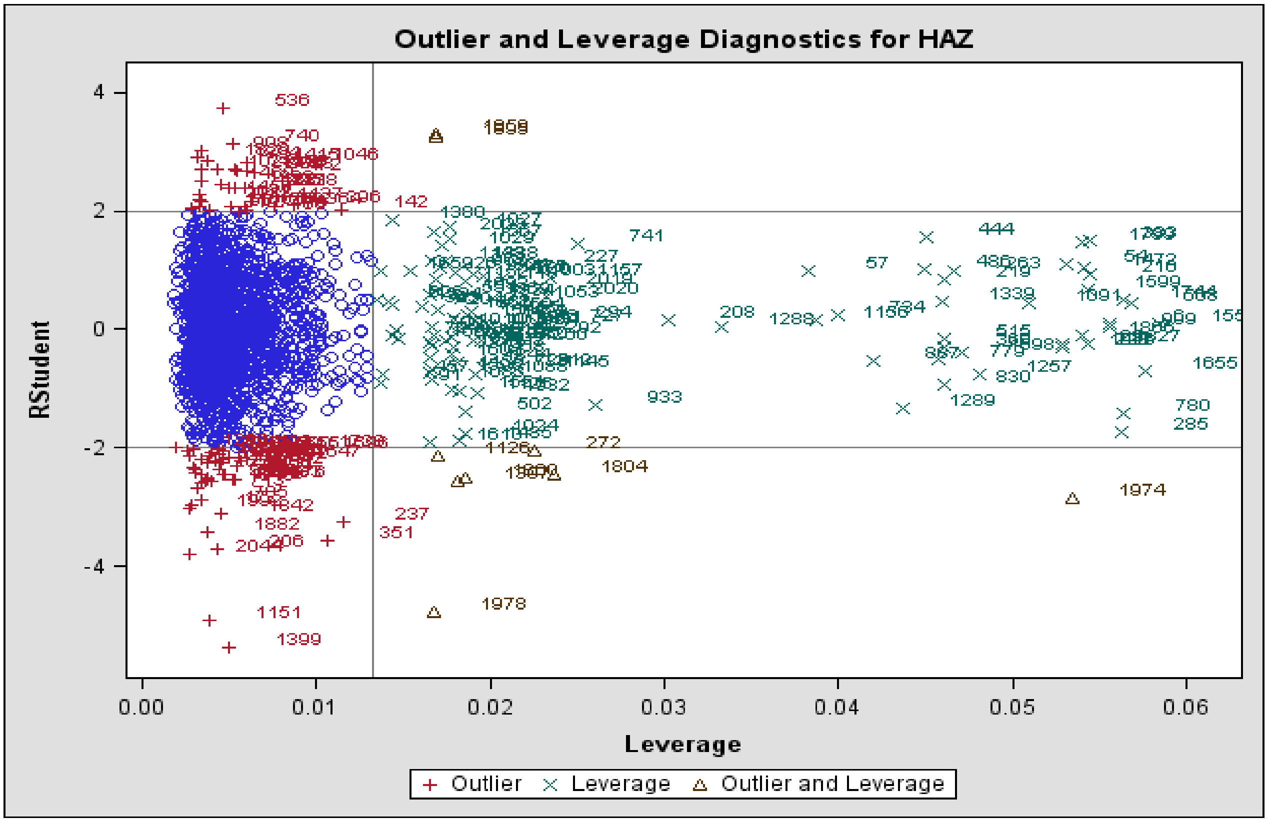
Check homoescedasticity and independence of residuals for HAZ

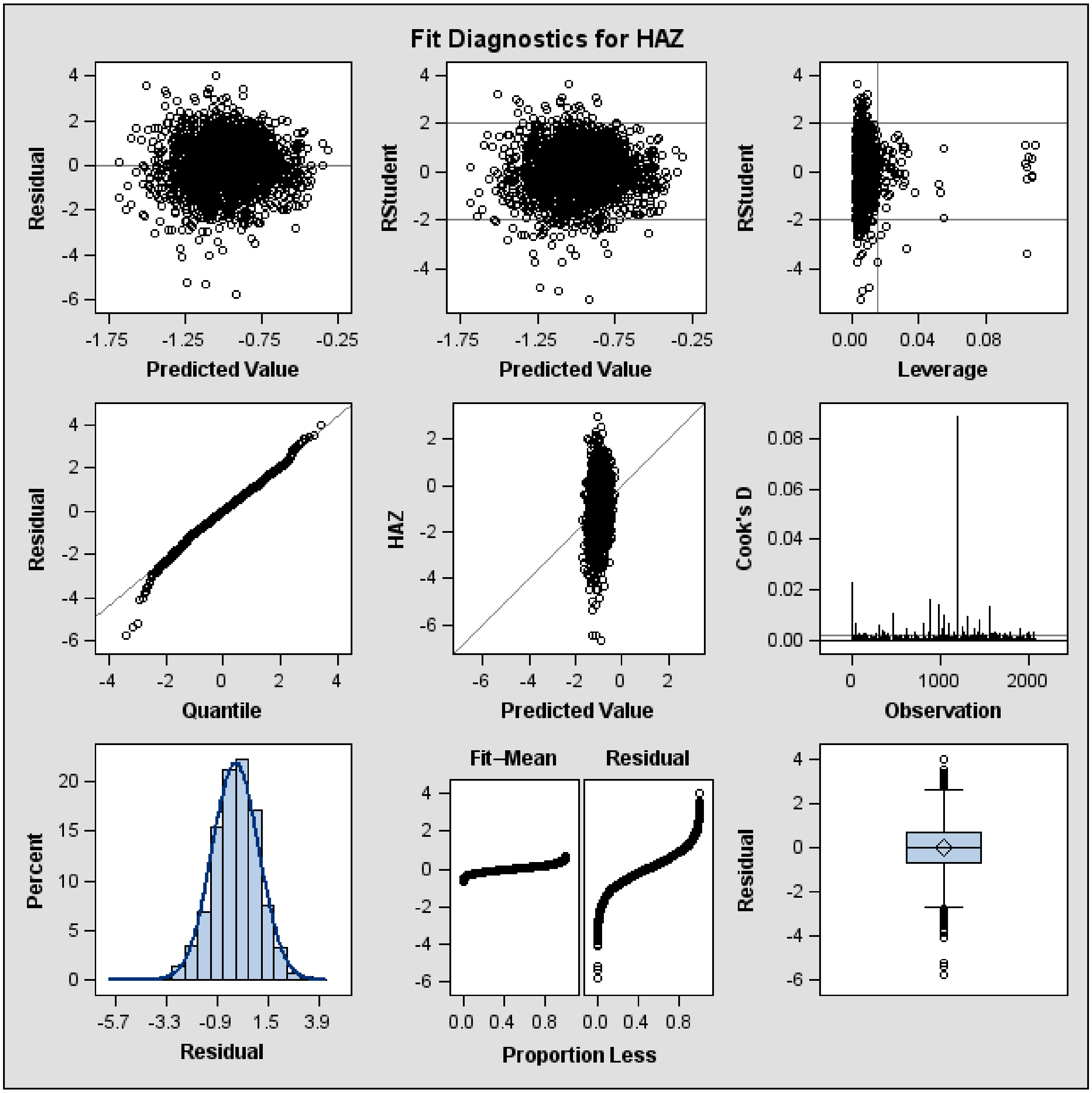


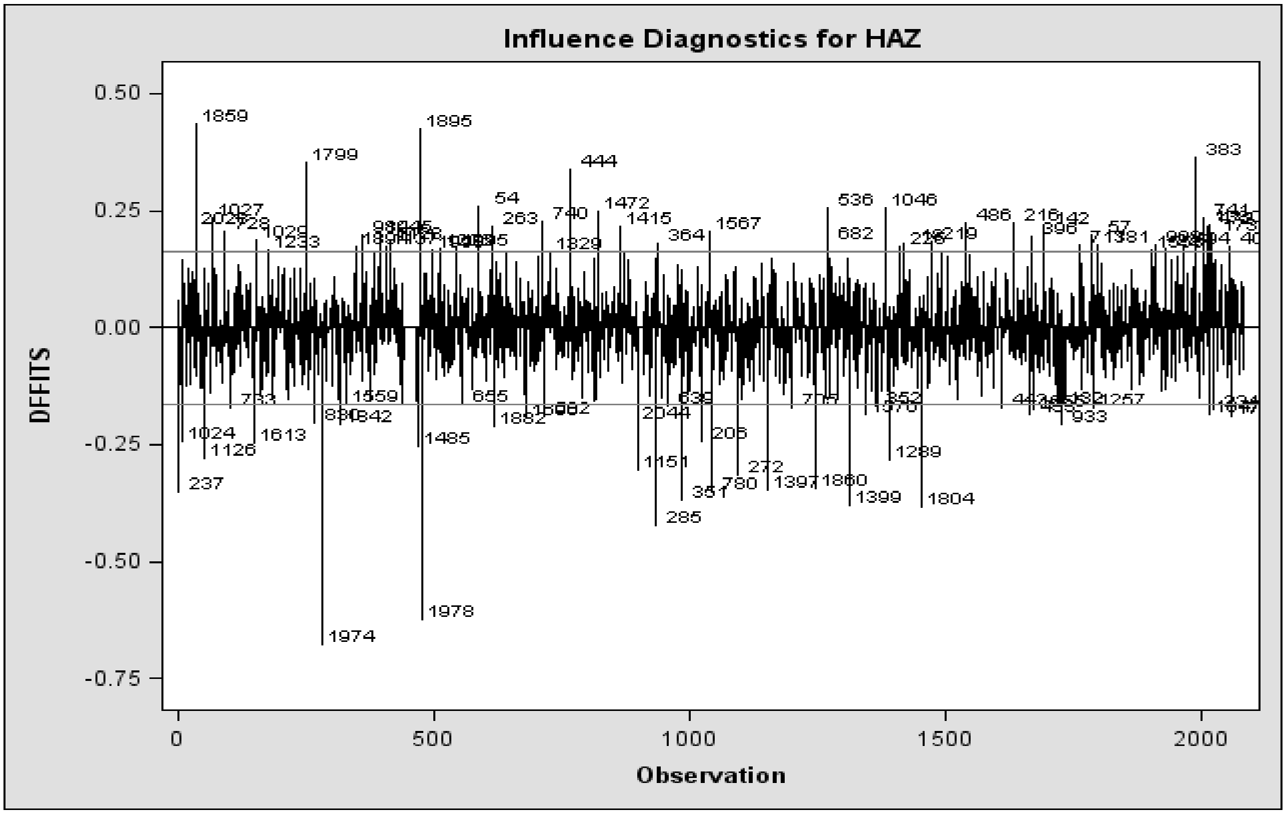


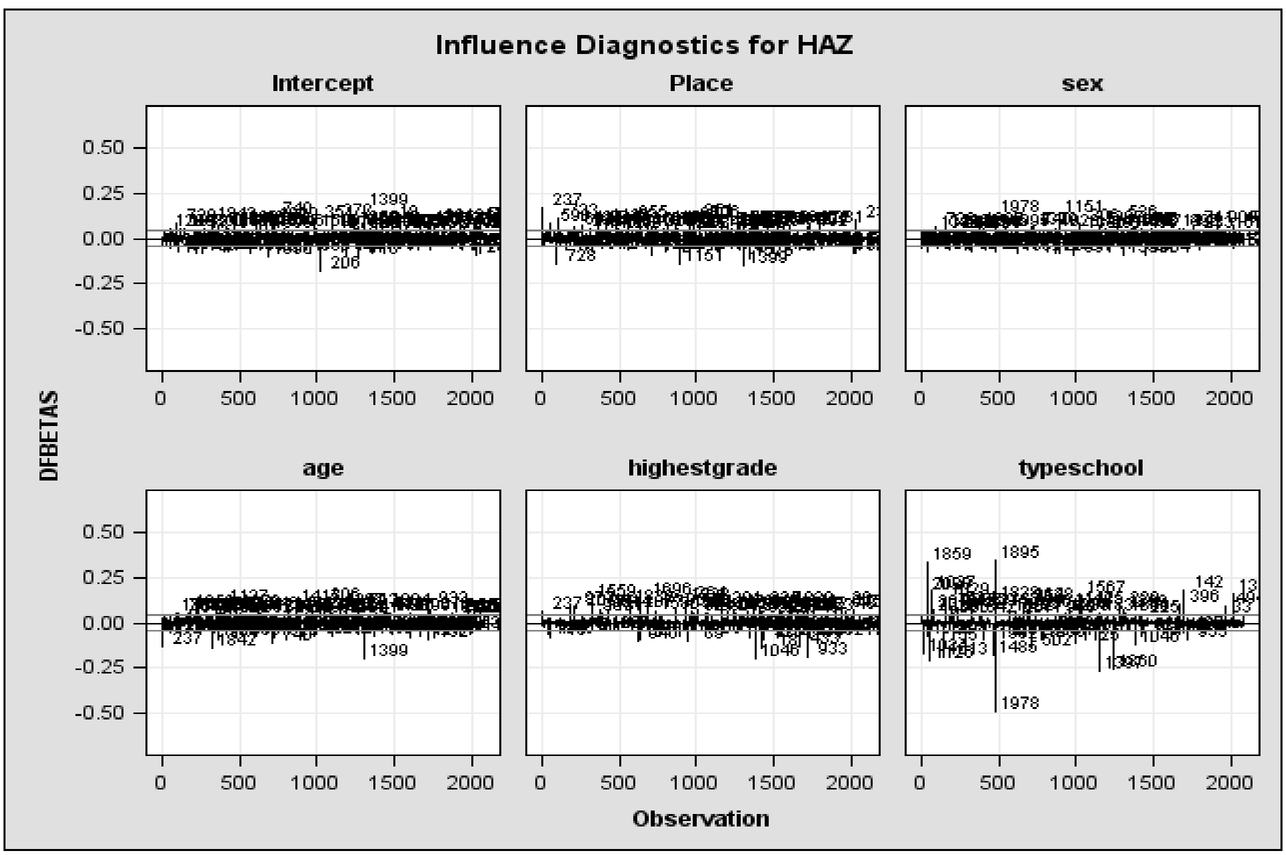

Check the mean and normality of residuals for HAZ
Residual
6
4
2
0
-2
-4
-6
-4
-3
-2
-1
0
1
2
3
4
Normal Quantiles

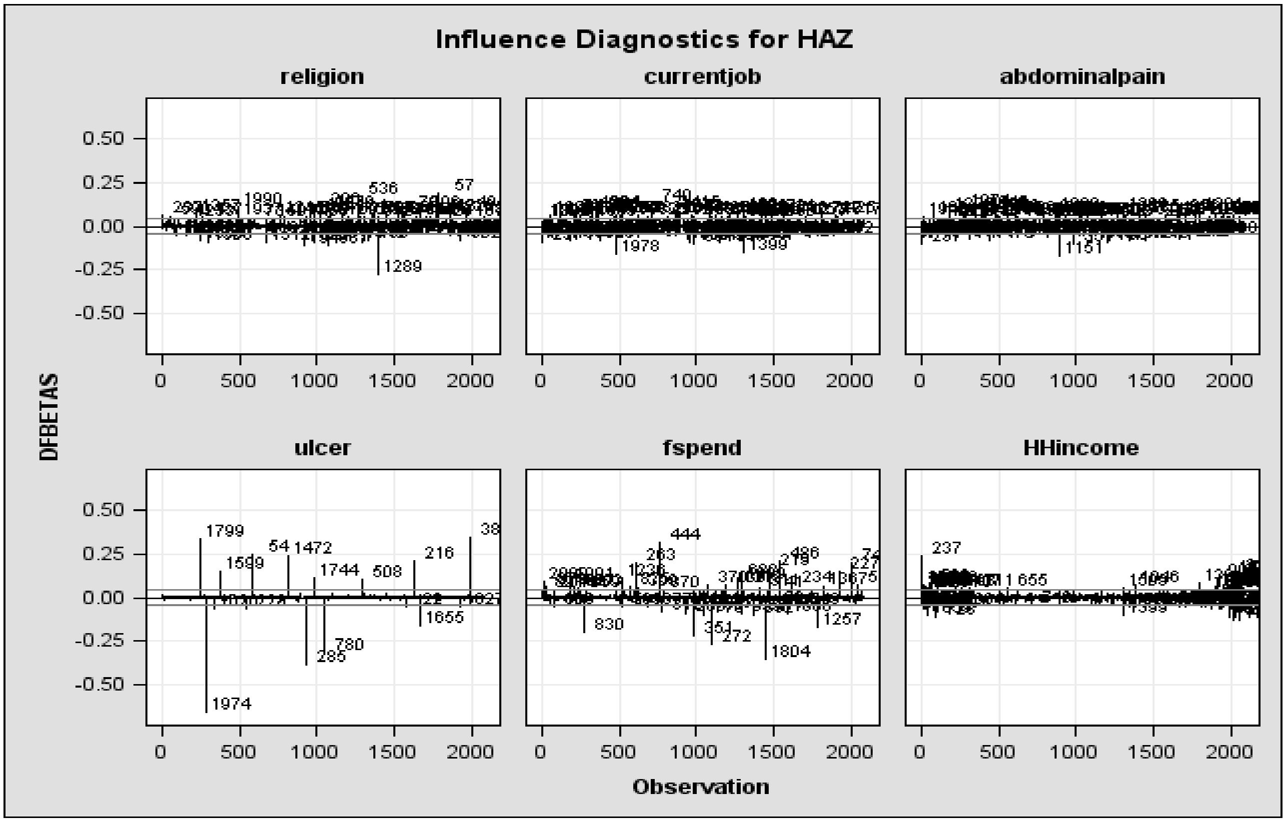

Cook's D for HAZ
Cook's D
0.03
0.02
0.01
0.00
0
500
1000
1500
2000
Observation
1974
1978
1859
1895
285
1399
1804
383

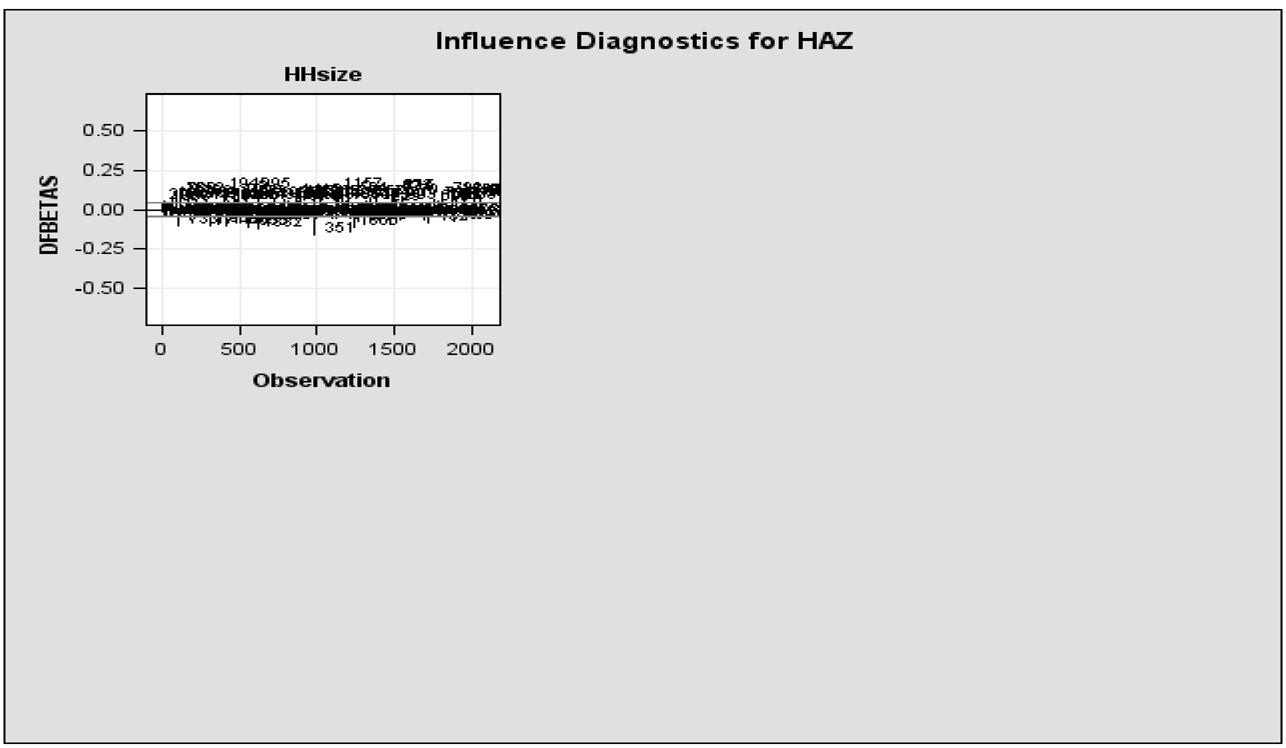

Outlier and Leverage Diagnostics for HAZ
RStudent
Leverage
4
2
0
-2
-4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Outlier
Leverage
Outlier and Leverage

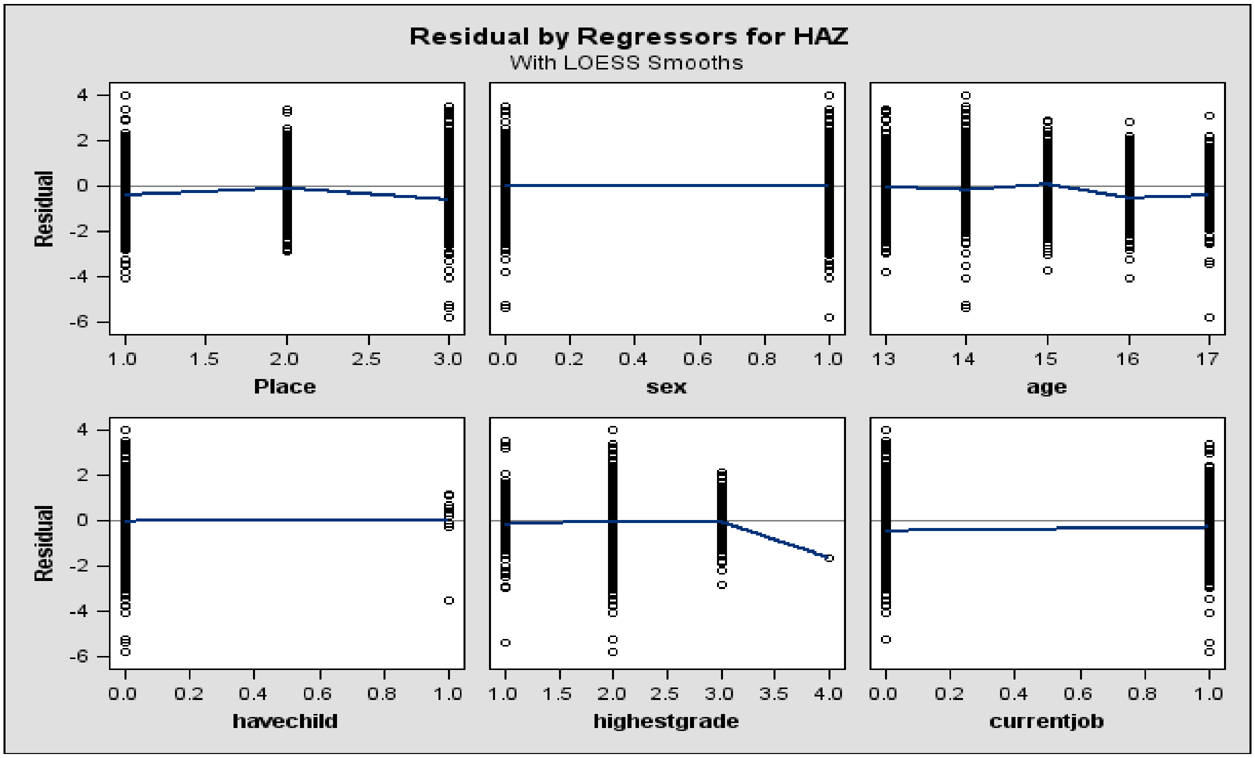

Fit Diagnostics for HAZ
Residual
Predicted Value
RStudent
Predicted Value
RStudent
Leverage
Residual
Quantile
HAZ
Predicted Value
Cook's D
Observation
Percent
Residual
Fit–Mean
Residual
Proportion Less
Residual

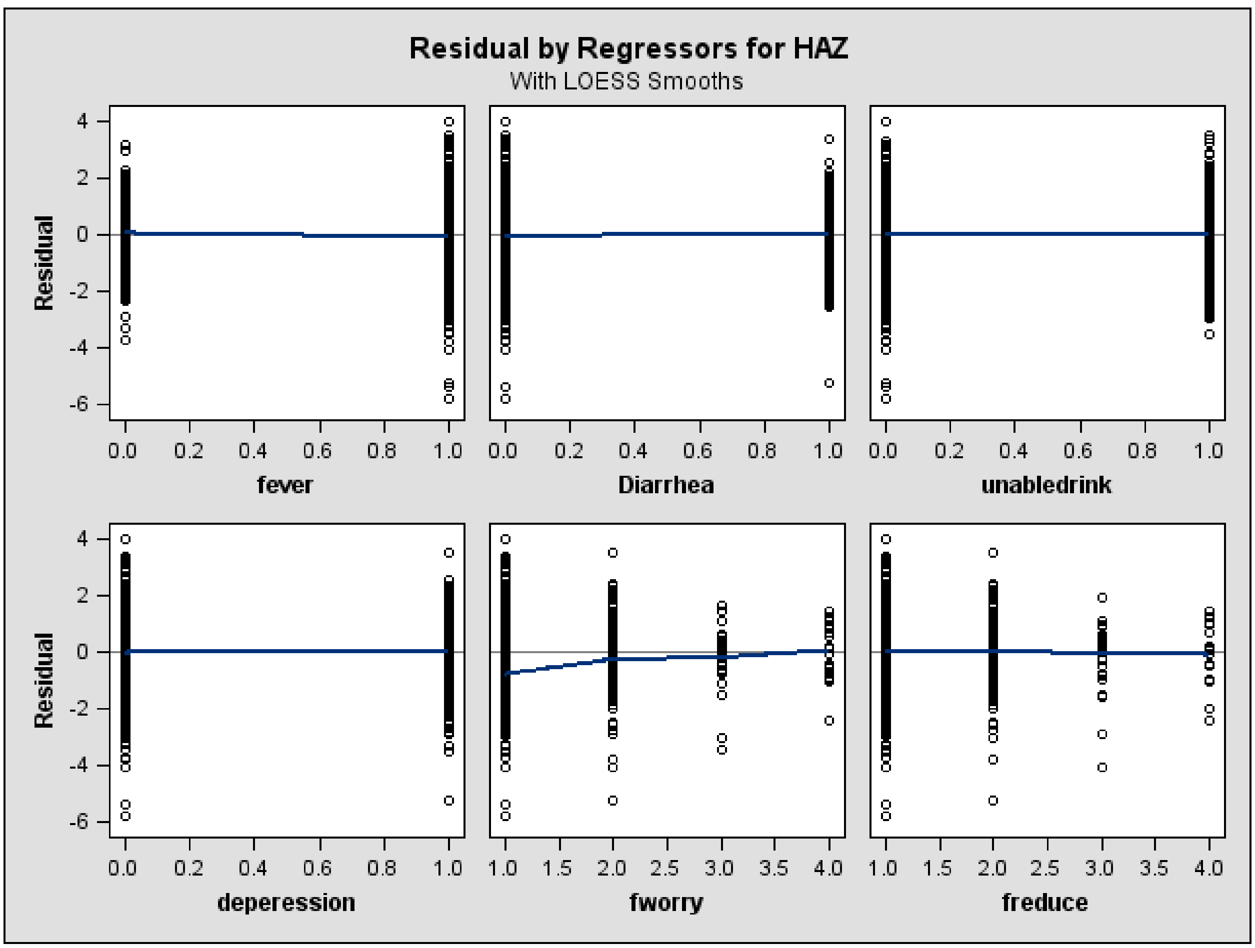

Influence Diagnostics for HAZ
DFFITS
0.50
0.25
0.00
-0.25
-0.50
-0.75
0
500
1000
1500
2000
Observation

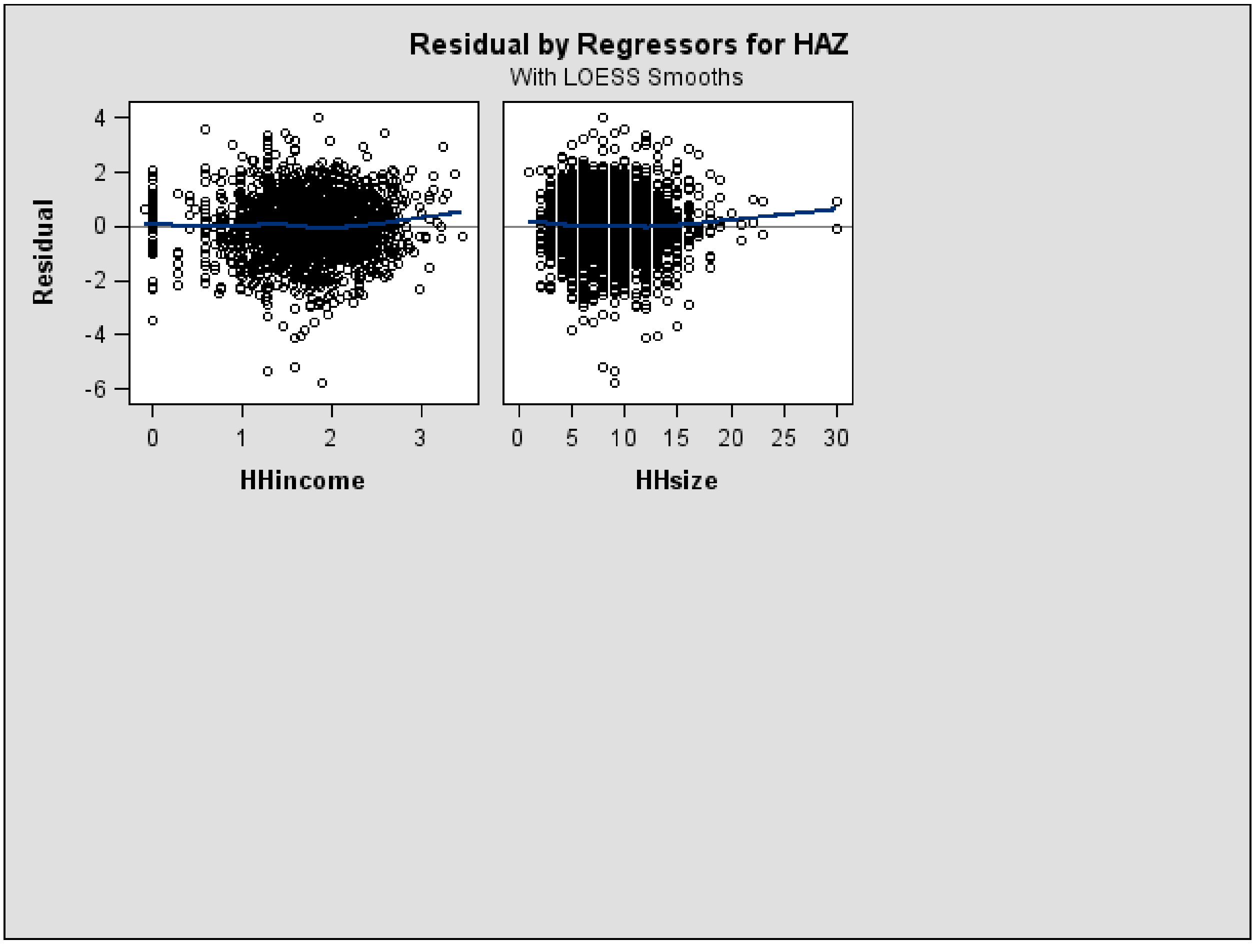

Influence Diagnostics for HAZ
Intercept
Place
sex
age
highestgrade
typeschool
DFBETAS
0.50
0.25
0.00
-0.25
-0.50
0
500
1000
1500
2000
Observation


Influence Diagnostics for HAZ
religion
currentjob
abdominalpain
ulcer
fspend
HHincome
DFBETAS
Observation

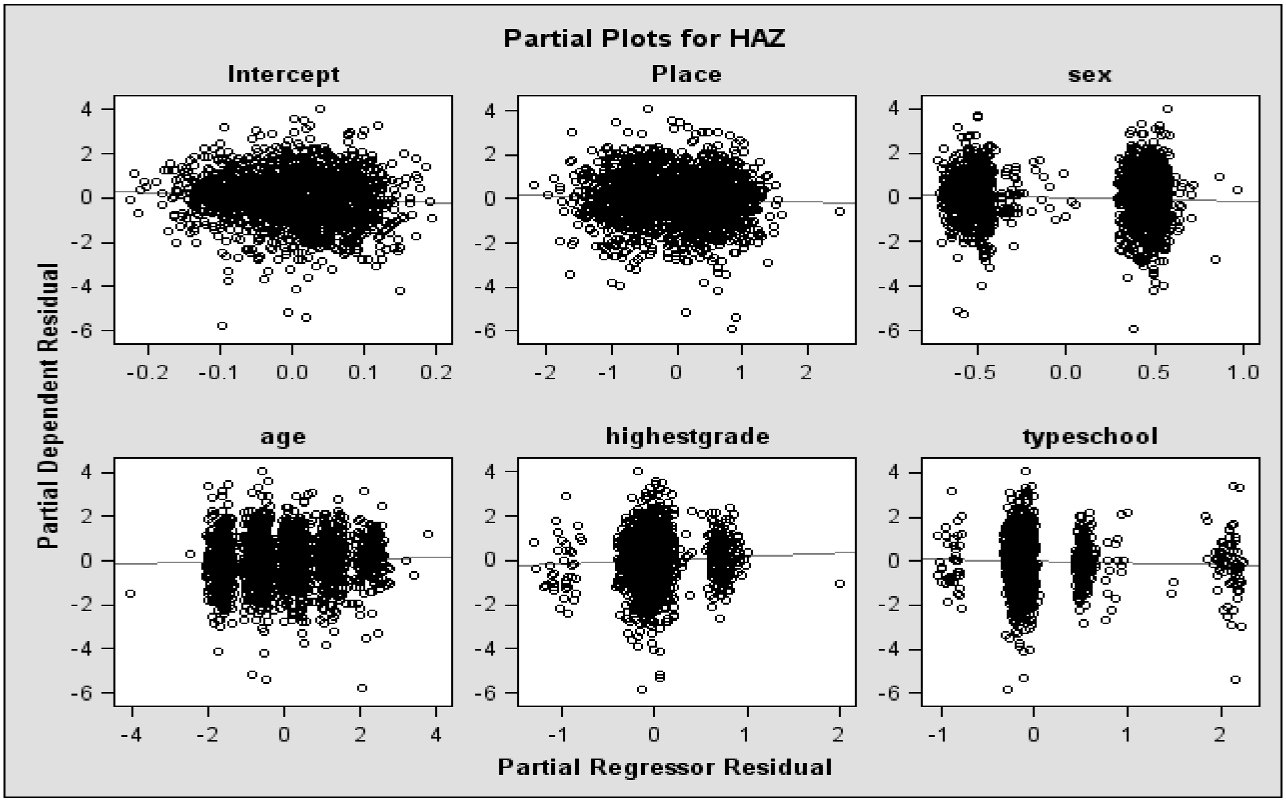

Influence Diagnostics for HAZ
HHsize
DFBETAS
Observation

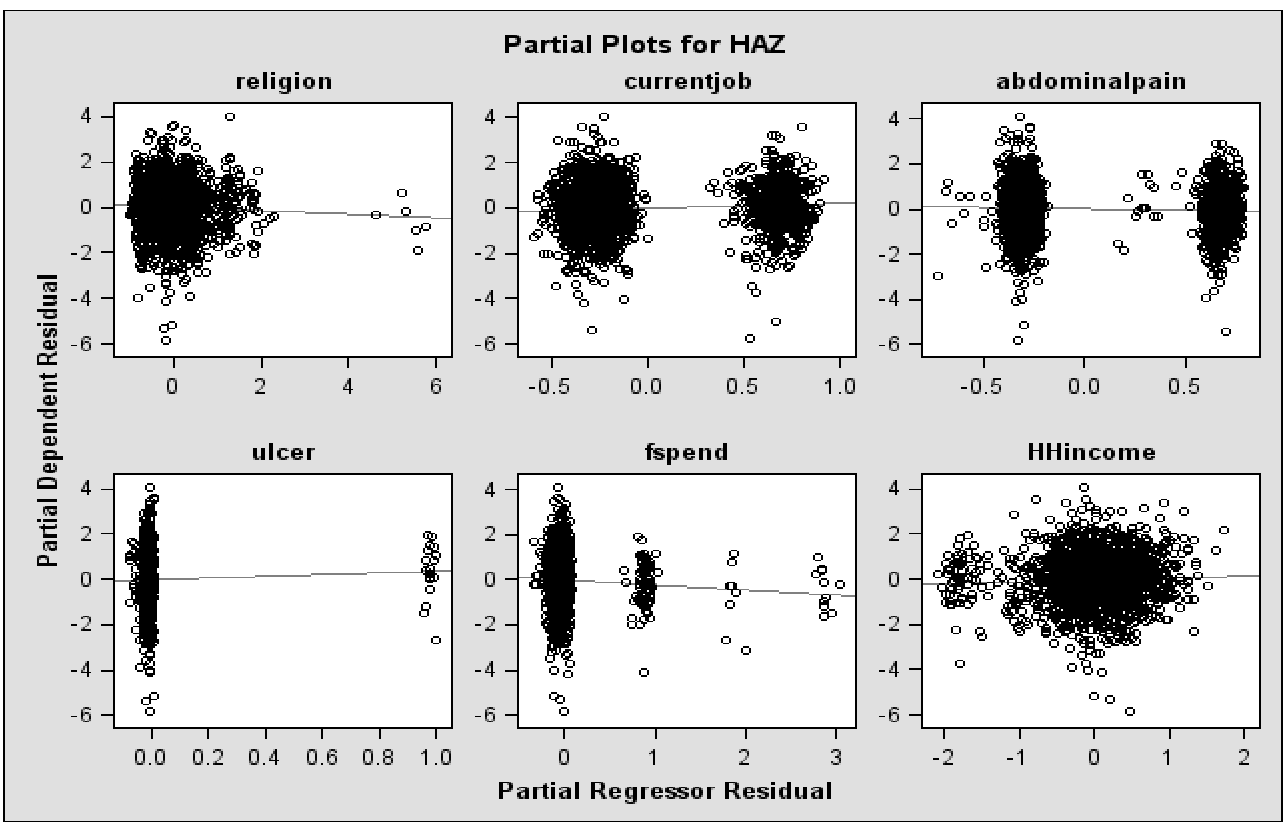

Residual by Regressors for HAZ
With LOESS Smooths
Residual
Place
sex
age
havechild
highestgrade
currentjob

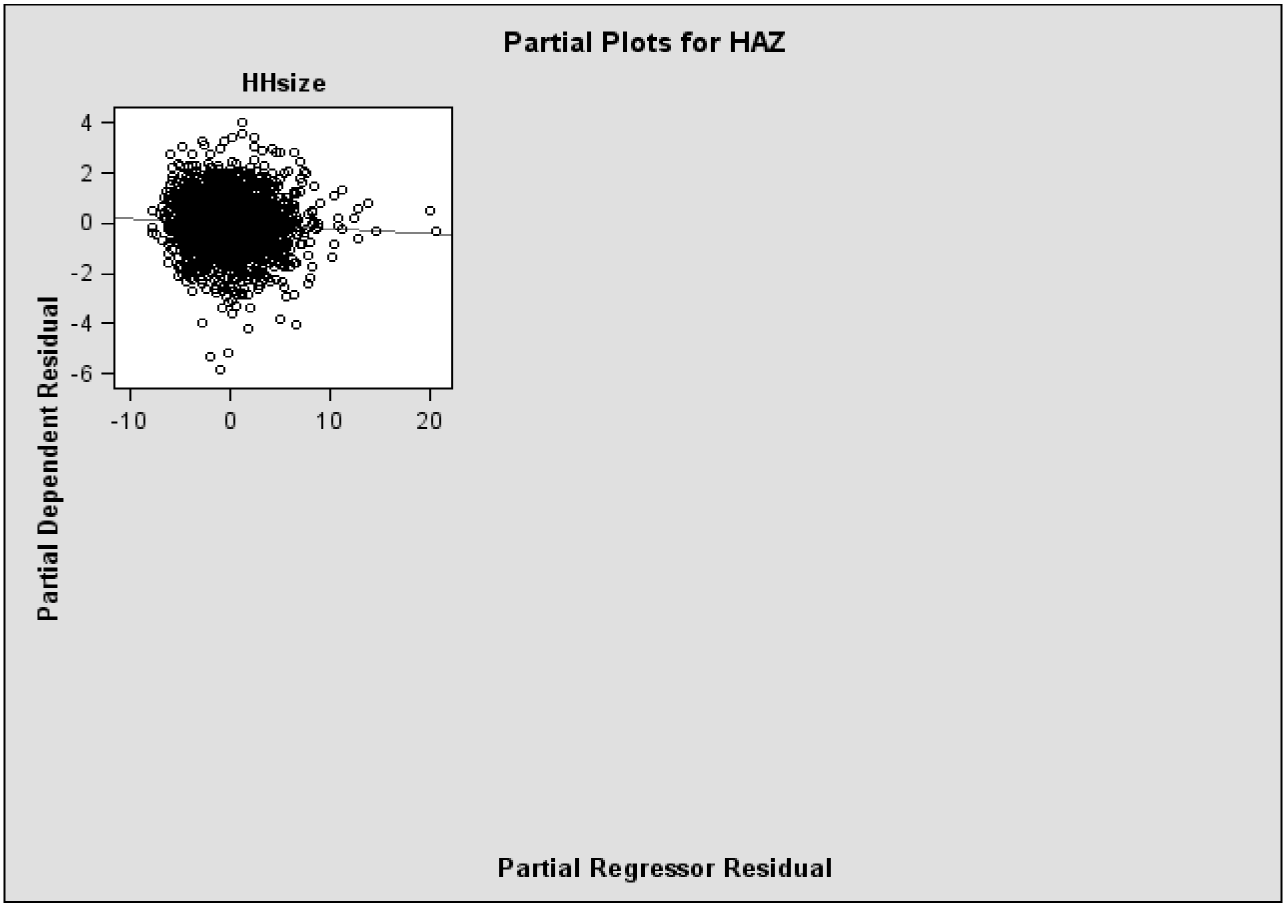

Residual by Regressors for HAZ
With LOESS Smooths
Residual
fever
Diarrhea
unabledrink
deperession
fworry
freduce


Residual by Regressors for HAZ
With LOESS Smooths
Residual
4
2
0
-2
-4
-6
0
1
2
3
HHincome
0
5
10
15
20
25
30
HHsize

Partial Regression Residual Plot






Partial Plots for HAZ
HHsize
4
2
0
-2
-4
-6
-10
0
10
20
Partial Dependent Residual
Partial Regressor Residual

Appendix B: Results of correlation coefficients

Pearson Correlation Coefficients for BAZ, N = 2084
Prob > |r| under H0: Rho=0

Covariates	Place	Sex	age	have child	highest-grade	current job	fever	Diarrhea	unable drink	depression	fworry	Freduce	HHincome	HHsize
Place	1.000	0.059	-0.123	0.015	-0.313	0.109	-0.042	0.043	-0.074	-0.117	-0.054	-0.071	-0.330	0.302
		0.007	<.0001	0.498	<.0001	<.0001	0.058	0.050	0.001	<.0001	0.014	0.001	<.0001	<.0001
sex	0.059	1.000	-0.008	-0.014	-0.010	0.102	-0.037	-0.001	-0.010	0.017	-0.086	-0.117	-0.036	0.009
	0.007		0.698	0.525	0.638	<.0001	0.088	0.976	0.659	0.434	<.0001	<.0001	0.101	0.676
age	-0.123	-0.008	1.000	-0.016	0.295	0.084	-0.041	-0.036	-0.071	0.039	-0.016	0.006	0.068	-0.070
	<.0001	0.698		0.460	<.0001	0.000	0.062	0.100	0.001	0.076	0.461	0.776	0.002	0.001
have child	0.015	-0.014	-0.016	1.000	0.009	-0.034	0.013	-0.011	0.000	-0.009	-0.006	-0.007	-0.011	0.006
	0.498	0.525	0.460		0.698	0.118	0.559	0.621	0.987	0.683	0.795	0.736	0.609	0.792
highest-grade	-0.313	-0.010	0.295	0.009	1.000	-0.095	-0.011	-0.007	0.045	0.027	-0.053	-0.042	0.161	-0.095
	<.0001	0.638	<.0001	0.698		<.0001	0.605	0.750	0.039	0.210	0.015	0.058	<.0001	<.0001
current job	0.109	0.102	0.084	-0.034	-0.095	1.000	-0.009	0.029	-0.024	0.006	0.051	0.038	-0.069	-0.006
	<.0001	<.0001	0.000	0.118	<.0001		0.671	0.179	0.268	0.773	0.020	0.080	0.002	0.796
fever	-0.042	-0.037	-0.041	0.013	-0.011	-0.009	1.000	0.016	0.219	0.049	0.002	0.008	-0.065	-0.034
	0.058	0.088	0.062	0.559	0.605	0.671		0.467	<.0001	0.025	0.937	0.729	0.003	0.124
Diarrhea	0.043	-0.001	-0.036	-0.011	-0.007	0.029	0.016	1.000	0.180	0.114	0.014	0.006	-0.036	0.015
	0.050	0.976	0.100	0.621	0.750	0.179	0.467		<.0001	<.0001	0.538	0.800	0.099	0.500
Unable drink	-0.074	-0.010	-0.071	0.000	0.045	-0.024	0.219	0.180	1.000	0.252	0.087	0.070	-0.011	-0.010
	0.001	0.659	0.001	0.987	0.039	0.268	<.0001	<.0001		<.0001	<.0001	0.002	0.628	0.641
Depression	-0.117	0.017	0.039	-0.009	0.027	0.006	0.049	0.114	0.252	1.000	0.167	0.185	0.003	-0.035
	<.0001	0.434	0.076	0.683	0.210	0.773	0.025	<.0001	<.0001		<.0001	<.0001	0.898	0.109
fworry	-0.054	-0.086	-0.016	-0.006	-0.053	0.051	0.002	0.014	0.087	0.167	1.000	0.806	-0.046	-0.003
	0.014	<.0001	0.461	0.795	0.015	0.020	0.937	0.538	<.0001	<.0001		<.0001	0.036	0.876
freduce	-0.071	-0.117	0.006	-0.007	-0.042	0.038	0.008	0.006	0.070	0.185	0.806	1.000	-0.050	-0.023
	0.001	<.0001	0.776	0.736	0.058	0.080	0.729	0.800	0.002	<.0001	<.0001		0.022	0.300
HHincome	-0.330	-0.036	0.068	-0.011	0.161	-0.069	-0.065	-0.036	-0.011	0.003	-0.046	-0.050	1.000	0.027
	<.0001	0.101	0.002	0.609	<.0001	0.002	0.003	0.099	0.628	0.898	0.036	0.022		0.218
HHsize	0.302	0.009	-0.070	0.006	-0.095	-0.006	-0.034	0.015	-0.010	-0.035	-0.003	-0.023	0.027	1.000
	<.0001	0.676	0.001	0.792	<.0001	0.796	0.124	0.500	0.641	0.109	0.876	0.300	0.218	

Pearson Correlation Coefficients for HAZ, N = 2084
Prob > |r| under H0: Rho=0

Covariates	Place	Sex	age	highestgrade	typeschool	religion	currentjob	abdominalpain	ulcer	fspend	HHincome	HHsize
Place	1.000	0.059	-0.123	-0.313	0.172	-0.380	0.109	0.018	-0.023	-0.105	-0.330	0.302
		0.007	<.0001	<.0001	<.0001	<.0001	<.0001	0.404	0.297	<.0001	<.0001	<.0001
Sex	0.059	1.000	-0.008	-0.010	-0.003	-0.046	0.102	0.058	0.013	-0.099	-0.036	0.009
	0.007		0.698	0.638	0.905	0.038	<.0001	0.008	0.560	<.0001	0.101	0.676
Age	-0.123	-0.008	1.000	0.295	-0.014	0.045	0.084	-0.055	0.002	0.023	0.068	-0.070
	<.0001	0.698		<.0001	0.521	0.042	0.000	0.012	0.932	0.286	0.002	0.001
highestgrade	-0.313	-0.010	0.295	1.000	-0.509	0.195	-0.095	-0.017	0.014	-0.017	0.161	-0.095
	<.0001	0.638	<.0001		<.0001	<.0001	<.0001	0.439	0.512	0.446	<.0001	<.0001
Typeschool	0.172	-0.003	-0.014	-0.509	1.000	-0.109	0.056	-0.012	-0.021	0.020	-0.097	0.036
	<.0001	0.905	0.521	<.0001		<.0001	0.010	0.595	0.330	0.357	<.0001	0.096
Religion	-0.380	-0.046	0.045	0.195	-0.109	1.000	-0.064	-0.021	0.009	0.060	0.180	-0.181
	<.0001	0.038	0.042	<.0001	<.0001		0.003	0.329	0.684	0.006	<.0001	<.0001
Currentjob	0.109	0.102	0.084	-0.095	0.056	-0.064	1.000	0.045	-0.011	0.052	-0.069	-0.006
	<.0001	<.0001	0.000	<.0001	0.010	0.003		0.040	0.619	0.019	0.002	0.796
Abdominal pain	0.018	0.058	-0.055	-0.017	-0.012	-0.021	0.045	1.000	0.086	0.046	-0.028	-0.005
	0.404	0.008	0.012	0.439	0.595	0.329	0.040		<.0001	0.035	0.194	0.814
Ulcer	-0.023	0.013	0.002	0.014	-0.021	0.009	-0.011	0.086	1.000	0.055	0.023	-0.007
	0.297	0.560	0.932	0.512	0.330	0.684	0.619	<.0001		0.012	0.298	0.734
Fspend	-0.105	-0.099	0.023	-0.017	0.020	0.060	0.052	0.046	0.055	1.000	-0.002	-0.064
	<.0001	<.0001	0.286	0.446	0.357	0.006	0.019	0.035	0.012		0.942	0.004
HHincome	-0.330	-0.036	0.068	0.161	-0.097	0.180	-0.069	-0.028	0.023	-0.002	1.000	0.027
	<.0001	0.101	0.002	<.0001	<.0001	<.0001	0.002	0.194	0.298	0.942		0.218
HHsize	0.302	0.009	-0.070	-0.095	0.036	-0.181	-0.006	-0.005	-0.007	-0.064	0.027	1.000
	<.0001	0.676	0.001	<.0001	0.096	<.0001	0.796	0.814	0.734	0.004	0.218	

Appendix C: Description of Variables included in the Analysis

Table: 3.2.3 Response variable

Variable	definition of variable	representation of variable
Underweight	BMI for age z-score	BAZ
Stunting	Height for age z-score	HAZ

- **Predictor variables**

Table: 3.2.3 Socio- economic Variables

Variables	Categories	Coding
place of residence(place)	Urban	1
	Semi-urban	2
	Rural	3
Marital status of the adolescent (maritalstatus)	Single	1
	Married	2
	Divorced	3
	Widowed	4
Do you have a child? (havechild)	No	0
	Yes	1
Highest grade completed(highestgrade)	no education	1
	Primary	2
	Secondary	3
type of school completed (typeschool)	Government	1
	Private	2
	Community	3
	Other	4
religion(religion)	Muslim	1
	Orthodox	2
	Protestant	3
	Catholic	4
	Traditional Religion	5
	None	6
	Other	7
currently in a job (currentjob)	No	0
	Yes	1
household income(Hhincome)		
household size(Hhsize)		
Mothers education(materdu)	no education	1
	Primary	2
	Secondary	3

fathers education(fatherdu)	no education	1
	Primary	2
	Secondary	3

Table: 3.2.3 Demographic Variables

Variables	Categories	Coding
sex of the adolescent (sex)	Female	0
	Male	1
age of the adolescent (age)		

Table: 3.2.3 Health and Risk factors

Variables	Categories	Coding
fever(fever)	No	o
	Yes	1
cough(cough)	No	o
	Yes	1
difficult breathing(breathing)	No	o
	Yes	1
diarrhea(diarrhea)	No	o
	Yes	1
vomiting(vomiting)	No	o
	Yes	1
unable to drink or eat (unabledrink)	No	o
	Yes	1
abdominal pain (abdominalpain)	No	o
	Yes	1
Genital discharge or ulcer (ulcer)	No	o
	Yes	1
depression/extrem sadness/worry(depression)	No	o
	Yes	1
sleep under insectcide treated mosquito bed net(ITN)	No	o
	Yes	1
currently smoke tobacco(smoking)	No	o
	Yes	1
how many cigaretes smoke(howsmoking)		
does household smoker(hhsmoker)	No	o
	Yes	1
in the last 3 months, how many days do you worry about run of food(fworry)	Never	1
	1-7 days	2

	8-21 days	3
	more than 21 days	4
in the last 3 months, how many days have you reduce the number of meals eaten in a day(freduce)	Never	1
	1-7 days	2
	8-21 days	3
	more than 21 days	4
in the last 3 months, how many days, have you had to spend the whole day without eating(fspend)	Never	1
	1-7 days	2
	8-21 days	3
	more than 21 days	4
in the last 3 months, how many days, how many days have you had to ask for food or money to buy food(fask)	Never	1
	1-7 days	2
	8-21 days	3
	more than 21 days	4
Food insecurity(insec)	Secure	0
	non-secure	1

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