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Estimating Toddlers Growth Median in Kertosari Village of Banyuwangi City Using Local Linear Nonparametric Regression

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Abstract: One of the health indicators as a measure of success in achieving SDGs is the nutritional status of children under five. Nutritional status of children under five can be measured by age (A), weight body (W), height (H). These three variables are presented in the form of three indicators anthropometry, namely: Weight by Age (W/A), Height by Age (H/A) and Body Weight according to Height (W/H) or Body Mass Index by Age (BMI/A). Based on those anthropometric indexes, underweight is a nutritional status of toddlers characterized by a lack of ***weight,*** *height, and BMI. Talking about underweight, there are 2,878 toddlers out of 42,597 total toddlers in Banyuwangi or 6.8% of Banyuwangi toddlers are underweight. In this paper we discuss estimating median of toddlers growth in four sub-districts covered by Public Health Care Centre (PHCC) Kertosari of Banyuwangi city, a city in East Java Province, Indonesia based on weight, height, and BMI using local linear nonparametric regression for designing median standard growth charts of toddlers which would be compared with WHO standard growth charts. The W/A, H/A, and BMI/A growth charts of toddlers in Banyuwangi show that the growth of boys is greater than that of girls. In addition, W/A and H/A growths of toddlers in Banyuwangi are less than those of toddlers based on WHO-2005 standard growth chart but there is a different behavior for BMI/A toddlers in Banyuwangi when compared to the WHO-2005 standard growth chart.*

Keywords — Median of toddlers growth, weight, height, BMI, local linear estimator.

1. INTRODUCTION

In Indonesia, each sub-district has one Public Health Care Centre (PHCC) called "PUSKESMAS". In the Banyuwangi City District, Banyuwangi Regency, East Java Province, there is one PHCC located in Kertosari Village and it is called PUSKESMAS-Kertosari. The PUSKESMAS-Kertosari covers four working areas, namely Kertosari Village, Karangrejo Village, Panderejo Village and Kepatihan Village. One of the health indicators as a measure of success in achieving SDGs is the nutritional status of children under five. Nutritional status of children under five can be measured by age (A), weight body (W), height (H). These three variables are presented in the form of three indicators anthropometry, namely: Weight by Age (W/A), Height by Age (H/A) and Body Weight according to Height (W/H) or Body Mass Index by Age (BMI/A). Based on those anthropometric indexes, underweight is a nutritional status of toddlers characterized by a lack of weight, height, and BMI. Talking about underweight, there are 2,878 toddlers out of 42,597 total toddlers in Banyuwangi or 6.8% of Banyuwangi toddlers are underweight [1].

In Indonesia, the nutritional status of toddlers are recorded in a towards health card called “Kartu Menuju Sehat” or KMS. An instrument containing normal growth curves for toddlers based on the anthropometric index W/A is presented by the KMS. In Indonesia, at present the use of KMS is based on WHO-2005 anthropometric standards which is based on the Z-Score curves for medians of W/A, H/A, and BMI/A. In designing WHO-2005 standard growth chart (WHO-2005 SGC), samples of toddlers aged 0-60 months were taken from Brazil, Ghana, India, Norway, Oman, and the United States. These samples are considered to represent regions of the world that are recommended as an assessment of global nutritional status [2-3]. However, there are different characteristics that make a difference in chart patterns from the WHO-2005 SGC including Indonesia especially Kertosari Village. Therefore, an effort that can be done to overcome the discrepancy is to design a KMS chart locally using data on toddlers whose physical condition is in accordance with toddlers in Indonesia especially in Kertosari Village. Growth charts for toddlers every age show different patterns at each stage [4]. The pattern of toddlers growth curve does not form a linear curve or a particular shape so the appropriate approach to analyze data of toddlers growth is nonparametric regression modeling. There are several estimators to estimate regression function of the nonparametric regression model. They are splines and kernel estimators [5–22], local polynomial estimators [23–24], and local linear estimators [25–29], and one of which is the local linear estimator with the advantage of being able to overcome data patterns that show a sharp rise or fall with the help of knots, and the resulting curve is relatively smooth.

Various studies on designing charts of toddler growth standards locally carried out by [30] in Padang City, but the underweight samples in this study were not differentiated by sex. Researches by [18, 22, 25, 28] have differentiated the sex of toddlers and found that the results of the toddler growth chart design curve in East Java were lower than the WHO-2005 standard using local linear estimators. The growth standard graph was designed using percentile values for example median values. In addition to the median value, a standard toddler growth chart can be designed based on the Z-Score. The advantage of using the Z-Score based on median values is that the calculation results are more accurate and can be compared for each age group and the anthropometric index because the assessment is based on standard deviation values. Hence, calculations by using the Z-Score for median of W/A,

H/A, and BMI/A can indicate the problem of malnutrition which is more optimal compared to conventional systems [22].

In designing a standard growth chart according to weight-for-age (W/A), height-for-age (H/A) and BMI-for-age (BMI/A) for toddlers with a nonparametric regression approach, there are four variables used, namely toddler weight, toddler height, toddler BMI , and toddler age for each sex. Also, we can design standard growth chart for toddlers use semiparametric regression approach. The use of the semiparametric regression approach was also carried out by [18, 21, 22] to design a standard growth chart for children under five in East Java as a determinant of wasting nutrition status based on the least square spline estimator. The growth of toddlers who are different each age will be appropriate if approached with nonparametric regression, while the toddler sex variable is a parametric component as a dummy variable.

Based on the description above, we are interested in conducting research to estimate median growth of toddlers in four sub-districts covered by PHCC Kertosari of Banyuwangi city based on W/A, H/A, and BMI/A using local linear estimator of nonparametric regression model.

2. Materials and Methods

In this section, we provide brief overview of all material and methods we used, i.e., nonparametric regression model, local linear estimator, selection of optimal bandwidth, cross validation, coefficient of determination, and data of toddlers.

2.1. Nonparametric Regression Model

Nonparametric regression model is a model used in determining the relationship pattern between the response variable (*y*) and the predictor variable (*t*) where the function of the regression curve or the pattern of the two variables is unknown. Generally, the nonparametric regression model follows equation [5, 7, 26]:

$$y_i = m(t_i) + \varepsilon_i \;;\; i = 1,2,\dots,n \qquad (1)$$

where ε_i is random error assumed as independent with zero mean and variance σ^2, and $m(t_i)$ is regression function.

2.2. Local Linear Estimator

The regression function in equation (1) could be estimated by using local linear estimator through the following equation [26]:

$$\widehat{m}(t) = \mathbf{x}(t_0)\widehat{\boldsymbol{\beta}}(t_0) \qquad (2)$$

where the estimated parameter $\widehat{\boldsymbol{\beta}}(t_0)$ is obtained by taking the solution of weighted least square (WLS) optimization as follows:

$$Q(t_0) = [\mathbf{y} - \mathbf{x}(t_0)\boldsymbol{\beta}(t_0)]^T \mathbf{K}_h(t_0)[\mathbf{y} - \mathbf{x}(t_0)\boldsymbol{\beta}(t_0)] \qquad (3)$$

Hence, we obtain:

$$\widehat{\boldsymbol{\beta}}(t_0) = [\mathbf{x}^T(\mathbf{t}_0)\mathbf{K}_h(\mathbf{t}_0)\mathbf{x}(\mathbf{t}_0)]^{-1}\mathbf{x}^T(\mathbf{t}_0)\mathbf{K}_h(\mathbf{t}_0)\mathbf{y} \qquad (4)$$

Based on equations (2) and (4), the estimated regression function of model (1) based on local linear estimator is as follows:

$$\widehat{m}(t) = \mathbf{x}(t_0)[\mathbf{x}^T(\mathbf{t}_0)\mathbf{K}_h(\mathbf{t}_0)\mathbf{x}(\mathbf{t}_0)]^{-1}\mathbf{x}^T(\mathbf{t}_0)\mathbf{K}_h(\mathbf{t}_0)\mathbf{y} \qquad (5)$$

2.3. Cross Validation for Selecting Optimal Bandwidth

Bandwidth controls of the balance between the smoothness and goodness of fit of function estimate to the data [5, 7]. One method to get an optimal bandwidth (h_{opt}) is cross-validation method [5, 7, 26]. That is:

$$h_{opt} = Min\ \frac{1}{n}\sum_{i=1}^{n}\left[y_i - \widehat{m}_{n,i}^{(h)}(t_i)\right]^2 \qquad (6)$$

2.4. Coefficient of Determination

The coefficient of determination (R^2) describes a accuracy measurement of regression function [26]. The purpose of calculating the R^2 value is to find out the variation of the response variable (*y*) that can be explained by the predictor variable (*x*) together. The coefficient of determination can be calculated by the following formula:

$$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \qquad (7)$$

where $SSE = \sum_{i=1}^{n}(y_i - \hat{f}(t_i))^2$ and $0 \le R^2 \le 1$.

2.5. Data of Toddlers

The data used in this study are secondary data on weight, height, BMI, and gender of children aged 0–60 months in four sub-districts covered by Publict Health Care Centre (PHCC) or PUSKESMAS Kertosari of Banyuwangi city East Java Province, Indonesia. Data collection was conducted in 2020 in four sub-district covered by PHCC Kertosari of Banyuwangi city. The data obtained in the form of cross-sectional data amounted to 42,597 observations consisting of boys and girls toddlers.

3. Results and Discussion

In this section we describe results and discussion of estimating median growth of girls and boys toddlers. In the following table we give the computational results to the data.

Table 1. Values of CV, Bandwidth, MSE and Coefficient of Determination.

Anthropo-metric indexes	CV Minimum	*h*	MSE	R^2
Height	6.373162	8.56	4.751253	97.45
Weight	0.2997432	6.10	0.237426	97.28
BMI	0.4467779	2.97	0.399758	60.30

Next, plots of bandwidth values versus cross validation (CV) values for height, for weight, and for body mass index (BMI) are given in Figure1, Figure 2, and Figure 3, respectively.

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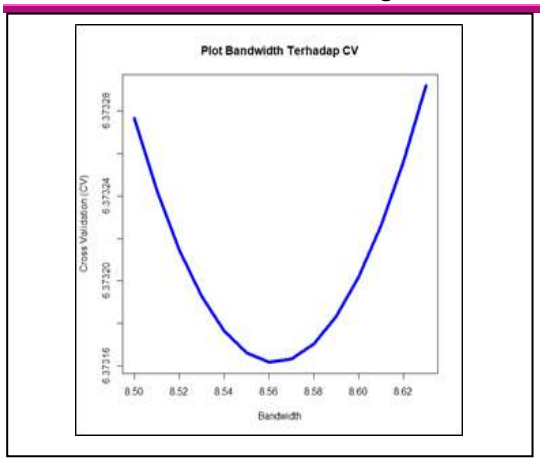


Figure 1. Plot Bandwidth versus CV for Height.

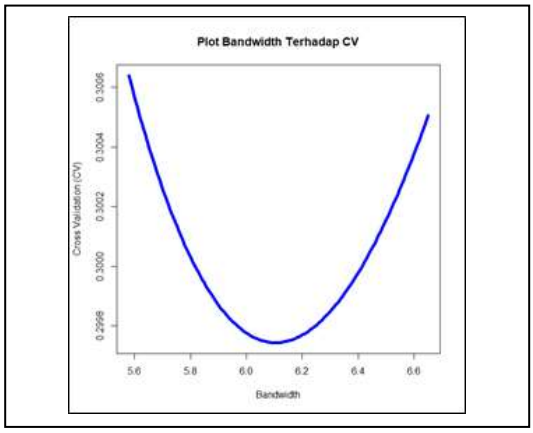


Figure 2. Plot Bandwidth versus CV for Weight.

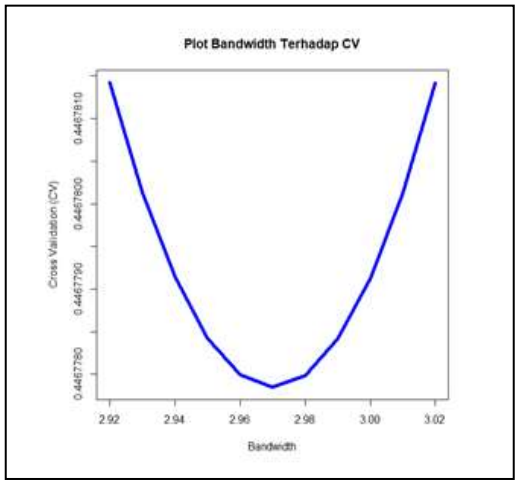


Figure 3. Plot Bandwidth versus CV for BMI.

Based on Figure 1, Figure 2, and Figure 3, we obtain the estimated models for height, weight, and BMI of toddlers given in equations (8), (9), and (10), respectively.

$$\hat{y} = \begin{cases} 56.765 - 1.346x + 1.385(t - t_0) & \text{for} \quad t_0 = 0 \\ 72.323 - 1.346x + 0.985(t - t_0) & \text{for} \quad t_0 = 12 \\ 82.550 - 1.346x + 0.731(t - t_0) & \text{for} \quad t_0 = 24 \\ 90.799 - 1.346x + 0.662(t - t_0) & \text{for} \quad t_0 = 36 \\ 98.509 - 1.346x + 0.626(t - t_0) & \text{for} \quad t_0 = 48 \end{cases}$$

(8)

where $t \in (t_0 - 8.56\,, t_0 + 8.56)$,

$$\hat{y} = \begin{cases} 4.994 - 0.426x + 0.394(t - t_0) & \text{for} \quad t_0 = 0 \\ 8.973 - 0.426x + 0.216(t - t_0) & \text{for} \quad t_0 = 12 \\ 11.002 - 0.426x + 0.150(t - t_0) & \text{for} \quad t_0 = 24 \\ 12.786 - 0.426x + 0.137(t - t_0) & \text{for} \quad t_0 = 36 \\ 14.424 - 0.426x + 0.146(t - t_0) & \text{for} \quad t_0 = 48 \end{cases}$$

(9)

where $t \in (t_0 - 6.10\,, t_0 + 6.10)$, and

$$\hat{\boldsymbol{y}} = \begin{cases} 15.292 - 0.126x + 0.297(t - t_0) & \text{for} \quad t_0 = 0 \\ 16.840 - 0.126x + 0.058(t - t_0) & \text{for} \quad t_0 = 12 \\ 16.207 - 0.126x + 0.043(t - t_0) & \text{for} \quad t_0 = 24 \\ 15.563 - 0.126x + 0.032(t - t_0) & \text{for} \quad t_0 = 36 \\ 14.912 - 0.126x + 0.052(t - t_0) & \text{for} \quad t_0 = 48 \end{cases}$$

(10)

where $t \in (t_0 - 2.97\,, t_0 + 2.97)$.

Finally, based on equations (8), (9), and (10), we get plots of height estimate, weight estimate, and BMI estimate for toddlers (boys and girls) which given in Figure 4, Figure 5, and Figure 6, respectively.

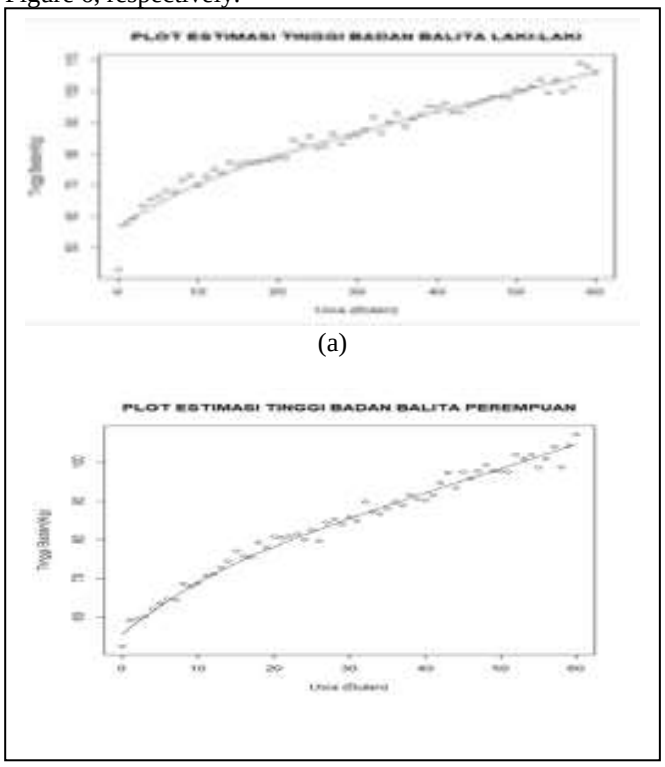
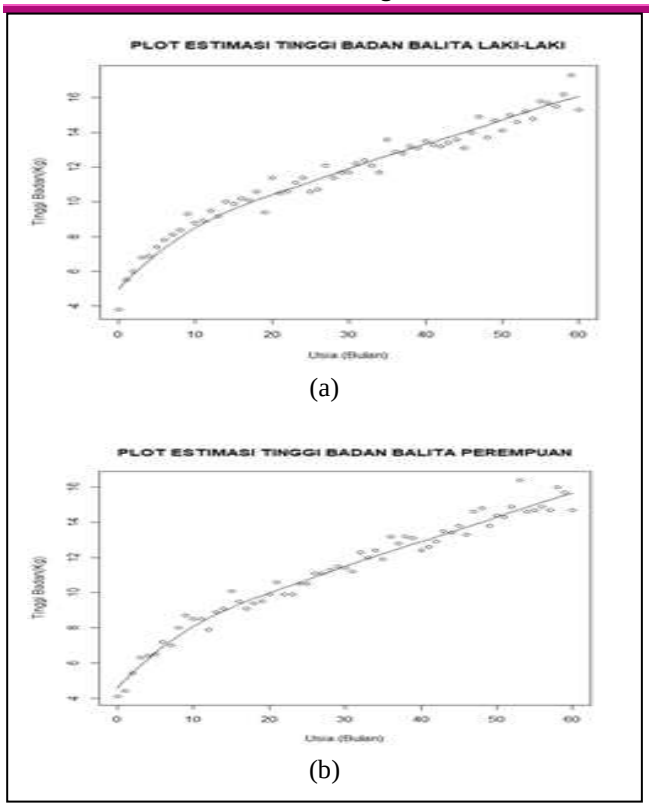


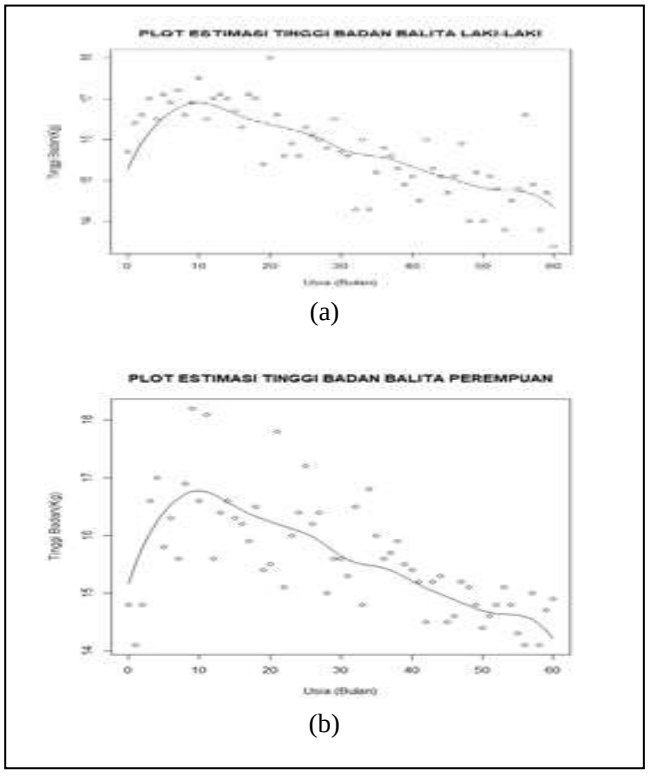
Figure 4. Plots of Height Estimates for Boys (a) and for Girls (b) Toddlers.



(a)

(b)

Figure 5. Plots of Weight Estimates for Boys (a) and for Girls (b) Toddlers.



(a)

(b)

Figure 6. Plots of BMI Estimates for Boys (a) and for Girls(b) Toddlers.

Next, we also get the plots depict the comparison between the heights estimates of boys and girls, the weight estimates of boys and girls, and the BMI estimates of boys and girls. The plots are presented in Figure 7, Figure 8, and Figure 9, respectively.

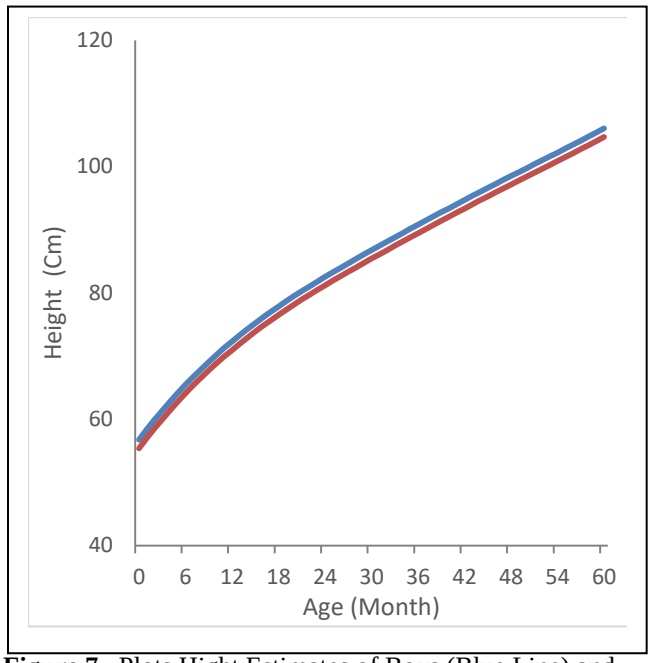


Figure 7. Plots Hight Estimates of Boys (Blue Line) and Girls (Red Line).

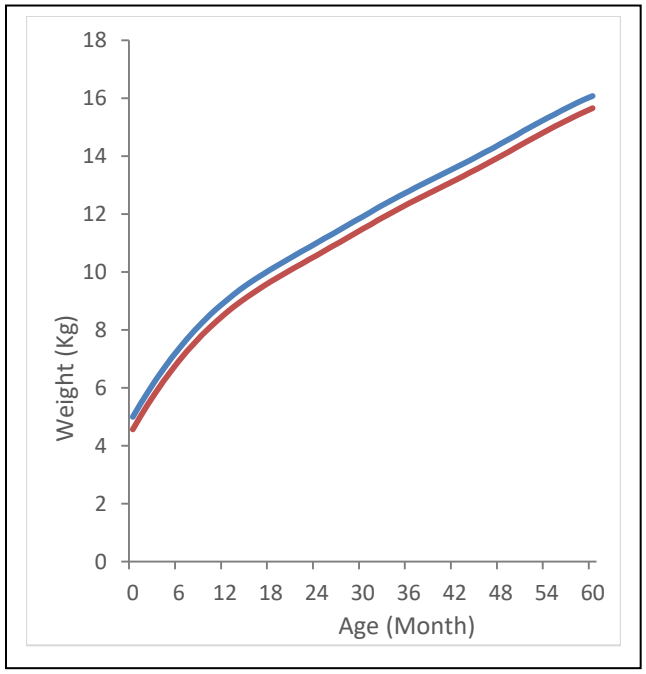


Figure 8. Plots Weight Estimates of Boys (Blue Line) and Girls (Red Line).

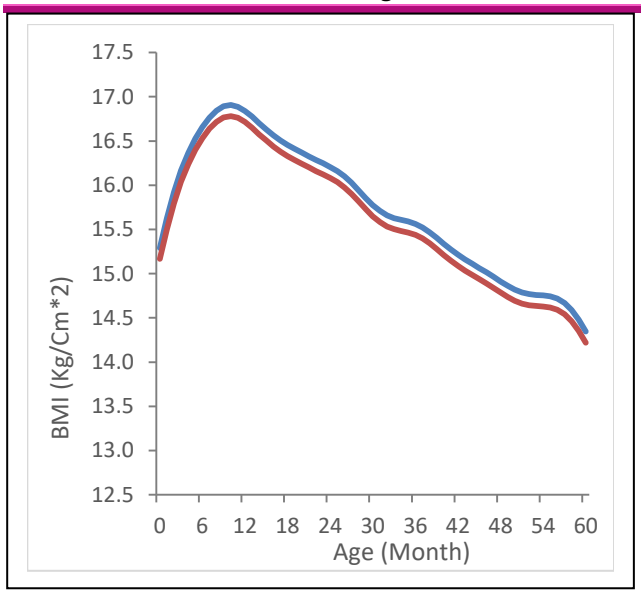


Figure 9. Plots BMI Estimates of Boys (Blue Line) and Girls (Red Line).

Figure 7, Figure 8, and Figure 9 show that the height, the weight, and the BMI of toddlers Boys are higher than those of toddlers girls.

Next, we compare these results with height, weight, and BMI for toddlers based on WHO-2005 standard as presented in the following Figures 10–15.

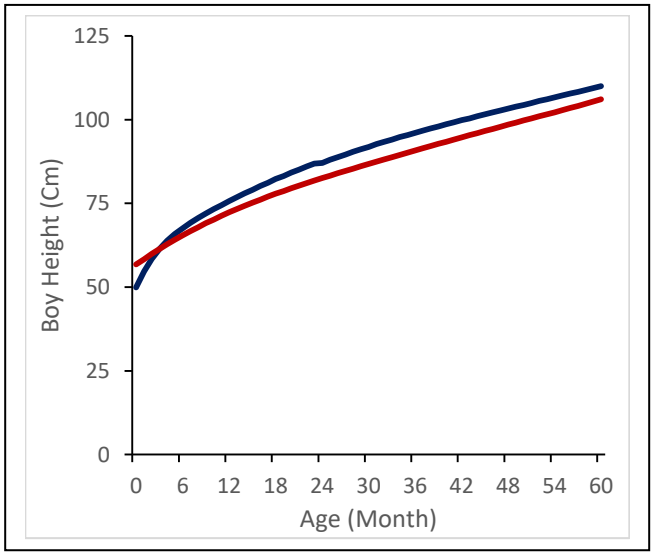


Figure 10. Plots Height Estimates of Boy Toddlers in District Banyuwangi (Red Line) and Boy Toddlers Based on WHO-2005 Standard (Blue Line).

Figure 10 shows that height for boy toddlers in District Banyuwangi are smaller than those for boy toddlers based on the WHO-2005 standard.

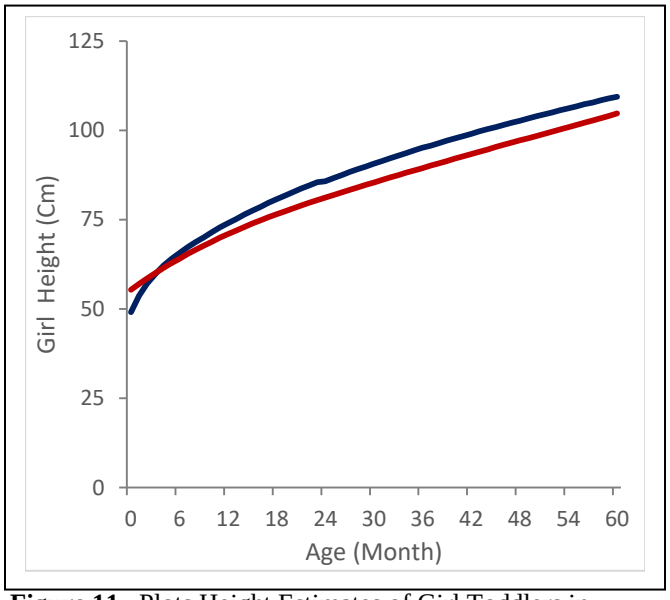


Figure 11. Plots Height Estimates of Girl Toddlers in District Banyuwangi (Red Line) and Girl Toddlers Based on WHO-2005 Standard (Blue Line).

Figure 11 shows that height for girl toddlers in District Banyuwangi are smaller than those for girl toddlers based on the WHO-2005 standard.

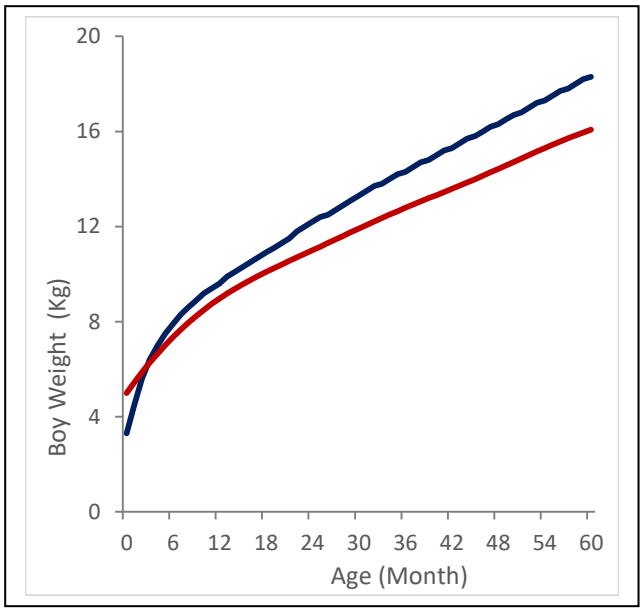


Figure 12. Plots Weight Estimates of Boy Toddlers in District Banyuwangi (Red Line) and Boy Toddlers Based on WHO-2005 Standard (Blue Line).

Figure 12 shows that weight for boy toddlers in District Banyuwangi are smaller than those for boy toddlers based on the WHO-2005 standard.

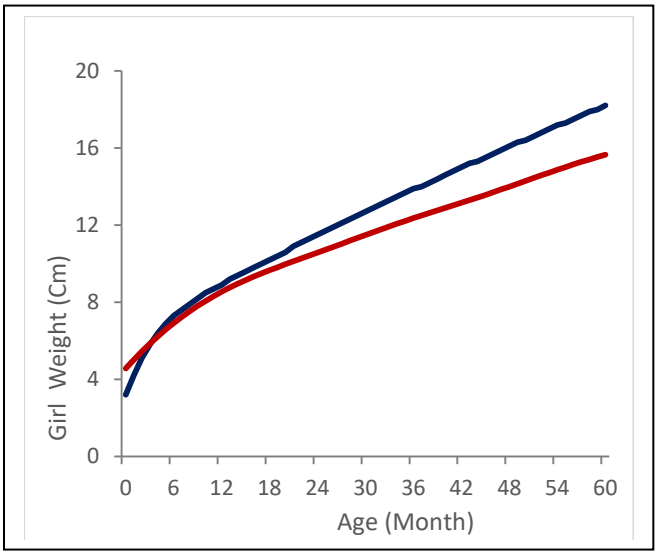


Figure 13. Plots Weight Estimates of Girl Toddlers in District Banyuwangi (Red Line) and Girl Toddlers Based on WHO-2005 Standard (Blue Line).

Figure 13 shows that weight for girl toddlers in District Banyuwangi are smaller than those for girl toddlers based on the WHO-2005 standard.

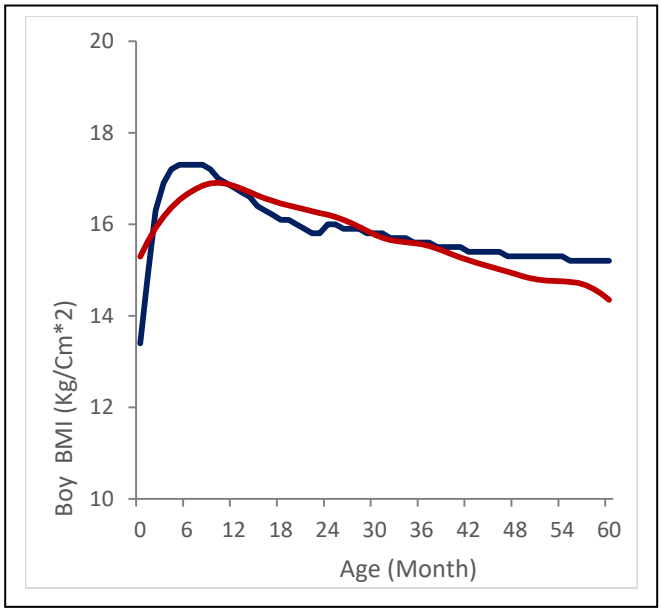


Figure 14. Plots BMI Estimates of Boy Toddlers in District Banyuwangi (Red Line) and Boy Toddlers Based on WHO-2005 Standard (Blue Line).

Figure 14 shows that the BMI for boy toddlers in District Banyuwangi aged $10\,months \leq age \leq 20\,months$ are greater than those for boy toddlers based on the WHO-2005 standard.

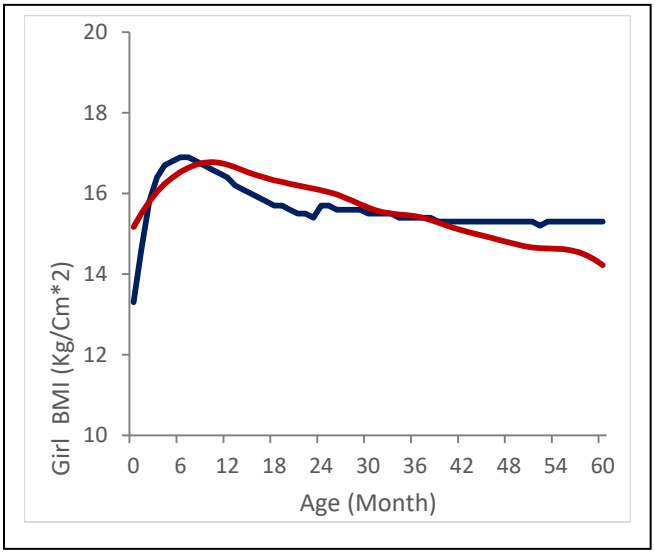


Figure 15. Plots BMI Estimates of Girl Toddlers in District Banyuwangi (Red Line) and Girl Toddlers Based on WHO-2005 Standard (Blue Line).

Figure 15 shows that the BMI for girl toddlers in District Banyuwangi aged $9\,months < age \leq 40\,months$ are greater than those for girl toddlers based on the WHO-2005 standard.

4. Conclusion

In general the height, weight and BMI of boy toddlers exceeds that of girl toddlers. Also, height and weight for both boy and girl toddlers are increasing along with the age of the toddlers. Meanwhile, the BMI for boys and girls continues to increase until they reach the age of 20 months, after which they tend to decrease with increasing age. In addition, height and weight for toddler boys and toddler girls are smaller than those for toddlers based on the WHO-2005 standard. Meanwhile, the BMI for boys aged $10\,months \leq age \leq 20\,months$, and BMI for girls aged $9\,months < age \leq 40\,months$ are greater than those for toddlers based on the WHO-2005 standard.

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