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Health Card Design for Height of Children in Bondowoso Based on Z-Score Curves Using Least Square Spline Estimator

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Abstract: *Nutritional status monitoring in Indonesia is done with the help of health card called KMS (Kartu Menuju Sehat) based on the WHO 2005 standard. The standard is based on data from six countries that are less representative of the Asian region, so it can affect the accuracy of nutritional status assessment in Indonesia. Bondowoso Regency is one of the areas that has quite high stunting cases. The high stunting case is probably caused by the lack of accuracy of WHO 2005 to determines the nutritional status of children in Bondowoso. The goal of this paper is to design standart growth chart of height for ages of children in Bondowoso, Indonesia. The growth chart design which is based on the z-score curve using least square spline is suitable in modeling the growth of children that tend to change at every age. Z-score for estimating the growth chart is calculated based on LMS methods. Based on the results of the analysis, both boy and girl curves satisfy the goodness of fit criterion with* average *R-square value 98.94% for boys and average R-square value of 98.78% for girl. The growth curves for children height in Bondowoso has a lower standard compared to WHO 2005.*

Keywords—health card; least square spline; LMS

1. INTRODUCTION

Childhood is a critical period when a child is in the process of physical growth. In childhood, children experience a process of rapid growth and development. During their development, children are very vulnerable to nutritional problems, lack of fulfillment of nutrition in children can lead to decreasing of physical development, intelligence, mental, and the ability of children's interaction with the environment.

One problem caused by lack of fulfillment of nutritional intake is stunting. The stunting incidence of children is a major nutritional problem in Indonesia. The prevalence of stunting in Indonesia is higher than other countries in Southeast Asia such as Myanmar, Vietnam and Thailand. The nutritional status of children in Indonesia is based on Health Card called *KMS (Kartu Menuju Sehat)* which refers to the WHO 2005 anthropometry standard. However, the WHO 2005 anthropometric standard was designed based on data from six countries: the United States, Brazil, Norway, Ghana, Oman, and India. It is feared that this could affect the accuracy of nutritional status assessments in Indonesia. According to Julia [1] and Batubara [2], sample selection that represents the ethnic diversity of the population is less able to represent ethnic minorities. Socio-economic, geographical and genetic conditions need to be considered in designing anthropometric standards. Cameron and Hawley [3] in their research conducted in the United Kingdom also stated that it is better to use local children growth standards in accordance with the local socio-economic background. Therefore, designing a local child growth standard is very important to do.

There are some research on local children growth charts that have been done previously. The design of children growth charts in Surabaya using linear local methods by Chamidah and Rifada [4] has different patterns based on gender. Researches that has been done by Atmarita [5] and Chamidah et al. [6] carried out lower standard growth chart than WHO 2005. The design of children weight growth charts in Padang using quadratic spline estimators by Yosefanny et al. [7] showed changes in the pattern of increase at a certain age. Patterns on the growth of children that changes at every age can be estimated using nonparametric regression using least square spline estimator. Least square spline is a segmented polynomial model, the smoothing parameter in the least square spline estimator is able to follow the fluctuating pattern of data. Until now, researchs on local standard growth chart still uses percentile curve [4-9], therefore this research is based on z-score curve according to WHO 2005 standards for *KMS* in Indonesia. Bondowoso is one of the regions in Indonesia that needs local growth charts. This is because Bondowoso District has a severe case of stunting because it has a prevalence of 30-39%. In 2016 it was found to be 34.6% of stunting cases and increased to 38.3% in 2017. This prevalence is still quite high because based on WHO standards, an area can be categorized well if the prevalence of stunting is less than 20% [10].

There are two purpose in this reasearch, the first is to designing a Health Card by local standard growth chart of children height in Bondowoso with a z-score curve based on the least square spline estimator. The second purpose is to determine the percentage of nutritional status of children in Bondowoso based on height growth standards for children in Bondowoso and based on WHO anthropometric standards 2005.

2. LITERATURE REVIEW

2.1 Z-Score Based on LMS Method

Z-Score in the cut off i SD in each age (t) calculated by the LMS method can be expressed in:

$$Z_{iSD}(t) = M(t)[1 + L(t)S(t)i]^{1/L(t)}, \text{ i = -3, -2, ... , 3} \quad (1)$$

where L(t) is a Box-Cox value at age (t), M(t) is median at age (t) and S(t) is coefficient of variation at age (t) according to de Onis et al. [11]. Cole [12] explains that Box-Cox value for age (t) can be calculated as follows:

$$L(t) = -A(t)/(2B(t)) \quad (2)$$

where

$$A(t) = \log(S_a(t)/S_h(t))$$

$$B(t) = \log(S_a(t)S_h(t)/S_g(t)^2)$$

where S_a(t), $S_g(t)$ and S_h respectively are arithmetic coefficient of variation, geometric coefficient of variation and harmonic coefficient of variation at age (t).

Furthermore, the median at age (t) can be calculated using the following formula:

$$M(t) = M_g(t) + [M_a(t) - M_h(t)]\, L(t)/2 + [M_a(t) - 2M_g(t) + M_h(t)]\, L(t)^2/2 \quad (3)$$

where $M_a(t), M_g$(t) dan M_h(t) respectively are arithmetic mean, geometric mean and harmonic mean at age (t).

The coefficient of variation at age (t) can be calculated using the following formula:

$$S(t) = S_g(t)\exp(A(t)\, L(t)/4) \quad (4)$$

where S_g(t) is geometric coefficient of variation at age (t) and L(t) is Box-Cox value for age (t) based on (2).

The arithmetic value mentioned above is the original value of the data. The geometric value is the logarithmic transformation value where the data is given 0 for the rank of transformation, while the harmonic value is the reciprocal transformation value where the data is given -1 for the rank of transformation.

2.2 Estimation of Least Square Spline

According Hardle [13], paired data $\{(t_1, y_1), (t_2, y_2), \ldots, (t_n, y_n)\}$ follows the nonparametric regression model:

$$y_i = f(t_i) + \varepsilon_i \quad (5)$$

where f is a regression function to be estimated, dan ε_i is error random assumed to be independent with mean zero and variance σ^2. The regression function $f(t_i)$ in (5) is estimated with least square spline estimator, so it can be expressed as follows:

$$\underset{\sim}{\hat{f}}(t) = X(\underset{\sim}{\hat{\beta}}) \quad (6)$$

where $\underset{\sim}{\hat{\beta}}$ is obtained by using Ordinary Least Square (OLS) method by minimizing the following function :

$$Q = \left(y - X\underset{\sim}{\hat{\beta}}\right)^T \left(y - X\underset{\sim}{\hat{\beta}}\right)$$

$$= y^T y - 2\underset{\sim}{\hat{\beta}}^T X^T y + \underset{\sim}{\hat{\beta}}^T X^T X \underset{\sim}{\hat{\beta}} \quad (7)$$

and we get:

$$\underset{\sim}{\hat{\beta}} = (X^T X)^{-1} X^T y \quad (8)$$

Based on (6) and (8), the form of a least square spline estimator for (t) can be written as follows:

$$\underset{\sim}{\hat{f}}(t) = X(X^T X)^{-1} X^T y \quad (9)$$

We use least square spline approach then we need the smoothing parameter including order and knot. Smoothing parameter serves to control the smoothness of the regression curve. In this study we use Generalized Cross Validation (GCV) criterion, by selecting the minimum value of the following GCV:

$$GCV = \frac{n^{-1}\sum_{i=1}^{n}(y_i - \hat{y_i})^2}{(\frac{1}{n}trace[I-H])^2} \quad (10)$$

2.3 Goodness of Fit

According to Rawlings et al. [14], the coefficient of determination (R^2) is one of the criteria for goodness of fit or suitability of the model that aims to see how well the predictor variable (x) in the model can explain variations in the response variable (y). The coefficient of determination can be calculated through the following formula:

$$R^2 = \frac{SS(Regr)}{SS(Total)} = \frac{\sum(\hat{Y} - \bar{Y})^2}{\sum(Y - \bar{Y})^2} \quad (11)$$

where $0 \leq R^2 \leq 1$.

3. RESULT AND DISCUSSION

The data used in this analysis is secondary data that consists of observation data of body height (cm), age (month), and sex of children. There are 7188 observation data for boy and 6539 observation data for girl obtained from Public Health Center (Puskesmas) in Bondowoso.

The z-score values in cut off -3SD, -2SD, 0SD, +2SD, and +3SD of height of children in every age is used to get the best model estimation. The best model can be obtained by looking for the minimum GCV value, the smallest MSE, and the largest value of R-square at each point value of knots. The result of the optimal order and knot based on the

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minimum GCV criterion in every z-score is showed in Table 1 as follows:

Table 1: The optimal knot based on GCV for boy

Z-Score	Order	Knot	MSE	GCV	R-sq
(-3SD)	1	6, 24	2.4590	2.8162	98.50%
(-2SD)	2	6, 24	0.9046	1.0733	99.45%
(0SD)	1	6, 12, 24, 48	0.1316	0.1618	99.93%
(2SD)	2	12	1.9696	2.2443	99.02%
(3SD)	1	6, 12	4.8820	5.5913	97.78%

Table 2: The optimal knot based on GCV for girl

Z-Score	Order	Knot	MSE	GCV	R-sq
(-3SD)	2	24	3.6011	4.1243	97.59%
(-2SD)	2	6, 24	1,3597	1.6560	99.10%
(0SD)	2	6, 12, 24, 36	0.1432	0.1827	99.92%
(2SD)	2	6, 12	1.8254	2.1659	99.12%
(3SD)	2	6	4.2024	4.8129	98.17%

Based on Table 1 and Table 2, R-square value for growth chart obtained from the average R-square value. Based on Tabel 1, R-square value for boy's growth chart is 98.94% and R-square value for girl's growth chart is 98.78%.

The results as in Table 1 are used for estimating children growth chart for boy in KMS based on least square spline estimator that can be showed in Fig. 1 as follows:

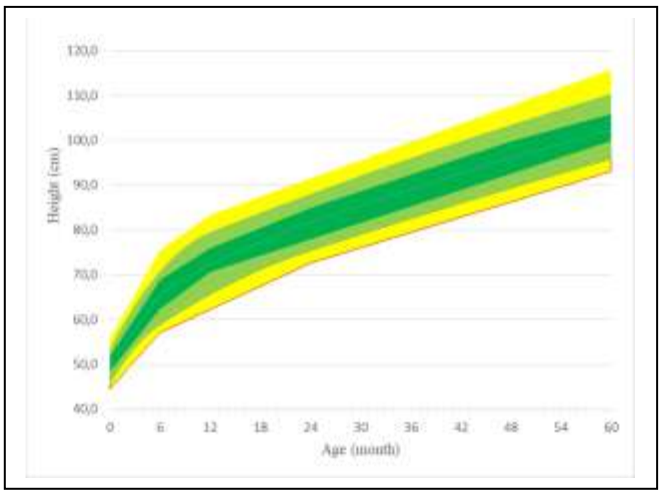

Fig. 1. *Chart of KMS for boy's height in Bondowoso*

The results as in Table 2 are used for estimating children growth chart for boy in KMS based on least square spline estimator that can be showed in Fig. 2 as follows:

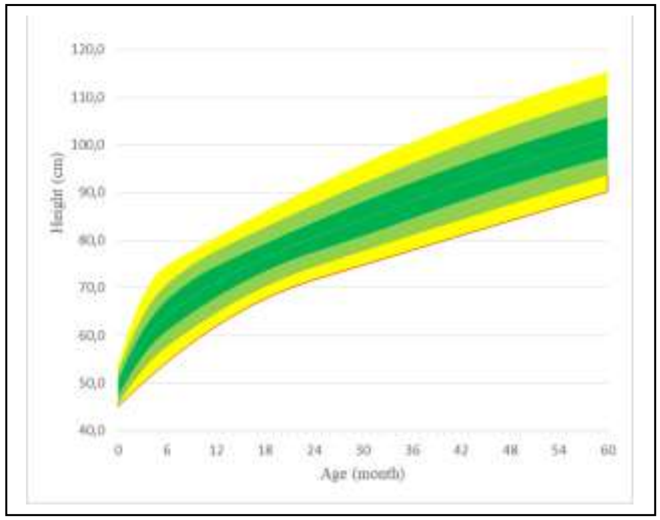

Fig. 2. *Chart of KMS for girl's height in Bondowoso*

The comparison results of children nutritional status based on Bondowoso Standard Chart (Local) and WHO-2005 Standard Chart by sex (boy and girl) as given in Table 3.

Table 3: Percentage of nutritional status for boy and girl

Nutritional Status	Boy		Girl	
	Local	*WHO 2005*	*Local*	*WHO 2005*
Severely Stunted	1.93%	11.41%	1.53%	8.99%
Stunted	3.28%	25.72%	3.02%	23.80%
Normal	85.06%	59.46%	86.69%	63.64%
Overheight	9.73%	3.41%	8.76%	3.57%

According to Table 3, the percentage of nutritional status, stunted for children under five years old in Bondowoso for both boy and girl based on least square spline charts are less than those based on WHO-2005 standard growth charts. In general, the least square spline standard growth charts of height for both boy and girl have the evaluator standard which are lower than the standard charts of WHO 2005. This condition occurs because the samples used to design the least square spline standard growth charts, i.e., children under five years old in Bondowoso, physically have characteristics that different from samples used to design the WHO 2005 standard charts, i.e., Brazil, Ghana, India, Norway, Oman and the United States.

4. CONCLUSION

The standard growth chart of height for age by using the nonparametric least square spline estimator can explain the growth patterns of children in Bondowoso well because it has average R-square value for boy 98.94% and 98.78% for girl.

Nutritional status monitoring using local standar growth chart least square apline describes children condition more accurately than using standard WHO 2005.

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