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Logistic Regression and Growth Charts to Determine Children Nutritional and Stunting Status: A Review

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Abstract

Children malnutrition and stunting are still common in Indonesia. Although Indonesia has succeeded in reducing malnutrition and stunting rates over the past few years, these two issues must still be considered as something serious in order to prevent the increasing number of malnutrition and stunting rates in the future. This study aims to analyze the suitable logistic regression methods and growth charts to reduce the number of children with malnutrition and stunting status. Based on the analysis of previous studies and theories, researchers have found that multinomial logistic regression is the most suitable method to measure children nutritional and stunting status because it can provide more specific results, such as malnutrition, undernutrition, normal nutrition and obese. WHO growth charts – weight-for-age chart that already exists in Kartu Menuju Sehat (KMS) – is suitable to be applied in monitoring child's nutritional status because Indonesia's Anthropometric Standards Assessing Nutritional Status of Children are developed based on WHO Standards. To be able to perform Indonesian children stunting status measurement, WHO length-for-age or height-for-age growth chart needs to be applied.

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Keywords: malnutrition; stunting; nutritional status; logistic regression; growth charts

1. Introduction

Malnutrition and stunting are still become the main issues that occur in the world. Almost half of the mortality rate in children under 5 years old in Asia and Africa caused by malnutrition. This causes the death of 3 million children per year[1]. In the year of 2011, Indonesia is ranked 5 of 81 countries with the largest number of stunted children in the world that reached 7.547.000 children. Indonesia is reported to have a larger number of stunting children than some African countries, such as Ethiopia, Democratic Republic of the Congo, Kenya, Uganda and Sudan. During the year of 2007-2011, Indonesia is reported to have moderate and severely wasting, underweight and overweight children that reached 13%, 18% and 14% respectively[2]. In 2012, the mortality rate of children under 5 years in Indonesia reaches 152.000

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people. At least 400 Indonesian children die every day due to low economic rates and infections, such as pneumonia and diarrhea[3]. In 2013, Indonesia has a tendency of child prevalence to be underweight based on indicator of weight-for-age of 19.6%, which is divided into malnutrition status of 5.7% and under nutrition status of 13%, and stunting based on the indicator of height-for-age of 37.2%. The percentage has increased from 2010, that is 4.9% for malnutrition status, 13.0% for under nutrition status and 35.6% for stunting status[4]. Meanwhile, according to DKI Jakarta Provincial Health Profile in 2014, West Jakarta ranked first with malnutrition status with the number reached 319 of 522 children[5]. In particular, according to West Jakarta Health Profile 2014, Palmerah area has 61 of 550 children who are likely to suffer from malnutrition[6].

Even though Indonesia has successfully managed to reduce the number of under-five stunting children from 48% in 1995 to 36% in 2010 and under-five underweight children from 30% in 1995 to 18% in 2010, Indonesia should not be lulled. Indonesia still have to improve health services to overcome children malnutrition and stunting problems because the number can be increased at anytime as ever happened in Timor Leste, Nepal and Madagascar as shown in Figure 1.

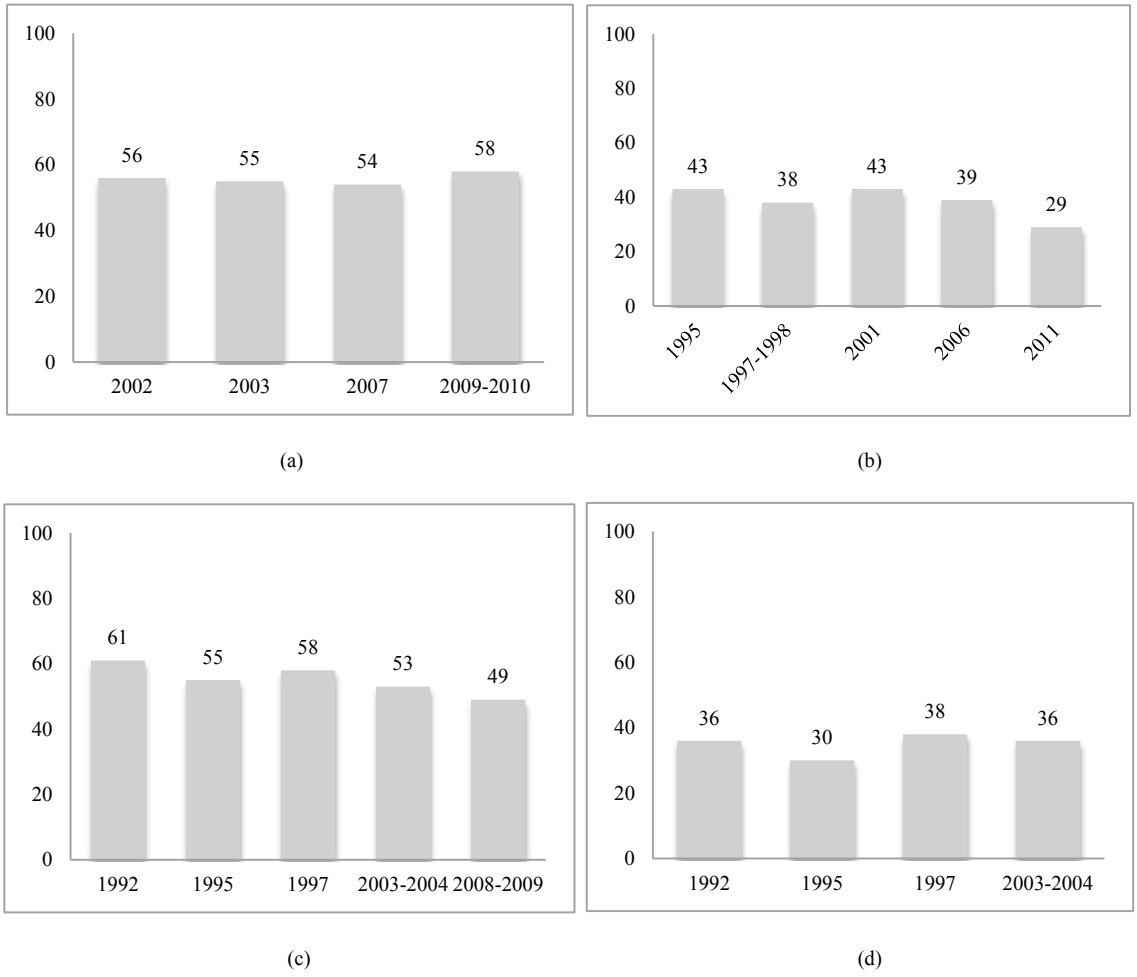

Figure 1: (a) Percentage of under-five stunted children in Timor Leste; (b) Percentage of under-five underweight children in Nepal; (c) Percentage of under-five stunted children in Madagascar; (d) Percentage of under-five underweight children in Madagascar

As shown in Figure 1a, Timor Leste has managed to reduce the number of stunted children from 2002 to 2007, but then the percentage rose to 58% during the year of 2009-2010. Underweight trends in Nepal showed a decline during the year of 1997-1998, but then increased by 5% in 2001 as shown in Figure 1b.

Madagascar successfully declined the number of stunted and underweight children from 1992 to 1995, but in 1997 the percentage of stunted and underweight children rose to 58% and 38% respectively as shown Figure 1c and 1d[2]. Another study also mentioned that sub-Saharan Africa had to deal with the increasing number of undernutrition children until the late of 1990s[7].

To prevent the escalation of children malnutrition and stunting problems in the future, researchers conduct a study on the measurement of nutritional and stunting status of Indonesian children. Based on studies of nutritional and stunting status in children who have done before, there are various methods and growth charts used. In this paper, researchers perform a literature study, make comparison between one another and find the most suitable method and growth chart for measuring the nutritional and stunting status of Indonesian children.

2. Nutritional Status

2.1. Anthropometric Standard for Children Nutritional Status in Indonesia

According to the Decree of the Minister of Health of the Republic of Indonesia number 1995/Menkes/SK/XII/2010, assessment of the nutritional status of children in Indonesia refers to WHO Anthropometric Standard 2005. The indicator for measuring the nutritional status of children is based on age measurements calculated in full months. The length of the body for children aged 0 to 24 months measured in supine state (if measured in standing condition, the measurement result should be corrected by adding 0.7 cm) and height for children older than 24 months measured in standing position (if measured in supine state, the measurement result should be corrected by adding 0.7 cm). The results of the measurement are presented in the form of weight-for-age to determine underweight and severely underweight status, length-for-age or height-for-age to determine stunted and severely stunted status and weight-for-length or weight-for-height to determine wasted and severely wasted. Furthermore, based on z-score, the nutritional status of children is categorized as follows[8]:

Table 1. Nutritional status category.

Classification	Status	Z-score
Based on weight-for-age for children aged 0-60 months	Malnutrition	< -3 SD
	Undernutrition	-3 SD to < -2 SD
	Normal Nutrition	-2 SD to 2 SD
	Obese	> 2 SD
Based on length-for-age or height-for-age for children aged 0-60 months	Very Short	-3 SD
	Short	-3 SD to < -2 SD
	Normal	-2 SD to 2 SD
	Tall	> 2 SD
Based on weight-for-length or weight-for-height for children aged 0-60 months	Very Thin	< -3 SD
	Thin	-3 SD to < -2 SD
	Normal	-2 SD to 2 SD
	Fat	> 2 SD
Based on Body Mass Index-for-Age for children aged 5-18 years	Very Thin	< -3 SD
	Thin	-3 SD to < -2 SD
	Normal	-2 SD to 1 SD
	Fat	> 1 SD to 2 SD
	Obese	> 2 SD

In Indonesia, child growth monitoring is done by Health and Nutrition Integrated Service Center (Posyandu). Posyandu program is supported by Indonesia's government and held every month in every village level. The operations of Posyandu is supported by cadre or village health volunteers[9]. Since 1970, Posyandu used Kartu Menuju Sehat (KMS) to record and monitor the growth of under-five children based on weight-for-age indicator. The latest KMS that has been revised in 2008 provides growth charts based on WHO Anthropometric Standard 2005 as shown in Figure 2. KMS for girls is different from boys. It can be seen from the color of KMS, where the KMS for boys is blue with the description "for boys" and the KMS for girls is pink with the description "for girls". Besides weight and age, weight-for-age growth chart in KMS also contains data about weighing time, exclusive breastfeeding, and the minimum standard of weight gain per month[10].

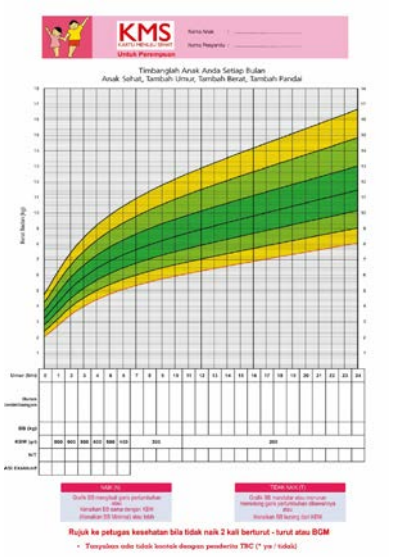

Figure 2: Weight-for-age growth chart for girls [10]

2.2. Anthropometric Standard for Children Nutritional Status in Other Countries

United States has been using Centers for Disease Control and Prevention (CDC) growth charts as a national reference to measure the growth of children and teens ages 2 to 19 years from 1970 to 1990[11]. European countries, such as Netherlands, United Kingdom, Germany, and France, were also had their own country-specific growth charts[12]. Several studies have been conducted to find whether the national standards are better than international standards in measuring children nutritional and stunting status. Although international standard, such as WHO Anthropometric Standard, claimed to be used globally and can described healthy growth that can lead to maximization of long-term health[13], studies were found that it can not be used as the only standard for measuring children nutritional and stunting status. Country-specific anthropometric standards were still considered to be more accurate[12–18]. Meanwhile, another study was found that WHO Anthropometric Standard may be appropriate for measuring children nutritional and stunting status[19]. It was aligned with CDC suggestion to health care providers in United States to use WHO growth charts to monitor the growth of 0 to 2-year-old children[20] because CDC and WHO weight-for-length growth charts have similarity which can provide similar estimation about child's obesity status in age 5 through growth monitoring during 2 years of life [21].

2.3. Children Malnutrition and Stunting Studies

Various studies regarding to malnutrition and stunting among children have been done before. Study conducted in Brazil and Bangladesh have found that overweight mothers had a higher risk to have children with excess weight but breastfeeding duration over 12 months could be a protective factor to suppress excess body weight in children[22, 23]. Non-exclusive breastfeeding practice could lead children to stunting (70.5%), moderate wasting (59.5%) and underweight (74.6%)[24]. Study conducted in Indonesia concluded that mothers with height less than 150 cm tended to have a higher risk of having stunting children (74.5%) than normal children (60.5%) but there was no significant relationship between maternal height with children energy adequancy and nutritional status[25]. Study conducted in Indonesia also found that children nutritional status have a strong association with Acute Respiratory Infections (ARI) and malnourished children are more likely infected by ARI[26]. In India, per capita income, maternal illiteracy, maternal occupation, and adequacy of maternal dietary knowledge are factors that can influence nutritional status of school children[27]. Working mothers are likely to have undernourished, stunting, wasted and underweight children at 1.14, 1.20, 1.21 and 1.31 times greater risk respectively[28].

Based on the explanation above, we know that each region has various backgrounds that affect children nutritional and stunting status. To find the most related factors to children nutritional and stunting status in Indonesia, certain statistical methods should be applied. There are many statistical methods that can be used, one of them is regression.

3. Children Nutrition and Stunting Status Modeling

3.1. Regression

Regression is a conceptual process that uses an equation or model to find the relationship between a response or dependent variable with a set of explanatory or predictor variables. Regression approach is generally done by taking data, determining the suitable model, and evaluating the suitability with statistical science[29]. Regression has been frequently used in studies of children nutritional and stunting status. Some of the studies have been listed in Table 2.

Table 2. Application of regression in previous children nutritional and stunting status studies.

Method	Study Area	Sample Size	Result
Quantile Regression	Ethiopia	14.070 women (aged 15-49 years) and 6.033 men (aged 15-59 years)	Mother's long term health status and level of education and age have various impact to long-term and current child health and nutritional status. Mother with higher education levels are tend to give more resources to their daughters, but child health and nutritional status will probably decrease with mother's age[30].
	Asia, Africa and Latin America	16 developed countries in Africa, 7 developed countries in Asia, and 4 develop countries in Latin America	As the poverty rates decreased, child wasting rates will also decreased[31].
Cox's Regression	Brazil	189 children and adolescents in Pediatric Intensive Care Unit (PICU) Joana de Gusmão Children's Hospital, Santa Catarina, Brazil	41.2% children in PICU were malnourished based on height-for-age Z-score. Prevalence of malnutrition occurred in 18.6% of children based on weight-for-height Z-score and 22.1% of children based on body mass index-for-age Z-score. Duration of mechanical ventilation really associated with malnutrition[32].
Poisson Regression	Jamaica	375 cases of Severe Acute Malnutrition (SAM) in 204 urban and rural communities	Major crime has a strong association with SAM, but not with level of education, poverty index and environmental heavy metal exposure[33].
Poisson Regression and OLS Regression	China	3.000 respondents (aged 18-64 years)	Undernourished children, especially during the late childhood, are likely to have various health problems at adulthood, such as chronic diseases and physical pains, acute illness, risk of insomnia and depression and high blood pressure or low lung capacity. Children who rarely consume nutrient-rich food at age 14, such as meat, fish, milk, soy products, fruits and sweets, have a tendency to be short and gain more weight as an adult[34].
Logistic Regression	French	4.048 children aged 5-7 years and 3.619 children aged 7-11 years in south-west French	Low socio-economic status, absence of breakfast and high sedentary activity tend to have a close relationship with overweight and obesity in French primary-school children[35].

Method	Study Area	Sample Size	Result
	Nigeria	300 mother-child dyad (150 each from rural and urban communities)	Undernourished mothers in urban communities have 11 to 12 times higher risk having underweight and wasting children. Stunted mothers in rural communities are 7 times more likely to have stunted children[36].
	Brazil	554 mothers with children who attend private schools in the Federal District, Brazil	Male children's nutritional status tend to be underestimated by 153% higher than female children. Otherwise, female children's nutritional status were likely overestimated by 124% higher than male children. Nutritional status of non-overweight children had a higher probability of being underestimated. Mothers with high level of education were also have a higher possibility to underestimate their children's nutritional status. Overweight children had a 94% higher possibility of being overestimated and younger mothers (below 35 years old) had a higher chance to overestimate their children's nutritional status[37].
Multiple Logistic Regression	Brazil	385 patients in Intensive Care Unit (ICU)	175 patients in ICU were malnourished. Malnutrition associated with the length of mechanical ventilation and ICU stay, but not with mortality[38].
	Guatemala	373 mothers with children aged 6-23 months	The place of interview (suburban), being male, being ages 13-18 months, being born at home, being of Mayan, having a mother with low level of education and short stature, ethnicity, and having ever received iron supplementation were significantly related with stunting[39].
Multiple and Binomial Logistic Regression	Nairobi	5.156 children aged 0-42 months	Mother's education, child's weight at birth, child's gender, marital status, parity or child's birth order, pregnancy intentions, health seeking behaviour from the mother, and socio-economic status are strongly associated with stunting[40].
Multinomial Logistic Regression	Nepal	5.262 cases of underweight and wasted children from Nepal Demographic and Health Survey 2006	Mother's Body Mass Index (BMI) and child's size at birth are strongly associated with children's nutritional status. Female children have a higher tendency of stunted, underweight and wasted than male children. Female headed households tend to have stunted children[41].
Multinomial and Binary Logistic Regression	Nepal	12.674 women (aged 15-49 years) in 10.826 households	Severe food-insecurity households has 51% stunted and 41% underweight children. Therefore, food insecurity has a significant association with malnutrition among children in Nepal[42].
Binary Logistic Regression	Romania	30 schools in four cities (Iasi, Roman, Targu Frumos and Podu Iloaie)	School children with high socio-economic status have a higher risk for being overweight or obese. It is related with the consumption of French Fries, chips and confectionery[43].

Method	Study Area	Sample Size	Result
	Indonesia	4.101 children aged 2-4.9 years in Indonesia	Lower birth weight (< 2.5 kg), being breastfed for 6 months or more, having underweight or under stature mother or father and maternal low level of education have a strong relationship with stunting and underweight. Children aged 2-2.9 years, had male gender, had overweight or obese mother or father and had father with low level of education will probably have higher risk of being overweight or obese[44].
Ordinal Logistic Regression	Ethiopia	628 under-five children in Sheka Zone, South West Ethiopia	Child feeding status, duration of breast feeding, child's size at birth, timing of child put to the breast after birth, preceding birth interval, had fever in the last two weeks, and had diarrhea in the last two weeks were highly associated with child malnutrition[45].
	Indonesia	3.660 children aged 0-60 months	Age, sex, and height of the children affect significantly to children nutritional status[46].

Logistic regression is often used in various studies related to children nutritional and stunting status as seen in Table 2. According to Talpová (2014), logistic regression is a technique used to analyze data with the dependent variable in groups, especially in the field of biomedicine, ecology, finance, as well as research related to education and meteorology[47]. In addition, logistic regression is the most commonly used method for determining binary models in response to data[48]. There are two types of logistic regression, binary and multinomial logistic regression. Researchers can employ binary logistic regression when the independent variables are continous or categorical and the dependent variable is dichotomous. Multinomial logistic regression can be employed when the dependent variable has more than two options or not dichotomous[49]. Das and Rahman once conducted a study in 2011 to compare the reliability of ordinal and binary logistic regression in determining children malnutrition predictors in Bangladesh. The study concluded that ordinal logistic regression methods are better than binary logistic regression[50].

3.3. Outlier

Outlier is a deviating value found in a collection of observations. A value can be regarded as an outlier if it has a large difference from other values. Outlier can lead to a pecularity and incorrectness of data analysis[51]. Outlier may occur because of too much data has to be processed, where the process of entering data may not be done with careful inspection and screening. Outlier can be caused by human error, mechanical faults, natural disasters or deviations that do occur in the population. Deviation can occur between independent variables (leverage points), dependent variables (vertical outliers) or both independent and dependent variables. Outlier detection can be done by single-case deletion approach by masking and swamping the subset. Since single case-deletion approach often fail to detect grouped or influential outliers, group deletion approach can be applied to make the subset completely free from outliers[52].

Outlier can be found when logistic regression applied. Outlier in binary logistic regression is when y is equal to 0, the corresponding fitted probability close to 1, and vice versa, when y is equal to 1, the fitted probability value close to 0[53]. There are some methods to identify an outlier, such as the standardized Pearson residuals. These methods can only identify single outlier. For multiple outlier, the generalized of standardized Pearson residuals can be used[54].

3.4. Multicollinear

Multicollinearity may occur when two or more independent variables have a very strong linear relationship and the effect of every one of them are hard to separated from the dependent variable. Severe multicollinearity is hard to handle because it can escalate the estimation of coefficient variance and make the estimations very responsive to changes that can lead to unstable and uneasy interpretation of the coefficient. Multicollinearity can reduce the strength of statistical analysis, switch the coefficients' signs, and make it harder to make the right model. In 1970, Ridge Regression Estimation Method was introduced by Hoerl and Kennard to reduce multicollinearity. Ridge regression has

minimum variance by adding by adding insignificant bias to the estimation[55]. There are several methods that can be used for collinearity detection, including latent variable methods and tree based models which are specifically designed for collinearity. Generalized Linear Model (GLM) in combination with penalised methods and threesold-based pre-selection are the most suitable method to detect multicollinearity and even better than methods specifically designed for collinearity. Ridge principal component regression used in a penalised regression model was claimed to be the most well-performed method[56].

4. Discussion

4.1. Logistic Regression

According to previous studies, the most common methods used to determine child nutritional status are binary, multinomial and ordinal logistic regression. Binary logistic regression methods are generally used when the result of independent variable has only two possible answers. In binary logistic regression, there are two kind of trials, which are identical and independent. The results of identical trials allow the same probabilty of success to every trials, while the results of independent trials have absolutely no association with each other. Ordinal logistic regression can be employed when the outcomes categories are list in order, for example from low to high or from high to low. This is slightly different with nominal logistic regression, where nominal logistic regression has no consecutive category. Multinomial logistic regression methods may occur when some trials have more than two possible answers. In other words, multinomial logistic regression can be applied to trials involving independent variable and the same various category choices for each trials[53].

Based on researchers' view, ordinal logistic regression is not suitable to determine the nutritional status of children. Although children nutritional status consists of various categories, such as "malnutrition", "undernutrition", "normal nutrition" and "obese", sorting them in a certain order, whether low to high or high to low does not seem relevant. If ordinal logistic regression is still employed, it will lead to the assumption that "obese" is better than "normal nutrition".

Binary logistic regression could be possible to be applied in determining nutritional status of children because all children have the same probability and the result between one child with another has no relation whatsoever. The only consequence of binary logistic regression is that the categories used can only consist of two types, which are "normal nutrition" and "poor nutrition". Thus, "malnutrition", "undernutrition" and "obese" will be included in the same category, that is "poor nutrition", and "normal nutrition" is still in the category of "normal nutrition".

Multinomial logistic regression is the most suitable method that can be applied to determine the nutritional status of children because the results examination can be more specific. The results of the examination can directly provide diagnosis whether the child is malnourished, undernutritioned, well-nourished or obesed.

The development of logistic regression covers the existence of outlier and multicollinearity. If outlier occur in categorical response data then robust logistic regression is a way to handle it. When there is a high collinearity between independent variables then ridge logistic regression is a method to cope with. So what if outlier and multicollinearity occur together? The robust logistic ridge regression is the method that can handle both cases but in binary response data[58]. The problem can arise when multinomial logistic regression is applied. The existence of multicollinearity can identified using variance inflation factor (VIF) but outlier in multi category data can be a hard work for researcher.

4.2. Growth Charts

Posyandus in Indonesia only use weight-for-age growth chart up to now. Based on Z-scores provided by Anthropometric Standard for Children Nutritional Status in Indonesia, weight-for-age indicator can only define children nutritional status (malnutrition, undernutrition, normal, and obese). To be able to measure children stunting status, length-for-age or height-for-age growth chart is needed. Since Indonesian anthropometric standard is referring to WHO Anthropometric Standard 2005, researchers found that WHO length-for-age or height-for-age growth chart may be appropriate to define children stunting status in Indonesia.

5. Conclusion and Future Works

Logistic regression methods are widely used to determine children nutritional and stunting status. The most common logistic regression methods that have been used regarding to children nutritional status studies are binary, multinomial and ordinal logistic regression. Researchers assume that multinomial logistic

regression is the most suitable method to employ in this research because it can provide more specific results, such as “malnutrition”, “undernutrition”, “normal nutrition” and “obese”.

The use of growth charts can be an effective way to monitor child growth. Most countries prefer to use growth charts based on their own anthropometric standards as they are considered to be more accurate. Based on these findings, researchers consider that the employment of anthropometric standards from Minister of Health of the Republic of Indonesia remains a top priority. Because the Indonesian government only provides weight-for-age growth chart in KMS, it is necessary to employ length-for-age or height-for-age growth chart to be able to measure children stunting status. Since both Indonesian and WHO anthropometric standards are the same, WHO length-for-age or height-for-age growth chart may be appropriate to measure children stunting status in Indonesia.

Future works will focus on the application of logistic regression method to find the relationship between children’s age, gender, height, weight, infectious diseases that children have ever experienced, birth order, breastfeeding duration, amount of child feeding per day, household income, family expenses, maternal level of education, occupation, height, weight, knowledge of children nutrition and enviromental hygiene and number of family members with children nutritional status. Researches will also focus on the development of web application that will be used by health workers in Posyandu to determine children nutritional and stunting status and mobile application that will be used by parents to monitor the the growth of their children.

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