Magnesium Intake and Stunting were Associated with Obesity among Adolescent Girls

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ABSTRACT

The double burden of malnutrition remains a problem in Indonesia. Over and undernutrition problems have been observed in all age groups, including adolescent girls, in which growth and development are critical in this period. The study was aimed to assess the association between nutrient intake, stunting, and overweight. This was a cross-sectional study involving 360 female students from four secondary schools in Majene, Indonesia. A logistic regression analysis was used to detect the risk of association. The present study found that the prevalence of stunting was higher than overweight and obesity (31.7%, 14.2%, 2.2%, respectively). Among obese students, 37.5% of them were stunted, and had low magnesium intake (83.1%). The logistic regression result showed that stunting (AOR= 3.22; 95% CI 1.509 to 6.868; p=0.002) and magnesium intake (AOR= 0.28; 95%CI 0.137 to 0.586; p=0.001) were factors associated with obesity among the students (p<0.05). An adequate magnesium intake may be beneficial to prevent the incidence of obesity, while stunting may increase the risk of obesity among adolescent girls.

Keywords: *Dietary intake, double burden of malnutrition, adolescent health*

ABSTRAK

Beban ganda malnutrisi masih menjadi masalah di Indonesia. Masalah kelebihan dan kekurangan gizi telah diamati pada semua kelompok umur, termasuk remaja putri, di mana pertumbuhan dan perkembangan sangat penting pada periode ini. Penelitian ini bertujuan untuk menilai hubungan antara asupan gizi, stunting, dengan kegemukan. Studi potong lintang telah dilakukan yang melibatkan 360 siswa perempuan dari empat sekolah menengah di Majene, Indonesia. Analisis regresi logistik digunakan untuk mendeteksi asosiasi risiko. Penelitian ini menemukan bahwa prevalensi stunting lebih tinggi daripada kelebihan berat badan dan obesitas (masing-masing 31,7%, 14,2%, 2,2%). Diantara siswi yang obes, 37.5% diantaranya mengalami stunting, dan mempunyai asupan magnesium rendah (83.1%).Hasil regresi logistik menunjukkan bahwa stunting (AOR=3,22; CI95% 1.509 hingga 6.868; p= 0,002) dan asupan magnesium (AOR=0,28; CI95% 0.137 hingga 0.586; p=0,001) merupakan faktor yang berhubungan dengan obesitas pada siswi. Asupan magnesium yang cukup dapat bermanfaat untuk mencegah kejadian obesitas, sedangkan stunting dapat meningkatkan risiko obesitas pada remaja putri.

Kata kunci: Asupan makanan, beban ganda malnutrisi, kesehatan remaja

INTRODUCTION

Adolescence is a transitional period between children and adults and is critical for the incidence of obesity and obesity-related illness in later life (Otitoola, Oldewage-Theron and Egal, 2020). Overnutrition in adolescent girls is one of the current global issues because the proportion of overweight or obesity is increasing rapidly throughout the world, which is considered a global epidemic problem for better socio-economic conditions of the community. In general, being overweight is more common than obesity in boys and girls (Musaiger *et al.*, 2012).

The prevalence rates of overweight and obesity in adolescent girls in various countries such as Iran are 24.1% and 6.5%, respectively (Abiri, Sarbakhsh and Vafa, 2019). Overweight in Libya (26.6%), Kuwait (20.8%), and Syria (19.7%), while obesity is highest in Kuwait (20.6%) (Musaiger *et al.*, 2012). In addition to the Arabian Peninsula, overweight and obesity among adolescent

girls were also found in South Africa, namely overweight (21.1%) and obesity (3.1%), in Ethiopia, overweight (8.4%) and obesity (4.7%), and in the USA, between the 1980s and 2014, the prevalence of obesity increased from about 10% to 21% (ACOG, 2017). In China, proportion of obesity was 17.2% (He *et al.*, 2016). The results of a study showed 7 member countries of ASEAN between 2007 and 2013, the prevalence of overweight/obesity in adolescent girls aged 13-15 years was 8.3%. Brunei Darussalam was the highest while Myanmar was the lowest (36.1% vs 3.4%) (Pengpid and Peltzer, 2016). In Indonesia, the prevalence of overnutrition among adolescent girls in 2018 was approximately 16% (MoH, 2018).

Various aspects, including nutritional transition, high socioeconomic status, access to good quality foods, ethnicity, low physical activity, poor dietary habits, puberty time, poor sleep behavior, and genetics, have been associated with obesity (Musaiger *et al.*, 2012; ACOG, 2017). In addition, there are possibilities that undernutrition during pregnancy (intrauterine environment) also contribute to obesity in adolescence/adulthood (Hoffman *et al.*, 2000).

Obesity during the adolescence period is found to be a strong risk factor contributing to obesity later in life. A study found that around 50% to 80% of obese adolescents continue to be obese in adulthood (Abiri et al., 2019). Adolescents also face medical, psychological, and reproductive health challenges that determine their health outcomes in adults (ACOG, 2017). Emerging evidence suggests that overnutrition increases population health concerns among adolescents in low-middle income countries (Christian and Smith, 2018).

According to the basic health research report (2018), adolescent girls aged 13-15 and 16-18 years old in West Sulawesi experienced stunting (39.26% and 42.64%, respectively). Meanwhile, overweight/obesity was also relatively high 14.26% and 14.15%, respectively). The reports indicated that adolescent girls are facing the double burden of malnutrition. Teenage girls who experience the double burden of nutrition problems have the opportunity to pass through the double burden of nutrition problems to the next generation, leading to disturbed human development, intergenerational poverty, and poor economic growth (MoH, 2018).

Adolescents are increasingly considered important as the potential targeted age group for nutritional intervention in Indonesia. Proper intervention to this group can cut the intergenerational chain of poverty and malnutrition (Watson *et al.*, 2019). This study was aimed to explore the nutritional status of adolescent girls and what factors contributed to obesity. This study was also aimed to assess the relationship between nutritional intake, stunting, and obesity.

MATERIAL AND METHOD

This study was a cross sectional conducted from March to April 2021. The study locations were in 4 high-level schools (2 tertiary and 2 secondary schools) in Majene Regency. A total of 360 female students involved in this study.

Prior to data collection, research assistants were trained. Dietary intake was measured using 2 x 24-hour recall form. Nutrients contents for ready-to-eat foods and beverages was collected based on nutrition facts on the packaging label. The average daily nutritional intake was calculated using the NutriSurvey software for Windows. The main nutrient assessed in this study was magnesium. However, other nutrients were also assessed in this study because they play a role in affecting magnesium absorption, including

protein, dietary fiber, and fat (Hall and Guyton, 2014; Wibawa, 2016). Macronutrient intake is considered sufficient to meet the nutritional adequacy rate (RDA) if the value is >80% RDA, and micronutrients are considered adequate if the value is >77% RDA (Gibson, 2005).

Measurement of upper arm circumference using a tape measure (d = 0.1 cm) and is declared to have chronic energy deficiency if the result is < 23.5 cm. Body weight was measured using a digital scale (d=0.1 kg), height was measured using a microtoice (d=0.1 cm). The measurement results are used to calculate the HAZ and BAZ indices using Anthroplus software. It is declared stunting if the HAZ-score value is <-2 SD, overweight if the BAZ value is 1SD to 2SD, and obesity is > 2SD (MoH, 2020). Anemia is characterized with the hemoglobin value below than 12 g/dl (WHO, 2011). The measurement was carried out using HemoCue. This research was conducted after obtaining ethical approval from the Health Research Ethics Committee, Hasanuddin University Medical School.

RESULT AND DISCUSSION

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Table 1 shows the characteristics obese and non-obese participants. There were significantly different for characteristics between obese and non-obese students except fathers' and mothers' occupation status (p>0.05). For the nutrient intakes, fibre, vitamin D, and Zinc were not significantly different between the two groups.

Table 1. Characteristics of study participants

Variable	Obese (n=59)	Non Obese (n=301)	*P* Value
Father's occupation (Non-Formal)	43 (72.9)	232 (77.1)	0.295
Mother's occupation (Non-Formal)	46 (78.0)	253 (84.1)	0.170
Father's education (Low)	17 (28.8)	146 (48.5)	0.004
Mother's education (Low)	20 (33.9)	151 (50.2)	0.015
Age (years)	14.64.±1.4	14.17.±1.6	0.072
Weight (kg)	59.59.±8.8	41.56.±6.7	0.000
Height (cm)	151.57.±5.4	152.76.±79.2	0.000
HAZ (SD)	-1.37.±0.7	-1.66.±0.9	0.005
Stunting	9 (15.3)	105 (34.9)	0.002
Energy (kkal)	1065.2±488.1	1295±558	0.003
Fat (g)	46±25.4	54.6±27	0.023
Protein (g)	43±20.4	54.7±41.4	0.014
Carbohydrate (g)	123.1±66.5	155.6±82	0.004
Fiber (g)	5.69±9.91	4.92±3.86	0.134
Vitamin D (mcg)	5.1±4.9	6,0±5.2	0.207
Vitamin E (mcg)	3.4±2.3	4.1±2.6	0.041
Zn (mg)	4.1±2.4	4.8±3.0	0.062
Fe (mg)	4.7±3.5	6.4±5.5	0.034
Magnesium (mg)	228.1±110.6	321±228.1	0.001

Data are expressed as mean± standard deviation or frequency and (percentage).

Fulfillment of Teenage Nutrition Adequacy

Based on the results of a 2x24-hour recall (Table 2), majority of participants have a nutrient intake less than recommendation (>80% RDA for macronutrients and >77% RDA for micronutrients). Almost all nutritional intakes of adolescent girls who are classified as less than the RDA are more commonly found in the obese group than those who are not obese, except for fiber and vitamin D.

Table 2. Nutrient intakes between obese and non-obese participants

Variable	Obese (n = 59)	Non-obese (n = 301)	*P* Value
Macronutrient (≤80% RDA)			
Energy (kkal)	49 (83.1)	230 (76.4)	0.173
Fat (g)	42 (71.2)	164 (54.5)	0.012
Protein (g)	39 (66.1)	155 (51.5)	0.027
Carbohydrate (g)	57 (96.6)	255(84.7)	0.007
Fiber (g)	57 (96.6)	299 (99.3)	0.127
Micronutrient (≤77% RDA)			
Vitamin D (mcg)	9 (15.3%)	47 (15.6)	0.562
Vitamin E (mcg)	59 (100.0)	297 (98.7)	0.487
Fe (mg)	56 (94.9)	243 (80.7)	0.004
Zn (mg)	51 (86.4)	248 (82.4)	0.292
Mg (mg)	49 (83.1)	180 (59.8)	0.000

Prevalence of overweight, obesity and stunting

Of the total female adolescents studied (n = 360), 14% of them was overweight, 2.2% was obese, and 31.7% was stunted. Among obese adolescent girls, 37.5% were stunted (Figure 1).

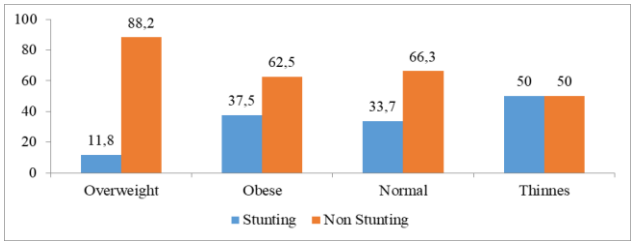

Figure 1. Double Burden of Malnutrition in Girls Adolescent

Based on the results of the multivariate logistic regression test (Table 3), it was found that there was a significant effect between magnesium intake and stunting with the incidence of obesity after controlling for other variables related to obesity with coefficient values of 1,259 and 1,169, respectively. Adolescent girls with adequate magnesium intake tend to have a lower obesity risk by 0.284 times than children with a lack of magnesium intake. In other words, an increase of 1 mg of magnesium intake can reduce the risk of obesity by 0.284 times significantly. In addition, stunting significantly affects the incidence of obesity with a coefficient value of 1.169. Adolescent girls who experience stunting have a risk of 3.22 times being obese.

Table 3. Multivariat logistic regression of factors associated with obesity

Variable	n(%)	B	*P* Value	AOR (95% CI)
Magnesium Intake (Ref: Inadequate)	131(36.4)	-1.259	0.001	0.284 (0.137 - 0.586)
▪ Adequate (>77%RDA)				
Nutritional Status (Ref: Not Stunted)	9(15.3)	1.169	0.002	3.220 (1.509 - 6.868)
▪ Stunting				
Constant		2.258	0.000	9.563

The prevalence rate of overnutrition in adolescent girls found in this research was 16.2% (14% overweight, 2.2% obesity), and these figures are similar to the national prevalence of Indonesia in 2018 (MoH, 2018). This finding is much lower than that of adolescent girls in South Africa with overweight was 21.1%, and obesity was 4.6% (Otitoola, Oldewage-Theron and Egal, 2020). Compared with Asian countries, the prevalence of overweight adolescent girls (13.7%) is almost the same as our findings in this study (14%). In comparison, obesity is 3 times higher in Asian adolescent girls (6.2%) (Mazidi *et al.*, 2018) and 5 times higher (10.5%, 95% CI 9,2 – 11,8) from the results of a systematic review analysis on adolescent girls aged 12-18 years in Ecuador (Hajri, Angamarca-Armijos and Caceres, 2021). The stunting prevalence of the present study is relatively higher than the national stunting prevalence (MoH, 2018).

The findings from this research also show that the majority of young women have macronutrient and micronutrient intakes that are classified as little/less than the RDA recommendation, except for vitamin D which is less than 20% which is classified as lacking. This shows that adolescent girls who suffer from obesity may be experiencing metabolic disorders caused by chronic malnutrition that afflicts adolescent girls, namely stunting by 31.7%. This result is supported by a study from Bidad et.al (2008) showing that carbohydrate and iron intake were less in obese and overweight female adolescents (Bidad *et al.*, 2008).

Among the two factors that influence the incidence of obesity in adolescent girls, stunting was the most influential (AOR=3.229) compared to magnesium intake (AOR=0.284). The results of this study are in line with the findings in 8 provinces in Indonesia in

children aged 6-12 years. The national report in 2010 shows that stunting gives 2.33 times the risk of being overweight (OR = 2.33, 95%CI: 2, 06-2.61); thus there is a significant relationship between stunting and overweight in school-age children in Indonesia (Yasmin, Kustiyah and Dwiriani, 2019). Similar findings in South Africa in children aged 36-119 months was reported (Symington *et al.*, 2016).

The relationship between stunting and obesity in adolescence shows that chronic malnutrition during growth (during pregnancy, childhood, and from one generation to another) can negatively affect fat metabolism for overweight/obese adolescent girls. Early malnutrition can permanently "program" the individual to increase and/or maintain fat stores. Obesity can occur in individuals who experienced growth retardation in early life. Early life nutrition programs tend to produce hormonal effects on linear growth restriction but not on potential weight gain (Popkin, Richards and Montiero, 1996).

In addition, stunting causes a series of important changes in metabolic aspects, namely lower energy expenditure, more susceptibility to the effects of high fat intake, lower fat oxidation, and impaired regulation of food intake. The results of the study by Sawaya and Roberts (2003) reported the link between stunting and obesity can be through two basic mechanisms, (1) effect on obesity and growth rate and (2) effect on energy balance and fat oxidation (Sawaya and Roberts, 2003).

In the first mechanism, children who suffer from malnutrition experience changes in metabolism in all tissues and body systems, namely low metabolism. The provision of high-energy foods to malnourished children implies that children are hungry, perhaps because their low body fat stores have triggered signals that promote hyperphagia. Rapid weight gain following malnutrition causes children to be fatter and have proportionately less muscle tissue than children of the same age and weight-for the same height as those who have never been malnourished. This is due to an imbalance of growth regulators, namely growth hormone and other growth factors, resulting in a higher proportion of fat and a lower proportion of lean tissue. Several cohort studies of stunted children showed a marked increase in body weight for height or BMI but were not followed by an increase in height for age.

In addition, in one longitudinal study, a group of stunted and non-stunted adolescent schoolgirls followed for two years showed a range of metabolic differences. Those who were stunted demonstrated susceptibility to gaining weight-for-height (weight/height index) when a higher fat diet was consumed and also had a higher central fat accumulation (waist-to-hip ratio).

For the second mechanism, energy regulation is influenced by the balance of carbohydrate and fat intake. Carbohydrates can be stored less than fat because of its high turnover rate and a quick depletion. The higher the dietary fat content, the more total food (and energy) needs to be consumed to maintain carbohydrate intake and storage. Person can gain more weight due to have increased energy intake. Fat oxidation is associated with weight gain. Chronically malnourished patients had a higher 12-hour post-absorption basal (Respiratory Quotient) than well-nourished individuals, indicating higher carbohydrate oxidation and lower fat oxidation rates. For stunted children, the RQ was significantly higher, and consequently fasting fat oxidation was significantly lower, which is a predictor of obesity.

In addition, total energy expenditure is lower in short children. The indicators indicate important metabolic changes in

children who were previously malnourished (low height for age but normal weight for height). A series of physiological changes in pygmy individuals are align with basic research on growth rates, fuel utilization, and energy balance.

The results of studies in several countries such as Russia, Brazil, China, and South Africa by Popkin et al. (1996) proved the relationship between stunting and overweight in children aged 3-9 years (Popkin, Richards and Montiero, 1996). Individuals who survive chronic malnutrition are most likely those who have physiological adaptation mechanisms and environmental conditions that can reduce the long-term effects of undernutrition. In addition, Hoffman (2000) reported that children who suffer from chronic malnutrition at an early age are positively related to overweight/obesity in adolescence and adulthood. This occurs because children who suffer from chronic malnutrition have impaired fat oxidation (low-fat oxidation) so that the fat that is not oxidized will be stored (Hoffman *et al.*, 2000).

The present study also found that magnesium intake is a factor that significantly influences the incidence of obesity. The data show that adequate magnesium intake can protect the incidence of obesity in adolescent girls. Magnesium plays important role as a cofactor of more than 300 enzymatic reactions (Al Alawi, Majoni and Falhammar, 2018). Several key enzymes of the glucose oxidation pathway depend on Mg2+, which will activate B1 to thiamine diphosphate (TDP) as a coenzyme of oxidative metabolism in glucose (Piuri *et al.*, 2021). Through its critical role in regulating enzymatic processes and glucose metabolism, magnesium can probably determine individual's weight (Hruby *et al.*, 2013). Magnesium also plays pivotal role in ATP synthesis and activates almost all glycolytic enzymes and the citric acid cycle (Levy *et al.*, 2020).

Many studies have confirmed that obese children have an increased incidence of micronutrient deficiencies, including magnesium, selenium, cobalt, potassium, zinc, copper, iron, and chromium (ul Hassan *et al.*, 2017), and 27% of obese women have magnesium deficiency and 15% in women who are not obese as found by Farhanghi et al, (2009) (Farhanghi, Mahboob and Ostadrahimi, 2009). Thus, the mean serum magnesium is lower in overweight and obese children than in normal children (ul Hassan *et al.*, 2017). Several previous studies have confirmed that low serum magnesium is associated with obesity (Zaakouk, Hassan and Tolba, 2016; ul Hassan *et al.*, 2017; Shamnani *et al.*, 2018).

Stunting coexisting obesity among adolescent girls may have negative implications for increasing the risk of non-communicable diseases later in life, leading to threatening their future life.

The study acknowledges the determination of obesity status based on BMI for age z-score as the study limitation. Because using BMI for age z-score cannot be used to assess body fat directly.

CONCLUSION

The study concluded that stunting and magnesium intake significantly affect obesity in adolescent girls. An adequate magnesium intake can reduce the risk of obesity among adolescent girls. Therefore, nutrition-health education interventions are needed for adolescent girls to reduce the double burden of malnutrition and its effects in the future.

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