Original Research

The Indonesian Journal of Public Health
Vol 19. No. 2 August 2024
p- ISSN 1829-7005 e- ISSN 2540-8836

PROFILE OF METABOLIC SYNDROME COMPONENTS IN OBESE ADOLESCENTS: STUNTING VS. NON-STUNTING

Muhammad Harits[1], Nur Aisiyah Widjaja[1*], Meity Ardiana[3]
[1]Clinical Medical Student, Faculty of Medicine, Airlangga University, Indonesia
[2]Child Health Department, Faculty of Medicine, Airlangga University, Indonesia
[3]Cardiology and Vascular Medicine Department, Faculty of Medicine, Airlangga University, Indonesia
Correspondence address: Nur Aisiyah Widjaja
Email: nuril08@yahoo.com

ABSTRACT

Introduction: Stunted children are more likely to become obese, with a prevalence of 1.33% in children under the age of five. **Aims:** To evaluate the metabolic syndrome (MetS) profile in overweight/obese adolescents who are either stunted or not, and to determine the associations between stunting characteristics (height-for-age z-score, or HAZ) and anthropometric measurements (waist circumference, hip circumference, and waist-to-hip ratio), as well as MetS indicators. **Methods:** A retrospective observational study was conducted focusing on adolescents who were overweight or obese. Subjects were divided into 2 groups based on height-for-age z-score (HAZ): stunting group and non-stunting group. Subject numbers were determined by total sampling due to the number of stunted being small. **Results:** The prevalence of MetS in stunting overweight/ obese adolescents was 18.75%, dominated by female. There was a significant difference on BMI (34.60 (26.80-45.09) vs. 31.11 (27.34-40.13, p=0.040), waist-to-height ratio (0.63 (0.54-0.73) vs. 0.58 (0.52-0.64), p=0.005), hip circumference (111.27 (95-135) vs. 102.50 (87-114) cm, p=0.012) and systole blood pressure (124.37 (110-140) vs. 116.25 (100-130) mmHg, p=0.032), greater in stunting subjects than non-stunting. Waist-to-hip ratio was lower in stunting than non-stunting (0.85 (0.69-0.97) vs. 0.92 (0.81-0.99), p=0.012). HAZ was correlated negatively with BMI (r=-0.358, p=0.044), but correlated positively with hip circumference (r=0.215, p=0.023). **Conclusion:** Adolescents who were stunted and overweight/obese exhibited higher values for BMI, waist-to-height ratio, hip circumference, and systolic blood pressure compared to non-stunted individuals who were overweight/obese. There was a correlation between the height-for-age z-score and both BMI and waist-to-hip ratio.

Keywords: stunting, overweight, obesity, adolescents, metabolic syndrome

INTRODUCTION

Malnutrition, which refers to undernutrition and overnutrition, is a global health problem related to children and adolescents. In 2013, almost 161 million children under the age of 5 experienced stunted growth, while more than 42 million children in the same age group were affected by overweight and obesity. There was a phenomenon that the prevalence of childhood stunting was decreased, but overweight/obesity was increased (Minh Do et al., 2018), due to the switch of traditional diets with insufficient nutrients need to energy-dense diets during the intervention programs (Rosdy and Sabri, 2022) or nutritional transition toward modern food (Sachdev et al., 2021).

Stunting, as the chronic form of undernutrition, impacted more than 29.1% of children under 5 years old (Ssentongo et al., 2021). Stunted children had a 2.3-times higher risk to develop obesity (Yasmin et al., 2019). A community survey found that the prevalence of overweight/obesity linked to stunting was 5.8% in boys and 6.8% in girls (Sawaya et al., 1995). However, the mechanism of stunting causing obesity is still unclear until now. The coexistence of stunting with overweight/obesity was believed to be caused by changes in epigenetic mechanisms, including such as DNA methylation, histone modification,

Cite this as: Harits, M., Widjaja, N.A and Ardiana, M, (2024). Profile of Metabolic Syndrome Components in Obese Adolescents: Stunting Vs. Non-Stunting. The Indonesian Journal of Public Health, 19(2), 302-315. https://doi.org/10.20473/Ijph.v19i2.2024.302-315

 License doi: 10.20473/ijph.vl19i2.2024. 302-315 Received 21 June 2023, received in revised form 28 May 2024, Accepted 30 May 2024, Published online: August 2024. Publisher by Universitas Airlangga

and non-coding RNA (ncRNA) (Zhou et al., 2020).

Some propose that the mechanism for energy savings in stunted children is the change of lipid oxidation, leading to increased storage of excess fat in the body. (Al-Taiar et al., 2021), Mainly in the central region, there is a decrease in fat oxidation, a decrease in energy expenditure, and an increase in insulin resistance (Soliman et al., 2021), which then causes a triple-burden of malnutrition (Zentek et al., 2011). The term "coexistence" refers to the simultaneous presence of undernutrition (particularly stunting), micronutrient deficiency, and overnutrition, specifically overweight/obesity (Meenakshi, 2016), This increases the risk of several health problems, including poor cognitive function (undernutrition), coronary vascular diseases (CVD), type 2 diabetes mellitus (T2DM), hypertension, dyslipidemia, and childhood mortality (Sunuwar et al., 2020). The coexistence of undernutrition and overnutrition at the same time affects children (under 2 years old) and adolescents at critical nutritional periods (Rosdy and Sabri, 2022), with different levels (individual, household, and country) (Modjadji et al., 2022).

The "fetal origin hypothesis," which held that inadequate nutrition during pregnancy causes an adaptation to program future NCDs like obesity, type 2 diabetes, and cardiovascular disease, and postnatal nutrition raised the hypothesis known as "early origins" of adult disease, which holds that both overnutrition and undernutrition increase the risk of fatness (overweight/obesity) due to adiposity programming (Martorell et al., 2001). Due to insulin resistance (IR), being overweight or obese raises the chance of developing metabolic syndrome (MetS), a collection of interrelated risk factors for cardiovascular disease that includes dyslipidemia, hypertension, and hyperglycemia (Rochlani et al., 2018). The study revealed that an adult's height is associated with an increased risk of premature death. However, for every 6.5 cm increase in height, the risk of premature death from pulmonary embolism, ruptured aortic aneurysm, melanoma, and cancers of the pancreas, endocrine and nervous systems, ovary, breast, prostate, colorectum, blood, and lung was reduced by 3% (Emerging Risk Factors Collaboration, 2012). Overweight/obesity is defined as BMI (body mass index) more than the 85^{th} percentile in gender and age-specific charts. When the BMI was greater than the 99th percentile, it was considered as severe obesity. BMI was used due to it was correlated with adiposity and excess weight in population levels. But BMI did not quantify the total body adiposity (Güngör, 2014). Childhood BMI showed a specific pattern, in which, during the first years of life, there was a rapid increase. However, it decreased until roughly the age of six, at which point it increased once more, a phenomenon known as the "adiposity rebound" (Rolland-Cachera et al., 1984). Several studies have investigated the risk factors associated with the coexistence of stunting with overweight/obesity, including the child's age (6-23 months-old), maternal age ($\geq$ 28 years-old), childbirth order (+3 children) (Sebsbie et al., 2022), low socioeconomic status, maternal height (short), household size, maternal obesity (Fernald and Neufeld, 2007), and demographic and environmental factors (Hammoda et al., 2022). Nonetheless, it was discovered that a higher BMI in adolescence is linked to an early adiposity rebound (12 years old) (Koyama et al., 2014), and BMI correlated with the risk of T2DM (Eriksson et al., 2003) and CVD (Baker et al., 2007) in adult life.

MetS is a complex interaction of many intrinsic and extrinsic factors, such as visceral fat, chronic inflammation and insulin resistance, all of which impair the metabolic function. The pathophysiology encompasses several mechanisms, including genetic and epigenetic factors, lifestyle and environmental (eating habits, physical activity); all these factors cause a fat deposition in the abdominal region (visceral fats), which then triggers the metabolic alteration, including IR, chronic inflammation and neurohormonal activation (Fahed et al., 2022).

In this instance, the MetS profile of overweight/obese adolescents with and without stunting is compared, and the MetS component (fasting blood glucose, triglyceride, HDL-c, blood pressure) and anthropometric parameters (waist circumference, hip circumference, and waist-to-hip ratio) are correlated with the stunting parameters (HAZ). So the aim of this study is to compare the metabolic profile of obese adolescents with stunting and obese adolescents without stunting.

METHODS

An analytic observational study using cross-sectional design during October - December 2019 was conducted on overweight/obese adolescents aged 13-18 years old who studied in Senior and Junior High School in Surabaya and Sidoarjo, resulting in 339 subjects with normal, overweight and obese. The study used the global school-based student health survey to asses several behaviors, but we did not use it in this article, as the article reflects the differences of metabolic profile and the anthropometric measurements. Height-for-age z-score investigation was enrolled using WHO AnthroPlus (offline version, WHO) to assess stunting, and found 16 obese adolescents were stunted. Based on the results, we divide the subjects into two groups: stunted (16 subjects) vs. non-stunted (16 subjects) obese adolescents. The determination of stunted group was based on World Health Organization (WHO) criteria according to height-for-age z-score (HAZ) results; stunted was described as HAZ < -2.00 SD (de Onis and Branca, 2016).

The inclusion criteria for this study were: healthy overweight/obese adolescents aged 13-18 years-old, and willing to participate in this study by signing informed consent (done by the parents), did not smoke, did not consume alcohol or drugs. We excluded those who had hormone therapy, were taking lipidemias medication or other drugs that may affect the lipid profiles, body composition and blood pressure, had steroids therapy, or antibiotic therapy (had infections), and who had endocrine or immune disorders.

MetS was determined: 1. For adolescents aged 10-16 years old: if there was a central obesity (waist circumference $\geq$ 90th percentile based on WHO waist circumference table. For boys at the circumference of $\geq$ 88 cm, and $\geq$ 85 cm for girls) accompanied with at least two other signs: a. blood pressure $\geq$ 90th percentile (systole $\geq$130/diastole $\geq$ 85 mmHg); b. hypertriglyceridemia, if the triglyceride levels $\geq$ 110 mg/dl; c. low level HDL-c, if the HDL-c levels $\leq$ 40 mg/dl, and < 50 mg/dl for girls d. hyperglycemia, if fasting blood glucose (FBG) levels were $\geq$ 110 mg/dl. 2. For adolescents aged more than 16 years old: if there was a central obesity (waist circumference $\geq$ 90th percentile based on WHO waist circumference table. For boys at the circumference of $\geq$ 94 cm, and $\geq$ 80 cm for girls) accompanied with at least two other signs: a. blood pressure $\geq$ 90th percentile (systole $\geq$130/diastole $\geq$ 85 mmHg); b. hypertriglyceridemia, if the triglyceride levels $\geq$ 150 mg/dl; c. low level HDL-c, if the HDL-c levels <40 mg/dl for boys, and < 50 mg/dl for girls; d. hyperglycemia, if fasting blood glucose (FBG) levels were $\geq$ 100 mg/dl (Zimmet et al., 2007).

Subject numbers were determined by total sampling; due to the number of stunted being small, only 16 subjects; we used "fixed disease sampling," while, for non-stunted obese adolescents, we selected the subjects using simple random sampling (non-fixed sampling). The incidence of MetS in stunted with overweight/obesity was 18.75% (3/16), but this incidence was only seen in females, no MetS was found in males. For this reason, the obese adolescents were chosen by consecutive sampling for the MetS were also female (3/16) as described above.

The researchers visited the schools to present the health complications due to obesity to the parents with the permission of the schools head after the screening. The subjects were asked to fast for eight hours (last supper at 9 pm) before the blood were drawn via vena cubiti in the morning (8-9 am) by the laboratory employee. After the blood was taken for 10 ml, it was placed into a tube containing EDTA to examine blood glucose and lipid profile (HDL-c, LDL-c, triglyceride, and total cholesterol). After that the tubes containing blood samples were placed into a cooling box for transporting to the lab for further analysis using Elisa methods (Laboratorium Kedung Doro).

The anthropometric measurements used for screening include the following: height (Seca 213 stadiometer), waist circumference (Seca measuring tape 201), hip circumference (Seca measuring tape 201), and body weight (Seca Robusta 813 digital scale). Overweight/obesity was determined based on the WHO anthro plus offline version.

To ascertain the impact of HAZ on the MetS component and anthropometric measurements, statistical analysis was conducted using the test of normality and homogeneity ($p>0.05$ was considered normal and homogenous), independent sample T-test or Mann Whitney, Fischer exact test, Spearman Rho or Pearson correlation, and linear regression. The study has been registered for ethical clearance and declared to be appropriate by the Ethics Committee of Health Study of Dr. Soetomo General Hospital, Surabaya, on January 2, 2022, number: 0742/LOE/301.4.2/I/2022.

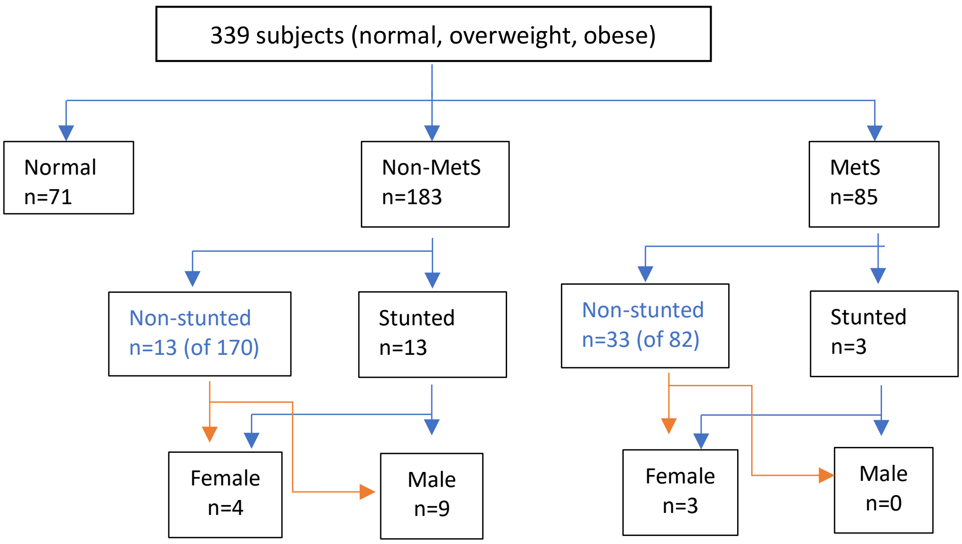

Figure 1. Flowchart for subject selection

RESULT

Due to the limited result of stunted (only 16 subjects), we only enrolled 32 subjects, as summarized in Table 1. Mean age for the study was 192.34 $\pm$ 6.80 months old, the youngest one was 161 months old, and the oldest one was 224 months old. There was no significant difference in age [192.62 (168-224) vs. 192.06 (161-224) months old, p=0.933], BMI-for-age z-score [2.91 (2.02-4.26) vs. 2.56 (2.00-3.56), p=0.101], body weight [76.78 (54.80-98.10) vs. 2.45 (640-106) kg, p=0.205], fasting blood glucose [87.56 (80-125) vs. 85.12 (80-91) mg/dl, p=0.820], lipid profile: total cholesterol [168.69 (127-208) vs. 176.75 (123-265) mg/dl, p=0.523], HDL-c [43.56 (25-57) vs. 44.50 (37-54) mg/dl, p=0.671], LDL-c 113.13 (76-146) vs. 115.62 (68-212) mg/dl, p=0.832] and triglyceride [98.63 (52-175) vs. 97.63 (32-260) mg/dl, p=0.956], diastolic blood pressure [81.87 (70-90) vs. 77.19 (60-100) mmHg, p=0.187], fasting insulin [18.45 (7.96-29.18) vs. 16.74 (4.47-30.31) µU/ml, p=0.525] and HOMA IR [4.03 (1.67-9.01) vs. 4.98 (1.72-22.34), p=0.519].

However, there was a notable variation in BMI [34.60 (26.80-45.09) vs. 31.11 (27.34-40.13) kg/m^2, p=0.040], waist-to-height ratio [0.63 (0.54-0.73) vs. 0.58 (0.52-0.64), p=0.005], hip circumference [111.27 (95-135) vs. 102.50 (87-114) cm, p=0.016] and systole blood pressure [124.37 (110-140) vs. 116.25 (100-130) mmHg, p=0.032] higher in stunted obese adolescents. The stunted group's waist-to-hip ratio was noticeably lower than the non-stunted group's [0.85 (0.69-0.97) vs. 0.92 (0.81-0.99), p=0.012].

There was no discernible change in the prevalence of obesity and overweight (p=0.220), MetS (p=1.000), abdominal obesity (p=0.722), hyperglycemia (p=1.000), low level of HDL-c (p=1.000), hypertriglyceridemia (p=1.000), and hypertension (p=0.716). This study also noted that the incidence of MetS in stunted subjects was higher in female adolescents (3 subjects), but not found in male (zero).

Table 1. Subjects' characteristics

Subjects' characteristics	**x ± SD n=32**	**Stunted (n=16) Median (min-max)**	**Non-stunted (n=16) Median (min-max)**	**p**
Age, months	192.34 ± 6.80	192.62 (168-224)	192.06 (161-224)	0.933[1]
Gender, n(%)				1.000[2]
- Male	18 (56.25)	9 (56.25)	9 (56.25)	
- Female	14 (43.75)	7 (43.75)	7 (43.75)	
BMI	32.85 ± 4.84	34.60 (26.80-45.09)	31.11 (27.34-40.13)	0.040[1*]
BMI-for-age z-score	2.73 ± 0.60	2.91 (2.02-4.26)	2.56 (2.00-3.56)	0.101[1]
Category of BMI-for-age z-score, n(%)				0.220[2]
- Overweight	24 (75)	10 (62.5)	14 (87.5)	
- Obesity	8 (25)	6 (37.5)	2 (12.5)	
Metabolic syndrome, n(%)				1.000[2]
- Metabolic syndrome	6 (18.75)	3 (18.75)	3 (18.75)	
- Non-metabolic syndrome	26 (81.25)	13 (81.25)	13 (81.25)	
Body weight, kg	79.62 ± 12.51	76.78 (54.80-98.10)	82.45 (640-106)	0.205[1]
Body height, cm	155 ± 8.25	148.90 (143-157)	161.09 (153-173)	0.000[1*]
HAZ	-1.47 ± 1.06	-2.35 (-2.82-(-2.01))	-0.58 (-1.50-1.28)	0.000[1*]
Waist circumference, cm	93.80 ± 8.45	93.81 (80.50-112)	93.78 (80-107)	0.992[1]

Subjects' characteristics	**x ± SD n=32**	**Stunted (n=16) Median (min-max)**	**Non-stunted (n=16) Median (min-max)**	**p**
Waist circumference criteria, n(%)				0.722[2]
- Abdominal obesity	29 (90.63)	10 (62.5)	14 (87.5)	
- Non-abdominal obesity	3 (9.37)	6 (37.5)	2 (12.5)	
Waist-to-height ratio	0.61 ± 0.05	0.63 (0.54-0.73)	0.58 (0.52-0.64)	0.005[1*]
Hip circumference, cm	106.89 ± 10.58	111.27 (95-135)	102.50 (87-114)	0.016[1*]
Waist-to-hip ratio	0.88 ± 0.08	0.85 (0.69-0.97)	0.92 (0.81-0.99)	0.012[1*]
Fasting blood glucose, mg/dl	86.34 ± 7.87	87.56 (80-125)	85.12 (80-91)	0.820[3]
Fasting blood glucose criteria, n(%)				1.000[2]
- Hyperglycemia	1 (3.13)	1 (18.25)	0 (0)	
- Normal blood glucose	31 (96.87)	15 (93.75)	16 (100)	
Total cholesterol, mg/dl	172.71 ± 34.99	168.69 (127-208)	176.75 (123-265)	0.523[1]
HDL-c, mg/dl	44.03 ± 6.10	43.56 (25-57)	44.50 (37-54)	0.671[1]
HDL-c category, n(%)				1.000[2]
- Low level of HDL-c	19 (59.38)	10 (62.5)	9 (56.25)	
- Normal HDL-c	13 (40.62)	6 (37.5)	7 (43.75)	
LDL-c, mg/dl	114.38 ± 32.55	113.13 (76-146)	115.62 (68-212)	0.832[1]
Triglyceride, mg/dl	98.13 ± 50.12	98.63 (52-175)	97.63 (32-260)	0.956[1]
Triglyceride category, n(%)				1.000[2]
- Hypertriglyceridemia	5 (15.63)	2 (12.5)	3 (18.75)	
- Non-hypertriglyceridemia	27 (84.37)	14 (87.5)	13 (81.25)	
Systole blood pressure, mmHg	120.31 ± 10.85	124.37 (110-140)	116.25 (100-130)	0.032[1*]
Diastole blood pressure, mmHg	79.53 ± 8.83	81.87 (70-90)	77.19 (60-100)	0.187[3]
Blood pressure category, n(%)				0.716[2]
- Hypertension	12 (37.5)	7 (43.75)	5 (31.25)	
- Normal	20 (62.5)	9 (56.25)	11 (68.75)	
Fasting Insulin, µU/ml	17.54 ± 6.82	18.45 (7.96-29.18)	16.74 (4.47-30.31)	0.525[1]
HOMA IR	4.54 ± 3.84	4.03 (1.67-9.01)	4.98 (1.72-22.34)	0.519[1]

[1]Independent sample T-test; [2]Fischer exact test; [3]Mann-Whitney U test, *significant if p>0.05

Table 2 summarizes the correlation of HAZ as the indicator of stunting with anthropometrics and MetS component, which shows that HAZ was correlated negatively with BMI (r=-0.358, p=0.044) and correlated positively with hip circumference (r=0.215, p=0.023). However, HAZ did not correlate with other MetS parameters, including waist circumference, blood pressure, HDL-c, triglyceride, and fasting blood glucose (p>0.05).

Table 2. Correlation and linear regression between HAZ with anthropometric measurements and MetS component

Anthropometric and MetS component	**r**	**p**	**Constanta**	**β**	**Standardized coefficient β**	**R**	**R^2**
BMI	-0.358	0.044*	1.115	-0.079	-0.358	0.358	0.128
BMI-for-age z-score	-0.246	0.175	-0.273	-0.437	-0.246	0.246	0.060
Waist circumference	0.215	0.237	-4.005	0.027	0.215	0.215	0.046
Hip circumference	-0.198	0.277	0.660	-0.020	-0.198	0.198	0.039
Waist-to-hip ratio	0.401	0.023*	-6.162	5.324	0.401	0.401	0.161
Fasting blood glucose	-0.166	0.364	0.466	-0.022	-0.166	0.166	0.028
HDL-c	0.160	0.381	-2.695	0.028	0.160	0.160	0.026
Triglyceride	-0.147	0.421	-1.161	-0.003	-0.147	0.147	0.022
Systole blood pressure	-0.317	0.077	2.263	-0.031	-1.829	0.317	0.100
Diastole blood pressure	-0.222	0.223	0.651	-0.027	-0.222	0.222	0.049

*Significant if p<0.05

DISCUSSION

There are several points to be highlighted in this study. First, MetS was experienced by stunted obese female adolescents; obese and stunting adolescents had higher BMI, waist-to-height ratio, hip circumferences and waist-to-hip ratio.

Our study reveals that MetS in stunting with obesity was only experienced by females, even though the number was small (3 of 16 subjects). In a Sao Paolo study, it was discovered that. while female stunted children gained less lean mass and had a larger percentage of fat mass than normal children, male stunted children gained more fat but gained less lean mass (Martins et al., 2004). But a statement said that short stature on women had negative effects, and increases the cardiovascular disease (Parker et al., 1998), which means indirectly that stunting women are likely more susceptible to be obese with MetS than men. It was also stated that MetS component is common in individuals with percentage of body fat more than 25% in males or above 30% in females (Özdemir, 2015). This pattern revealed that the distribution and metabolism of fat mass differed between the sexes, with women having a higher percentage of body fat than men. Women store fat mostly in the gluteal-femoral region, whereas men store it predominantly in the visceral region (Gavin and Bessesen, 2020). But, subcutaneous fat distribution was found to be higher at the biceps and subscapular location, and to tend to accumulate on the upper half of the body (trunk or arms) in a research on stunted Senegalese female adolescents (Bénéfice et al., 2001). However this study was enrolled in normal stunting adolescents, not in overweight/obese stunting adolescents.

Stunting adolescents tend to have higher BMI as they have lower fat oxidation than non-stunting adolescents. It counted as 9% lower fasting fat oxidation (Hoffman et al., 2000). A study also noted that stunted children had higher body fat and BMI than non-stunted as the result of energy savings (metabolic efficiency) or low energy expenditure due to lack of nutrition intake (Savanur and Ghugre, 2016). Others also highlight that stunted children had high respiratory quotient and carbohydrate oxidation (Muhammad, 2018).

Overweight/ obese stunting adolescents had larger hip circumference than non-stunting obese adolescents. In this instance, we propose that there was a disparity in the distribution of fat between teenage girls and boys. Central obesity is predominant in boys due to fat distribution tends to occur on the upper body segmentation (android segment), especially on the abdomen area. Testosterone causes a specific subcutaneous deposit due to catecholamine-stimulated lipolysis specifically, time- and concentration-dependent in fat cells (Gavin dan Bessesen, 2020). Testosterone has specific receptors which, in certain conditions will cause the reduction of β-adrenergic receptors (Holland et al., 2016). For girls, the fat accumulation happens on hips and thighs or gynecoid segment. Naturally girls in puberty stage have bigger hip and thighs due to fat distribution, and total fat distribution is bigger on the pelvis area compared to boys (Bacopoulou et al., 2015; Link and Reue, 2017; Rodd and Sharma, 2016).

Stunting in early life has been hypothesized to be MetS in adult life due to the alteration in body composition (Rolfe et al., 2018). However, the scientific evidence is still contradicted. An investigation of childhood stunting toward MetS has been conducted in Brazilian young adults stated that stunting was not associated with MetS components. However, this study shows that. while stunting had a negative association with waist circumference, triglycerides, and HDL-c in women.it had a positive association with triglycerides in males (Grillo et al., 2016).

Other study revealed that fasting respiratory quotation was higher, while resting energy expenditure (REE) and postprandial thermogenesis was comparable with normal children, which reflected that stunting children had lower fasting fat oxidation, but higher carbohydrate oxidation (Muhammad, 2018). This condition made the stunted adolescents vulnerable to raised BMI. Even mild stunting (HAZ <-1.4 SD) made the sufferer susceptible to overweight/obese due to high fat diet (Sawaya et al., 1995). As stated by Popkin et al. (1996), stunted children had 1.7 to 7.8-fold chance for being overweight/ obese , due to body fat gain rather than lean mass gain (Martins et al., 2004).

A study in Iran, assessing the effect of short stature (stunting after 5 years-old) found that the prevalence of abdominal obesity, hypertension and MetS was greater than those with normal height and weight (Safari et al., 2021). But this study did not compare the effect of short stature on MetS component.

Our study found that hip circumference was significantly higher in stunting obese adolescents, but other study reveals no significant difference on hip circumference (Reid et al., 2018). We suspect that puberty was impacting on this hip circumference. A study in adolescents showed that boys had fat deposits in central body, while girls had them in gynoid area (Staiano and Katzmarzyk, 2012). However, two-way Anova showed that gender did not contribute to hip circumference (106.89 vs. 116.91 cm in male and female respectively), p=0.561), but stunting was significantly contributed (p=0.005). When the analysis was divided based on gender, female subjects with stunting had wider hip circumference than female non-stunting (116.91 [99-135] vs. 99.00 [87-113] cm, p=0.009), but there was no significant difference in male in both stunting and non-stunting (106.89 [95-121] vs. 105.22 [95-114], p=0.664). Stunted girls tend to gain subcutaneous fat more than non-stunted girls (Kruger, 2005), and, in short stature adults, women had higher risk of being overweight and higher sitting weight ratio. Children with stunting exhibited a larger ratio of the head to the trunk and a slower rate of growth in the tibia (Henriques et al., 2018).

According to another study, adolescents with mild stunting accumulated more fat in their abdomens and had higher levels of insulin and HOMA IR than adolescents without the condition of stunting (Santos et al., 2010), but our study showed that both stunting and non-stunting obese adolescents had similar waist circumference. Waist circumference was used to estimate the prevalence of central obesity and forecast the occurrence of non-communicable illnesses (NCDs) (Schwandt and Haas, 2012). A study also noted that central obesity was common in female adolescents (Kimani-Murage et al., 2010). However, in stunting subjects aged 9-19 years old (HAZ<-1.00 until -2.00 SD), there was an increment of insulin at a lower waist circumference (58.25 cm) (Santos et al., 2010). According to other research included here, one of the main metabolic changes in stunting people is an increase in plasma insulin, which can be detected at a lower WC cut-off point than in non-stunting people.

Non-stunting children and adolescents had higher waist circumference than stunting children and adolescents, but insulin concentration was significantly higher in stunting. While other MetS components showed no significant different, except fasting blood glucose, it was higher in stunting compared to non-stunting but there was no significant difference (Clemente et al., 2014). Based on those studies, in the case of stunting, we cannot use waist circumference for assessing MetS or insulin resistance. Therefore, additional anthropometric measurements like the waist-to-hip ratio or hip circumference may be helpful. Nonetheless, a research found no discernible variation in the waist-to-hip ratio between stunted and non-stunting individuals (Naude et al., 2010; Wilson et al., 2011), but waist-to-height ratio was significantly higher in stunting children (cut-off was 0.5). In adolescents with short stature it showed that short stature adolescents had larger waist-to-height ratios (Fayasari et al., 2019), which indicated abdominal obesity (Naude et al., 2010). Other study also noted that stunted children had higher body fat, waist-to-height ratios and BMI (Savanur and Ghugre, 2016). In the case of BMI, the study was in line with ours. In Maya community children, BMI has a strong predictor value to represent adiposity indicators, particularly abdominal obesity, but sitting height had bad predictors (Wilson et al., 2011). Additionally, it was discovered that children who were stunted at the age of two had a higher BMI at the age of seventeen than those who were not (Walker et al., 2007).

A study in stunted orphanage children at adolescence showed that the stunting children had higher systolic blood pressure (116.9 vs. 106.6 mmHg, p=0.108) (Reid et al., 2018), which was in line with this study. However, compared to non-stunting, other indicators like insulin, triglycerides, total cholesterol, low-density lipoprotein cholesterol, and HOMA-IR were significantly higher (Reid et al., 2018), which was in contrast with this study. It was apparent that taller individuals lived longer than shorter ones. Height has been linked with atherosclerosis-related risks for stroke and coronary heart disease (CHD). (Smith et al., 2000). Height correlated negatively with systolic and diastolic blood pressure (Dyer et al., 1990). Shorter height was associated with hypertension in adult population. Also, it was found that 10 cm increment of height, had a protective effect against hypertension by 10% (Das Gupta et al., 2019). A study in adolescents showed that systolic correlated with weight, while height was correlated with diastolic blood pressure. However this result was sex dependent and correlated with waist circumference (Song, 2014).

This study had many limitations such as it did not investigates the role of hypoadiponectinemia in MetS pathological mechanisms, or other external factors such as dietary habits, physical activity, and sleep duration.

CONCLUSIONS

Overweight or obese adolescents who are stunted have higher BMI compared to overweight or obese adolescents who are not stunted. Additionally, stunted overweight or obese adolescents also have higher waist-to-height ratio, hip circumference, waist-to-hip ratio, and systolic blood pressure compared to non-stunted overweight or obese adolescents. The height-for-age z-score showed a correlation with both BMI and waist-to-hip ratio.

REFERENCES

Al-Taiar, A., Alqaoud, N., Sharaf Alddin, R., Alanezi, F., Subhakaran, M., Dumadag, A., Albatineh, A.N., 2021. Stunting and Combined Overweight with Stunting among Schoolchildren in Kuwait: Trends over a 13-Year Period. *Med. Princ. Pract*. 30, 515–521. https://doi.org/10.1159/000518533

Bacopoulou, F., Efthymiou, V., Landis, G., Rentoumis, A., Chrousos, G.P., 2015. Waist circumference, waist-to-hip ratio and waist-to-height ratio reference percentiles for abdominal obesity among Greek adolescents. *BMC Pediatr*. 15, 1–9. https://doi.org/10.1186/s12887-015-0366-z

Baker, J.L., Olsen, L.W., Sørensen, T.I.A., 2007. Childhood Body-Mass Index and the Risk of Coronary Heart Disease in Adulthood. *N. Engl. J. Med*. 357, 2329–2337. https://doi.org/10.1056/NEJMoa072515

Bénéfice, E., Garnier, D., Simondon, K.B., Malina, R.M., 2001. Relationship between stunting in infancy and growth and fat distribution during adolescence in Senegalese girls. *Eur. J. Clin. Nutr*. 55, 50–58. https://doi.org/10.1038/sj.ejcn.1601121

Clemente, A.P.G., Santos, C.D.D.L., Martins, V.J.B., Albuquerque, M.P., Fachim, M.B., Sawaya, A.L., 2014. Lower waist circumference in mildly-stunted adolescents is associated with elevated insulin concentration. *J. Pediatr. (Rio. J)*. 90, 479–485. https://doi.org/10.1016/j.jped.2014.01.015

Das Gupta, R., Haider, S.S., Hashan, M.R., Rahman, M.A., Sarker, M., 2019. Association between height and hypertension in the adult Nepalese population: Findings from a nationally representative survey. *Heal. Sci. Reports* 2, 1–7. https://doi.org/10.1002/hsr2.141

de Onis, M., Branca, F., 2016. Childhood stunting: A global perspective. *Matern. Child Nutr*. 12, 12–26. https://doi.org/10.1111/mcn.12231

Dyer, A.R., Elliott, P., Shipley, M., 1990. Body Mass Index versus Height and Weight in Relation to Blood Pressure. *Am. J. Epidemiol*. 131, 589–596. https://doi.org/10.1093/oxfordjournals.aje.a115543

Emerging Risk Factors Collaboration, 2012. Adult height and the risk of cause-specific death and vascular morbidity in 1 million people: Individual participant meta-analysis. *Int. J. Epidemiol*. 41, 1419–1433. https://doi.org/10.1093/ije/dys086

Eriksson, J.G., Forsén, T., Tuomilehto, J., Osmond, C., Barker, D.J.P., 2003. Early adiposity rebound in childhood and risk of Type 2 diabetes in adult life. *Diabetologia* 46, 190–194. https://doi.org/10.1007/s00125-002-1012-5

Fahed, G., Aoun, L., Zerdan, Morgan Bou, Allam, S., Zerdan, Maroun Bou, Bouferraa, Y., Assi, H.I., 2022. Metabolic Syndrome: Updates on Pathophysiology and Management in 2021. *Int. J. Mol. Sci.* 23. https://doi.org/10.3390/ijms23020786

Fayasari, A., Huriyati, E., Julia, M., 2019. Body Composition of Adolescent of Shorter Stature. *Pakistan J. Nutr.* 18, 711–715. https://doi.org/10.3923/pjn.2019.711.715

Fernald, L.C., Neufeld, L.M., 2007. Overweight with concurrent stunting in very young children from rural Mexico: Prevalence and associated factors. *Eur. J. Clin. Nutr.* 61, 623–632. https://doi.org/10.1038/sj.ejcn.1602558

Gavin, K.M., Bessesen, D.H., 2020. Sex Differences in Adipose Tissue Function. *Endocrinol Metab Clin North Am* 49, 215–228. https://doi.org/10.1016/j.ecl.2020.02.008

Grillo, L.P., Gigante, D.P., Horta, B.L., De Barros, F.C.F., 2016. Childhood stunting and the metabolic syndrome components in young adults from a Brazilian birth cohort study. *Eur. J. Clin. Nutr.* 70, 548–553. https://doi.org/10.1038/ejcn.2015.220

Güngör, N.K., 2014. Overweight and obesity in children and adolescents. JCRPE *J. Clin. Res. Pediatr. Endocrinol.* 6, 129–143. https://doi.org/10.4274/jcrpe.1471 1

Hammoda, A.., El Sallamy, R., Atlam, S.-E., Alshishtawy, M., 2022. A study of risk factors contributing to the occurrence of excess weight with concurrent stunting in preschool children in Egypt. *Tanta Med. J.* 50, 48. https://doi.org/10.4103/tmj.tmj_118_21

Henriques, A., Teixeira, V., Cardoso, H.F.V., Azevedo, A., 2018. The influence of stunting on obesity in adulthood: Results from the EPIPorto cohort. *Public Health Nutr.* 21, 1819–1826. https://doi.org/10.1017/S1368980018000460

Hoffman, D.J., Sawaya, A.L., Verreschi, I., Tucker, K.L., Roberts, S.B., 2000. Why are nutritionally stunted children at increased risk of obesity? Studies of metabolic rate and fat oxidation in shantytown children from Sao Paulo, Brazil. *Am. J. Clin. Nutr.* 72, 702–707. https://doi.org/10.1093/ajcn/72.3.702

Holland, A.M., Roberts, M.D., Mumford, P.W., Mobley, C.B., Kephart, W.C., Conover, C.F., Beggs, L.A., Balaez, A., Otzel, D.M., Yarrow, J.F., Borst, S.E., Beck, D.T., 2016. Testosterone inhibits expression of lipogenic genes in visceral fat by an estrogen-dependent mechanism. *J. Appl. Physiol.* 121, 792–805. https://doi.org/10.1152/japplphysiol.00238.2016

Kimani-Murage, E.W., Kahn, K., Pettifor, J.M., Tollman, S.M., Dunger, D.B., Gómez-Olivé, X.F., Norris, S.A., 2010. The prevalence of stunting, overweight and obesity, and metabolic disease risk in rural South African children. *BMC Public Health* 10, 1–13. https://doi.org/10.1186/1471-2458-10-158

Koyama, S., Ichikawa, G., Kojima, M., Shimura, N., Sairenchi, T., Arisaka, O., 2014. Adiposity rebound and the development of metabolic syndrome. *Pediatrics* 133. https://doi.org/10.1542/peds.2013-0966

Kruger, H.S., 2005. Stunted girls have greater subcutaneous fat deposits: What type of intervention can improve the health of stunted children? *Nutrition* 21, 1153–1155. https://doi.org/10.1016/j.nut.2005.07.001

Link, J.C., Reue, K., 2017. Genetic Basis for Sex Differences in Obesity and Lipid Metabolism. *Annu. Rev. Nutr*. 37, 225–245. https://doi.org/10.1146/annurev-nutr-071816-064827

Martins, P.A., Hoffman, D.J., Fernandes, M.T.B., Nascimento, C.R., Roberts, S.B., Sesso, R., Sawaya, A.L., 2004. Stunted children gain less lean body mass and more fat mass than their non-stunted counterparts: a prospective study. *Br. J. Nutr*. 92, 819–825. https://doi.org/10.1079/BJN20041274

Martorell, R., Stein, A.D., Schroeder, D.G., 2001. Early nutrition and later adiposity. *J. Nutr*. 131, 874S-880S. https://doi.org/10.1093/jn/131.3.874S

Meenakshi, J. V., 2016. Trends and patterns in the triple burden of malnutrition in India. *Agric. Econ*. (United Kingdom) 47, 115–134. https://doi.org/10.1111/agec.12304

Minh Do, L., Lissner, L., Ascher, H., 2018. Overweight, stunting, and concurrent overweight and stunting observed over 3 years in Vietnamese children. *Glob. Health Action* 11. https://doi.org/10.1080/16549716.2018.1517932

Modjadji, P., Masilela, L.N., Cele, L., Mathibe, M., Mphekgwana, P.M., 2022. Evidence of Concurrent Stunting and Obesity among Children under 2 Years from Socio-Economically Disadvantaged Backgrounds in the Era of the Integrated Nutrition Programme in South Africa. *Int. J. Environ. Res. Public Health* 19. https://doi.org/10.3390/ijerph19192501

Muhammad, H.F.L., 2018. Obesity as the Sequel of Childhood Stunting: Ghrelin and GHSR Gene Polymorphism Explained. *Acta Med. Indones*. 50, 159–164.

Naude, D., Kruger, H., Pienaar, A., 2010. Differences in body composition, body proportions and timing of puberty between stunted and non-stunted adolescents. *African J. Phys. Heal. Educ. Recreat. Danc*. 15. https://doi.org/10.4314/ajpherd.v15i4.49554

Özdemir, A., 2015. Adolescent obesity. *Int. J. Caring Sci*. 8, 484–487.

Parker, D.R., Lapane, K.L., Lasater, T.M., Carleton, R.A., 1998. Short stature and cardiovascular disease among men and women from two southeastern New England communities. *Int. J. Epidemiol*. 27, 970–975. https://doi.org/10.1093/ije/27.6.970

Popkin, B.M., Richards, M.K., Montiero, C.A., 1996. Stunting is associated with overweight in children of four nations that are undergoing the nutrition transition. *J. Nutr*. 126, 3009–3016. https://doi.org/10.1093/jn/126.12.3009

Reid, B.M., Harbin, M.M., Arend, J.L., Kelly, A.S., Dengel, D.R., Gunnar, M.R., 2018. Early Life Adversity with Height Stunting Is Associated with Cardiometabolic Risk in Adolescents Independent of Body Mass Index. *J Pediatr*. 202, 143–149. https://doi.org/10.1016/j.jpeds.2018.06.047

Rochlani, Y., Pothineni, N.V., Kovelamudi, S., Mehta, J.L., 2018. Metabolic syndrome: pathophysiology, management, and modulation by natural compounds. Ther. Adv. *Vaccines* 9, 259–261. https://doi.org/10.1177/1753944717711379

Rodd, C., Sharma, A.K., 2016. Recent trends in the prevalence of overweight and obesity among Canadian children. *CMAJ* 188, E313–E320. https://doi.org/10.1503/cmaj.150854

Rolfe, E.D.L., França, G.V.A. de, Vianna, C.A., Gigante, D.P., Miranda, J.J., Yudkin, J.S., Horta, B.L., Ong, K.K., 2018. Associations of stunting in early childhood with cardiometabolic risk factors in adulthood. *PLoS One* 13, 1–13. https://doi.org/10.1371/journal.pone.0192196

Rolland-cachera, M., Patois, E., Bellisle, F., Semp, M., 1984. Adiposity rebound in children: A simple indicator for predicting obesity. *Am. J. Clin. Nutr.* 39, 129–135. https://doi.org/10.1093/ajcn/39.1.129

Rosdy, N.M.M.N.M., Sabri, B.A.M., 2022. Addressing the Double Burden of Malnutrition using the Life Course Perspective. *Malaysian J. Med. Heal. Sci.* 18, 305–310. https://doi.org/10.47836/mjmhs.18.6.39

Sachdev, H.S., Porwal, A., Sarna, A., Acharya, R., Ramesh, S., Kapil, U., Kurpad, A. V., 2021. Intraindividual double-burden of anthropometric undernutrition and “metabolic obesity” in Indian children: a paradox that needs action. *Eur. J. Clin. Nutr.* 75, 1205–1217. https://doi.org/10.1038/s41430-021-00916-3

Safari, O., Ejtahed, H.S., Namazi, N., Heshmat, R., Arjmand, R., Karbalahi Saleh, S., Seif, E., Shahsanai, A., Motlagh, M.E., Esmaeili Abdar, M., Qorbani, M., Kelishadi, R., 2021. Association of short stature and obesity with cardio-metabolic risk factors in Iranian children and adolescents: the CASPIAN-V study. *J. Diabetes Metab. Disord.* 20, 1137–1144. https://doi.org/10.1007/s40200-021-00831-1

Santos, C.D.D.L., Clemente, A.P.G., Martins, V.J.B., Albuquerque, M.P., Sawaya, A.L., 2010. Adolescents with mild stunting show alterations in glucose and insulin metabolism. J. *Nutr. Metab.* 2010. https://doi.org/10.1155/2010/943070

Savanur, M.S., Ghugre, P.S., 2016. BMI, body fat and waist-to-height ratio of stunted v. non-stunted Indian children: A case-control study. *Public Health Nutr.* 19, 1389–1396. https://doi.org/10.1017/S1368980016000215

Sawaya, A.L., Dallalj, G., Solymos, G., Sousa, M.H. de, Ventura, M.L., Roberts, S.B., Sigulem, D.M., 1995. Obesity and malnutrition in a Shantytown population in the city of Sao Paulo, Brazil. *Obes. Res.* 3 Suppl 2, 107s-115s. https://doi.org/10.1002/j.1550-8528.1995.tb00453.x

Schwandt, P., Haas, G.-M., 2012. Waist Circumference in Children and Adolescents from Different Ethnicities. In Yuca, S..A. (ed.), *Childhood Obesity*. https://doi.org/10.5772/17936

Sebsbie, A., Minda, A., Ahmed, S., 2022. Co-existence of overweight/obesity and stunting: it’s prevalence and associated factors among under - five children in Addis Ababa, Ethiopia. *BMC Pediatr.* 22, 1–10. https://doi.org/10.1186/s12887-022-03445-5

Smith, G.D., Hart, C., Upton, M., Hole, D., Gillis, C., Watt, G., Hawthorne, V., 2000. Height and risk of death among men and women: Aetiological implications of associations with cardiorespiratory disease and cancer mortality. *J. Epidemiol. Community Health* 54, 97–103. https://doi.org/10.1136/jech.54.2.97

Soliman, A., De Sanctis, V., Alaaraj, N., Ahmed, S., Alyafei, F., Hamed, N., Soliman, N., 2021. Early and long-term consequences of nutritional stunting: From childhood to adulthood. *Acta Biomed*. 92, 1–12.

Song, Y.H., 2014. The correlation of blood pressure with height and weight in Korean adolescents aged 10-19 years; The Korean National Health and Nutrition Examination Surveys (2009-2011). *Korean J. Pediatr*. 57, 35–40. https://doi.org/10.3345/kjp.2014.57.1.35

Ssentongo, P., Ssentongo, A.E., Ba, D.M., Ericson, J.E., Na, M., Gao, X., Fronterre, C., Chinchilli, V.M., Schiff, S.J., 2021. Global, regional and national epidemiology and prevalence of child stunting, wasting and underweight in low- and middle-income countries, 2006–2018. *Sci. Rep*. 11, 1–12. https://doi.org/10.1038/s41598-021-84302-w

Staiano, A.E., Katzmarzyk, P.T., 2012. Ethnic and sex differences in body fat and visceral and subcutaneous adiposity in children and adolescents. *Int. J. Obes*. 36, 1261–1269. https://doi.org/10.1038/ijo.2012.95

Sunuwar, D.R., Singh, D.R., Pradhan, P.M.S., 2020. Prevalence and factors associated with double and triple burden of malnutrition among mothers and children in Nepal: Evidence from 2016 Nepal demographic and health survey. *BMC Public Health* 20, 1–11. https://doi.org/10.1186/s12889-020-8356-y

Walker, S., Chang, S., Powell, C., 2007. The association between early childhood stunting and weight status in late adolescence. *Int. J. Obes*. 31, 347–352. https://doi.org/10.1038/sj.ijo.0803383

Wilson, H.J., Dickinson, F., Griffiths, P.L., Azcorra, H., Bogin, B., Inês Varela-Silva, M., 2011. How useful is BMI in predicting adiposity indicators in a sample of Maya children and women with high levels of stunting? *Am. J. Hum. Biol*. 23, 780–789. https://doi.org/10.1002/ajhb.21215

Yasmin, G., Kustiyah, L., Dwiriani, C.M., 2019. Stunted Children Has Higher Risk of Overweight: A Study on Children Aged 6-12 Years in Eight Provinces in Indonesia. *Pakistan J. Nutr*. 18, 455–463. https://doi.org/10.3923/pjn.2019.455.463

Zentek, J., Buchheit-Renko, S., Ferrara, F., Vahjen, W., Van Kessel, A.G., Pieper, R., 2011. Nutritional and physiological role of medium-chain triglycerides and medium-chain fatty acids in piglets. *Anim. Health Res. Rev*. 12, 83–93. https://doi.org/10.1017/S1466252311000089

Zhou, L.Y., Deng, M.Q., Zhang, Q., Xiao, X.H., 2020. Early-life nutrition and metabolic disorders in later life: a new perspective on energy metabolism. *Chin. Med. J*. (Engl). 133, 1961–1970. https://doi.org/10.1097/CM9.0000000000000976

Zimmet, P., Alberti, G.K.M.M., Kaufman, F., Tajima, N., Silink, M., Arslanian, S., Wong, G., Bennett, P., Shaw, J., Caprio, S., 2007. The metabolic syndrome in children and adolescents - An IDF consensus report. *Pediatr. Diabetes* 8, 299–306. https://doi.org/10.1111/j.1399-5448.2007.00271.x