



Published by DiscoverSys

Blood pressure and glomerular filtration rate in obese adolescents



CrossMark

Gusti Ayu Putu Sri Satya Mahayani^{1*}, I Made Arimbawa¹, Ida Bagus Subanada¹,
I Wayan Dharma Artana¹, I Nyoman Budi Hartawan¹, I Ketut Suarta¹

ABSTRACT

Background: Obesity in children has the potential to increase the risk of morbidity and even death in the future. One of the diseases that are at risk due to obesity is hypertension and also impaired kidney function. Glomerular filtration rate differences in obese and normal-weight children are somehow contradictory. This study aims to prove the difference in blood pressure and kidney function in adolescents with obese and non-obese.

Methods: A cross-sectional study was conducted among high school children in Denpasar. Subjects were classified as obese and non-obese. The Mann-Whitney test was used to assess the mean difference of blood pressure, whereas the Independent t-test was used to determine the mean difference of GFR. Multivariate analysis was performed with logistic regression and ANCOVA. Data were

analyzed using SPSS version 20 for Windows.

Results: A total of 68 subjects with obese and 52 subjects with non-obese were included in this study. Systolic and diastolic blood pressure in the obese group was higher than in a non-obese group, with the mean difference in systolic and diastolic blood pressure was 29 mmHg ($P < 0.001$) and 18 mmHg ($P = 0.002$), respectively. Obesity increases the risk of hypertension 9.78 times (95% CI: 1.86-51.39; $P = 0.007$), and obese adolescents have an average GFR of 11.51 lower than non-obese (95% CI: 17.32 – (-5.69); $P < 0.001$).

Conclusion: Hypertension is higher in obese adolescents than non-obese, while glomerular filtration rate is lower than non-obese adolescents.

Keywords: Obesity, Hypertension, Glomerular Filtration Rate, Adolescents

Cite this Article: Mahayani, G.A.P.S.S., Arimbawa, I.M., Subanada, I.B., Artana, I.W.D., Hartawan, I.N.B., Suarta, I.K. 2020. Blood pressure and glomerular filtration rate in obese adolescents. *Bali Medical Journal* 9(3): 844-848. DOI: [10.15562/bmj.v9i3.2061](https://doi.org/10.15562/bmj.v9i3.2061)

¹Department of Child Health,
Faculty of Medicine, Universitas
Udayana, Sanglah General
Hospital, Denpasar, Bali, Indonesia

INTRODUCTION

Hypertension (HT) has long been known as a health problem. In adolescents, hypertension is also a problem because adolescents who experience hypertension can continue into adulthood and have a high risk of morbidity and mortality.¹ The risk factors for HT include obesity, family history of HT, change in dietary habits, decreased physical activity, and increasing stress.¹

Obesity is a disorder characterized by excessive accumulation of body fat tissue, increasing in prevalence and is a health problem throughout the world.^{2,3} The majority of obesity in children and adolescents has increased in various countries, including Indonesia.^{3,4} Obesity in children and adolescents is estimated to increase the risk of hypertension 3-5 times, and there is a positive relationship between obesity in children with hypertension as reported in various countries.²⁻⁵

There is clear evidence of an association between being overweight and an increased risk of kidney disease in adults.⁵ The same relationship is also seen in children and adolescents who are obese, although there are still conflicts about glomerular filtration rate (GFR) in children with obese and non-obese. Obesity is a risk factor for the development and progression of kidney disease, which can still be modified.^{4,5} Efforts to prevent obesity and treat

obese children and adolescents have a considerable impact on the incidence, development, and comorbidities of kidney disease. The present study was conducted to prove the difference in blood pressure and kidney function in adolescents with obese and non-obese.

METHODS

A cross-sectional study was conducted among high school children in Denpasar aged 15-17 years from October 2019 until April 2020. Eligible subjects were enrolled by *consecutive sampling* and agreed to participate in the study. Exclusion criteria were subjects with Diabetes Mellitus (DM) and didn't come when taking the blood serum. The final sample included 4 high schools in Denpasar, representing 4 districts in Denpasar. Written informed consent was obtained from the parents of all the participating children.

Height percentile and body mass index (BMI) percentile were determined by using Centres for Disease Control (CDC) growth charts (2–20 years, CDC and Prevention growth charts, USA): obesity was defined as BMI $\geq 95^{\text{th}}$ percentile, and non-obese was BMI $< 95^{\text{th}}$ percentile for age and gender.⁶ The diagnosis and classification of hypertension were based on 'The 4th Report on Diagnosis, Evaluation and Treatment of High Blood pressure (BP) in

*Corresponding to:
Gusti Ayu Putu Sri Satya Mahayani;
Department of Child Health,
Faculty of Medicine, Universitas
Udayana, Sanglah General
Hospital, Denpasar, Bali, Indonesia;
satya.mahayani@gmail.com

Table 1. Characteristics of subjects based on nutritional status

Variable	Groups (N=120)	
	Obese (n=68)	Non-Obese (n=52)
Gender, n (%)		
Boys	33 (63.5)	19 (36.5)
Girls	35 (51.5)	33 (48.5)
Age (Years), n (%)		
15 years	10 (43.5)	13 (56.5)
16 years	54 (72)	21 (28)
17 years	4 (18.2)	18 (81.8)
Weight (kg) (mean±SD)	68.2±9.5	58.1±6.5
Height (cm), median (min-max)	165 (147-183)	165 (150-181)
Family history, n (%)		
Present	23 (71.9)	9 (28.1)
None	45 (51.1)	43 (48.9)
Salt intake (g/day), median (min-max)	4.0 (2.8-5.8)	3.3 (2.6-5.4)

Table 2. Distribution of hypertension based on nutritional status

Variable	Groups (N=120)		PR	95% CI	p
	Hypertension (N=31)	Non-Hypertension (N=89)			
Obese, n (%)					
Yes	26 (38.2)	42 (61.8)	3.97	1.6-9.6	<0.001*
No	5 (9.6)	47 (90.4)			

CI= confidence interval; PR= prevalence ratio; *Statistically significant if p-value less than 0.05

Table 3. Distribution of GFR value based on nutritional status

Variable	Mean±SD	Mean Difference	95% CI	P
GFR (ml/min/1.73 m ²)				
Obese	129.05±15.25	-12.62	-18.56 –	<0.001*
Non-Obese	141.67 (17.53)		(-6.68)	

CI=confidence interval; SD=standard deviation; GFR: glomerular filtration rate; *Statistically significant if p-value less than 0.05

Table 4. Comparison of blood pressure based on nutritional status

Variable	Obese (n=68)	Non-obese (n=52)	Mean rank	P
Systolic BP (mmHg), median (min-max)	120 (97-150)	110 (90-130)	29.24	<0.001*
Diastolic BP (mmHg), median (min-max)	80 (60-90)	70 (60-112)	18.56	0.002*

*Mann-Whitney test: Statistically significant if p-value less than 0.05

Children and Adolescents, 2004: hypertension (HT) in this study was defined from prehypertension and above (BP levels $\geq 90^{\text{th}}$ percentile).⁷ Blood pressure was measured separately three times during one

visit, after a minimum of 5 minutes rest, with a mercury *sphygmomanometer*. The GFR was calculated by using original Schwartz [$k \times \text{length (cm)} / \text{creatinine (mg/dL)}$]: k was 0.70 if male ≥ 13 years and 0.55 otherwise.⁸ Salt intake is the total amount of salt sourced from the food consumed by the subject. The description of salt intake is obtained from food recall 3x24 hours since it was used as a sample. Family history is a record of health information covering three generations of families, including relatives, parents, aunts and uncles, and grandparents, regarding the history of hypertension and DM. All the data is recorded using a questionnaire that was completed by the subjects.

Data were entered into a computer program. The *Mann-Whitney test* was used to assess the mean difference of blood pressure, whereas the *Independent t-test* was used to evaluate the mean difference of GFR. Multivariate analysis was performed with logistic regression and ANCOVA. Data were analyzed using SPSS version 20 for Windows.

RESULTS

Total subjects obtained amounted to 120, consisting of 68 obese and 52 were non-obese. The distribution of boys and girls in the obese group is greater than the non-obese group (Table 1), with the largest population being 16 years. Family history (HT or DM) was higher in the obese group by 23 (71.9%) with a median salt consumption of 4.02 (2.8-5.8) grams/day (Table 1). Most obese groups are present a familial history (71.9%) of hypertension (Table 3).

Hypertension in the obese group was more significant than the non-obese group (Table 2), with a prevalence ratio of 3.97 (95% CI: 1.6-9.6; $P < 0.001$). Glomerular filtration rate in the obese and non-obese groups are shown in Table 3. Table 3 shows the mean GFR value in the obese group is lower than the non-obese group with a mean difference of 12.62 ml/min/1.73 m² (95% CI: -18.56 – (-6.68); $P < 0.001$).

Systolic and diastolic blood pressure in the obese group was higher than in a non-obese group, with the mean difference in systolic and diastolic blood pressure was 29 mmHg ($P < 0.001$) and 18 mmHg ($P = 0.002$), respectively (Table 4).

Multivariate analysis was performed to determine the pure relationship between obesity to blood pressure and GFR after calculating confounding variables, namely age, sex, family history, and salt intake (Table 5). The result found obesity increases the risk of hypertension 9.78 times (95% CI: 1.86-51.39; $P = 0.007$), and obese adolescents have an average GFR of 11.51 lower

Table 5. Multivariate analysis of the relationship between obesity and hypertension (logistic regression) as well as between obesity and GFR (ANCOVA) after controlling for age, sex, family history, and salt intake.

Variable	Hypertension				GFR		
	SE	OR	95% CI	p	B	95% CI	p
Obesity	0.84	9.78	1.86 to 51.39	0.007	-11.51	-17.32 to -5.69	<0.001*
Age	0.67	0.33	0.08 to 1.23	0.097	-1.63	-6.09 to 2.84	0.473
Male	0.75	0.12	0.03 to 0.52	0.004	-10.77	-16.29 to -5.26	<0.001*
Family history	0.62	3.04	0.89 to 10.35	0.075	2.22	-4.18 to 8.61	0.494
High salt intake	0.72	33.32	8.06 to 137.71	<0.001	9.85	3.19 to 16.50	0.004*

*Statistically significant if p-value less than 0.05; OR: odds-ratio; SE: standard error; GFR: glomerular filtration rate; CI= confidence interval

than non-obese (95% CI: 17.32 to -5.69, $P<0.001$) (Table 5).

DISCUSSION

This study included adolescents as research subjects because the prevalence of adolescents with obesity has increased, including in Indonesia. National and Bali Province Riskesdas data in 2013 showed that the highest majority of obese adolescents was 13 to 15 years. Denpasar regency was one of the cities with the highest prevalence of obese adolescents in Bali Province.⁹ This study found a more significant proportion of obesity than non-obese in both boys (63.5% vs. 36.5%) and girls (51.5% vs. 48.5%). A previous study by Malik M and Bakir A also found a high prevalence of obesity in both boys and girls by 20.2% and 22.9%.¹⁰ The high prevalence of obesity in both boys and girls adolescents was also reported in a previous study by Rutkowski B et al. and Kumar P et al.¹¹ This increased prevalence of obesity is associated with an increased time spent in sedentary activities and decreased levels of physical activity, related cardiovascular risk factors, including HT and insulin resistance.¹

Adolescents who come from families with a history of hypertension have a greater risk of suffering from hypertension than families without a history of hypertension.⁴ Adroque HJ and Madias NE, regarding the pathogenesis of potassium and sodium in hypertension, mentioned hereditary factors affecting primary hypertension through several genes involved in vascular regulation and sodium reabsorption by the kidneys.¹² In this study, a greater family history of hypertension or DM was found in the obese group (71.9%) than non-obese (28.1%).

Predisposing factors for primary hypertension are quite a lot, namely race, sex, family/ genetic history, and influencing factors such as salt consumption, stress, and obesity. Obesity is often associated with primary hypertension and is found in almost 50% of cases.¹³ Feld LG and Corey H found around 85-95% in adolescents with

primary hypertension.¹⁴ Adolescents with primary hypertension are mostly asymptomatic and are often detected only at a routine examination.

In this study, the incidence of hypertension in obese adolescents 3.97 times compared to non-obese adolescents, with systolic and diastolic blood pressure, was higher in the obese group rather than a non-obese group with a mean difference for systolic and diastolic blood pressure was 29 mmHg ($P<0.001$) and 18 mmHg ($P=0.002$) respectively. A meta-analysis study conducted by Rosner B et al. also found that children with BMI $> P90$ had a 2.5-3.7 times higher chance of hypertension than children who had normal weight.¹⁵ Research conducted in Minahasa by Kembuan IY et al. found that obese subjects were 3.4 times more likely to develop hypertension.¹⁶

Multivariate analysis showed that obesity increased the risk of hypertension by 9.78 times. Obesity is known to affect the occurrence of hypertension with various pathways. The hypothesis is most likely to explain hypertension in obesity if hypertension is associated with a complex interaction between sodium retention, activation of the sympathetic nervous system, the renin-angiotensin-aldosterone system (RAAS), and insulin resistance.¹³ Obesity also causes decreased arterial compliance, decreased distensibility, and decreased endothelial function that plays a role in hypertension occurrence.¹⁷ Multivariate analysis also found male sex results reduced the risk of hypertension by 88% (OR= 0.12; 95%CI: 0.03-0.52; $P=0.004$), and also adolescents who consume high salt have a 33 times risk of hypertension compared to normal salt consumption. This result is in line with the previous study by Malik M and Bakir A, who also mention that hypertension in girls (5-17 years) is higher than in boys with research conducted in urban areas.¹⁰ Current social and cultural factors are said to play a role, namely more women and especially teenage girls tend to spend most of their time at home. They usually have less time to exercise and spend more time socializing by involving food in these activities. Different results

were suggested by Badeli H et al. and Mohammed H et al., who found higher blood pressure in adolescent boys than girls.^{5,18} Excessive salt diets can cause hypertension because salt holds water, thereby increasing blood volume, which will result in increased pressure in the arteries.¹⁹

This study's glomerular filtration rate showed a mean difference of 12.62 ml/min/1.73 m², where the mean GFR in the obese group was 129.05 ml/min/1.73 m² (15.25), and the mean GFR in the non-obese was 141.67 ml/min/1.73 m² (17.53). This study's results are supported by research conducted in Turkey by Duzova A et al., which shows that the mean value of GFR in obese children was lower, 122.7 ml/min/1.73 m² compared to 128.2-133.3 ml/min/1.73 m² in other groups.³ Multivariate analysis showed that the obese group had an average GFR of 11.51 lower than the non-obese group (CI 95% -17, 32 to -5.69), P <0.001). Obesity is associated with various risk factors, including hyperinsulinemia, hypertension, glucose metabolism and hyperlipidemia, RAAS activation, oxidative stress, and pro-inflammatory cytokines. Among these risk factors, decreased insulin sensitivity is an essential factor in the relationship between obesity and metabolic complications, leading to chronic kidney disease (CKD). Different results were found by Koulouridis E et al. which showed a higher GFR in obese children reflecting the stage of hyperfiltration.²⁰ In contrast, Goknar N et al., and Cindik N et al. found no difference in GFR between obese and non-obese children.^{21,22}

The study also showed that gender and salt intake influenced the decrease in GFR, with women having an average GFR of 10.77 times lower than men and high salt intake increasing the likelihood of a GFR decrease of 9.85 times. Some studies mention the reduction in GFR is more quickly seen in women. It was explained that women might have a higher GFR than men in young adults due to greater body surface area, which can cause a faster rate of GFR reduction similar to that seen in renal pathology related to hyperfiltration. Second, as a woman's age increases, the impact of estrogen on hemodynamics and kidney structure decreases due to a gradual decrease in estrogen levels even before the menopause.²³ High salt intake has a damaging effect on glomerular hemodynamics, induces hyperfiltration and increases glomerular filtration fraction and pressure. A decrease in proteinuria is consistently observed in patients with restricted salt consumption, regardless of blood pressure changes.²⁴⁻²⁶

This study's limitation is that this study has not been able to fully control the confounding factors because stress factors and physical activity have not

been included in the questionnaire. The method used in this study was a cross-sectional method so that the assessment of blood pressure and GFR in this study does not consider the duration of obesity.

CONCLUSION

Hypertension is higher in obese adolescents than non-obese, while glomerular filtration rate is lower than non-obese adolescents. There was a statistically significant difference between hypertension, GFR, and blood pressure based on nutritional status. In addition, obesity increases the risk of hypertension 9.78 times and obese adolescents have an average GFR of 11.51 lower than non-obese significantly.

CONFLICT OF INTEREST

No conflict of interest was declared.

ETHICS CONSIDERATION

Ethical approval for the study was obtained from the Federal Minister of Health and the Ministry of Education in Sanglah Hospital and a research permit to a senior high school in Denpasar is issued by the Bali Provincial One-stop Investment and Integrated Services Office.

FUNDING

The authors are responsible for the study's funding without the involvement of grants, scholarships, or other funding resources.

AUTHORS CONTRIBUTION

All of the authors equally contribute to the study from the conceptual framework, data gathering, data analysis until reporting the results of study through publication.

REFERENCES

1. Kumar P, Kumar D, Ranjan A, Singh CM, Pandey S, Agarwal N. Prevalence of Hypertension and its Risk Factors Among School Going Adolescents of Patna, India. *J Clin Diagn Res.* 2017;11(1):SC01-SC04.
2. Gauer R, Belprez M, Rerucha C. Pediatric hypertension: often missed and mismanaged. *J Fam Pract.* 2014;63(3):129-136.
3. Duzova A, Yalçinkaya F, Baskin E, Bakkaloglu A, Soylemezoglu O. Prevalence of hypertension and decreased glomerular filtration rate in obese children: results of a population-based field study. *Nephrol Dial Transplant.* 2013;28 Suppl 4:iv166-iv171.
4. Sorof JM, Lai D, Turner J, Poffenbarger T, Portman RJ. Overweight, ethnicity, and the prevalence of hypertension in school-aged children. *Pediatrics.* 2004;113(3 Pt 1):475-482.
5. Badeli H, Hassankhani A, Naeemi Z, Hosseinzadeh S, Mehrabi S, Pourkarimi M, et al. Prevalence of Hypertension

- and Obesity-related Hypertension in Urban School-aged Children in Rasht. *Iran J Kidney Dis.* 2016;10(6):364-368.
6. Ziegler EE. The CDC and Euro Growth Charts. *World Rev Nutr Diet.* 2015;113:295-307.
 7. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. *Pediatrics.* 2004;114(2 Suppl 4th Report):555-576.
 8. Schwartz GJ, Furth SL. Glomerular filtration rate measurement and estimation in chronic kidney disease. *Pediatr Nephrol.* 2007;22(11):1839-1848.
 9. Pranata S, Fauziah Y, Budisuari MA, Kusriani I. Status Gizi. Riset Kesehatan Dasar dalam Angka Provinsi Bali. Jakarta: Lembaga Penerbitan Badan Penelitian dan Pengembangan Kesehatan Kementerian Kesehatan RI. 2013, p.248-75.
 10. Malik M, Bakir A. Prevalence of overweight and obesity among children in the United Arab Emirates. *Obes Rev.* 2007;8(1):15-20.
 11. Rutkowski B, Czarniak P, Król E, Szcześniak P, Zdrojewski T. Overweight, obesity, hypertension and albuminuria in Polish adolescents--results of the Sopkard 15 study. *Nephrol Dial Transplant.* 2013;28 Suppl 4:iv204-iv211.
 12. Adrogue HJ, Madias NE. Sodium and potassium in the pathogenesis of hypertension. *N Engl J Med.* 2007;356(19):1966-1978.
 13. Chen S. Essential hypertension: perspectives and future directions. *J Hypertens.* 2012;30(1):42-45.
 14. Feld LG, Corey H. Hypertension in childhood. *Pediatr Rev.* 2007;28(8):283-298.
 15. Rosner B, Cook N, Portman R, Daniels S, Falkner B. Blood pressure differences by ethnic group among United States children and adolescents. *Hypertension.* 2009;54(3):502-508.
 16. Kembuan IY, Kandou G, Kaunang WPJ. Hubungan obesitas dengan penyakit hipertensi pada pasien poliklinik Puskesmas Touluaan Kabupaten Minahasa Tenggara. *Paradigma.* 2016;4(2):16-35.
 17. Tounian P, Aggoun Y, Dubern B, et al. Presence of increased stiffness of the common carotid artery and endothelial dysfunction in severely obese children: a prospective study. *Lancet.* 2001;358(9291):1400-1404.
 18. Mohammed H, Ghosh S, Vuvor F, Mensah-Armah S, Steiner-Asiedu M. Dietary intake and the dynamics of stress, hypertension and obesity in a peri-urban community in Accra. *Ghana Med J.* 2016;50(1):16-21.
 19. Appel LJ, Frohlich ED, Hall JE, Pearson TA, Sacco RL, Seals DR, et al. The importance of population-wide sodium reduction as a means to prevent cardiovascular disease and stroke: a call to action from the American Heart Association. *Circulation.* 2011;123(10):1138-1143.
 20. Koulouridis E, Georgalidis K, Kostimpa I, Koulouridis I, Krokida A, Houliara D. Metabolic syndrome risk factors and estimated glomerular filtration rate among children and adolescents. *Pediatr Nephrol.* 2010;25(3):491-498.
 21. Goknar N, Oktem F, Ozgen IT, Torun E, Kucukkoc M, Demir AD, et al. Determination of early urinary renal injury markers in obese children. *Pediatr Nephrol.* 2015;30(1):139-144.
 22. Cindik N, Baskin E, Agras PI, Kinik ST, Turan M, Saatci U. Effect of obesity on inflammatory markers and renal functions. *Acta Paediatr.* 2005;94(12):1732-1737.
 23. Fenton A, Montgomery E, Nightingale P, Peters AM, Sheerin N, Wroe AC, et al. Glomerular filtration rate: new age- and gender- specific reference ranges and thresholds for living kidney donation. *BMC Nephrol.* 2018;19(1):336.
 24. Santos EMD, Brito DJA, França AKDCT, Lages JS, Santos AMD, Salgado Filho N. Association between estimated glomerular filtration rate and sodium excretion in urine of African descendants in Brazil: a population-based study. *J Bras Nefrol.* 2018;40(3):248-255.
 25. Pertiwi GAR, Aryawangsa AAN, Prabawa IPY, Manuaba IBAP, Bhargah A, Ratni NWS, et al. Factors associated with visit-to-visit variability of blood pressure in hypertensive patients at a Primary Health Care Service, Tabanan, Bali, Indonesia. *Family Medicine and Community Health.* 2018;6(4):191-199.
 26. Bhargah A, Muliarta M, Prabawa IPY, Manuaba IBAP, Bhargah V. Post-Exercise Hypotension Phenomenon in Elderly after Aerobic Exercise. *Journal of Global Pharma Technology.* 2018;10(6):323-327



This work is licensed under a Creative Commons Attribution