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RELATIONSHIP OF DEGREE OF OBESITY TO URINARY ALBUMIN CREATININE RATIO IN OBESE ADOLESCENTS

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Abstract

The increasing prevalence of obesity in adolescents, which is a severe global health problem, focuses on the relationship between the degree of obesity and the ratio of urine creatinine albumin. This study aimed to evaluate the association between the degree of obesity in adolescents and the urinary albumin creatinine ratio as an indicator of kidney health. This study used observational analytical research methods with a *cross-sectional approach in* obese adolescents. This research was conducted in 4 secondary schools in Manado, including SMP Negeri 8 Manado, SMP Negeri 4 Manado, SMA Katholik Rex Mundi Manado, and SMA Kristen Eben Haezer Manado. The results showed a relationship between the degree of obesity in obese adolescents and an increase in urinary albumin creatinine ratio, where the heavier the degree of obesity, the ratio tends to increase.

Keywords: Adolescent Obesity, Urinary Albumin Creatinine Ratio, Kidney Health.

INTRODUCTION

Adolescence is a typical phase of life due to rapid physical growth, with changes in body composition, sexual and psychological maturation.[1] *World Health Organization* (WHO) defines adolescents as individuals who fall into the age group of 10-18 years.[2] Adolescent age is an age group that is prone to nutritional problems.[3] Increased overweight (*overweight*) and obesity in children and adolescents have become major public health problems that have become epidemics.[1]

Obesity according to WHO (2000), is an excessive accumulation of fat as a result of an imbalance in energy intake (*energy intake*) with the energy used (*energy expenditure*) for a long time.[4] Excessive accumulation of fat such as obesity and *overweight* can interfere with health.[5] *Overweight* and obesity has seen a significant increase over the past few decades.[1] WHO (2021) reported that in 2016 there were more than 340 million children and adolescents aged 5-19 years who were overweight or obese. As of 2020, 39 million children under the age of 5 are overweight or obese.[5]

Centers for Disease Control and Prevention (2022) also reports that in the United States obesity poses a poor risk to the health of children and adolescents.[6] In Indonesia, Basic Health Research data (2018) also shows that the prevalence of obesity and obesity in adolescents aged 13-15 is 11.2% and 4.8% respectively. While the prevalence of adolescents aged 16-18 is 9.5% obese and 4% obese.[7]

The rapid increase in obesity in Indonesia is due to some people switching from traditional diets to processed products. In addition, a poor diet in children, adolescents and adults is characterized by high intake of foods and drinks high in sugar, salt, excessive fat, lack of consumption of fruits and vegetables and lack of physical activity.[8,9]

Complications of obesity such as diabetes, hypercholeterolemia, hypertension, cancer, and depression, are expected to increase with the age of adolescents today.[10] Obesity during adolescence is a strong predictor of obesity and higher mortality in adulthood.[1] Overweight and obesity in children and adolescents are risk factors for cardiovascular disease and decreased kidney function in chronic kidney disease.[11–14] Epidemiological data also show that obesity is associated with an increased risk of kidney injury in children.[15]

Albumin detected in urine is a sign of kidney disease.[16] Models used to predict kidney failure always use albuminuria (urinary albumin creatinine ratio (UACR)) or proteinuria (*urinary protein-creatinine ratio/UPCR*).[17] UACR is most often applied to diagnose albuminuria.[16] Urinary albumin excretion is classified into normoalbuminuria (<30 mg per day or UACR <30 mg/g), microalbuminuria (30-300 mg per day or UACR 30-300 mg/g *equivalent* with 3.4-34 mg/mmol), and macroalbuminuria (>300 mg per day or UACR >300 mg/g).[18] Microalbuminuria refers to a state in which urinary albumin excretion is very high, but often goes undetected.[19]

Microalbuminuria (MA) is a risk factor for morbidity and mortality of cardiovascular disease and kidney disease.[20–25] Zhang et al (2022) also report that Urinary Albumin Creatinine Ratio is an important risk factor for all-cause mortality in the community population, even if under normal circumstances with UACR <30 mg/g, occurs in people with high normal values (10 mg/g<UACR<30 mg/g) then the risk of death will also increase.[26]

Hemayati et al (2020) reported that the prevalence of microalbuminuria increased significantly with an increase in BMI.[27] Research conducted by Adam (2013) on obese and non-obese students showed that there was an association between obesity and increased albuminuria on examination of the urinary creatinine albumin ratio.[28] Nguyen et al (2008) stated that among adolescents who are overweight, microalbuminuria is associated with cardiovascular and kidney risk factors in the future.[29]

Nguyen et al (2008) reported that microalbuminuria was found in 8.9% of adolescents, where the prevalence of microalbuminuria was higher among adolescents who were not overweight than among adolescents who were overweight. The albumin/creatine ratio decreases with increasing BMI scores. However, among overweight adolescents, microalbuminuria was associated with future cardiovascular and kidney risk factors.[29]

Study *cross sectional* conducted by Larkins et al (2019) on a population of children aged 11-12 years in Australia by measuring the ratio of urine creatinine albumin also found that albuminuria was detected in 15.1% of children, including 20.8% in women and 10.1% in men. Albuminuria is common in children in Australia, worrying because of the risk of kidney and cardiovascular disease, even death.[30] Given the increasing population of adolescents is the reason for the need for this age group to be a concern.[3]

Previous studies have focused more on the obese population in general. Studies evaluating the relationship between obesity and UACR according to the degree of obesity are still difficult to find in the literature. Based on this, researchers are interested in knowing the relationship between the degree of obesity to UACR in obese adolescents. The formulation of the problem of this study is to determine whether there is a relationship between the degree of obesity in obese adolescents with the ratio of urine creatinine albumin.

The aim of the study was to evaluate the association, while the research hypothesis suggested a correlation between the degree of obesity and the ratio of urine creatinine albumin in obese adolescents. His statistical hypothesis states that H0: there is no relationship, while H1: there is a relationship.

Its benefits include theoretical contributions by enriching the literature on the relationship between obesity and urinary creatinine albumin ratio, as well as its applicative benefits in providing a reference for preventive measures for impaired renal function in obese adolescents and providing information to predict kidney function based on the severity of obesity in such adolescents.

METHODS

This study was conducted using observational analytical research methods with a *cross-sectional* approach in obese adolescents. This research was conducted in 4 secondary schools in Manado including, SMP Negeri 8 Manado, SMP Negeri 4 Manado, SMA Katholik Rex Mundi Manado, SMA Kristen Eben Haezer Manado. The four schools had previously been surveyed by researchers on age, sex, nutritional status, height, and weight and found a number of obese adolescents to be included in the study. The study and sampling were conducted between September and December 2023.

Population and Research Sample

The study population was obese adolescents aged 10 to 18 years in Junior High School and Senior High School in Manado city around RSUP Prof. Dr. R. D. Kandou. The sample of this study was a portion of the affordable population that met the criteria:

Inclusion criteria**:**

- Respondents ranged in age from 10 to 18 years.
- Are patients with obesity (BMI ≥30 kg/m2 or BMI/U >p95)
- Parents agree to participate and are willing to sign *informed consent*

Exclusion criteria:

- Chronic kidney disease

The minimum sample size required in this study is determined based on the correlative analysis sample formula:

$$n_1 = \frac{2\sigma^2 \left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2}{\Delta^2}$$

Information:

α = Error rate

1 – β = *power*

Z = kuantil standard normal

α = 0.05 →$Z_{1-\frac{\alpha}{2}}$ = 1.96

1 – β = 0.8 →$Z_{1-\beta}$ = 0.84

UACR variance from previous study = 33.4

Δ = large *margin of error* desired

With effect size = = 0.75 $\frac{\sigma^2}{\Delta^2}$→ Δ = 38.567

A minimum sample of 18 samples was obtained for each category of obesity.

Ethics Committee Considerations

The research was carried out under the approval of the Health Research and Development Ethics Committee of RSUP Prof. dr. R. D. Kandou, Manado with letter number No.229/EC/KEPK-KANDOU/XI/2023. In the implementation of this research, every action taken is accompanied by providing information and with the permission of parents through the signing of *informed consent*.

In this study, the independent variables consisted of the degree of obesity categorized as mild or severe, as well as Body Mass Index per Age (BMI/U) measured numerically. Meanwhile, the dependent variable was the urinary creatinine albumin ratio (UACR), also measured numerically.

Research instruments include stationery, parental/guardian consent forms, patient medical record status, child scales, height gauges, gloves, and CDC 2000 standard growth chart for height and CDC 2022 chart for BMI/U according to age and sex.

The research procedure involves approval from the Ethics Committee, anamnesis and physical examination by the researcher, as well as the collection of urine samples and laboratory examination by trained officers, with the results recorded in the research form for subsequent analysis.

Data Analysis

The description of each variable is done according to the type of distribution. Category variables are displayed as frequency and percentage. Meanwhile, the centering and spread values of numerical variables are presented according to the results of the distribution normality assessment both through graphs such as histograms, boxplots, and density curves, as well as Kolmogorov-smirnov and Shapiro Wilk normality tests. In normally distributed ones, descriptive tabulations include mean values and standard deviations (SD).

In contrast, numerical variables whose distribution deviates from normality are given as the median and interquartile range (*IQR*). Bivariate analysis of each independent variable against the dependent variable using ANOVA, independent T-test and Point-Biserial test.

Multivariate analysis of all independent variables against dependent variables using multiple linear regression. The results of linear regression analysis are reported as coefficients using a 95% confidence interval, and *a* p-value. Data analysis was performed using SPSS application version 26.0.

Research flow

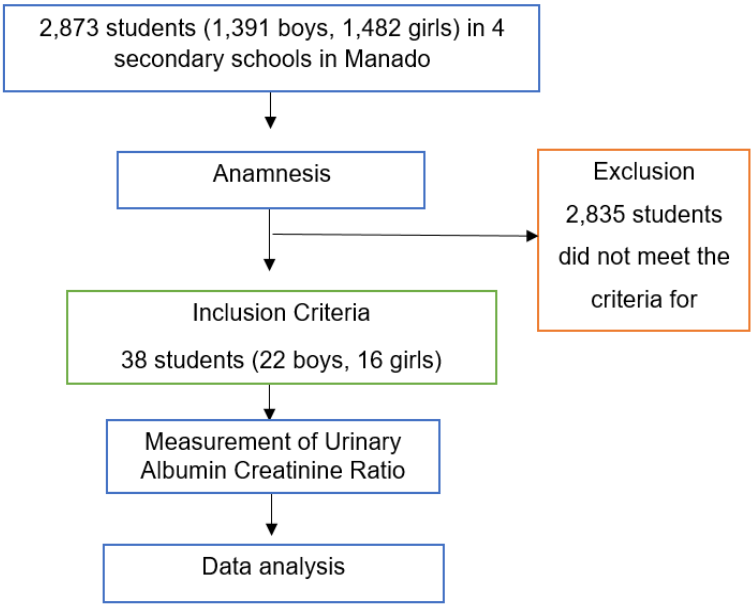

Figure 1: Research Flowchart

RESULTS

Characteristics of Research Samples

This study was conducted from September 2023 to December 2023 on obese children in junior and senior high schools in Manado City. This research was conducted at SMP Negeri 8 Manado (Male Students: 589 Female Students: 601), SMP Negeri 4 Manado (Male Students: 338 Female Students: 308), Rex Mundi Catholic High School Manado (Male Students: 264, Female Students: 413) and Eben Haezer Christian High School Manado (Male Students 200, Female Students 160). In this study, 38 obese adolescents met the inclusion criteria, of which 22 (58%) were boys and 16 (42%) were girls. Twenty of them fall into the category of mild obesity and 18 of them fall into the category of severe obesity. From all samples, the lowest age was 13 years, the highest was 17 years with an average of 14.9 years. The lowest weight was 55 kg and the highest was 95.1 kg, averaging 73.2 kg. The lowest height is 140 cm, the highest is 170 cm with an average of 151.5 cm. The lowest percentage of BMI by age was 100.2%, the highest was 146.5%, the average was 117.45% compared to the 95th percentile on the 2022 CDC chart according to sex and age.

Table 1: Adolescent characteristics in the study (n = 38)

Gender	n(%)	Mean (Standard Deviation)
Degrees of Obesity **Mild obesity** **Severe Obesity**	 20 (52, 6%) 18 (47, 4%)	- --
Age	-	14,9 (1,394)
Weight (kg)	-	73,224 (8,4349)
Height (cm)	-	1,515 (0,0884)
BMI/Age (%)	-	117,450 (13,1923)
UACR (mg/g) *	-	28,1 (21,5)

Description: * n=36, two error data.

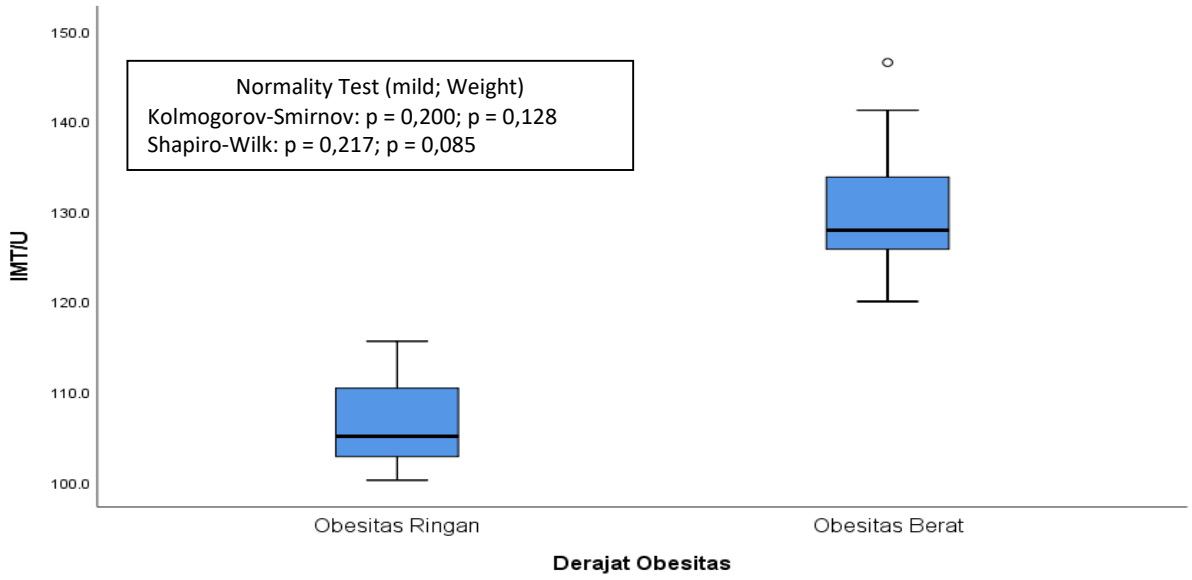

Figure 2: Distribution of BMI/U according to the degree of obesity.

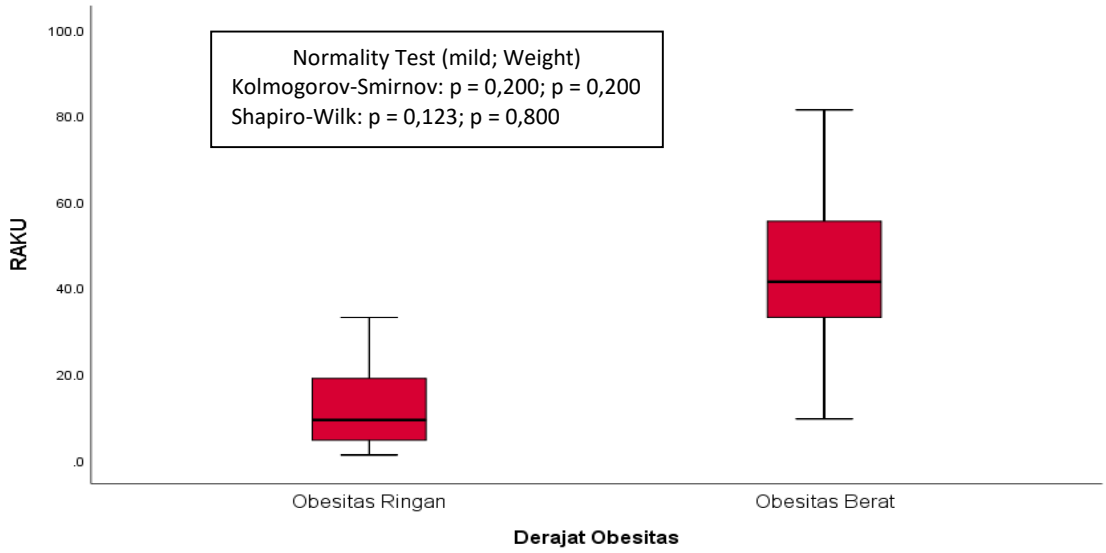

Figure 3: Distribution of UACR according to the degree of obesity.

The relationship between obesity and UACR

The average urinary albumin creatinine ratio in the study sample was 28.1 ± 21.5 mg/g. The study also showed a significant positive correlation between *Urinary Albumin Creatinine Ratio* and BMI. A strong correlation with a value of r = 0.88 illustrates that the higher the BMI/U in obese adolescents, the higher the albumin-creatinine ratio in their urine. The results of the BMI regression test on UACR values were obtained with every increase of 1 degree BMI/U compared to the 95th percentile on the 2022 CDC chart according to age and sex, the average UACR increased by 1.4 mg/g in this study.

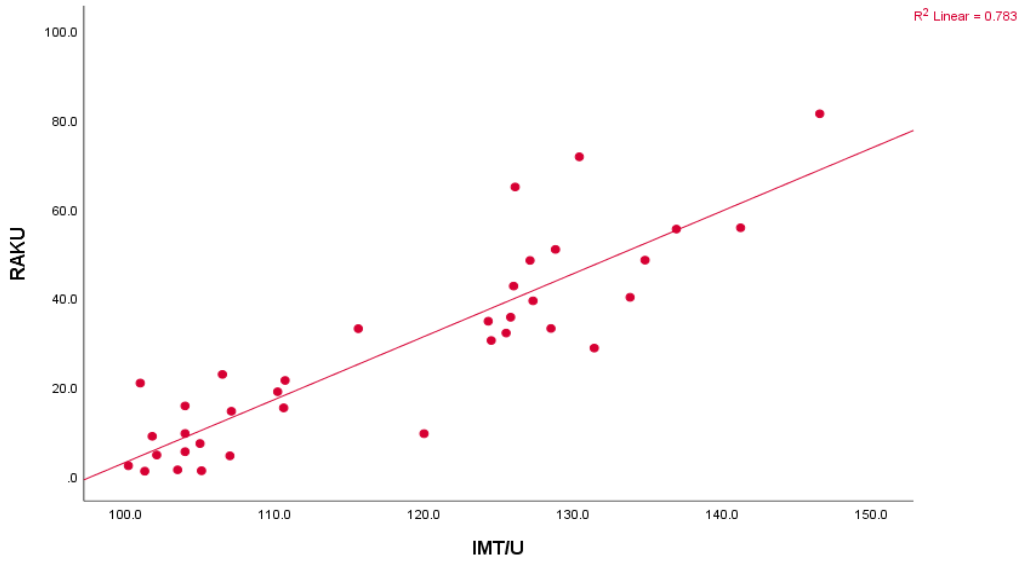

Figure 4: Scatter diagram of the relationship between BMI/U (percentage compared to 95th percentile on the 2022 CDC) and UACR value (r=0.88; p<0.001)

The relationship between the degree of obesity and UACR

Based on obesity classification, UACR values in severe obesity (44.6 ± 17.1) were higher than values in mild obesity (11.6± 9.2). The mean UACR value in the mild obesity group was 11.6 mg/g while the mean UACR value in the severe obesity group was 44.6 mg/g. The Point-Biserial correlation test of the relationship between the degree of obesity and UACR, obtained r = 0.78 with a value of p < 0.001 showed a strong positive relationship between the two variables. From the results of the regression test of the degree of obesity against UACR, it was found that children with severe obesity had an average UACR value of 33.0 mg/g higher than children with mild obesity, with a p value of <0.001.

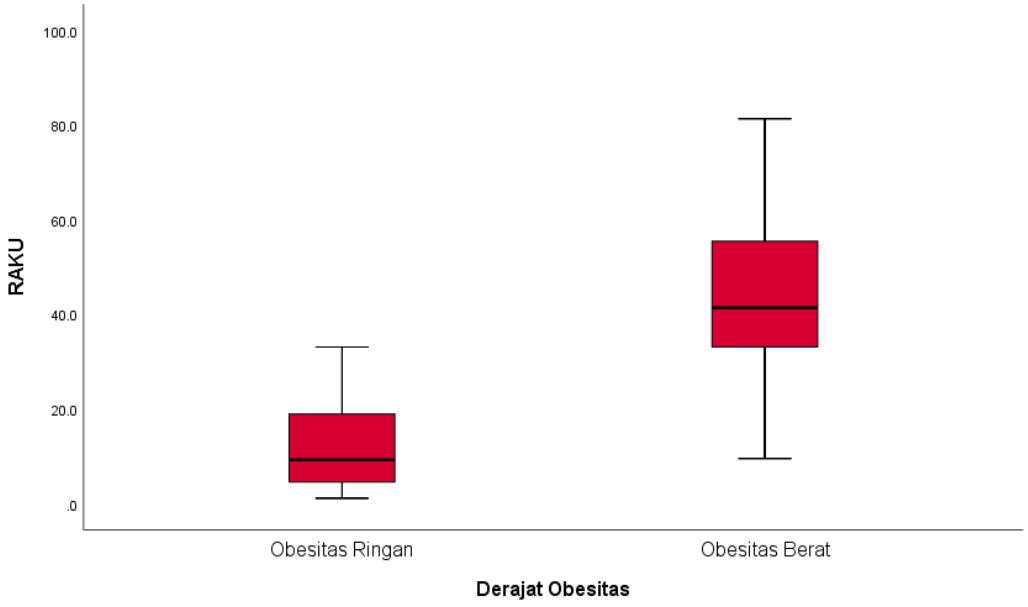

Figure 5: Box plot of the relationship between obesity degree and UACR (Test T = 7.2; p<0.001)

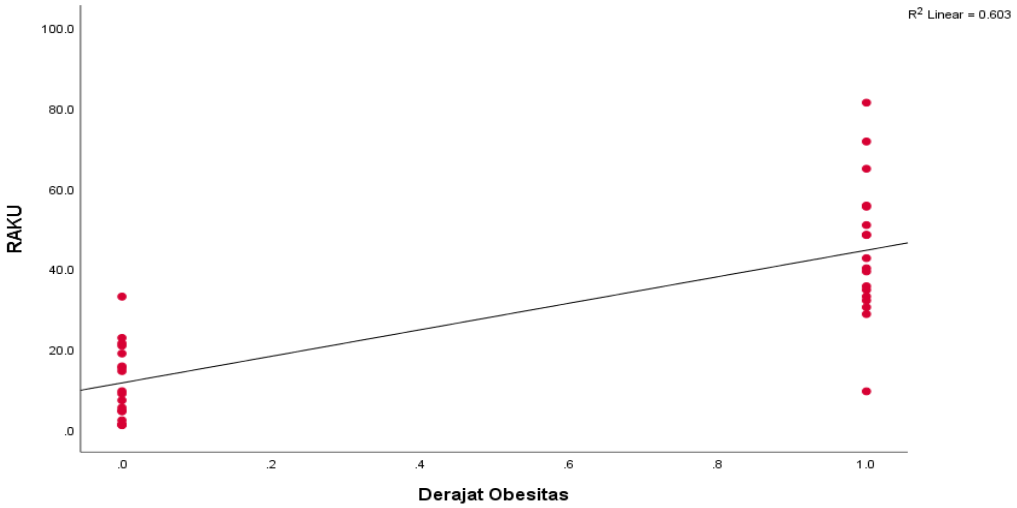

Figure 6: Point-Biserial correlation diagram of the degree of obesity relationship with UACR (r = 0.78; p<0.001)

Table 2: Regression Analysis of BMI/you and degree of obesity against UACR

Variable	Beta	*p value*
BMI/Age	**1,4**	**<0,001**
Degrees of Obesity	**33,0**	**<0,001**

DISCUSSION

In this study, a sample of 38 adolescents who were included in the obese category and met the inclusion criteria, where 22 (58%) adolescents were boys and 16 (42%) were girls. The mean age of the study sample was 14.9 years. The average weight gained 73,224 kg with SD 8,4349.

The average height was 1.515 meters with SD 0.0884. The average percentage of BMI/U is 117.450 with SD 13.1923. The prevalence of obese children and adolescents based on the 2018 Riskesdas basic health research, the prevalence of obesity in North Sulawesi adolescents aged 13-15 years is 5.14 – 8.48%, aged 16-18 years 3.55 – 7.02%, while in Manado City adolescents aged 13-15 years are 2.44 – 11.66%, aged 16-18 years 2.45 – 16.01%.[7]

The average UACR value in this study was 28.1 mg/g with SD 21.5. In a cross-sectional study conducted by Du et al (2014) on 2,889 populations found that BMI is a risk factor for high UACR, where obesity significantly increases UACR (RR=1.82; p<0.001) compared to populations without obesity.[60]

Another study was also conducted by Dittmann et al (2013) on 3,749 subjects with obesity had a high risk of increased RIS, which showed a u-shaped relationship between markers of central fat distribution and UACR in the general population and obese subjects had a higher risk of kidney disorders.[61] Research by Csernus et al (2005) found that obese children and adolescents had a higher increase in UACR[62] Albuminuria has also been linked to insulin resistance in overweight adolescents.[29]

The results of this study are also supported by research conducted by Xiao et al, in which a large number of adolescents with severe obesity had evidence of early renal dysfunction, one of which was characterized by increased levels of UACR. This is because obesity, and especially severe obesity, has an important pathophysiology in

the occurrence of kidney damage.[82] The relationship between obesity (BMI/U, percentage compared to the 95% percentile on the CDC 2022 BMI chart) and UACR was tested by correlation coefficient analysis and regression obtained a value of r = 0.88 with a value of p < 0.001. These results suggest there is a perfectly positive relationship between obesity (expressed in BMI/U) and the urinary albumin creatinine ratio, with the strength of a perfectly meaningful relationship (p < 0.001).

The relationship between the two variables graphically can be seen in the scatter diagram, where the increase in BMI/U, the higher the urinary albumin creatinine ratio. These findings are similar to those conducted by Du et al, where in univariate logistic analysis, compared with normal-weight, overweight subjects (OR = 1.47; P<0.001) and obesity (OR = 2.17; P<0.001) each had a significantly increased risk of UACR. Similarly, compared with normal subjects, participants with central obesity also had a significantly increased risk of UACR (OR = 1.93; P<0.001).

After adjusting for confounding variables, compared with the normal group, obesity (OR = 1.61; P = 0.001) and central obesity (OR = 1.31; P = 0.007) still has an increased risk of UACR.[83] These results were also similar to other studies by Qin et al, conducted on subjects with central and peripheral obesity, having a higher risk of increased UACR, even after adjusting for several factors (OR: 1.14; 95% CI: 1.07 to 1.12; p<0.001), this risk was also increased in the male population.[77]

The relationship between the degree of obesity and UACR, tested with an independent sample T-test obtained a result of t = 7.2 with a value of p < 0.001. The results of the Point-Biserial correlation test between the two variables gave a strong positive correlation result with r = 0.78 and a p value of <0.001. The mean UACR in the severe obesity group (44.6 ± 17.1 mg/g) was higher than in the mild obesity group (11.6 ± 9.2 mg/g). With the regression analysis test of the degree of obesity against UACR, it was found that the group of children with severe obesity had an average UACR value of 33.0 mg/g higher than the group of children with mild obesity. Obesity can increase kidney damage directly through hemodynamic and hormonal effects.[47]

The biological mechanisms by which obesity contributes to CKD are still not fully understood, but obesity can increase kidney damage through direct and indirect mechanisms. Indirect mechanisms of CKD development in obesity include coexisting conditions such as diabetes and hypertension.

While direct mechanisms include hemodynamic and hormonal effects that cause glomerular hyperperfusion (increased renal plasma flow) and glomerular hyperfiltration (increased GFR), which is a process hypothesized to occur due to vasodilation of renal afferent arterioles. This results in increased glomerular capillary pressure, which can further lead to increased urinary albumin excretion (urine protein loss of 30-300 mg per 24 hours), followed by open proteinuria (urine protein loss of >300 mg per 24 hours), progressive decline in kidney function (decreased GFR), and finally ESRD.[47] Obesity-related kidney disease can be prevented or slowed down with weight loss and lifestyle modifications.[84]

Pardede et al (2017) explained that the degree of albuminuria and microalbuminuria in obese children is higher than in children who are not obese or normal. This indicates dysfunction of the glomerulus and renal tubules as a result of obesity.[51] Increased UACR at a young age is associated with obesity, metabolic syndrome and impaired glucose metabolism in obese children.[18,76,32]

Rutkowski et al (2006) also explain that being overweight is associated with various functional/structural lesions of the kidneys. The spectrum ranges from glomerulomegaly with or without focal or segmental glomerulosclerosis, to diabetic nephropathy, to renal carcinoma and nephrolithiasis. Kidney injury is characterized by microalbuminuria or mild proteinuria, especially in the presence of hypertension. The occurrence of microalbuminuria and/or chronic renal insufficiency is associated with an increased number of metabolic syndrome components, namely central obesity, elevated fasting blood glucose levels, hypertriglycerides, low HDL, and hypertension. In the long term, end-stage renal failure may develop, Increased BMI is especially dangerous in patients with decreased renal functional mass and other kidney diseases.

Hyperfiltration is essential in the pathogenesis of obesity-related glomerulopathy. Several active proteins are produced in central adipose tissue such as leptin, proinflammatory cytokines, plasminogen-1 activator inhibitors, angiotensinogens, and growth factors (*transforming growth factor-beta1*), as well as low levels of protective adiponectin, which contributes to kidney injury.[84] Csernus et al found obese children had a significantly higher urinary albumin creatinine ratio than healthy children (interquartile range 12.9 mg/g versus 5.1 mg/g; p = 0.003). Obese children have higher rates of albuminuria than normal-weight children, indicating early glomerular and renal tubular dysfunction as a result of obesity itself.

UACR in obese children is associated with certain metabolic disorders associated with obesity, and also with metabolic syndrome. Increased excretion of urinary proteins such as the presence of albumin in the urine indicates hyperfiltration and premature kidney damage. This has been shown to be as related as in adult obesity. Increased urinary albumin excretion can be an indicator of impaired glomerular permeability which is also a marker of kidney damage and represents an increase in transcapillary albumin leakage that reflects endothelial dysfunction and causes vascular damage.[62]

Research by Csernus et al found an increase in albuminuria in obese children and this is associated with the presence of several features of metabolic syndrome, in particular a significant association was found with impaired carbohydrate metabolism (hyperinsulinemia and impaired glucose tolerance). These findings are consistent with previous studies in adults showing an association between microalbuminuria and insulin resistance or elevated blood glucose levels and provide further evidence for the hypothesis of a central role of insulin resistance in the development of metabolic syndrome and increased cardiovascular risk in subjects with increased urinary albumin excretion.

Possible mechanisms linking hyperinsulinemia to increased urinary albumin excretion include increased glomerular hemodynamic pressure and endothelial dysfunction resulting in increased transcapillary albumin leakage. UACR increased almost 2-fold in obese children with hypercholesterolemia compared to obese children with normal cholesterol levels, indicating the importance of high cholesterol levels in the development of kidney damage due to obesity.[62]

Nguyen et al showed that overweight adolescents with impaired glucose tolerance, insulin resistance, and hypertension had microalbuminuria similar to those found in previous studies in adults. Increased intraglomerular capillary pressure due to overweight can lead to glomerular hyperfiltration.

This has the potential to cause microalbuminuria through endothelial dysfunction triggered by hypertension, diabetes mellitus, or smoking. Csernus et al found that children with obesity and impaired glucose homeostasis (including hyperinsulinemia and impaired glucose tolerance) had higher UACR than normal-weight children. This supports the central role of such factors in the development of kidney damage. Insulin resistance associated with adiposity can lead to endothelial dysfunction with increased permeability leading to loss of albumin and other molecules involved in lipid accumulation and inflammation of blood vessel walls.

Overall, these abnormalities may represent pathophysiological processes of kidney damage observed in children with obesity.[29] A study by Musa et al (2021), conducting UACR examination on 128 children and adolescents with obesity, found that an increase in UACR was statistically significant positively correlated with body weight, BMI and waist circumference.[85] The study concluded that UACR increases significantly in children and adolescents with obesity, where early detection of albumin in the urine can help prevent further obesity-induced kidney disease.

This study has limitations, namely the method of examining samples using urine at any time, even though confounding factors control has been carried out on the study sample. Examination of albumin levels in urine 24 hours may show different results.

CONCLUSION

The results showed a relationship between the degrees of obesity in obese adolescents with an increase in the urinary albumin creatinine ratio, where the heavier the degree of obesity, the ratio tends to increase. Therefore, it is recommended to check the urinary albumin creatinine ratio in adolescents who are obese as an effort to detect early and prevent kidney damage.

In addition, control of obesity is also recommended as a further preventive measure against kidney damage. Furthermore, further research may need to be done to distinguish between current urine and 24-hour urine outcomes to gain a deeper understanding of the relationship between obesity and kidney damage risk in adolescents.

References

1) Nicolucci A, Maffeis C. The adolescent with obesity: what perspectives for treatment? Ital J Pediatr 2022; 48: 1–9.

2) WHO. Adolescent health, https://www.who.int/southeastasia/health-topics/adolescent-health (2023, accessed 8 May 2023).

3) Simbolon D. Model Prediksi Indeks Massa Tubuh Remaja Berdasarkan Riwayat Lahir dan Status Gizi Anak. Kesmas: National Public Health Journal 2013; 8: 19.

4) Kementerian Kesehatan RI. Pedoman Umum Pengendalian Obesitas. Jakarta, 2015.

5) WHO. Obesity and overweight, https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (2021, accessed 1 May 2023).

6) CDC. Childhood Obesity Facts | Overweight & Obesity | CDC, https://www.cdc.gov/obesity/data/childhood.html (2022, accessed 7 May 2023).

7) Kementerian Kesehatan RI. Laporan Nasional RISKESDAS 2018. Jakarta: Badan Penelitian dan Pengembangan Kesehatan, 2019.

8) Unicef. Analisis Lanskap Kelebihan Berat Badan Dan Obesitas Di Indonesia. Jakarta: UNICEF, 2022.

9) WHO SEA Indonesia. Indonesia: Obesity rates among adults double over past two decades, https://www.who.int/indonesia/news/detail/04-03-2021-indonesia-obesity-rates-among-adults-double-over-past-two-decades (2021, accessed 11 May 2023).

10) Patel C, Warhadpande M, Jacobson MS. Adolescent obesity. 2023; 790–803.

11) Gelber RP, Kurth T, Kausz AT, et al. Association between body mass index and CKD in apparently healthy men. American journal of kidney diseases : the official journal of the National Kidney Foundation; 46. Epub ahead of print November 2005. DOI: 10.1053/j.ajkd.2005.08.015.

12) Rutkowski P, Klassen A, Sebekova K, et al. Renal disease in obesity: the need for greater attention. Journal of renal nutrition : the official journal of the Council on Renal Nutrition of the National Kidney Foundation; 16. Epub ahead of print July 2006. DOI: 10.1053/j.jrn.2006.04.017.

13) Gunta SS, Mak RH. Is obesity a risk factor for chronic kidney disease in children? Pediatric nephrology (Berlin, Germany); 28. Epub ahead of print October 2013. DOI: 10.1007/s00467-012-2353-z.

14) Reilly J, Methven E, McDowell Z, et al. Health consequences of obesity. Archives of disease in childhood; 88. Epub ahead of print September 2003. DOI: 10.1136/adc.88.9.748.

15) Musa N, Ramzy T, Hamdy A, et al. Assessment of urinary podocalyxin as a marker of glomerular injury in obesity-related kidney disease in children and adolescents with obesity compared to urinary albumin creatinine ratio. Clin Obes; 11. Epub ahead of print August 2021. DOI: 10.1111/cob.12452.

16) Ren F, Li M, Xu H, et al. Urine albumin-to-creatinine ratio within the normal range and risk of hypertension in the general population: A meta-analysis. The Journal of Clinical Hypertension 2021; 23: 1284.

17) Schneider MF, Muñoz A, Ku E, et al. Estimation of Albumin-Creatinine Ratio From Protein-Creatinine Ratio in Urine of Children and Adolescents With CKD. American journal of kidney diseases : the official journal of the National Kidney Foundation 2021; 77: 824.

18) Seo MH, Lee J-Y, Ryu S, et al. The Effects of Urinary Albumin and Hypertension on All-Cause and Cardiovascular Disease Mortality in Korea. American Journal of Hypertension 2017; 30: 799.

19) Cho MH, Kim KS, Chung S. Microalbuminuria Is Associated with Lower Weight and Taller Height in Adolescence. Tohoku J Exp Med 2017; 243: 151–157.

20) Schmieder RE, Schrader J, Zidek W, et al. Low-grade albuminuria and cardiovascular risk : what is the evidence? Clinical research in cardiology : official journal of the German Cardiac Society; 96. Epub ahead of print May 2007. DOI: 10.1007/s00392-007-0510-3.

21) Yuyun MF, Khaw K-T, Luben R, et al. A prospective study of microalbuminuria and incident coronary heart disease and its prognostic significance in a British population: the EPIC-Norfolk study. American journal of epidemiology; 159. Epub ahead of print 1 February 2004. DOI: 10.1093/aje/kwh037.

22) Jager A, Kostense PJ, Ruhé HG, et al. Microalbuminuria and peripheral arterial disease are independent predictors of cardiovascular and all-cause mortality, especially among hypertensive subjects: five-year follow-up of the Hoorn Study. Arteriosclerosis, thrombosis, and vascular biology; 19. Epub ahead of print March 1999. DOI: 10.1161/01.atv.19.3.617.

23) Ninomiya T, Perkovic V, Galan BE de, et al. Albuminuria and kidney function independently predict cardiovascular and renal outcomes in diabetes. Journal of the American Society of Nephrology : JASN; 20. Epub ahead of print August 2009. DOI: 10.1681/ASN.2008121270.

24) Gerstein HC, Mann JFE, Yi Q, et al. Albuminuria and Risk of Cardiovascular Events, Death, and Heart Failure in Diabetic and Nondiabetic Individuals. JAMA 2001; 286: 421–426.

25) Arnlöv J, Evans JC, Meigs JB, et al. Low-grade albuminuria and incidence of cardiovascular disease events in nonhypertensive and nondiabetic individuals: the Framingham Heart Study. Circulation; 112. Epub ahead of print 16 August 2005. DOI: 10.1161/CIRCULATIONAHA.105.538132.

26) Zhang A, Li M, Qiu J, et al. The relationship between urinary albumin to creatinine ratio and all-cause mortality in the elderly population in the Chinese community: a 10-year follow-up study. BMC Nephrology; 23. Epub ahead of print 2022. DOI: 10.1186/s12882-021-02644-z.

27) Hemayati R, Kaseb F, Ghadiri-anari A, et al. The relationship between microalbuminuria, overweight and obesity. J Nephropathol 2020; 9: e41–e41.

28) Adam RN. Hubungan Obesitas Dengan Peningkatan Kadar Albuminurin Pada Mahasiswa Fakultas Kedokteran Unsrat Program Studi Kedokteran Umum. eCl; 1. Epub ahead of print 12 November 2013. DOI: 10.35790/ecl.1.3.2013.3238.

29) Nguyen S, McCulloch C, Brakeman P, et al. Being Overweight Modifies the Association Between Cardiovascular Risk Factors and Microalbuminuria in Adolescents. Pediatrics 2008; 121: 37.

30) Larkins NG, Kim S, Carlin JB, et al. Albuminuria: population epidemiology and concordance in Australian children aged 11–12 years and their parents. BMJ Open 2019; 9: 75.

31) Notoatmodjo S. Kesehatan Masyarakat Ilmu dan Seni. Jakarta: Rineka Cipta, 2007.

32) CDC. About Child and Teen BMI. Centers for Disease Control and Prevention, https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html (2022, accessed 7 May 2023).

33) Abarca-Gómez L, Abdeen ZA, Hamid ZA, et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128·9 million children, adolescents, and adults. The Lancet 2017; 390: 2627–2642.

34) Lobstein T, Jackson-Leach R, Moodie PML, et al. Child and adolescent obesity: part of a bigger picture. Lancet (London, England) 2015; 385: 2510.

35) Kansra AR, Lakkunarajah S, Jay MS. Childhood and Adolescent Obesity: A Review. Frontiers in Pediatrics; 8. Epub ahead of print 2020. DOI: 10.3389/fped.2020.581461.

36) WHO. Noncommunicable diseases: Childhood overweight and obesity, https://www.who.int/news-room/questions-and-answers/item/noncommunicable-diseases-childhood-overweight-and-obesity (2020, accessed 6 May 2023).

37) Telisa I, Hartati Y, Haripamilu AD. Faktor Risiko Terjadinya Obesitas Pada Remaja SMA. 1 2020; 7: 124–131.

38) Bhuiyan MU, Zaman S, Ahmed T. Risk factors associated with overweight and obesity among urban school children and adolescents in Bangladesh: a case–control study. BMC Pediatr 2013; 13: 1–6.

39) Grace GA, Edward S, S G. A Case Control Study on Risk Factors of Obesity Among Adolescents. Natl J Community Med 2022; 13: 374–378.

40) Neutzling MB, Taddei JAA, Gigante DP. Risk factors of obesity among Brazilian adolescents: a case–control study. Public Health Nutrition 2003; 6: 743–749.

41) Kumar S, Singh R, Singh AK. To Study the Risk Factors Associated with Overweight and Obesity among Adolescents in Patna, Bihar. IJCMR; 5. Epub ahead of print September 2018. DOI: 10.21276/ijcmr.2018.5.9.6.

42) Supariasa IDN, Bakri B, Fajar I. Penilaian Status Gizi. Jakarta: Penerbit Buku Kecokteran ECG, 2012.

43) Kementerian Kesehatan RI. Klasifikasi Obesitas setelah pengukuran IMT. Direktorat P2PTM, https://p2ptm.kemkes.go.id/infographic-p2ptm/obesitas/klasifikasi-obesitas-setelah-pengukuran-imt (2018, accessed 11 May 2023).

44) WHO. WHO European Regional Obesity Report 2022. Geneva, 2022.

45) Kementerian Kesehatan RI. Peraturan Menteri Kesehatan Republik Indonesia Nomor 2 Tahun 2020 Tentang Standar Antropometri Anak.

46) Sinha A, Kling S. A Review of Adolescent Obesity: Prevalence, Etiology, and Treatment. OBES SURG 2009; 19: 113–120.

47) Garland JS. Elevated body mass index as a risk factor for chronic kidney disease: current perspectives. Diabetes, metabolic syndrome and obesity : targets and therapy; 7. Epub ahead of print 29 July 2014. DOI: 10.2147/DMSO.S46674.

48) Kidney International Supplements. Chapter 1: Definition and classification of CKD. Kidney International Supplements 2013; 3: 19.

49) Iseki K, Ikemiya Y, Kinjo K, et al. Body mass index and the risk of development of end-stage renal disease in a screened cohort. Kidney international; 65. Epub ahead of print May 2004. DOI: 10.1111/j.1523-1755.2004.00582.x.

50) Wang Y, Chen X, Song Y, et al. Association between obesity and kidney disease: a systematic review and meta-analysis. Kidney international; 73. Epub ahead of print January 2008. DOI: 10.1038/sj.ki.5002586.

51) Pardede SO, Christine A, Andriana J. Gangguan Ginjal terkait Obesitas pada Anak. SP 2017; 18: 504.

52) Seegmiller JC, Miller WG, Bachmann LM. Moving Toward Standardization of Urine Albumin Measurements. EJIFCC 2017; 28: 258.

53) Basi S, Lewis JB. Microalbuminuria as a target to improve cardiovascular and renal outcomes. American journal of kidney diseases : the official journal of the National Kidney Foundation; 47. Epub ahead of print June 2006. DOI: 10.1053/j.ajkd.2006.02.182.

54) Deckert T, Feldt-Rasmussen B, Borch-Johnsen K, et al. Albuminuria reflects widespread vascular damage. The Steno hypothesis. Diabetologia; 32. Epub ahead of print April 1989. DOI: 10.1007/BF00285287.

55) Stehouwer CD, Nauta JJ, Zeldenrust GC, et al. Urinary albumin excretion, cardiovascular disease, and endothelial dysfunction in non-insulin-dependent diabetes mellitus. Lancet (London, England); 340. Epub ahead of print 8 August 1992. DOI: 10.1016/0140-6736(92)91401-s.

56) Keane WF, Eknoyan G. Proteinuria, albuminuria, risk, assessment, detection, elimination (PARADE): A position paper of the National Kidney Foundation. American Journal of Kidney Diseases 1999; 33: 1004–1010.

57) Dyer AR, Greenland P, Elliott P, et al. Evaluation of Measures of Urinary Albumin Excretion in Epidemiologic Studies. American journal of epidemiology 2004; 160: 1122.

58) Levey AS, Eckardt K-U, Tsukamoto Y, et al. Definition and classification of chronic kidney disease: A position statement from Kidney Disease: Improving Global Outcomes (KDIGO). Kidney International 2005; 67: 2089–2100.

59) Atkins RC, Briganti EM, Zimmet PZ, et al. Association between albuminuria and proteinuria in the general population: the AusDiab Study. Nephrology, dialysis, transplantation : official publication of the European Dialysis and Transplant Association - European Renal Association; 18. Epub ahead of print October 2003. DOI: 10.1093/ndt/gfg314.

60) Du N, Peng H, Chao X, et al. Interaction of obesity and central obesity on elevated urinary albumin-to-creatinine ratio. PloS one; 9. Epub ahead of print 3 June 2014. DOI: 10.1371/journal.pone.0098926.

61) Dittmann K, Hannemann A, Wallaschofski H, et al. U-shaped association between central body fat and the urinary albumin-to-creatinine ratio and microalbuminuria. BMC nephrology; 14. Epub ahead of print 17 April 2013. DOI: 10.1186/1471-2369-14-87.

62) Csernus K, Lanyi E, Erhardt E, et al. Effect of childhood obesity and obesity-related cardiovascular risk factors on glomerular and tubular protein excretion. European journal of pediatrics; 164. Epub ahead of print January 2005. DOI: 10.1007/s00431-004-1546-2.

63) Xie L, Wang B, Jiang C, et al. BMI is associated with the development of chronic kidney diseases in hypertensive patients with normal renal function. Journal of hypertension; 36. Epub ahead of print October 2018. DOI: 10.1097/HJH.0000000000001817.

64) Daniels M, DuBose SN, Maahs DM, et al. Factors Associated With Microalbuminuria in 7,549 Children and Adolescents With Type 1 Diabetes in the T1D Exchange Clinic Registry. Diabetes Care 2013; 36: 2639–2645.

65) Afkarian M. Diabetic kidney disease in children and adolescents. Pediatr Nephrol 2015; 30: 65–74.

66) Sierra-Diaz E, Rosa A de JC la, Lozano-Kasten F, et al. Non-Traditional Risk Factors of Albuminuria in the Pediatric Population: A Scoping Review. International Journal of Environmental Research and Public Health; 14. Epub ahead of print October 2017. DOI: 10.3390/ijerph14101231.

67) Hogan SI, Vupputuri S, Guo X, et al. Association of cigarette smoking with albuminuria in the United States: the third National Health and Nutrition Examination Survey. Renal failure; 29. Epub ahead of print 2007. DOI: 10.1080/08860220601098888.

68) Wu D, Yang H, Luo J, et al. Age- and gender-specific reference values for urine albumin/creatinine ratio in children of southwest China. Clinica chimica acta; international journal of clinical chemistry; 431. Epub ahead of print 20 April 2014. DOI: 10.1016/j.cca.2014.02.015.

69) Gutiérrez-Repiso C, Rojo-Martínez G, Soriguer F, et al. Factors affecting levels of urinary albumin excretion in the general population of Spain: the Di@bet.es study. Clin Sci (Lond) 2013; 124: 269–277.

70) Stothard JR, Sousa-Figueiredo JC, Khamis IS, et al. Urinary schistosomiasis-associated morbidity in schoolchildren detected with urine albumin-to-creatinine ratio (UACR) reagent strips. Journal of Pediatric Urology 2009; 5: 287–291.

71) Kwak BO, Chung S, Kim KS. Microalbuminuria in children with urinary tract infection. Korean Journal of Pediatrics 2010; 53: 840.

72) Yuyun MF. Microalbuminuria independently predicts all-cause and cardiovascular mortality in a British population: The European Prospective Investigation into Cancer in Norfolk (EPIC-Norfolk) population study. International Journal of Epidemiology 2004; 33: 189–198.

73) Okubo A, Nakashima A, Doi S, et al. High-normal albuminuria is strongly associated with incident chronic kidney disease in a nondiabetic population with normal range of albuminuria and normal kidney function. Clinical and experimental nephrology; 24. Epub ahead of print May 2020. DOI: 10.1007/s10157-019-01842-2.

74) Sung K-C, Ryu S, Lee J-Y, et al. Urine Albumin/Creatinine Ratio Below 30 mg/g is a Predictor of Incident Hypertension and Cardiovascular Mortality. Journal of the American Heart Association: Cardiovascular and Cerebrovascular Disease; 5. Epub ahead of print September 2016. DOI: 10.1161/JAHA.116.003245.

75) Xie X, Peng Z, Li H, et al. Association of Urine Albumin/Creatinine Ratio below 30 mg/g and Left Ventricular Hypertrophy in Patients with Type 2 Diabetes. BioMed Research International; 2020. Epub ahead of print 2020. DOI: 10.1155/2020/5240153.

76) Smith ER, Cai MMX, McMahon LP, et al. The value of simultaneous measurements of urinary albumin and total protein in proteinuric patients. Nephrology, dialysis, transplantation : official publication of the European Dialysis and Transplant Association - European Renal Association; 27. Epub ahead of print April 2012. DOI: 10.1093/ndt/gfr708.

77) Qin S, Wang A, Gu S, et al. Original research: Association between obesity and urinary albumin-creatinine ratio in the middle-aged and elderly population of Southern and Northern China: a cross-sectional study. BMJ Open; 11. Epub ahead of print 2021. DOI: 10.1136/bmjopen-2020-040214.

78) Bartz SK, Caldas MC, Tomsa A, et al. Urine Albumin-to-Creatinine Ratio: A Marker of Early Endothelial Dysfunction in Youth. J Clin Endocrinol Metab 2015; 100: 3393–3399.

79) Invitti C, Maffeis C, Gilardini L, et al. Metabolic syndrome in obese Caucasian children: prevalence using WHO-derived criteria and association with nontraditional cardiovascular risk factors. International journal of obesity (2005); 30. Epub ahead of print April 2006. DOI: 10.1038/sj.ijo.0803151.

80) Burgert TS, Dziura J, Yeckel C, et al. Microalbuminuria in pediatric obesity: prevalence and relation to other cardiovascular risk factors. Int J Obes 2006; 30: 273–280.

81) Chandra DA, Manampiring AE,. F. Prevalensi Obesitas Pada Remaja Sma Ypkm Di Kota Manado. J E-Biomedik [Internet]. 2014 May 15 [cited 2023 May 15];2(2). Available from: https://ejournal.unsrat.ac.id/index.php/ebiomedik/article/view/5431

82) Xiao N, Jenkins TM, Nehus E, Inge TH, Michalsky MP, Harmon CM, et al. Kidney function in severely obese adolescents undergoing bariatric surgery. Obesity. 2014 Nov;22(11):2319–25.

83) World Health Organization (WHO). Orientation programme on adolescent health for health-care providers. Geneva:WHO;2006

84) Sawyer SM, Afifi RA, Bearinger LH, Blakemore SJ, Dick B, Ezeh AC, et al. Adolescence: a foundation for future health. Lancet.2012;379:1630-40.

85) Musa N, Ramzy T, Hamdy A, Arafa N, Hassan M. Assessment of urinary podocalyxin as a marker of glomerular injury in obesity-related kidney disease in children and adolescents with obesity compared to urinary albumin creatinine ratio. Clin Obes. 2021 Aug;11(4):e12452. doi: 10.1111/cob.12452. Epub 2021 Apr 2. PMID: 33797164.