Original Article

Glomerular Hyperfiltration as Predictor of Cardiometabolic Risk Factors among Children and Adolescents: The Childhood and Adolescence Surveillance and Prevention of Adult-V Study

Roya Kelishadi[1], Mostafa Qorbani[2,3], Farahnak Assadi[4], Mohammad Esmaeil Motlagh[5], Shirin Djalalinia[6], Ali Shahsavari[1], Hasan Ziaodini[7], Majzoubeh Taheri[8], Gita Shafiee[3], Azadeh Aminianfar[9], Sajjad Esmaeili[1], Tahereh Aminaei[8], Morteza Mansourian[10], Ramin Heshmat[3]

[1]Department of Pediatrics, Child Growth and Development Research Center, Research Institute for Primordial Prevention of Non-communicable Disease, Isfahan University of Medical Sciences, Isfahan, Iran, [2]Non-communicable Diseases Research Center, Alborz University of Medical Sciences, Karaj, Iran, [3]Chronic Diseases Research Center, Endocrinology and Metabolism Population Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran, [4]Department of Pediatrics, Division of Nephrology, Rush University Medical Center, Chicago, Illinois, USA, [5]Department of Pediatrics, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran,

Abstract

Background: The prevalence of glomerular hyperfiltration and chronic kidney disease is increasing worldwide in parallel with obesity hypertension epidemic. The effect of increases in glomerular filtrations (GFR) in children with metabolic syndrome has not been studied. The purpose of the present study is to investigate the relationship between GFR and cardiometabolic risk factors in a large sample of pediatric population. **Methods:** In this nationwide survey, 3800 participants were selected by cluster random sampling from 30 provinces in Iran. Anthropometric measures, biochemical, and clinical parameters were measured. We also measured estimated GFR (eGFR) using the recently modified Schwartz equations and other known cardiometabolic risk factors such as elevated total cholesterol, high low-density lipoprotein cholesterol (LDL-C), and obesity. **Results:** The response rate was 91.5% (n = 3843). The mean and standard deviation (SD) (Mean ± SD) of eGFR for girls, boys, and total population were 96.71 ± 19.46, 96.49 ± 21.69, and 96.59 ± 20 ml/min/1.73 m^2, respectively. Overall, 38.7% of the participants did not have any cardiometabolic risk factor. In multivariate models, the risk of elevated systolic blood pressure (BP) (odds ratio [OR]: 1.48; 95% confidence interval [CI]: 1.08–2.02), elevated diastolic BP (OR: 1.48; 95% CI: 1.08–2.02), elevated LDL-C (OR: 1.35; 95% CI: 1.07–1.70), and obesity (OR: 1.70; 95%CI: 1.24–2.33) were significantly higher in participants with higher eGFR level than those with the lower level but not with low level of high-density lipoprotein cholesterol (OR: 0.72; 95% CI: 0.60–0.88). **Conclusions:** This study demonstrates an association between glomerular hyperfiltration and obesity-related hypertension in a large sample of the Iranian pediatric population, independently of other classical risk factors.

Keywords: *Cardiometabolic risk factors, children and adolescents, estimated glomerular filtration rate*

Introduction

There has been a marked worldwide increase in the prevalence of noncommunicable diseases (NCDs) such as obesity, hypertension, diabetes mellitus type 2 (T2DM), chronic kidney disease (CKD), and cardiovascular disease (CVD) over the last two decades.[1-3]

The NCDs largely contributing to the CVD, and CKD populations are T2DM and hypertension. The prevalence of CKD increases progressively with increasing body mass index (BMI) from 15% among people with BMI <25 kg/m^2 to about 40% among those with a BMI of >30 kg/m^2.[4-9]

Emerging data strongly suggest childhood obesity potentially plays a powerful role in influencing later susceptibility to CKD.[10-13]

Emerging data also suggest an adverse embryonic, fetal, or postneonatal environment and is responsible for epigenetic modifications (SGA, prematurity) leading to metabolic syndrome (MS) in later childhood. MS risk is higher in those born smaller who became obese as adolescents and adults.[14]

Prevention of CKD due to type 2 diabetes and obesity hypertension is likely possible, simply by careful glycemic therapy, a healthy lifestyle and by observing current guidelines for blood pressure (BP) control.[15-18]

Unfortunately, despite the demonstration of effective therapy, obesity-related CKD is still not being recognized or treated properly. Screening of high-risk patients,

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[6]*Development of Research Technology Center, Deputy of Research and Technology, Ministry of Health and Medical Education, Tehran, Iran,* [7]*Department of Health, Bureau of Health and Fitness, Ministry of Education and Training, Tehran, Iran, ,* [8]*Department of Epidemiology, Office of Adolescents and School Health, Ministry of Health and Medical Education, Tehran, Iran,* [9]*Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran,* [10]*Health Management and Economics Research Center, Iran University of Medical Sciences, Tehran, Iran*

Address for correspondence:
Dr. Mostafa Qorbani,
Non-communicable Diseases Research Center, Alborz University of Medical Sciences, Emam Ali Hospital, Karaj, Iran.
Dr. Ramin Heshmat,
Chronic Diseases Research Center, Endocrinology and Metabolism Population Sciences Institute, Tehran University of Medical Sciences, Tehran, Iran.
E-mail: mqorbani1379@yahoo.com; rheshmat@tums.ac.ir

referral and consultation with nephrologists, and even provision of therapy after diagnosis is inadequate. The burden of disease is also paralleled by the enormous cost for delivering CKD care.

Primary care providers are the first line of defense against obesity-related CKD. They can play a significant role in early diagnosis, treatment, patient education, and referral.

Thus, early identification of individuals at risk of NCDs at every stage of life course from before conception, fetal life, early childhood, through adolescents are essential to prevent or retard the CKD progression and improve patients' outcome.

Methods

The data of this study were collected as a part of the "National survey of school student high-risk behaviors"(2014–2015), as the fifth survey of the school-based surveillance system entitled Childhood and Adolescence Surveillance and Prevention of Adult NCDs study. Details on the methodology have been presented before,[19] and here, we report it in brief.

Study population and sampling framework

The study population consisted of students aged 7–18 years in urban and rural areas of 30 provinces in Iran. They were selected through multistage, stratified cluster sampling method. Sampling within each province was conducted according to the Student's residence area (urban or rural) and level of education (primary and secondary) using the proportional to size method and with equal sex ratio. Moreover, the number of samples of different educational grades in urban and rural areas was estimated according to the number of students in each grade. The total sample size calculated as 480 students in each province (48 clusters of 10 students); in each province, 14 clusters were randomly selected for biochemical test, i.e., a total of 4200 students.

Procedure and measurements

The students' questionnaire was derived from the World Health Organization (WHO)-Global School Student Health Survey. The validity and reliability of Farsi-translated questionnaire was assessed previously.[20]

A team of trained health-care experts recorded information by interview; they also performed the physical examinations under standard protocols[21] by using calibrated instruments. Weight was measured to the nearest 0.1 kg while individuals wearing a light cloth and height were measured without shoes to the nearest 0.1 cm. BMI was calculated by dividing weight (kg) to height squared (m^2). Waist circumference was measured using a nonelastic tape at a point midway between the lower border of the rib cage and the iliac crest at the end of normal expiration to the nearest 0.1 cm.

We used the WHO growth curves to define BMI categories, i.e., underweight as age- and sex-specific BMI <5th, overweight as sex-specific BMI for age of 85th–95th, and obesity as sex-specific BMI for >95th percentile.[22] Abdominal obesity was defined as waist/height ratio equal to or more than 0.5.[23]

BP was measured in the sitting position on the right arm using a mercury sphygmomanometer with an appropriate cuff size. It was measured 2 times at 5-min intervals, and the average was recorded.[24-25]

Eligible participants accompanied by parents were referred to the laboratory where 6 mL venous blood samples were collected after 12-h overnight fasting. All collection tubes were centrifuged at 2500–3000 ×g for 10 min. Immediately after centrifugation, serum samples were aliquot into 200 microliter tubes and stored at −70°C. All samples were transferred by cold chain to Isfahan Mahdieh Laboratory. Fasting blood glucose (FBG), triglyceride (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and creatinine were measured enzymatically by Hitachi autoanalyzer (Tokyo, Japan).

FBG ≥100 mg/dl, TG ≥100 mg/dl, TC ≥200 mg/dl, LDL-C ≥110 mg/dl, and high HDL-C <40-45 mg/dl were considered as abnormal.[17] Elevated BP was defined as either high systolic or diastolic (systolic BP [SBP], diastolic BP [DBP]) ≥90th percentile for age, gender, and height.[26,27]

The creatinine-based glomerular filtrations (GFR) defined as the milliliter of plasma that was cleared from creatinine in one minute. The estimated GFR (eGFR) was to avoid the timed urine collection according to the newly revised Schwartz equation.[26,27]

Ethical considerations

Study protocols were reviewed and approved by ethical committees and other relevant national regulatory organizations. The Research and Ethics council of Isfahan University of Medical Sciences approved the study (Project number: 194,049). After complete explanation of the study objectives and protocols, written informed consent and verbal consent were obtained from the parents and students, respectively.

Statistical analysis

Data were analyzed by using STATA package version, 11.0 (STATA Statistical Software: Release 11. College Station, TX: STATA Corp LP. Package), and $P < 0.05$ was considered as statistically significant. Data are expressed as mean and standard deviation (SD) (Mean ± SD) for continuous variables and as number (percentage) for categorical variables. The Student's *t*-test was used to compare mean differences between quantitative variables. Association between qualitative variables was assessed by Pearson Chi-square test. The mean of cardiometabolic risk factors across eGFR tertiles was compared by analysis of variance test. Correlation between eGFR and cardiometabolic risk factors was assessed using Pearson correlation coefficient test. Different logistic regression models were used to examine the association of eGFR and cardiometabolic risk factors. Model I: crude model (without adjustment); Model II: was adjusted for age, living area, sex, PA, ST, and SES, and Model III: additionally adjusted for BMI in all abnormality except weight disorders. All statistical analyses were performed using survey analysis method.

Results

The response rate was 91.5% (n = 3843); characteristics of the study participants are presented in Table 1. The mean ± SD for age and BMI were 12.28 ± 3.15 years and 18.48 ± 4.69 kg/m^2, respectively. The mean ± SD of eGFR was 96.71 ± 19.46, 96.49 ± 21.69, and 96.59 ± 20.66 ml/min/1.73 m^2 for girls, boys, and total population, respectively. The mean SBP and DBP were higher in boys than in girls; but mean levels of TG, LDL-C, and TC were higher in girls than in boys ([Table 1]. Overall, 38.7% of the participants did not have any cardiometabolic risk factor.

Table 2 presents the mean ± SD of cardiometabolic risk factors by tertile of eGFR. The range of eGFR level in tertile 1, 2, and 3 was considered <86.19, 86.19–103.25, and >103.25 ml/min/1.73 m^2, respectively. Tertile 3 of eGFR was associated with higher mean ± SD of weight (48.92 ± 16.98 kg) and BMI (19.59 ± 5.33 kg/m^2), respectively. Mean SBP and DBP were higher in tertile 2 (98.31 ± 13.00and 63.19 ± 10.04 mmHg, respectively) compared to tertile 1 (96.40 ± 13.23 and 61.86 ± 10.41 mmHg, respectively) and tertile 3 (101.49 ± 11.94 and 65.57 ± 9.76 mm Hg, respectively) compared to tertile 2. This finding suggests positive relationship between increases in eGFR and elevated BP. All cardiometabolic indexes (except for HDL-C and FBG) were higher in T3 of eGFR than in other two tertiles. HDL-C and FBG had no significant difference across the tertiles of eGFR.

Table 3 shows the prevalence of cardiometabolic risk factors by tertile of eGFR. The frequency of elevated SBP and DBP was significantly different across tertiles of eGFR.

The correlation of cardiometabolic risk factors with eGFR according to gender is presented in Table 4. In both genders, weakly positive significant correlations were documented between eGFR and all cardiometabolic and anthropometric variables except for FBG and HDL-C. The strongest correlations were documented for weight, followed by waist circumference.

Results of logistic regression models are presented in Table 5. In multivariate models, the risk of elevated BP (odds ratio [OR]: 1.48; 95% confidence interval [CI]: 1.08–2.02), elevated DBP (OR: 1.48; 95% CI: 1.08–2.02), elevated LDL (OR: 1.35; 95% CI: 1.07–1.70), and overweight (OR: 1.70; 95% CI: 1.24–2.33) in individuals with elevated eGFR (3rd tertile) was significantly higher than those in low level of eGFR. Moreover, elevated eGFR was associated with lower risk of low HDL-C (OR: 0.72; 95% CI: 0.60–0.88).

Discussion

In this study, we explored the association of MS with glomerular hyperfiltration in a large sample of the Iranian children. These results indicated that the obese conditions are associated with increases in GFR, irrespective of other known CKD risk factors, thus raising the possibility of an increased susceptibility of obesity to development of CKD and CVD.

Children with elevated eGFR tended to be obese, had a higher SBP and DBP and elevated LDL-C levels. The result findings also showed positive significant correlations between eGFR and all cardiometabolic and anthropometric variables in both girls and boys except for FBG and HDL-C levels.

Obesity-induced glomerular hyperfiltration is a well-defined entity and is a major risk factor involved in the pathogenesis of obesity-related CKD.[28-33] The findings of the present study further evidence the fetal and environmental origin of adult CKD and CVD onset.[14]

Recent studies in adults have documented the clustering of risk factors of chronic diseases as cardiovascular and renal diseases, including type 2 diabetes mellitus, glucose intolerance, central obesity, hypertension, atherogenic dyslipidemia, and microalbuminuria[34,35] Some of these factors, as chronic hyperglycemia and

Table 1: Characteristics of the participants by gender: The CASPIAN-V study

	Total	Boy	Girl	*P*
Age mean (SD) (year)1	12.28±3.15	12.39±3.14	12.17±3.16	<0.001
Living area$_2$				
Urban	10194 (71.4)	5150 (71.3)	5044 (71.6)	0.65
Rural	4080 (28.6)	2078 (28.7)	2002 (28.4)	
eGFR$_2$	96.59 (20.66)	96.49 (21.69)	96.71 (19.46)	0.74
Height (cm)$_1$	147.07 (17.53)	148.15 (18.77)	144.93 (15.93)	<0.001
Weight (kg)$_1$	41.54 (16.93)	42.36 (18.23)	40.41 (15.82)	<0.001
WC (cm)$_1$	66.63 (12.10)	67.65 (12.87)	65.76 (11.33)	<0.001
WHtR1	0.45 (0.06)	0.45 (0.06)	0.45 (0.06)	0.008
BMI (kg/m^2)$_1$	18.48 (4.69)	18.48 (4.96)	18.53 (4.43)	0.56
SBP (mmHg)$_1$	98.72 (12.91)	99.55 (13.43)	98.77 (12.72)	<0.001
DBP (mmHg)$_1$	63.53 (10.19)	64.08 (10.70)	63.57 (10.14)	0.004
FBG (mg/dL)$_1$	91.66 (12.13)	92.06 (12.91)	91.20 (11.14)	0.02
TG (mg/dL)$_1$	88.16 (45.27)	87.15 (45.52)	89.02 (44.78)	0.20
HDL-C (mg/dL)$_1$	46.16 (9.98)	46.21 (10.17)	46.16 (9.75)	0.86
LDL-C (mg/dL)$_1$	90.06 (22.64)	89.31 (22.90)	90.86 (22.26)	0.034
TC1	153.85 (27.47)	152.96 (28.06)	154.83 (26.67)	0.03
Physical activity$_2$				
Low	4454 (33.4)	2147 (31.9)	2307 (35.0)	<0.001
Moderate	4424 (33.2)	2219 (33.0)	2205 (33.4)	
Vigorous	4440 (33.3)	2360 (35.1)	2080 (31.6)	
Screen Time$_2$				
Low	11644 (83.8)	5863 (83.4)	5781 (84.3)	0.18
High	2243 (16.2)	1164 (16.6)	1079 (15.7)	
SES$_2$				
Low	4454 (33.4)	2147 (31.9)	2307 (35.0)	<0.001
Medium	4424 (33.2)	2219 (33.0)	2205 (33.4)	
High	4440 (33.3)	2360 (35.1)	2080 (31.6)	
Abdominal obesity$_2$	2972 (21.1)	1550 (21.6)	1422 (20.5)	0.08
Elevated SBP$_2$	438 (3.1)	210 (3.0)	228 (3.3)	0.25
Elevated DBP$_2$	1450 (10.4)	746 (10.5)	704 (10.2)	0.51
Elevated BP$_2$	1604 (11.5)	815 (11.5)	789 (11.4)	0.87
Elevated FBG$_2$	161 (4.2)	96 (4.8)	65 (3.5)	0.06
Elevated TG$_2$	1065 (27.7)	541 (26.9)	524 (28.6)	0.22
Low HDL-c$_2$	1134 (29.5)	658 (32.7)	476 (26.0)	<0.001
MetS$_2$	188 (5.0)	108 (5.5)	80 (4.5)	0.17
Number of MetS components$_2$				
0	1443 (38.7)	706 (35.9)	737 (41.7)	0.005
1	1357 (36.4)	747 (38.0)	610 (34.5)	
$_2$	744 (19.9)	403 (20.5)	341 (19.3)	
3	174 (4.7)	98 (5.0)	76 (4.3)	
4	14 (0.4)	10 (0.5)	4 (0.2)	
Obesity$_2$	1615 (11.4)	896 (12.5)	719 (10.3)	<0.001
Overweight$_2$	1330 (9.4)	621 (8.7)	709 (10.2)	0.002
Excess weight4	2945 (20.8)	1517 (21.2)	1428 (20.5)	0.32
Elevated TC$_2$	189 (4.9)	100 (5.0)	89 (4.9)	0.87
Elevated LDL-C$_2$	674 (17.5)	341 (16.9)	333 (18.2)	0.31

hypertension, have classically been recognized as risk factors for CKD and are still considered to be of its major underlying causes.[35] Some studies in adults have shown the link of cardiometabolic risk factors with renal disease and the higher risk of CKD by increasing number of cardiometabolic risk factors[8,36] The frequency of dyslipidemia, characterized by increased small particles LDL-C and VLDL and decreased levels of HDL-C, is more prevalent in CKD patients compared to general population.[34,35] Clustering of cardiometabolic factors and MS can be independently associated with higher risk of CKD;[35] on the other hand, CKD itself is an independent

Table 2: Mean (standard deviation) of cardiometabolic risk factors by tertile of eGFR: The CASPIAN V study

Variable	Tertile of eGFR *			*P* for trend
	T1	T2	T3	
Weight (kg)	35.27 (15.80)	40.44 (15.07)	48.92 (16.98)	<0.001
Height (cm)	138.33 (17.83)	146.65 (15.44)	156.27 (14.28)	<0.001
WC (cm)	63.01 (12.13)	66.66 (11.51)	70.23 (11.57)	<0.001
BMI (kg/m^2)	17.67 (4.49)	18.18 (3.95)	19.59 (5.33)	<0.001
WHtR	0.45 (0.06)	0.45 (0.06)	0.44 (0.06)	0.01
SBP (mmHg)	96.40 (13.23)	98.31 (13.00)	101.49 (11.94)	<0.001
DBP (mmHg)	61.86 (10.41)	63.19 (10.04)	65.57 (9.76)	<0.001
FBG (mg/dL)	92.08 (13.68)	91.13 (10.63)	91.76 (11.86)	0.50
TG (mg/dL)	87.60 (45.93)	85.91 (39.09)	90.96 (49.99)	0.06
HDL-C (mg/dL)	45.66 (10.15)	46.66 (10.19)	46.17 (9.58)	0.19
LDL-C (mg/dL)	88.50 (23.31)	90.48 (22.12)	91.18 (22.41)	0.003
TC (mg/dL)	151.69 (28.81)	154.33 (26.67)	155.55 (26.75)	<0.001

Table 3: Prevalence of cardiometabolic risk factors by tertiles of eGFR: the CASPIAN V study

Variable	Tertile of eGFR *			*P* for trend
	T1	T2	T3	
Abdominal obesity	262 (20.6)	264 (21.0)	236 (18.6)	0.28
Elevated SBP	31 (2.5)	32 (2.6)	30 (2.4)	0.96
Elevated DBP	97 (7.7)	110 (8.9)	138 (11.1)	0.01
Elevated BP	106 (8.4)	121 (9.8)	147 (11.8)	0.01
Elevated FBG	53 (4.2)	51 (4.0)	56 (4.4)	0.89
Elevated TG	353 (27.7)	333 (26.3)	371 (29.2)	0.26
Low HDL-c	397 (31.2)	357 (28.2)	375 (29.5)	0.26
MetS	57 (4.5)	66 (5.3)	65 (5.2)	0.60
Number of MetS components				
0	472 (37.5)	506 (41.0)	465 (37.5)	0.30
1	470 (37.4)	428 (34.7)	459 (37.0)	
2	258 (20.5)	235 (19.0)	251 (20.2)	
3	55 (4.4)	62 (5.0)	57 (4.6)	
4	2 (0.2)	4 (0.3)	8 (0.6)	
Obesity	138 (10.8)	126 (10.0)	151 (11.9)	0.29
Overweight	83 (6.5)	136 (10.8)	128 (10.1)	<0.001
Excess weight	221 (17.4)	262 (20.7)	279 (22.0)	0.01
High TC	72 (5.7)	52 (4.1)	63 (5.0)	0.19
High LDL-C	208 (16.3)	228 (18.0)	235 (18.5)	0.31

Table 4: Correlation coefficient of cardiometabolic risk factors and eGFR by sex: The CASPIAN V study

Variable	eGFR*		
	Total	Boys	Girls
Weight (kg)	0.35**	0.34**	0.37**
Height (cm)	0.83**	0.43**	0.47**
WC (cm)	0.26**	0.24**	0.28**
BMI (kg/m2)	0.16**	0.14**	0.19**
WHtR	-0.04*	-0.05**	-0.02
SBP (mmHg)	0.17**	0.17**	0.17**
DBP (mmHg)	0.15**	0.14**	0.16**
FBG (mg/dL)	-0.004	-0.02	0.02
TG (mg/dL)	0.09**	0.08**	0.10**
HDL-C (mg/dL)	0.01	0.01	0.01
LDL-C (mg/dL)	0.04**	-0.001	0.11**
TC (mg/dL)	0.07**	0.03	0.13**

risk factor for CVDs.[8,36] Moreover, cardiometabolic factors can be also associated with acute kidney injury.[37]

In our study, in both genders, higher eGFR was associated with anthropometric indices and cardiometabolic factors except than FBG and HDL-C. Limited population-based studies exist in this regard, and most of them have been conducted in adults. A study in Japanese adult population reported that cardiometabolic risk factors were associated with decreased GFR and in turn with CKD.[38,39] A study among African-American adults found that some cardiometabolic factors, including elevated BP, abdominal obesity, low HDL-C, high FBG, and TG, was associated with a decrease in GFR levels and CKD.[40] It is also reported that in Korean adults, changes in eGFR levels were in line with changes in cardiometabolic risk factors.[41] Contrary to these findings, a large study among Chinese adults did not confirm the association of decreased GFR with cardiometabolic risk factors as BMI, FBG, and TG.[42] In a study among children with CKD, in spite of treatment, with decreasing GFR, the prevalence of metabolic abnormalities increased by 2- to 4-fold.[42] Variations in the findings of studies on the association of metabolic abnormalities with GFR might be in part because of racial and ethnic differences.[43,44]

The present data suggest that the increased prevalence of cardiometabolic risk factors associated with glomerular hyperfusion could be the result of decreased number of functioning nephrons due to overweight and obesity. Association between renal hyperperfusion and hypertension has also been reported in obese patients secondary to glomerular capillary endothelial cell injury.[45] It is anticipated that glomerular hyperfiltration over a long period of time could result in further decline in eGFR and development of cardio MS. Moreover, it has been documented that patient with type 1 diabetes

Table 5: Association of cardiometabolic risk factors and eGFR in logistic regression analysis: The CASPIAN-V study

Variable	Tertile of eGFR*		
	T1	T2	T3
Abdominal obesity			
Model I	Reference	1.02 (0.84-1.24)	0.88 (0.72-1.07)
Model II	Reference	1.04 (0.84-1.28)	0.91 (0.73-1.13)
Elevated SBP			
Model I	Reference	1.04 (0.63-1.72)	0.98 (0.58-1.62)
Model II	Reference	1.15 (0.67-1.98)	1.29 (0.72-2.31)
Model III	Reference	1.14 (0.66-1.97)	1.23 (0.68-2.22)
Elevated DBP			
Model I	Reference	1.16 (0.87-1.54)	1.49 (1.13-1.96)**
Model II	Reference	1.18 (0.86-1.60)	1.55 (1.13-2.11)**
Model III	Reference	1.17 (0.86-1.60)	1.48 (1.08-2.02)**
Elevated BP			
Model I	Reference	1.17 (0.89-1.54)	1.45 (1.12-1.89)**
Model II	Reference	1.18 (0.88-1.59)	1.51 (1.12-2.04)**
Model III	Reference	1.18 (0.88-1.58)	1.48 (1.08-2.02)**
Elevated TG			
Model I	Reference	0.93 (0.78-1.11)	1.07 (0.90-1.27)
Model II	Reference	0.90 (0.75-1.09)	1.06 (0.87-1.28)
Model III	Reference	0.90 (0.75-1.09)	1.04 (0.86-1.27)
Low HDL-C			
Model I	Reference	0.86 (0.73-1.03)	0.92 (0.78-1.09)
Model II	Reference	0.80 (0.66-0.96)**	0.73 (0.60-0.89)**
Model III	Reference	0.80 (0.66-0.96)**	0.72 (0.60-0.88)**
ElevatedFBG			
Model I	Reference	0.96 (0.65-1.43)	1.06 (0.72-1.56)
Model II	Reference	0.99 (0.65-1.52)	1.06 (0.69-1.64)
Model III	Reference	0.99 (0.65-1.51)	1.03 (0.67-1.60)
MetS			
Model I	Reference	1.18 (0.82-1.71)	1.16 (0.80-1.67)
Model II	Reference	1.29 (0.88-1.91)	1.22 (0.81-1.84)
Model III	Reference	1.32 (0.89-1.96)	1.12 (0.74-1.70)
Elevated LDL-C			
Model I	Reference	1.12 (0.91-1.38)	1.16 (0.94-1.42)
Model II	Reference	1.18 (0.94-1.48)	1.34 (1.07-1.69)**
Model III	Reference	1.18 (0.95-1.48)	1.35 (1.07-1.70)**
Elevated TC			
Model I	Reference	0.71 (0.49-1.03)	0.87 (0.61-1.23)
Model II	Reference	0.77 (0.51-1.15)	1.23 (0.84-1.81)
Model III	Reference	0.77 (0.52-1.15)	1.25 (0.85-1.84)
Over weight			
Model I	Reference	1.72 (1.29-2.29)**	1.60 (1.20-2.14)**
Model II	Reference	1.68 (1.24-2.27)**	1.70 (1.24-2.33)**
Obesity			
Model I	Reference	0.91 (0.70-1.17)	1.11 (0.86-1.41)
Model II	Reference	0.97 (0.74-1.28)	1.27 (0.96-1.67)
Excess weight			
Model I	Reference	1.24 (1.01-1.51)**	1.34 (1.10-1.63)**
Model II	Reference	1.29 (1.04-1.59)**	1.21 (1.21-1.88)**

mellitus and elevated baseline GFR values are more prone to develop impaired renal function such as proteinuria and hypertension than those with normal or lower baseline GFR[44] Further, in a recent study, diabetic male adults experience higher mortality rate due to renal hyperperfusion than the females participants, suggesting that hypertriglyceridemia has been reported to have a positive correlation with the development of glomerular hyperperfusion.[45]

Thus, adiposity, elevated BP, dyslipidemia, and hyperglycemia are important risk factors for NCDs including cardiovascular and kidney diseases.[46] Therefore, early detection of NCDs that originate from early life, such as obesity and hypertension, is warranted in high-risk children and adolescents.

Study limitations and strengths

The main limitation of this study is the cross-sectional nature of data. The strengths are the novelty in the pediatric age group, the large sample size, and the nationwide coverage of the study.

Conclusions

MS categories and glomerular hyperfiltration are positively associated, independently of other known CKD risk factors, suggesting that the increases in GFR may represent an important modifying factor of the association between MS and CKD.

The findings of this large population-based study serve as confirmatory evidence on a correlation between cardiometabolic risk factors and elevated eGFR among children and adolescents. The relationship of some cardiometabolic risk factors with the elevated GFR levels observed in this study may be related to glomerular hyperfiltration. The study findings emphasize the importance of primordial/primary prevention of MS and the renal function screening of at-risk children and adolescents.

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Conflicts of interest

There are no conflicts of interest.

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