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Evaluation of Carotid Intima-Media Thickness and Other Cardiovascular Risk Factors in Children with Chronic Kidney Disease

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ABSTRACT

Objective: The onset of chronic kidney disease during childhood substantially increases the risk of cardiovascular complications in adulthood among affected patients. In such patients, chronic damage beginning in childhood has been linked to higher long-term mortality rates, and bone changes may also occur due to factors other than renal osteodystrophy. This study investigates the burden of cardiovascular risk among children with pre-dialysis chronic kidney disease and examines the relationship between skeletal mineral content and the progression of kidney dysfunction.

Materials and Methods: Echocardiographic assessment, carotid intima-media thickness measurements, ambulatory blood pressure monitoring, and bone mineral density analysis were performed on 50 pre-dialysis chronic kidney disease patients and control subjects. The results were compared between groups.

Results: Patients demonstrated higher carotid intima-media thickness, as well as greater left ventricular mass index and end-diastolic left ventricular mass, compared to controls. The early-to-late ventricular filling (E/A) ratios were normal, with no difference between groups. All patients were osteopenic from the early stage, with a mean Z score of -1.59±1.32. Both daytime and night-time systolic and diastolic blood pressure (BP) measured by ambulatory blood pressure monitoring (ABPM) were significantly higher in the patient group than in controls, and a non-dipping blood pressure pattern was also identified in patients.

Conclusion: Patients diagnosed with chronic kidney disease during the pediatric period demonstrate an elevated risk of cardiovascular complications from the time of diagnosis onwards. A possible correlation between reduced bone mineral density in these patients and cardiovascular events represents another factor that increases mortality and morbidity.

Keywords: Bone density, carotid intima-media thickness, child, chronic kidney diseases.

INTRODUCTION

Chronic kidney disease (CKD) has been identified as a major contributing factor to cardiovascular morbidity in both pediatric and adult populations. Increased mortality and morbidity due to cardiovascular disease (CVD) in adult CKD patients are closely associated with childhood-onset kidney dysfunction.[1]

Elevated blood pressure (BP) is recognized as a significant clinical indicator of disease progression in children with CKD.[2] Ambulatory blood pressure monitoring (ABPM) has been shown to be a superior method for cardiovascular risk stratification compared with home or office blood pressure measurement, as it allows early identification of hypertension-related complications before the onset of microalbuminuria.[3]

Measurement of carotid intima-media thickness (CIMT) and assessment of arterial stiffness may help identify patients at high risk of CVD due to subclinical arteriosclerosis observed in early CKD.[4]

Although findings of renal osteodystrophy (ROD) are less prevalent in patients with early-stage CKD, bone histology is known to deteriorate in patients as the disease progresses.[5] Dual-energy X-ray absorptiometry (DEXA) is a valuable, non-invasive approach to evaluating bone changes in CKD.[4] It has previously been established through a range of investigative studies that DEXA has the capacity to assess bone mineral abnormalities in pediatric patients with CKD.[6]

The present study evaluates cardiovascular risk in children with pre-dialysis CKD. To achieve this objective, we investigated the impact of CKD on cardiovascular outcomes using CIMT, ABPM, and echocardiographic results. A secondary aim was to identify disease-related bone changes by examining the relationship between bone mineral density (BMD) and CKD stage.

MATERIALS AND METHODS

This study was designed as a cross-sectional observational study. The sample size was determined based on the total number of eligible pre-dialysis CKD patients followed in our clinic during the study period who consented to participate. Fifty pediatric patients who had been followed for CKD during the pre-dialysis period were included in the study. The control group comprised 50 age- and sex-matched healthy children who attended our general pediatric outpatient clinics for routine follow-up visits and had no known renal or cardiovascular conditions. No additional matching was performed for Body Mass Index (BMI) or other clinical parameters. The Institutional Ethics Committee of Düzce University Faculty of Medicine approved the study protocol (date: 01.03.2021, ethics no: 2021/55). All procedures were conducted in accordance with the ethical standards outlined in the Declaration of Helsinki. Informed consent was obtained from all participants and their families. The etiologies of CKD in the study sample were reflux nephropathy (n=15), kidney hypoplasia/dysplasia (n=10), neurogenic bladder (n=6), bilateral multicystic dysplastic kidney (n=4), obstructive uropathy (n=4), hemolytic uremic syndrome (n=3), renovascular anomalies, (n=3) and autosomal dominant polycystic kidney disease (n=1), as well as four patients with CKD of unknown etiology. CKD was diagnosed and staged using the 2012 Kidney Disease: Improving Global Outcomes (KDIGO) guidelines.[7] Exclusion criteria were active infection, obesity, nephrotic proteinuria, heart failure, congenital heart disease, and the presence of prevailing cardiovascular risk factors, including diabetes, dyslipidemia, or tobacco exposure.

KEY MESSAGES

- This study evaluated cardiovascular risk in children with pre-dialysis CKD using CIMT, ABPM, and echocardiography, and explored the association between bone mineral density and CKD stage.
- Patients had significantly higher CIMT, LV mass/index, septal thickness, and BP, along with lower E values, compared to controls.
- Findings suggest early, subclinical cardiovascular remodeling in CKD patients, beginning in the pre-dialysis stage and associated with hypertension and hyperparathyroidism.

Serum samples were separated from the blood and used for routine biochemistry, as well as for the assessment of 25-OH vitamin D and intact parathyroid hormone (PTH) levels. The glomerular filtration rate (GFR) was calculated by measuring creatinine clearance in 24-hour urine. [8]

A Medset Scanlight III Padsy RR oscillometric device was used to measure 24-hour ABPM, with a suitably proportioned cuff positioned on the non-dominant arm. Blood pressure (BP) was recorded every 15 minutes during the daytime and every 30 minutes during the night. ABPM results were included if there were at least 30 total recordings and at least 8 night-time measurements. A mean systolic and/or diastolic BP above the 95th percentile for sex, age, and height was defined as hypertension. A 10% decrease in the night-time BP average compared with the daytime average was considered a dipping pattern.[9] BP measurements were evaluated according to American Heart Association recommendations.[10]

Participants were placed in a supine position for 30 minutes before CIMT measurement. Measurements were obtained

Table 1. Demographic and biochemical characteristics and ambulatory blood pressure measurements of the patient and control groups

	Patient (n=50)	Control (n=50)	p
Gender, n (%)			0.114
Girl	18 (36.0)	20 (40.0)	
Boy	32 (64.0)	30 (60.0)	
Age (years), mean±SD	11.31±5.08	10.08±3.33	0.217
BMI (kg/m^2), mean±SD	18.93±4.79	20.22±5.18	0.288
GFR (mL/min/1.73 m^2)	41.1 (44.5) [5.0–90.5]	126.2 (38.6) [100.5–184.3]	**<0.001**
Calcium (mg/dL)	9.84±0.72	9.70±0.30	0.247
Phosphorus (mg/dL)	4.53±1.05	4.74±0.55	0.276
Magnesium (mg/dL)	1.15±0.58	0.84±0.06	**<0.001**
Alkaline phosphatase (U/L)	198 (160) [67–546]	217 (99) [27–346]	0.766
Blood urea nitrogen (mg/dL)	26.7 (23.5) [11.9–86]	10.3 (3.1) [5–22]	**<0.001**
Creatinine (mg/dL)	1.37 (2.39) [0.54–8.60]	0.43 (0.16) [0.26–0.63]	**<0.001**
Vitamin D (ng/mL)	15.7 (14.5) [4.0–35.5]	17.8 (8.4) [4.5–27.3]	0.844
Parathyroid hormone (pg/mL)	84.2 (141.9) [18.3–503.5]	35.9 (31.1) [21.1–114.0]	**<0.001**
Total systolic average blood pressure (mmHg) (mean±SD)	116.03±15.03	101.24±4.19	**<0.001**
Total diastolic average blood pressure (mmHg) (mean±SD)	71.94±15.13	57.64±4.59	**<0.001**
Total mean arterial pressure average (mmHg) (mean±SD)	90.38±14.12	77.68±3.66	**<0.001**
Daytime systolic average blood pressure (mmHg) (mean±SD)	118.69±14.88	105.60±5.69	**<0.001**
Daytime diastolic average blood pressure (mmHg) (mean±SD)	73.59±14.76	63.84±6.78	**0.002**
Daytime mean arterial pressure (mmHg) (mean±SD)	93.08±13.72	83.12±5.15	**0.002**
Night-time systolic average blood pressure (mmHg) (mean±SD)	106.94±14.43	97.84±7.12	**0.006**
Night-time diastolic average blood pressure (mmHg) (mean±SD)	66.48±15.01	54.20±4.65	**<0.001**
Night-time mean arterial pressure average (mmHg) (mean±SD)	84.64±13.84	74.48±4.66	**0.002**
Non-dipping pattern, n (%)	44 (88.0%)	6 (12.0%)	**<0.001**

BMI: Body Mass Index; GFR: Glomerular filtration rate. Descriptive statistics are presented as mean±standard deviation (SD) or median (interquartile range) [minimum–maximum]. A p-value <0.05 was considered statistically significant.

using a 12 MHz linear probe and a Vivid I color Doppler ultrasound machine. The patient's neck was turned 45 degrees toward the opposite side; the 10 mm distal and 20 mm proximal segments of the carotid bulb were identified, and common carotid artery measurements were taken. Standard two-dimensional, M-mode, and Doppler flow echocardiographic measurements were performed in accordance with American Society of Echocardiography recommendations.[11] M-mode measurements were acquired from the parasternal long axis. Fractional shortening (FS) was calculated by dividing the difference between the left ventricular (LV) end-diastolic and end-systolic diameters by the LV end-diastolic diameter. The early diastolic velocity of mitral inflow (E), late diastolic velocity of mitral inflow (A), and the mitral early-to-late (E/A) ratio were derived from the mitral annulus.

The left ventricular mass (LVM) was calculated according to the Devereux formula,[12] followed by the calculation of the LVM index (LVMI), [(LVMI = LVM / body surface area (BSA)]. The LV relative wall thickness (RWT) was also calculated [RWT = (2 × posterior wall thickness in diastole (PWd) / left ventricular end-diastolic diameter (LVEDd)].

The BMD of the study group was measured using DEXA densitometry (QDR 4500 X-ray Bone Densitometer, Hologic Inc., 590 Lincoln St., Waltham, MA, 02154). Measurements of the lumbar region (L1-L4) with thin-mode scans were recorded in g/cm^2. BMD results were assessed using age-, sex-, and height-specific Z-scores. Participants with a Z-score <-1.0 were defined as osteopenic, whereas those with a Z-score ≤-2.5 were defined as severely osteopenic.[13]

Table 2. Echocardiographic results of the groups

	Patient (n=50)	Control (n=50)	p
CIMT (mm)	0.444±0.063	0.409±0.043	**0.017**
M-mode echocardiography and 2D cardiac measurements			
LVIDd	39.41±8.18	39.16±5.54	0.892
LVIDs	24.04±6.89	23.16±3.51	0.476
IVSd	8.15±1.90	7.00±1.35	**0.009**
IVSs	11.54±2.23	10.08±2.78	**0.018**
LVPWd	7.81±2.48	7.04±1.62	0.116
LVPWs	12.41±2.89	13.40±8.68	0.487
EF	69.15±9.44	70.60±7.11	0.503
FS	38.74±7.99	40.48±5.60	0.354
LVMass	109 (72) [22-312]	67 (55) [33-186]	**0.019**
LVMI	98.95±46	67.18±20.35	**0.002**
IVRT	58.69±15.19	70.13±34.44	0.060
IVCT	54.11±11.04	51.88±9.20	0.417
Evaluation of diastolic filling of the left ventricle			
E	0.127±0.038	0.152±0.034	**0.010**
A	0.094±0.112	0.086±0.021	0.740
E/A	1.819±0.501	1.858±0.467	0.758

CIMT: Carotid intima-media thickness; LVIDd: Left ventricular internal diastolic diameter; LVIDs: Left ventricular internal systolic diameter; IVSd: Intraventricular septum diastole; IVSs: Intraventricular septum systole; LVPWd: Left ventricular posterior wall diastolic thickness; LVPWs: Left ventricular posterior wall systolic thickness; EF: Ejection fraction; FS: Fractional shortening; LVMass: Left ventricular mass; LVMI: Left ventricular mass index; IVRT: Isovolumetric relaxation time; IVCT: Isovolumetric contraction time; E: Early diastolic velocity of mitral inflow; A: Late diastolic velocity of mitral inflow. Descriptive statistics are presented as mean± standard deviation or median (interquartile range) [minimum–maximum]. A p-value <0.05 was considered statistically significant.

Statistical Analysis

The normality of data distribution and the homogeneity of variances were evaluated using the Shapiro-Wilk and Levene tests, respectively. Depending on data distribution, group comparisons were conducted using the independent samples t-test, Welch test, or Mann-Whitney U test. Categorical variables were evaluated using Pearson's Chi-square test or Fisher's exact test, based on expected frequency assumptions. Associations between continuous variables were examined using Pearson or Spearman correlation coefficients, selected according to the distribution pattern. The statistical analysis was conducted by reporting descriptive statistics as the mean±standard deviation, the median with interquartile range, or the minimum and maximum values, depending on the data type. Categorical data were summarized using counts and percentages. All statistical analyses were performed using IBM SPSS Statistics software (Version 22.0; Armonk, NY). A p-value of less than 0.05 was considered to indicate statistical significance.

Multiple linear regression analyses were conducted to identify independent predictors of cardiovascular parameters. Dependent variables were left ventricular mass index and carotid intima-media thickness. Independent variables included serum phosphorus, parathyroid hormone, vitamin D, bone mineral density Z-scores, glomerular filtration rate (GFR), and mean systolic and diastolic blood pressure values. Variables were selected based on clinical relevance and significance in univariate analyses ($p<0.05$). A stepwise method was used for model building. The number of variables entered into the model was limited to maintain an appropriate subject-to-variable ratio.

RESULTS

The study sample of 50 patients comprised 18 girls and 32 boys. The age range of both groups was 5 to 18 years. There were no significant differences in sex or age distribution between the patient and control groups (Table 1). Of the patients, 11 (22%) had stage 2, 19 (38%) had stage 3, six (12%) had stage 4, and 14 (28%) had stage 5 disease. Blood urea nitrogen ($p<0.001$), creatinine ($p<0.001$), PTH ($p<0.001$), and magnesium ($p<0.001$) levels were significantly higher in patients than in controls, while GFR was lower ($p=0.001$). As shown in Table 1, no substantial differences were observed in the other biochemical parameters between the groups.

The mean Z score in the patient group was -1.59±1.32 [-1.5 (-4.1-0.7)]. Although lower height-adjusted BMD Z-scores were observed in the patient group, they were positively correlated with GFR (r=0.437, p=0.011). Of the patients, 36% (n=18) were osteopenic, 28% (n=14) were severely osteopenic, and 36% (n=18) had normal Z scores. Among patients with a PTH level >200 pg/mL, 27.2% (n=3) were osteopenic and 54.5% (n=6) were severely osteopenic. In the patient group, there was no statistically significant correlation between bone mineral density Z-scores and CIMT parameters (r=-0.020, p=0.914). Although a trend toward lower Z-scores was observed with increasing CKD stage, this relationship was not statistically significant (r=-0.148, p=0.452).

The patient group demonstrated significantly higher interventricular septal thickness in diastole (IVSd, p=0.009) and systole (IVSs, p=0.018), as well as higher left ventricular mass (p=0.019) and LVMI (p=0.002), while the E was lower (p=0.01). However, no significant differences were observed in the E/A ratio between the groups. In addition, the mean CIMT was found to be significantly higher in the patient group compared to the control group (p<0.05) (Table 2).

Both daytime and night-time systolic and diastolic BP measured by ABPM were significantly higher in the patient group than in the control group (p<0.001). In addition, 87.5% of the patient group and 12% of the control group demonstrated a non-dipping BP pattern (Table 1).

Correlations between the cardiac findings and laboratory results were also examined in this study. In the patient group, LVMI was negatively correlated with GFR (r=-0.474, p<0.001), and positively correlated with CIMT (r=0.424, p=0.001), total mean systolic BP (r=0.373, p=0.005), total mean diastolic BP (r=0.496, p<0.001), and PTH (r=0.389, p=0.001). No significant correlation was found between GFR and mean systolic or diastolic blood pressure in the patient group (r=0.127, p=0.488 for total systolic BP; r=0.006, p=0.974 for total diastolic BP). CIMT was positively correlated with both daytime (r=0.474, p=0.017) and night-time (r=0.550, p=0.005) systolic and diastolic BP in the patient group. There was also a weak positive correlation between CIMT and PTH (r=0.362, p=0.004), while CIMT and GFR were weakly negatively correlated (r=-0.357, p=0.005) (Fig. 1). Similarly, there was a moderate negative correlation between the z-score and phosphorus level (r=-0.429, p=0.013). A multiple regression analysis did not identify significant relationships between CKD-related mineral and bone disorder indicators (such as PTH and Z scores) and cardiovascular parameters. A multiple regression analysis was conducted using the variables found to be significantly associated with LVMI and CIMT in univariate analyses. Although some associations were identified, none retained statistical significance after multivariate adjustment for confounders. This loss of significance in the multivariate model prompted us to evaluate the possibility of multicollinearity. Diagnostic testing using the Variance Inflation Factor (VIF) and tolerance values demonstrated no significant multicollinearity (all VIF <2.0, all tolerance >0.5). Therefore, the observed changes in significance are more likely attributable to the limited sample size and the statistical adjustment for multiple covariates rather than to true multicollinearity.

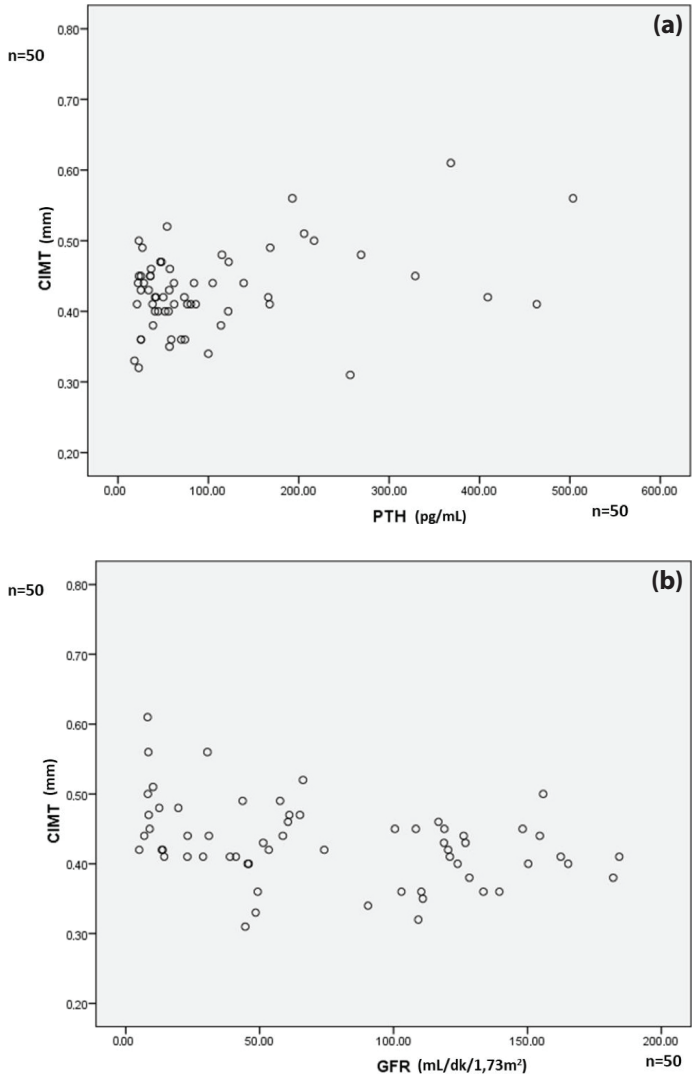

Figure 1. (a) Correlations between carotid intima-media thickness and parathyroid hormone in the patient group (n=50). **(b)** Correlation between carotid intima-media thickness and glomerular filtration rate in the patient group (n=50).

The correlations between numerical variables were analyzed using either Pearson or Spearman correlation analysis, depending on the data distribution.

DISCUSSION

It is well recognized that in children with CKD, both mortality and morbidity increase progressively as GFR declines. In adults, LV dysfunction, LV hypertrophy (LVH), increased CIMT, arterial stiffness, and coronary calcification predict cardiovascular complications, but their roles in pediatric CKD remain unclear. This study evaluated the cardiac effects of reduced kidney function and its association with CIMT, BP changes, and BMD in pre-dialysis pediatric CKD, indicating early cardiovascular risk.

Hypertension is a key CVD risk factor and affects renal, cardiac, and vascular health in CKD.[14] Although office BP readings were normal, ABPM detected elevated BP in patients. This suggests that hypertension may go undiagnosed, accelerating kidney damage and cardiovascular complications. BP regulation is often inadequate in CKD, even with treatment.[15]

In this study, the relationship between GFR and BP changes was also evaluated. No correlation was identified between BP and GFR in the patient group. This finding indicates that BP may be elevated even before the disease has reached an advanced stage. Nevertheless, a greater proportion of patients in the CKD group exhibited non-dipping BP patterns compared with the control group. The presence of normal office BP and a non-dipping BP pattern is a valuable finding, indicating that diagnosis is difficult and the risk of delayed treatment is high in the patient group.

Bone mineral metabolism disorders in CKD patients also increase cardiovascular mortality and morbidity. Abnormalities in calcium, phosphorus, magnesium, PTH, and vitamin D disrupt bone remodeling dynamics, with vitamin D deficiency playing a particularly detrimental role. In this study, serum magnesium levels were significantly higher in the patient group than in controls, although both remained within normal pediatric reference ranges. This unexpected result may reflect closer nutritional monitoring and possible supplementation in the CKD group, or measurement variability in the control group. Enhanced electrolyte regulation through regular clinical follow-up may help mitigate some metabolic imbalances; however, despite this, BMD loss may still contribute to adverse cardiac remodeling through mechanisms independent of renal osteodystrophy. Studies conducted previously have demonstrated that reduced BMD may be associated with an increased risk of cardiovascular complications among osteoporotic patients without comorbidities.[16] This relationship is independent of age and depends on other factors in adults. Many factors, such as hypertension, inflammation, cytokines, lipid metabolism abnormalities, vitamin D abnormalities, hyperparathyroidism, and increased homocysteine, are thought to contribute to this process. It is hypothesized that some of these factors play a pivotal role in the pathophysiology of CKD. In this study, low Z scores were found in most patients, but no correlation was observed between Z score and CIMT, one of the cardiovascular risk indicators. The absence of a correlation between Z-score and CIMT may be attributable to the influence of BMD determinants that are not associated with inflammation or arteriosclerosis. In these patients, inadequate and unhealthy nutrition, along with a sedentary lifestyle compared to their peers, may lead to a decrease in BMD. This study also showed that the CKD stage of the patient was not correlated with the Z score. This finding is consistent with those reported by Pluskiewicz et al.,[6] who stated that the severity of skeletal changes was comparable in children both pre-dialysis and on dialysis treatment. This suggests that BMD decreases in the early stages of the disease.

Two distinct but interrelated mechanisms have been identified in the development of CVD in CKD stage 5: LVH caused by mechanical or hemodynamic stress, and vascular disease, which can manifest as atherosclerosis and calcification.[17] Previous studies have reported an increase in concentric LVH with decreasing GFR.[18] Mitsnefes et al.[19] demonstrated that LVMI increased in 24% of children with stage 2-4 CKD in relation to LVH, and that stage 5 patients had higher rates of LVH and abnormal LV geometry. Another prospective study showed that the rate of LVH increased with advancing CKD stage. The researchers reported that effective control of anemia, BP, and hyperparathyroidism may prevent the development of LVH.[20] Pluta et al.[21] found that approximately 60% of adult CKD stage 1–3 patients had either concentric remodeling, concentric hypertrophy, or eccentric hypertrophy in the LV. In this study, it was observed that LVMI and interventricular septal (IVS) thicknesses were significantly increased in the patient group, a finding that aligns with the literature. Cardiac remodeling was observed in the absence of cardiovascular risk factors such as diabetes mellitus, smoking, and dyslipidemia, none of which were present in our pediatric cohort. In this context, particularly high PTH and phosphate levels may play a significant role in the etiology of cardiovascular events in CKD.[22] Vascular calcification is associated with LVH and is manifested by coronary artery disease, stiffening of the arterial wall, thickening of the intima-media layer, and increased pulse wave velocity. Based on these data, the increased CIMT and LVMI values in the present study may be considered highly correlated with higher PTH levels accompanying decreased GFR.

Another finding suggesting that CKD accelerates the progression of CVD is the increase in CIMT, which was higher in patients with pre-dialysis CKD than in the control group, and more pronounced as GFR decreased. Pluta et al.[21] also demonstrated a negative correlation between GFR and CIMT in CKD patients. Increased CIMT is an important diagnostic tool for predicting

cardiovascular events associated with arteriosclerosis.[23] Children diagnosed with CKD are prone to increased cardiovascular risk, which is associated with conventional risk factors such as high BP and an unhealthy diet.[24]

Ejection fraction (EF) and FS are important parameters used to assess LV systolic function, which decreases as CKD progresses due to several factors, including the volume load associated with the disease.[25] EF and FS values in this study were normal and did not show a significant difference between groups, even in those with LVH, which is a positive indicator. This situation highlights the importance of volume control, especially in patients with normal urine output and no fluid overload.

LV diastolic dysfunction is prevalent in CKD and contributes to advanced cardiovascular complications. Alterations in the E/A ratio are indicative of impaired LV relaxation. As LVM increases, E velocity tends to decline, and a reduced E/A ratio in CKD has been linked to anemia and volume overload.[26–28] Although numerous studies have reported a decrease in the E/A ratio among dialysis patients, the role of this ratio in pre-dialysis pediatric CKD remains uncertain. In the present study, no significant differences in E/A ratios were observed between the groups. This parameter, which is frequently impacted in the early stages, may deteriorate further as the disease progresses and dialysis becomes imperative.

Hypertension plays a key role in cardiovascular damage and heart failure progression. In this study, BP was significantly higher in the patient group than in controls and showed a positive correlation with CIMT. Early-onset hypertension may contribute to increased CIMT and cardiac risk. According to Oh et al.,[29] microinflammation, hyperparathyroidism, and hyperhomocysteinemia may independently promote arterial injury, potentially compounding the effects of elevated BP.

This study found a negative correlation between Z-scores and serum phosphorus in children with pre-dialysis CKD. As GFR declines, phosphorus levels rise, leading to calcium resorption and BMD loss through fluctuations in calcium and PTH.[5,30] Although phosphorus levels were not markedly elevated, this inverse relationship reflects expected physiology. Low bone density may contribute to disease progression beyond classical renal osteodystrophy mechanisms.

This study had some limitations. It is unethical to perform BMD measurements in the healthy group without complaints. Consequently, the fact that such measurements were performed only in the patient group represents a limitation of the study. Another limitation of this study is that bone quality criteria were not assessed using imaging modalities such as computed tomography or magnetic resonance imaging. Given the pediatric age of the participants, these procedures would not be appropriate. A further limitation is that blood pressure values were compared using raw means rather than standardized scores, which may limit precision; however, similar age and height distributions between groups reduce the impact of this limitation. In addition, the absence of tissue Doppler imaging limited the detailed evaluation of myocardial function.

CONCLUSION

This study evaluated the relationship between the decrease in BMD due to kidney failure and cardiovascular damage in pre-dialysis pediatric patients with CKD. The findings reveal that increased CIMT and LVMI, high BP, and hyperparathyroidism lead to cardiovascular remodeling in these patients, although no relationship was found between BMD and CIMT. In this study, it was shown that cardiovascular damage, which may affect morbidities and mortality in children with CKD, occurs in the early pre-dialysis period, presents without clear clinical findings, and begins with the onset of the disease.

Ethics Committee Approval: The Düzce University Non-Interventional Health Research Ethics Committee granted approval for this study (date: 01.03.2021, number: 2021/55).

Informed Consent: Informed consent was obtained from all participants and their families.

Conflict of Interest: The authors have no conflict of interest to declare.

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Author Contributions: Concept – NMS; Design – NMS; Supervision – BU, SK; Resource – NMS, NÇ, PK; Materials – NMS, NÇ, PK; Data Collection and/or Processing – NMS, MAS; Analysis and/or Interpretation – NMS, PK; Literature Search – NMS, PK; Writing – NMS, BU, SK.

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