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ORIGINAL RESEARCH
Pediatric Cardiology

The relationship between vitamin D levels and atrial conduction in children

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ABSTRACT

Objective: Although atrial arrhythmias are uncommon in childhood, they can cause serious clinical consequences. Early detection and proper management of risk factors are therefore crucial. Beyond its well-known role in bone metabolism, vitamin D has been shown to exert several effects on the cardiovascular system. However, data exploring the association between serum vitamin D levels and atrial conduction characteristics, especially in the pediatric population, remain limited. This study aimed to investigate the potential relationship between serum vitamin D concentrations and electrocardiographic parameters reflecting atrial conduction in healthy children.

Material and Methods: A total of 153 healthy children without systemic disease or regular vitamin supplementation were included. Serum 25-hydroxyvitamin D, calcium, phosphorus, magnesium, alkaline phosphatase, and parathyroid hormone levels were measured in all participants. Standard 12-lead resting electrocardiograms were used to evaluate atrial conduction. P-wave dispersion, maximum and minimum P-wave durations were analyzed.

Results: No significant differences were found among groups in terms of age or sex distribution. In children with vitamin D deficiency, maximum P-wave duration, mean P-wave duration, and P-wave dispersion values were significantly lower than those in children with insufficient or sufficient vitamin D levels ($p<0.05$). Conversely, minimum P-wave duration was significantly higher in the sufficient vitamin D group compared with the insufficient group ($p<0.05$). No significant differences were observed in average heart rate among the groups.

Conclusion: These findings suggest that vitamin D deficiency or insufficiency in healthy children may be associated with alterations in atrial conduction parameters. Such electrophysiological changes could predispose to tachyarrhythmias by increasing heterogeneity in atrial depolarization. Further large-scale, long-term studies are required to elucidate the mechanisms linking vitamin D status to cardiac conduction and to assess the potential protective effects of vitamin D supplementation.

Keywords: Atrial conduction; P wave dispersion; vitamin D.

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Çocuklarda D vitamini düzeyleri ile atriyal ileti arasındaki ilişki

ÖZET

Amaç: Çocukluk çağında atriyal aritmiler nadir görülse de ciddi klinik sonuçlara yol açabilir. Bu nedenle, risk faktörlerinin erken saptanması ve uygun şekilde yönetilmesi büyük önem taşır. D vitamininin kemik metabolizmasındaki bilinen rolünün yanı sıra kardiyovasküler sistem üzerinde de çeşitli etkileri olduğu gösterilmiştir. Ancak, serum D vitamini düzeyleri ile atriyal ileti özellikleri arasındaki ilişkiyi inceleyen veriler, özellikle pediatrik popülasyonda, oldukça sınırlıdır. Bu çalışmanın amacı, sağlıklı çocuklarda serum D vitamini düzeyleri ile atriyal iletiyi yansıtan elektrokardiyografik parametreler arasındaki olası ilişkiyi değerlendirmektir.

Gereç ve Yöntemler: Herhangi bir sistemik hastalığı veya düzenli D vitamini desteği kullanımı olmayan toplam 153 sağlıklı çocuk çalışmaya dâhil edildi. Tüm katılımcılarda serum 25-hidroksivitamin D, kalsiyum, fosfor, magnezyum, alkalen fosfataz ve paratiroid hormon düzeyleri ölçüldü. Atriyal iletiyi değerlendirmek için standart 12 derivasyonlu istirahat elektrokardiyogramı çekildi. P dalga dispersiyonu, maksimum ve minimum P dalga süreleri analiz edildi.

Bulgular: Gruplar arasında yaş ve cinsiyet dağılımı açısından anlamlı fark bulunmadı. D vitamini eksikliği olan çocuklarda maksimum P dalga süresi, ortalama P dalga süresi ve P dalga dispersiyonu değerleri, D vitamini yetersiz ve yeterli olan gruplara göre anlamlı olarak daha düşük bulundu ($p<0,05$). Buna karşılık, minimum P dalga süresi değeri, yeterli D vitamini grubunda yetersiz D vitamini grubuna göre anlamlı olarak daha yüksekti ($p<0,05$). Gruplar arasında ortalama kalp hızı açısından fark saptanmadı.

Tartışma: Bu bulgular, sağlıklı çocuklarda D vitamini eksikliği veya yetersizliğinin atriyal ileti parametrelerinde değişikliklerle ilişkili olabileceğini göstermektedir. Bu elektrofizyolojik değişiklikler, atriyal depolarizasyon sürecindeki heterojenitenin artmasına bağlı olarak taşiaritmi gelişimine yatkınlık oluşturabilir. D vitamini ile kardiyak ileti sistemi arasındaki ilişkiyi netleştirmek ve D vitamini desteğinin olası koruyucu etkilerini değerlendirmek için daha geniş kapsamlı ve uzun süreli çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Atriyal iletim; D vitamini; P dalgası dispersiyonu.

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INTRODUCTION

Tachyarrhythmias are relatively common cardiac rhythm disturbances in the pediatric population and may originate from various regions of the heart. Although atrial tachyarrhythmias are less frequent than other types, they can occur in children who have undergone congenital heart surgery, in those with cardiomyopathy, and, rarely, in otherwise healthy individuals (1). Clinical manifestations vary according to the patient's age and the type of tachyarrhythmia, ranging from asymptomatic presentation to palpitations, dyspnea, diaphoresis, dizziness, anxiety, fatigue, and visual disturbances. In some cases, these arrhythmias may result in sudden cardiac death. Therefore, early detection, identification of underlying risk factors, and appropriate management are of paramount importance. Vitamin D is primarily recognized for its role in bone mineralization and regulation of calcium-phosphate homeostasis. However, recent studies have demonstrated that vitamin D exerts pleiotropic effects on multiple organ systems, including the immune, endocrine, and cardiovascular systems (2). The cardiovascular effects of vitamin D are hypothesized to occur through modulation of inflammatory responses, regulation of vascular function, and control of the renin-angiotensin-aldosterone system (3). Several studies in adult populations have reported that low serum vitamin D levels are associated with an increased risk of cardiovascular diseases and mortality. Conversely, other investigations have found no significant association between vitamin D deficiency and cardiovascular risk markers such as blood pressure, lipid profile, or arterial stiffness (3–5). The P wave duration (Pw) and dispersion (Pwdis) serve as non-invasive indicators of atrial conduction abnormalities. Heterogeneity in atrial conduction and prolongation of Pw may facilitate reentrant mechanisms and thus increase the risk of atrial tachyarrhythmia. Nevertheless, studies evaluating the relationship between vitamin D levels and atrial conduction parameters in pediatric populations remain limited. The present study aimed to investigate the association between serum vitamin D levels and Pw, Pwdis, maximum P-wave duration (Pmax), and minimum P-wave duration (Pmin) in healthy children.

MATERIAL AND METHODS

This prospective study was conducted at the Pediatric Health and Diseases outpatient clinic of a university hospital. A total of 153 healthy children without systemic diseases and not using any medications or dietary supplements were enrolled in the study.

Biochemical Measurements

Serum levels of 25-hydroxyvitamin D (25[OH]D), calcium, phosphorus, magnesium, alkaline phosphatase (ALP), and parathormone (PTH) were measured in all participants. Based on serum 25(OH)D concentrations, participants were categorized into three groups: Group I consisted of 43 patients with vitamin D deficiency (<12 ng/mL), Group II consisted of 42 patients with vitamin D insufficiency (12–20 ng/mL), and Group III consisted of 68 patients with sufficient vitamin D (≥20 ng/mL). This classification was based on international guidelines and relevant literature (6).

Electrocardiographic Assessment

Twelve-lead electrocardiograms (ECGs) were obtained at rest using a Nihon-Kohden Cardiofax S ECG-2250 device, with a paper speed of 25 mm/s and calibration of 10 mm/mV. P-wave parameters were measured manually. For each derivation, the average of three consecutive beats was calculated. Measurements were completed in at least nine derivations, and each parameter was evaluated twice independently by two researchers to ensure reliability.

Definitions

- Pw: The interval from the onset to the end of the P-wave;
- Pmax: The longest P-wave duration among all derivations;
- Pmin: The shortest Pw among all derivations;
- Pwdis: The difference between Pmax and Pmin.

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics v26.0. Categorical variables were expressed as frequency and percentage. Continuous variables were presented as mean ± standard deviation, median, and interquartile range (IQR). Associations between categorical variables were assessed using the Chi-square test. Correlations between continuous variables were evaluated using Pearson or Spearman correlation analysis, depending on data distribution. In cases where comparisons were made between more than two independent groups with non-normally distributed data, the Kruskal-Wallis test was used. A p-value <0.05 was considered statistically significant.

Study Cohort and Thesis Derivation

The present study was derived from a prospectively collected pediatric cohort originally established for our doctoral thesis titled "Investigation of the Relationship Between Vitamin D Deficiency and Electrocardiographic Changes in Children." Although the same cohort was used, the thesis included separate predefined analyses addressing different electrophysiological mechanisms. While one analysis evaluated ventricular repolarization parameters and their association with ventricular arrhythmias, the current study specifically investigates atrial conduction parameters and atrial arrhythmogenic risk. The research objectives, primary outcomes, and statistical analyses of the two analyses are distinct.

Table 1. Comparison of demographic characteristics among the three groups

Vitamin D (ng/mL)	Group 1 (n=43) <12	Group 2 (n=42) 12–20	Group 3 (n=68) >20	p
Sex				0.079
Female	29 (67.4%)	23 (54.8%)	31 (45.6%)	
Male	14 (32.6%)	19 (45.2%)	37 (54.4%)	
Age (years)	12 (8–13)	8 (6–12)	9 (7–13)	0.073

Data are presented as n (%) or median (interquartile range, Q1–Q3). Chi-square test and Kruskal–Wallis test were used for group comparisons.

Ethical Approval

This study was approved by the Ethics Committee of Sakarya University (Date: 2021/10/14, Decision No. E-16214662-050.01.01-70470-177). Informed consent was obtained from all patients participating in the study. This study was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

No statistically significant differences were observed among the three groups in terms of age or sex distribution (p<0.05). Demographic characteristics of the participants are summarized in Table 1. Serum levels of calcium, phosphorus, and magnesium were within reference ranges in all participants, and no clinical symptoms or laboratory findings attributable to vitamin D deficiency were observed. Parathormone (PTH) levels were significantly higher in the vitamin D sufficient group compared to the insufficient and deficient groups (p<0.05). However, there was no significant difference between the insufficient and deficient groups (Table 2). No significant differences in heart rate were observed among the groups (p=0.203). Pmin was significantly higher in the vitamin D-sufficient group compared to the vitamin D-deficient group (p=0.001), and there was no significant difference between the deficiency group and the other two groups. Pmax, Pw, and Pwdis values were significantly higher in the vitamin D-insufficient and deficient groups compared to the sufficient group, and there was no significant difference between the insufficient and deficient groups (Table 3).

DISCUSSION

Vitamin D is primarily recognized as a steroid hormone involved in bone mineralization and the regulation of calcium-phosphate metabolism (2). However, recent studies have demonstrated that vitamin D exerts pleiotropic effects on multiple organ systems, including the cardiovascular system (3, 4). These effects include modulation of inflammatory responses, regulation of endothelial function, prevention of cardiac remodeling, and stabilization of electrophysiological conduction (3, 4).

In the present study, we investigated the association between serum vitamin D levels and electrocardiographic parameters

Table 2. Comparison of laboratory values among the three groups

Parameter	Group 1 (n=43)	Group 2 (n=42)	Group 3 (n=68)	p
PTH (pg/mL)	49.6 (34.6–69.7)	48.1 (34.3–69)	35.9 (30.2–43.1)[a,b]	<0.001
Ca (mg/dL)	9.82±0.44	9.62±0.43	9.84±0.46[b]	0.033
P (mg/dL)	4.57±0.76	4.46±0.56	4.7±0.67[b]	0.185
Mg (mg/dL)	2.1 (2–2.1)	2.1 (2–2.2)	2 (2–2.1)	0.313
ALP (U/L)	186 (134–242)	186.5 (152–234)	182 (146.5–223)	0.931

Data are presented as median (interquartile range, Q1–Q3) or mean±SD. Kruskal–Wallis test was used for group comparisons. a: Significantly different from Group 1; b: Significantly different from Group 2; PTH: Parathyroid hormone; Ca: Calcium; Mg: Magnesium; ALP: Alkaline phosphatase.

Table 3. Comparison of heart rate, Pmin, Pmax, Pw, and Pdis among the three groups

Parameter	Group 1 (n=43)	Group 2 (n=42)	Group 3 (n=68)	p
Heart rate (bpm)	87 (79–98)	83.5 (78–94)	82.5 (72.5–95.5)	0.203
Pmin (ms)	53.2 (40–60)	46.4 (40–53.2)	60 (49.8–60)[b]	0.001
Pmax (ms)	100 (90–106.4)	96.6 (86.4–106.4)	80 (73.2–84.8)[a,b]	<0.001
Pw (ms)	75 (72–78.5)	72.1 (69.6–75.9)	71.9 (66.6–73.9)[a,b]	<0.001
Pdis (ms)	46.4 (40–53.2)	46.4 (40–53.2)	26.4 (20–33.2)[a,b]	<0.001

Data are presented as median (interquartile range, Q1–Q3). Kruskal–Wallis test was used for group comparisons. a: Significantly different from Group 1; b: Significantly different from Group 2; Pmin: Minimum P-wave duration; Pmax: Maximum P-wave duration; Pw: P-wave duration; Pdis: P-wave dispersion.

reflecting atrial conduction (Pmax, Pmin, Pwdis) in a healthy pediatric population. Our findings demonstrated that children with vitamin D deficiency or insufficiency exhibited significantly longer P-wave durations and increased P-wave dispersion. This suggests that low vitamin D levels may be associated with atrial conduction abnormalities. P-wave duration and dispersion are non-invasive indicators reflecting heterogeneity in atrial depolarization and are considered markers for reentry mechanisms that predispose to atrial fibrillation (7, 8).

Previous studies have shown that Pmax and Pwdis are prolonged in various cardiac conditions, including dilated cardiomyopathy, hypertension, and mitral stenosis (7–9). Similar findings have been reported in pediatric populations. For example, Sert et al. (10) observed significantly longer Pmax and Pwdis durations in obese adolescents compared to controls, with positive correlations to cardiovascular risk factors. Arslan et al. (11) reported markedly prolonged Pwdis in children with atrial septal aneurysm. In a study by Kurt (12) on the effects of vitamin D deficiency in children on the cardiac conduction system and arterial stiffness, children with vitamin D deficiency had significantly longer Pmax and Pwdis durations compared to children with adequate and insufficient vitamin D levels.

Studies in adult populations also support an association between vitamin D deficiency and atrial conduction parameters. Canpolat et al. (13) demonstrated significantly lower vitamin D levels in patients with paroxysmal atrial fibrillation, with an inverse correlation to left atrial fibrosis. Recent systematic reviews and meta-analyses in adult populations have suggested an inverse association between serum 25-hydroxyvitamin D levels and the risk of atrial fibrillation, although findings vary across studies and populations (14, 15). These broader analyses support a potential link between vitamin D status and supraventricular arrhythmias, providing context for the electrophysiological associations observed in our pediatric cohort (12, 13).

These findings suggest that low vitamin D levels may increase atrial inflammation and fibrosis, leading to electrophysiological conduction disturbances. Potential mechanisms underlying these electrophysiological changes in vitamin D deficiency include atrial fibroblast activation and collagen accumulation (16), hypoxia due to inadequate coronary microcirculation, decreased homogeneity of myocardial electrical conduction, and activation of the renin-angiotensin system (17).

Nevertheless, some large-scale randomized controlled trials have reported that vitamin D supplementation does not significantly reduce the incidence of atrial fibrillation (18). These discrepant results may be attributed to differences in study populations, baseline vitamin D status, study designs, follow-up durations, and vitamin D dosing regimens (15–18). Further pediatric-focused studies are warranted to clarify these associations, particularly to evaluate potential age-specific electrophysiological effects of vitamin D on atrial conduction.

Finally, our study highlights the importance of evaluating atrial conduction parameters (Pmax, Pmin, Pwdis) in the context of vitamin D deficiency in children, providing a mechanistic rationale for early identification of individuals at risk for supraventricular arrhythmias and potential preventive interventions.

Strengths of the Study

Inclusion of only healthy children ensured a homogeneous study population. Manual measurement of electrocardiographic parameters with repeated evaluation enhanced data reliability.

Limitations of the Study

The study did not include follow-up; long-term arrhythmia development could not be assessed. Changes in P-wave parameters following vitamin D supplementation were not evaluated.

CONCLUSION

This study evaluated the relationship between serum vitamin D levels and atrial electrical conduction parameters in a healthy pediatric population. Our findings demonstrate that children with vitamin D deficiency or insufficiency exhibited significantly longer Pmax, Pw, and Pwdis durations compared to those with sufficient vitamin D levels. These results suggest that low vitamin D levels may increase atrial conduction heterogeneity and potentially predispose children to tachyarrhythmias. Therefore, serum vitamin D may serve as a potential biomarker for cardiac electrical stability in the pediatric population. Although there is no direct evidence linking these p-wave parameters to atrial tachyarrhythmias, vitamin D deficiency can alter atrial conduction and thus create a substrate for arrhythmia. Therefore, vitamin D levels should be considered when evaluating such patients, and Holter monitoring can help detect asymptomatic tachycardias. However, to establish causality and evaluate the effects of vitamin D supplementation on atrial electrophysiology, prospective, large-scale, and long-term studies are warranted.

Ethics Committee Approval: This study was approved by the Ethics Committee of Sakarya University (Date: 10/14/2021, Decision No.: E-16214662-050.01.01-70470-177).

Informed Consent: Informed consent was obtained from all patients participating in the study.

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Yazarlık Katkıları: Fikir – PDÇ; Tasarım – PDÇ, DA; Denetlemeler – PDÇ; Kaynaklar – PDÇ, DA; Malzemeler – DA; Veri toplanması ve/veya işleme – PDÇ, DA; Analiz ve/veya yorumlama – DA; Literatür araştırması – PDÇ; Yazım – DA, PDÇ; Eleştirel incelemeler – DA, PDÇ.

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