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Vitamin D Status in Children in the South Marmara Region in Turkey

Türkiye'nin Güney Marmara Bölgesi'ndeki Çocukların D Vitamini Durumu

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Abstract

Aim: This study aims to investigate the age, gender, and seasonal differences in vitamin D levels in children and to determine the prevalence of vitamin D deficiency.

Material and Method: Between January 2022 and December 2023, we retrospectively reviewed the records of children aged 0.1–17 years who had their serum 25-hydroxyvitamin D (25(OH) D) levels checked in the pediatric outpatient clinics of Bursa City Hospital. Children were divided into four groups according to age (0.1–1, 2–5, 6–11, and 12–17 years), three groups according to 25(OH)D levels (vitamin D deficiency=below 12 ng/mL, vitamin D insufficiency=between 12–20 ng/mL, and vitamin D sufficiency=above 20 ng/mL), and four groups according to seasons.

Results: The 25(OH)D levels of 41,899 children were analyzed, comprising 19,738 (47.1%) boys and 22,161 (52.9%) girls. The median (minimum-maximum) values were 18.6 (3–145) ng/mL. Girls exhibited lower levels compared to boys [16.8 (3–136) ng/mL in girls vs. 20.3 (3–145) ng/mL in boys, $p<0.001$]. Vitamin D deficiency was 22.8% (15.5% in boys and 29.2% in girls, $p<0.001$), and vitamin D insufficiency was 32.9% (32.9% in boys and 32.9% in girls, $p=0.970$). In 55.6% of patients, 25(OH)D levels were below 20 ng/mL (48.4% of boys and 62.1% of girls, $p<0.001$). Observations revealed a decline in 25(OH)D levels with advancing age, notably plummeting during winter and spring while peaking in autumn and summer.

Conclusion: Adolescents, particularly girls, exhibited the lowest 25(OH)D levels during winter and spring. Consequently, we advocate the development of public health strategies to prevent vitamin D deficiency in this group.

Keywords: Vitamin D deficiency, vitamin D insufficiency, 25-hydroxyvitamin D, children

Öz

Amaç: Çalışmamızın amacı çocuklarda D vitamini düzeylerindeki yaş, cinsiyet ve mevsimsel farklılıkları araştırmak ve D vitamini eksikliği prevalansını belirlemektir.

Gereç ve Yöntem: Ocak 2022-Aralık 2023 tarihleri arasında Bursa Şehir Hastanesi çocuk polikliniklerinde serum 25-hidroxi vitamin D (25(OH)D) düzeyi ölçümü yapılan 0.1-17 yaş arası çocukların kayıtları retrospektif olarak incelendi. Çocuklar yaşa göre dört gruba (0.1-1, 2-5, 6-11 ve 12-17 yaş); serum 25(OH)D vitamini düzeylerine göre üç gruba (D vitamini eksikliği (12 ng/mL altı), D vitamini yetersizliği (12-20 ng/mL arası) ve D vitamini yeterliliği (20 ng/mL üstü)); ve mevsimlere göre dört gruba ayrıldı.

Bulgular: 19738'i (%47,1) erkek ve 22161'sı (%52,9) kız olmak üzere 41899 çocuğun 25(OH)D düzeylerinin ortanca ve (minimum-maximum) 18,6 (3-145) ng/mL olup kızlarda erkeklerden daha düşüktü [kızlarda 16,8 (3-136) ng/mL ve erkeklerde 20,3 (3-145) ng/mL $p<0,001$]. D vitamini eksikliği %22,8 (erkeklerde %15,5 ve kızlarda %29,2, $p<0.001$) ve D vitamini yetersizliği %32,9 (erkeklerde %32,9 ve kızlarda %32,9, $p=0.970$) idi. Hastalarımızın %55,6'sında 25(OH) D düzeyi 20 ng/mL'nin altındaydı (erkeklerin %48,4'ü ve kadınların %62,1'i, $p<0,001$). 25(OH)D düzeyleri artan yaşla birlikte azalmıştır; en düşük seviyeler kış ve ilkbaharda, en yüksek seviyeler ise sonbahar ve yaz aylarında bulunmuştur.

Sonuç: En düşük 25(OH)D düzeyi adolesanlarda, özellikle de kız adolesanlarda kış ve ilkbahar mevsiminde bulunmuştur. Bu nedenle, bu grup için D vitamini eksikliğini önlemeye yönelik halk sağlığı stratejilerinin geliştirilmesi gerektiğini düşünüyoruz.

Anahtar Kelimeler: D vitamini eksikliği, D vitamini yetersizliği, 25(OH)D, çocuk

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INTRODUCTION

Vitamin D, a steroidal prohormone, plays a crucial role in regulating calcium and phosphate metabolism, and influencing the musculoskeletal, renin-angiotensin, cardiovascular systems, and immunity. Vitamin D deficiency can primarily lead to osteomalacia across all age groups and rickets during childhood. Additionally, studies have linked vitamin D deficiency with immune system disorders, type 1 diabetes mellitus, multiple sclerosis, ulcerative colitis, rheumatoid arthritis, cardiovascular diseases, cancer, and mood disorders.[1,2]

The primary source of vitamin D is sunlight. While foods like fish, liver, milk, and eggs contain vitamin D, they can only fulfill a small fraction of the requirements.[3–5] Numerous factors, including skin color, air pollution, season, sun angle, cultural clothing, gender, sedentary lifestyle, genetic predisposition, obesity, and dietary habits, influence Vitamin D levels.[6,7] Two biochemical parameters assess vitamin D levels: 1,25-dihydroxyvitamin D and 25-hydroxyvitamin D (25[OH]D). The 25(OH)D level offers more comprehensive insights into the body's vitamin D reserves due to its longer half-life and significantly higher blood concentration than the other vitamin D metabolites.[5] Therefore, 25(OH)D levels were tested to determine vitamin D status in this study.

Vitamin D deficiency presents a global public health concern. Untreated deficiencies during childhood can predispose individuals to serious ailments later in life. Similar to many countries worldwide, Türkiye conducts epidemiological studies and implements national vitamin D prophylaxis programs to identify at-risk age groups and prevent deficiencies. As part of this effort, oral vitamin D3 prophylaxis at a dose of 400 IU/day is routinely administered to children aged 0–1 year, aligning with practices in many other countries.[8] In the South Marmara Region, where this study is conducted, most of the population resides in Bursa, a densely populated and highly industrialized city characterized by high-rise buildings, which increases the susceptibility to vitamin D deficiency. Assessing the prevalence of vitamin D deficiency in this region is crucial to facilitating the implementation of necessary interventions. Therefore, by collecting data from all regions, regional and national strategies can be developed to prevent vitamin D deficiency.

This study aims to examine the age groups, gender, and seasonal differences of serum 25(OH)D levels in children under the age of 18 who presented to Bursa City Hospital, a third-level hospital in the south Marmara Region of Turkey, to determine the frequency of vitamin D deficiency and to investigate the related factors.

MATERIAL AND METHOD

The study was carried out with the permission of Bursa City Hospital Faculty of Medicine Clinical Researches Ethics Committee (Date: 07.02.2024, Decision No: 2024-1/8).

This study involved a retrospective review of records belonging to children aged 0.1–17 years, except newborns, who underwent 25(OH)D level testing at the pediatric outpatient clinics of Bursa City Hospital between January 2022 and December 2023. Data on age, gender, and 25(OH) D results of the children were obtained from the hospital automation system. In cases where multiple vitamin D levels were assessed in the same patient, only the initial measurement was considered for inclusion in this study. The determination of 25(OH)D levels was carried out using the chemiluminescence-immunoassay method.

The children were categorized into four age groups: 0.1–1, 2–5, 6–11, and 12–17 years. Following the 2015 global consensus recommendation, 25(OH)D levels were classified into three categories: vitamin D deficiency (below 12 ng/mL), vitamin D insufficiency (between 12–20 ng/mL), and vitamin D sufficiency (above 20 ng/mL).[9] Furthermore, individuals with 25(OH)D levels below 20 ng/mL were identified (comprising both deficiency and insufficiency). They were then further grouped based on the seasons: spring (March to May), summer (June to August), autumn (September to November), and winter (December to February). 25(OH)D levels of children were analyzed according to gender, age groups, and seasons.

Statistical Analysis

The statistical analysis of this study was conducted using the Statistical Package for the Social Sciences for Windows, version 26.0. Categorical variables were expressed as n (%), while median (minimum-maximum) values were employed when data did not conform to normality. Descriptive analyses were employed to assess the distribution and frequency of the data, with chi-squared tests utilized to compare two independent groups in frequency data. Normality analysis was performed using the Kolmogorov–Smirnov test. The Mann–Whitney U test was applied to compare two independent groups that did not adhere to a normal distribution. The Kruskal–Wallis test was also employed to compare three or more independent groups that did not follow a normal distribution. Post-hoc analysis was conducted using the ANOVA test if a significant difference was detected. The significance level was set at $p < 0.05$ for all statistical analyses.

RESULTS

This study comprised 41,899 children with a median age of 7 (0.1–17) years. The median ages of the 19,738 (47.1%) boys and 22,161 (52.9%) girls were 8 (0.1–17) and 6 (0.1–17) years, respectively. The median 25(OH)D levels of the children in this study were 18.6 (3–145) ng/mL, which were lower in girls than in boys [16.8 (3–136) ng/mL in girls and 20.3 (3–145) ng/mL in boys, $p<0.001$]. When 25(OH)D levels were compared according to genders in four different age groups, it was found that 25(OH)D levels were statistically significantly lower in boys in the 0.1-1 age group ($p=0.003$) and lower in girls in other age groups ($p<0.001$ in all three age groups, see also. **Table 1**'s Age section). 25(OH)D levels were consistently lower in girls than in boys across all seasons (p<0.001 in all four seasons) (see **Table 1** and **Figure 1**). When compared by gender in the same season and in different age groups, it was observed that girls generally had lower 25(OH)D levels than boys (see also. **Table 1**'s Seasons section). Additionally, the lowest 25(OH)D levels were found in girls aged 12–17 years [9.6 (3–97) ng/mL in the spring season], while the highest levels were found in boys aged 0.1–1 year [36.1 (3.4–138) ng/mL in the winter season].

Table 1. Comparison of 25(OH)D serum levels according to gender.

Median (min-max)	Male 25 OH) D, ng/mL	Female 25 (OH) D, ng/mL	p
Total	20.3 (3-145)	16.8 (3-136)	<0.001
Age (year)/season			
0.1-1Spring	33.6 (3.3-95.7)	35.1 (3.9-117)	0.154
Summer	35.6 (3.2-111)	35.7 (4.4-96.2)	0.831
Autumn	34.0 (3-110)	35.8 (4.2-117)	0.073
Winter	33.2 (3.5-145)	36.1 (3.4-138)	0.021
Total	34.5 (3-145)	35.7 (3.4-136)	0.003
2-5 Spring	19.6 (3.1-96.7)	18.7 (3.2-110)	0.006
Summer	25.3 (4.3-75.1)	24.2 (3.6-117)	0.001
Autumn	23.5 (3.4-86.8)	22.3 (4.5-116)	<0.001
Winter	18.6 (3.2-105)	18.4 (3.3-139)	0.511
Total	22.0 (3.1-105)	21.1 (3.2-139)	<0.001
6-11 Spring	15.4 (3.3-85.2)	13.4 (3-102)	<0.001
Summer	23.7 (3.3-82)	19.9 (3.4-57.9)	<0.001
Autumn	21.9 (4.9-62.2)	19.1 (3.1-116)	<0.001
Winter	15.8 (3.4-94.4)	13.9 (3-78.3)	<0.001
Total	19.1 (3.3-94.4)	(3-116)	<0.001
12-17 Spring	13.3 (3.3-93.7)	9.6 (3-97)	<0.001
Summer	20.6 (3.8-75)	14.2 (3-116)	<0.001
Autumn	19.5 (4.4-84.8)	13.3 (3.1-67.8)	<0.001
Winter	14.0 (3.1-102)	10.0 (3-70.6)	<0.001
Total	17.0 (3.1-102)	11.7 (3-116)	<0.001
Season			
Spring	17.3 (3.1-96.7)	14.2 (3-117)	<0.001
Summer	24.1 (3.2-111)	19.9 (3-117)	<0.001
Autumn	22.4 (3-110)	19.0 (3.1–117)	<0.001
Winter	16.9 (3-145)	14.0 (3-136)	<0.001

25 (OH) D= 25-hydroxyvitaminD

Among the age groups, the highest 25(OH)D levels were found in girls aged 0.1 to 1 year [35.7 (3.4–136) ng/mL], while the lowest value was observed in girls aged 12 to 17 years [11.7 (3–116) ng/mL]. Serum 25(OH)D levels were observed to decrease with increasing age in both sexes across all seasons (p<0.001 for each) (**Table 2**).

Upon examining 25(OH)D levels according to seasons, differences were noted across all seasons, ranked from low to high as winter, spring, autumn, and summer. In boys, no significant difference was observed between the winter and spring seasons, with levels increasing in autumn and summer, respectively. Among girls, 25(OH)D levels were ranked lowest in winter, followed by spring, autumn, and summer. When evaluating 25(OH)D levels according to seasons within age groups, no significant difference was found between seasons in both sexes within the 0.1–1 age group. In other age groups, the seasons with the lowest 25(OH)D levels for both sexes were spring and winter, with no significant difference between them; these seasons were succeeded by autumn and summer from low to high (**Table 3** and **Figure 2**).

In this study, vitamin D deficiency was observed in 22.8% of participants (15.5% in boys and 29.2% in girls, p < 0.001), while vitamin D insufficiency was noted in 32.9% (32.9% in boys and 32.9% in girls, p=0.970). Vitamin D deficiency was least prevalent in boys aged 0.1–1 year (5%) and most prevalent in girls aged 12–17 years (51.6%). When assessing vitamin D deficiency across seasons, the lowest levels were found in boys (4.4%) during the summer season, whereas the highest levels were observed in girls (39.6%) during the spring season (see **Table 4**).

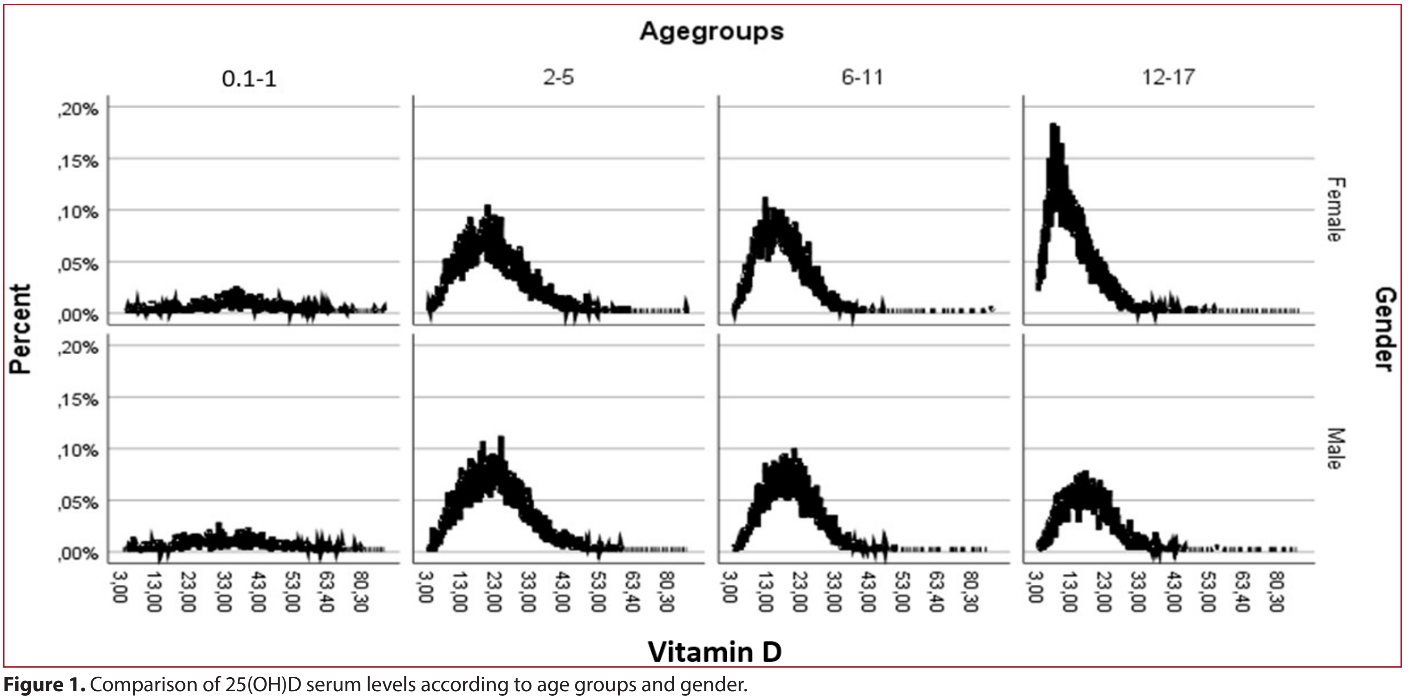

Figure 1. Comparison of 25(OH)D serum levels according to age groups and gender.

Table 2: Comparison of 25(OH)D serum levels according to age groups.

Median (min-max)	0.1-1 year 25(OH)D ng/mL	2-5 25(OH)D ng/mL	6-11 25(OH)D ng/mL	12-17 25(OH)D ng/mL	p (p1-p6)
M	34.5 (3-145)	22.0 (3.1-105)	19.1 (3.3-94.4)	17.0 (3.1-102)	<0.001
F	35.7 (3.4-136)	21.1 (3.2-139)	16.5 (3-116)	11.7 (3-116)	<0.001
Total	35.1 (3-145)	21.5 (3.1-139)	17.7 (3.0-116)	13.6 (3-116)	<0.001
Seasons					
Spring					
M	33.6 3.3-95.7)	19.6 3.1-96.7)	15.4 3.3-85.2)	13.3 3.3-93.7)	<0.001
F	35.1 3.9-117)	18.7 3.2-110)	13.4 3-102)	9.6 3-97)	<0.001
Total	34.5 3.3-117)	19.2 3.1-110)	14.6 3-102)	11.0 3-97)	<0.001
Summer					
M	35.6 3.2-111)	25.3 4.3-75.1)	23.7 3.3-82)	20.6 3.8-75)	<0.001
F	35.7 4.4-96.2)	24.2 3.6-117)	19.9 3.4-57.9)	14.2 3-116)	<0.001
Total	35.6 3.2-111)	24.7 3.6-117)	21.8 3.3-82)	16.8 3-116)	<0.001
Autumn					
M	34.0 3-110)	23.5 3.4-86.8)	21.9 4.9-62.2)	15.8 3.4-94.4)	<0.001
F	35.8 4.2-117)	22.3 4.5-116)	19.1 3.1-116)	13.9 3-78.3)	<0.001
Total	35.2 3-117)	23.0 3.4-116	20.6 3.1-116)	14.9 3.0-94.4)	<0.001
Winter					
M	33.2 3.5-145)	18.6 3.2-105)	15.8 3.4-94.4)	14.0 3.1-102)	<0.001
F	36.1 3.4-138)	18.4 3.3-39)	13.9 3-78.3)	10.0 3-70.6)	<0.001
Total	34.9 3.4-145)	18.4 3.2-139)	14.9 3.0-94.4)	11.3 3-102)	<0.001

25 (OH) D= 25-hydroxyvitaminD, M=Male, F=Female, p1=0-1/2-5, p2=0-1/6-11, p3=0-1/12-17, p4=2-5/6-11, p5=2-3/12-17, p6=6-11/12-17, p1-p2-p3-p4-p4-p5 and p6 all <0.001

Table 3: Comparison of 25(OH)D serum levels according to seasons.

Median (Min-max)	Spring 25(OH)D ng/mL	Summer 25(OH)D ng/mL	Autumn 25(OH)D ng/mL	Winter 25(OH)D ng/mL	p	p1	p2	p3	p4	p5	p6
M	17.3 (3.1-96.7)	24.1 (3.2-111)	22.4 (3-110)	16.9 (3-145)	<0.001	<0.001	<0.001	0.375	<0.001	<0.001	<0.001
F	14.2 (3-117)	19.9 (3-117)	19 (3.1-117)	14 (3-136)	<0.001	<0.001	<0.001	0.049	<0.001	<0.001	<0.001
Total	15.7 (3-117)	22.1 (3-117)	20.8 (3-117)	15.4 (3-145)	<0.001	<0.001	<0.001	0.009	<0.001	<0.001	<0.001
Age											
M	33.6 3.3-95.7)	35.6 3.2-111)	34.0 3-110)	33.2 3.5-145)	0.129						
F	35.1 3.9-117)	35.7 4.4-96.2)	35.8 4.2-117)	36.1 3.4-138)	0.920						
Total	34.5 3.3-117)	35.6 3.2-111)	35.2 3-117)	34.9 3.4-145)	0.229						
2-5											
M	19.6 3.1-96.7)	25.3 4.3-75.1)	23.5 3.4-86.8)	18.6 3.2-105)	<0.001	<0.001	<0.001	0.076	<0.001	<0.001	<0.001
F	18.7 3.2-110)	24.2 3.6-117)	22.3 4.5-116)	18.4 3.3-39)	<0.001	<0.001	<0.001	0.795	<0.001	<0.001	<0.001
Total	19.2 3.1-110)	24.7 3.6-117)	23.0 3.4-116)	18.4 3.2-139)	<0.001	<0.001	<0.001	0.055	<0.001	<0.001	<0.001
6-11											
M	15.4 3.3-85.2)	23.7 3.3-82)	21.9 4.9-62.2)	15.8 3.4-4.4)	<0.001	<0.001	<0.001	0.056	<0.001	<0.001	<0.001
F	13.4 3-102)	19.9 3.4-57.9)	19.1 3.1-116)	13.9 3-78.3)	<0.001	<0.001	<0.001	0.868	0.378	<0.001	<0.001
Total	14.6 3-102)	21.8 3.3-82)	20.6 3.1-116)	14.9 3.0-4.4)	<0.001	<0.001	<0.001	0.077	<0.001	<0.001	<0.001
12-7											
M	13.3 3.3-93.7)	20.6 3.8-75)	19.5 4.4-84.8)	14.0 3.1-102)	<0.001	<0.001	<0.001	0.984	0.026	<0.001	<0.001
F	9.6 3-97)	14.2 3-116)	13.3 3.1-67.8)	10.0 3-70.6)	<0.001	<0.001	<0.001	0.983	<0.001	<0.001	<0.001
Total	11.0 3-97)	16.8 3-116)	15.9 3.1-84.8)	11.3 3-102)	<0.001	<0.001	<0.001	0.948	<0.001	<0.001	<0.001

25 (OH) D= 25-hydroxyvitaminD, M=Male, F=Female, p1=spring-summer, p2=spring-autumn, p3=spring-winter, p4= summer-autumn, p5= summer-winter, p6= autumn-winter

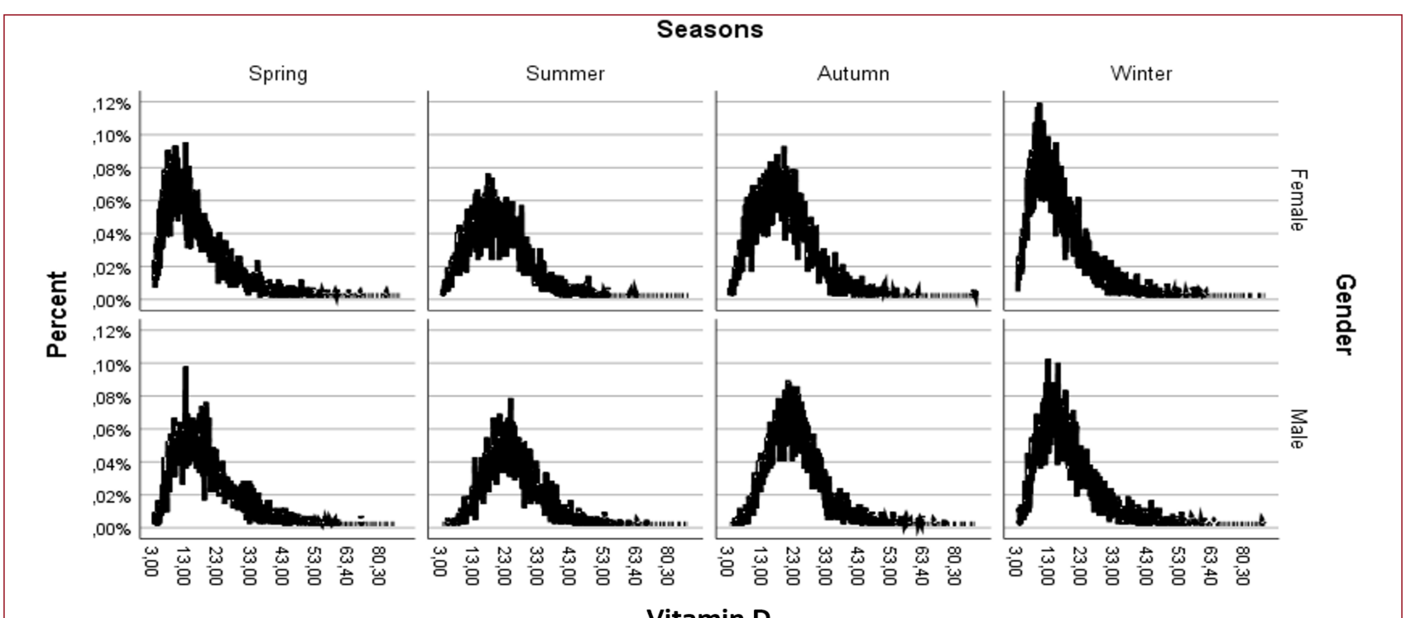

Figure 2. Comparison of 25(OH)D serum levels according to seasons and gender.

Table 4: Distribution of children aged 0-17 years according to vitamin D deficiency-insufficiency and sufficiency groups

	Vitamin D deficiency N (%)	Vitamin D insufficiency N (%)	Vitamin D sufficiency N (%)	Total N (%)
Male	3059 (15.5)	6485 (32.9)	10194 (51.6)	19738 (100)
Female	6472 (29.2)	7298 (32.9)	8391 (37.9)	22161 (100)
Total	9531 (22.8)	13783 (32.9)	18585 (44.3)	41899 (100)
Age (year)				
0.1-1				
Male	106 (6.0)	147 (8.5)	1475 (85.5)	1728 (100)
Female	71 (5.0)	109 (7.7)	1236 (82.3)	1416 (100)
Total	177 (5.6)	256 (8.1)	2711 (86.3)	3144 (100)
2-5				
Male	947 (12.3)	2234 (29.2)	4478 (58.5)	7659 (100)
Female	1014 (14.1)	2241 (31.2)	3919 (54.7)	7174 (100
Total	1961 (13.2)	4475 (53.3)	8397 (56.5)	14833 (100)
6-11				
Male	946 (15.8)	2300 (38.5)	2732 (45.7)	5978 (100)
Female	1569 (25.4)	2577 (41.8)	2022 (32.8)	6168 (100)
Total	2515 (20.7)	4877 (40.2)	4754 (39.1)	12146 (100)
12-17				
Male	1060 (24.2)	1804 (41.3)	1509 (34.5)	4373 (100)
Female	3818 (51.6)	2371 (32.0)	1214 (16.4	7403 (100)
Total	4878 (41.4)	4175 (35.5)	2723 (23.1)	11776 (100)
Season				
Spring				
Male	1181 (25.0)	1715 (36.3)	1832 (38.7)	4728 (100)
Female	2066 (39.6)	1595 (30.6)	1557 (29.8)	5218 (100)
Total	3247 (32.7)	3310 (33.2)	3389 (34.1)	9946 (100)
Summer				
Male	183 (4.4)	1052 (25.1)	2952 (70.5)	4187 (100)
Female	832 (17.3)	1577 (32.8)	2400 (49.9)	4809 (100)
Total	1015 (11.3)	2629 (29.2)	5352 (59.5)	8996 (100)
Autumn				
Male	371 (6.9)	1640 (30.2)	3412 (62.9)	5423 (100)
Female	1189 (19.6)	2132 (35.1)	2753 (45.3)	6074 (100)
Total	1560 (13.6)	3772 (32.8)	6165 (53.6)	11497 (100)
Winter				
Male	1324 (24.5)	2078 (38.5)	1998 (37.0)	5400 (100)
Female	2385 (39.4)	1994 (32.9)	1681 (27.7)	6060 (100)
Total	3709 (32.4)	4072 (35.5)	3679 (32.1)	11460 (100)

Vitamin D deficiency=25 (OH) vitamin D <12 ng/mL; Vitamin D insufficiency=25(OH) vitamin D 12-20 ng/mL; Vitamin D sufficiency=25(OH)D>20 ng/mL.

Table 5: Comparison of children with 25(OH)D serum levels below 20 ng/mL according to gender.

	Male, n=19738 25(OH)D <20 ng/mL N (%)	Female, n= 22161 25(OH)D <20 ng/mL N (%)	Total, n=41899 25(OH)D <20 ng/mL N (%)	p
Total	9544 (48.4%)	13770 (62.1%)	23314 (55.6%)	<0.001
Age (year)/season				
0.1-1				
Spring	65 (14.7)	53 (14.5)	118 (14.6)	0.941
Summer	41 (10.9)	32 (10.1)	73 (10.5)	0.728
Autumn	70 (14.8)	46 (10.8)	116 (12.9)	0.074
Winter	77 (17.7)	49 (15.8)	126 (16.9)	0.493
Total	253 (14.6%)	180 (12.7)	433 (13.8%)	0.111
2-5				
Spring	947 (51.7)	962 (55)	1909 (53.3)	0.049
Summer	396 (24.9)	438 (28.8)	834 (26.8)	0.014
Autumn	708 (32.1)	761 (38)	1469 (34.9)	<0.001
Winter	1130 (55.6)	1094 (57.5)	2224 (56.5)	0.235
Total	3181 (41.5%)	3255 (45.4%)	6436 (43.4%)	<0.001
6-11				
Spring	1076 (73.8)	1164 (80.6)	2240 (77.2)	<0.001
Summer	350 (27.6)	665 (51.1)	1015 (39.5)	<0.001
Autumn	591 (38.6)	901 (54.9)	1492 (47)	<0.001
Winter	1229 (71.5)	1416 (79.5)	2645 (75.5)	<0.001
Total	3246 (54.3%)	4146 (67.2)	7392 (60.1)	<0.001
12-17				
Spring	808 (81)	1482 (89.3)	2290 (86.2)	<0.001
Summer	448 (47)	1274 (76.3)	1722 (65.7)	<0.001
Autumn	642 (53)	1613 (80.4)	2255 (70.1)	<0.001
Winter	966 (79.7)	1820 (88.2)	2786 (85)	<0.001
Total	2864 (65.5%)	6189 (83.6)	9053 (76.9%)	<0.001
Season				
Spring	2896 (61.3%)	3661 (70.2%)	6557 (65.9%)	<0.001
Summer	1235 (29.5 %)	2409 (50.1%)	3644 (40.5%)	<0.001
Autumn	2011 (37.1%)	3321 (54.7%)	5332 (46.4%)	<0.001
Winter	3402 (63%)	4379 (72.3%)	7781 (67.9%)	<0.001

25 (OH) D= 25-hydroxyvitaminD

Among the patients, 55.6% had 25(OH)D levels below 20 ng/mL (48.4% in boys and 62.1% in girls, p<0.001). While no difference was observed between sexes in the 0.1–1 age group across all seasons, girls exhibited a higher proportion of children with 25(OH)D levels below 20 ng/mL in both the 6–11 and 12–17 age groups across all seasons. The lowest incidence of children with 25(OH)D levels below 20 ng/mL was found in boys during the summer season in the 0.1–1 age group (10.1%), whereas the highest incidence was observed in girls during the spring season in the 12–17 age group (89.3%) (**Table 5**).

DISCUSSION

This study observed that vitamin D deficiency was most prevalent among adolescent girls during the winter and spring. Vitamin D deficiency has been linked to various diseases in children, including rickets, asthma, obesity, and autism.[10] Additionally, it has been associated with sepsis, Pediatric Risk of Mortality III score, prolonged hospitalization, and mechanical ventilator stay in critically ill patients admitted to intensive care units.[11] Given the widespread prevalence of vitamin D deficiency in this country and globally, it is paramount to identify at-risk groups and implement necessary preventive measures.

Cui et al.[12] reviewed 308 vitamin D prevalence studies with 7,947,359 participants of all age groups from 81 countries between 2000 and 2022 to investigate global vitamin D levels and reported that the estimated prevalence of serum 25(OH) D was 47.9% below 20 ng/mL and 15.7% below 12 ng/mL. The lowest prevalence of serum 25(OH)D below 20 ng/mL is observed in the African region at 18.9%, while the highest prevalence is reported in the Eastern Mediterranean region at 71.8%. Lower-middle-income countries have reported a prevalence of serum 25(OH)D < 20 ng/mL at 56.0%, whereas upper-middle-income countries have reported this rate at 38.2%.[12] In a 2022 global review of vitamin D status, a prevalence of 25(OH) <12 ng/mL was reported at 5% to 18%, and <20 ng/mL at 24% to 49%, with a relatively low overall prevalence of vitamin D deficiency in South America, Oceania, and North America, and a more moderate prevalence in Europe, Asia, and possibly Africa.[13] A systematic review and meta-analysis of publications from African countries reported an average 25(OH)D level of 27.1 ng/mL, with a prevalence of 25(OH)D <20 ng/mL at 34.2%, and <12 ng/mL at 18.5%.[14] This study observed a prevalence of 25(OH)D <12 ng/mL at 22.8% and <20 ng/mL at 55.6%, exceeding the world average. This discrepancy may be attributed to factors such as differences in sunlight exposure due to insufficient sunlight angles, limited sunny days owing to this country's high latitude location, reduced sunlight exposure due to factors like high-rise buildings and air pollution in urban areas where the majority of the population resides, as well as the clothing styles influenced by traditional and cultural norms.

The serum 25(OH)D levels were 21.6±13.3 ng/mL (mean± standard deviation) in the study of Yeşiltepe-Mutlu G et al., which included 108,742 subjects of all ages and regions in Turkey. The highest mean 25(OH)D level was 23.5±13.7 ng/mL in the Aegean region, while the lowest was 17.6±12.7 ng/mL in the Black Sea region. In the Marmara region, where this study was conducted, the mean was reported to be 21.6±14 ng/mL. The prevalence of vitamin D deficiency in Turkey as a whole was reported as 27%, with the lowest in the Aegean region at 22% and the highest in the Black Sea region at 42%. In the Marmara region, it was reported as 30%. Additionally, the prevalence of 25(OH)D levels below 20 ng/mL was reported as 51% in Turkey overall and 52% in the Marmara Region.[15] In the Erzincan study involving children aged 0–18 years, 25(OH)D levels were reported to be below 10 ng/mL in 8.36% and below 20 ng/mL in 42.33%.[16] Another study conducted in Ankara with 51,560 children aged 0–18 years reported a mean serum 25(OH)D level of 22.86±16 ng/mL, with 20% of children having vitamin D deficiency.[17] In a study conducted in the Aegean Region, the average serum 25(OH)D level in children aged 0–18 was reported as 28.00±15.55 ng/mL.[18] Furthermore, a study conducted in Gaziantep between March 2021 and March 2022, following the COVID-19 pandemic, reported the prevalence of 25(OH)D <10 ng/mL as 21.2% and <20 ng/mL as 64.5%.[19] The mean 25(OH)D level was reported to be 16.6±11.5 ng/mL in a study including adults in Bursa, where this study was conducted.[20] In this study, the median 25(OH)D level was 18.6 (3–145) ng/mL, with a prevalence of vitamin D deficiency at 22.8%, insufficiency at 32.9%, and 25(OH)D levels below 20 ng/mL at 55.6%. Although not all data from studies conducted in Turkey solely include children, it is notable that the prevalence of vitamin D deficiency and 25(OH)D levels below 20 ng/mL are akin to the Turkish average. Given that this region experiences moderate weather conditions—neither as rainy as the Black Sea region nor as sunny as the Aegean and Mediterranean regions—it is unsurprising that the findings align with the national average.

For various reasons, female adolescents and young adults are more likely to suffer from vitamin D deficiency. According to the global review report by Cui et al., the estimated prevalence of serum 25(OH)D below 20 ng/mL is 45.3% in boys and 53.3% in girls; if it falls below 12 ng/mL, it is 13.6% in boys and 17.8% in girls.[12] In a study of children aged 6–17 years, it was reported that the level of 25(OH)D in Chinese girls (18.7 ng/mL) is lower than in boys (20 ng/mL), and the prevalence of vitamin D deficiency in girls is higher than in boys (50% in boys, 56.5% in girls).[21] Another study involving Chinese individuals of all ages reported the mean 25(OH)D level as 17.6 ng/mL in men and 15.3 ng/mL in women.[22] In a systematic review and meta-analysis conducted in Iran, it was reported that the prevalence of 25(OH)D levels below 20 ng/mL in Iranian children was higher in girls than in boys (61% in girls and 35% in boys).[23] The study of Yeşiltepe-Mutlu G et al., encompassing Turkey, reported that the average 25(OH)D level was lower in girls than in boys (in boys: 23.2±12.5 (1–74.4) ng/mL; in girls: 21±13.4 (0.25–74.5) ng/mL). It was also noted that the prevalence of 25(OH)D levels <12 ng/mL and <20 ng/mL was higher in girls than in boys (18% and 45% in boys; 30% and 52% in girls).[15] Similar to this study, a study conducted with children in Ankara revealed that the average 25(OH)D level was lower in girls than in boys (in boys: 25.1±16.6 ng/mL; in girls: 21.0±15.5 ng/mL). Moreover, it was reported that the prevalence of 25(OH)D levels <12 ng/mL and <20 ng/mL was higher in girls than in boys (13.7% and 45.6% in boys; 26.1% and 61.4% in girls).[16] In another study conducted in adults in Bursa, it was reported that the average 25(OH)D level in women was lower than in men (19.5±9.9 ng/mL in men, 15.8±11.7 ng/mL in women).[20] As reported worldwide and in Turkey, low 25(OH)D levels and a high prevalence of vitamin D deficiency were observed, with <25(OH)D levels of 20 ng/mL being more common in girls in this study. Except for a few seasons in the 0.1–1 and 2–5 age groups, 25(OH)D levels were lower in girls than in boys in all other groups. Furthermore, the prevalence of 25(OH)D levels <20 ng/mL was higher in girls in all age groups except 0.1–1 (all seasons) and 2–5 years (winter).

According to customs and traditions in Turkey, when women reach a certain age, they tend to cover more of their body surface with clothing and spend less time outside the home than men, resulting in reduced sunlight exposure. This condition may explain why women, during a certain age, are more likely to experience vitamin D deficiency.

The primary factor contributing to the development of vitamin D deficiency is inadequate exposure to sunlight. Therefore, it is more prevalent in high-latitude countries where sunlight incidence angles are narrow, in urban areas characterized by high-rise buildings and air pollution, and during the winter and spring seasons when sunlight exposure is reduced.[12,13,21,22,24–26] Yeşiltepe-Mutlu G et al. reported in their study that vitamin D deficiency was most common in the Black Sea region due to its cloudy and rainy weather, particularly in the spring and winter seasons, and least typical in the Aegean region with abundant sunshine, especially during the summer season.[15] Additionally, a study conducted on adults in Bursa noted that the prevalence of 25(OH)D levels <20 ng/mL was highest from March to May and lowest from September to November.[20] This study observed a high prevalence of vitamin D deficiency during the spring and winter seasons, consistent with findings from studies conducted worldwide and in Turkey. This increase in prevalence during these seasons can be attributed to fewer hours of sunlight, reduced time spent outdoors, and limited sun exposure due to wearing thick clothing covering most parts of the body. Interestingly, it was found that 25(OH) D levels were lower in spring compared to autumn despite similar numbers of sunny days. This discrepancy may be explained by the fact that vitamin D levels, which rise during the summer, do not immediately decrease with the reduction in sunny days during autumn. Similarly, it could be because vitamin D levels, which notably decline during the winter months, do not immediately increase with the rise in the number of sunny days during the spring.

Numerous studies conducted in Turkey have consistently reported that the prevalence of vitamin D deficiency was lowest in the 0–1 age range and highest in adolescence. [15–17] The observation of the highest 25(OH)D levels in 0–1-year-olds indicates that vitamin D deficiency is least common in this age group, suggesting the success of prophylactic vitamin D treatment administered to infants. Like infants, adolescents undergo a period of rapid growth and development, resulting in increased vitamin D requirements. However, while prophylactic vitamin D supplementation is provided for the 0–1 age group, it is not administered to prevent vitamin D deficiency in adolescents. Consequently, although the issue of vitamin D deficiency is effectively addressed in infants, it persists among adolescents.

In this study, consistent with the literature, the lowest prevalence of vitamin D deficiency was found in the 0.1–1 age group and was the highest in adolescents. While assessing seasonal variability within individuals is the most appropriate method to determine whether vitamin D levels fluctuate seasonally, the vitamin D levels of the general population can serve as an indicator of insufficiency or deficiency. Although this study's data showed some variance between genders, its limitations warrant further investigation through more targeted and equivalent group studies to ascertain whether such differences truly exist.

Given the large number of cases in this study and its retrospective design, there are limitations such as the inability to conduct a detailed anamnesis (including factors like urban-rural lifestyle, prior vitamin D treatment, and clothing style), physical examinations, and additional laboratory tests aside from 25(OH)D.

CONCLUSION

This study observed lower 25(OH)D levels in girls compared to boys, with levels decreasing as age increased. The lowest levels were found during winter and spring, while the highest levels were observed during autumn and summer. Considering that the lowest 25(OH)D levels are seen in adolescents, particularly female adolescents, during winter and spring, this study advocates for the development of public health strategies to address vitamin D deficiency in this group. These strategies may include maximizing sunlight exposure, promoting outdoor physical activity, advocating for vitamin D-rich diets, and implementing prophylactic vitamin D therapy. In addition, the possibility of rickets should be taken into consideration in growing children whose 25(OH)D values are less than 20 ng/mL. Serum alkaline phosphatase, calcium, phosphorus, and parathyroid hormone levels should be measured in these children. If the child is younger than three years old or if there is a strong clinical suspicion of rickets due to risk factors or physical symptoms, a radiographic evaluation for rickets should be carried out. Although this study's data revealed some disparity between genders, given the study's limitations, further investigation through more targeted and equivalent group studies is warranted to clarify the extent of such differences.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Bursa City Hospital Faculty of Medicine Clinical Researches Ethics Committee (Date: 07.02.2024, Decision No: 2024-1/8).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

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

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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