ABSTRACT

Objective: This study aims to determine the zinc levels and the factors affecting zinc levels in children and adolescents aged 10-18. Zinc is an essential trace element that plays a critical role in various biological processes, including immune function, protein synthesis, and cell division. Adequate zinc levels are particularly important during periods of rapid growth, such as adolescence, as deficiencies can lead to impaired growth, increased susceptibility to infections, and delayed sexual maturation. Understanding the factors that influence zinc levels in this age group is crucial for developing effective nutritional and health interventions.

Methods: This is a retrospective, descriptive, correlational, and cross-sectional study conducted with 542 children and adolescents between the ages of 10-18 to determine zinc levels. Descriptive statistics were analyzed as numbers, percentages, and mean values. Chi-square test and linear regression analysis were used in the analysis of the data. The differences were considered to be statistically significant at p < 0.05.

Results: The average age of the patients is 13.64±2.63. Of the children participating in the study, 60.1% (n=326) are female and 39.9% (n=216) are male. It was determined that 12.7% (n=69) of the children had low zinc levels. There was no significant difference found between the zinc values of children according to gender (p>0.05). Although the percentage of children with low zinc levels increased as their age increased, this increase was not statistically significant (p>0.05). Zinc level was significantly predicted by the combination of the eight variables (p<0.001). The eight variables included in the model were found to explain 5.6% of the variance in zinc level.

Conclusions: It was found that zinc levels were significantly affected by LDL Cholesterol and iron. Although other variables were not significant on their own, they were found to have an impact on zinc levels when combined with LDL Cholesterol and iron. The interaction between LDL cholesterol, iron, and other variables creates a complex network affecting zinc levels in the body. We believe that monitoring and managing LDL cholesterol, iron, and zinc levels during adolescence will be beneficial in the prevention and treatment strategies of diseases such as cardiovascular diseases, diabetes, and chronic inflammatory conditions. We also believe that it will contribute to the development of health policies and help reduce healthcare costs.

Keywords: Adolescent, Zinc level, LDL Cholesterol, Iron

INTRODUCTION

Zinc levels in children aged 10-18 are important due to the many functions of zinc in the body (1). Zinc plays a role in many physiological processes, such as immune system functions, protein synthesis, cell division, wound healing, taste, and smell (2,3). Therefore, it is important for children and adolescents to have an adequate zinc intake. Factors affecting zinc levels include nutrition, age, gender, health status, and environmental factors. Inadequate consumption of foods rich in zinc can cause a deficiency. Foods such as red meat, chicken, pumpkin seeds, nuts, dairy products, whole grains, and seafood contain high amounts of zinc (4).
Studies have shown that both inadequate zinc intake and changes in zinc levels with age occur (5). Children and adolescents between the ages of 10-18 are in a period of growth and development. Therefore, their zinc needs may increase. In addition, male children may have higher zinc needs than female children. Some chronic digestive system diseases, such as Crohn's disease, affect zinc absorption and levels (6).

Adequate zinc intake is crucial during childhood and adolescence, with recommended daily allowances varying by age and gender. For children aged 10-13, boys and girls should aim for 8 mg/day, while adolescents aged 14-18 need 11 mg/day for boys and 9 mg/day for girls. Zinc-rich foods such as meat, seafood, dairy products, nuts, legumes, and fortified foods are essential to meet these requirements. Zinc plays a vital role in immune function, growth, DNA synthesis, and wound healing. Monitoring zinc intake through a balanced diet and, if necessary, supplements under healthcare guidance, along with regular health check-ups, ensures adequate nutritional support during these critical developmental stages, promoting overall health and preventing potential deficiencies (7).

Smoking can decrease zinc absorption. In addition, insufficient zinc content in water and soil in some regions can lead to zinc deficiency (8). For these reasons, a balanced and varied diet should be implemented, and environmental factors should be taken into account to ensure that children and adolescents receive adequate amounts of zinc. Blood zinc levels interact with many biochemical parameters (9,10). There is a reciprocal relationship between zinc and copper. Zinc can inhibit copper absorption, and high zinc levels can lead to copper deficiency. Zinc interacts with iron absorption, and high zinc levels can increase iron absorption (11). Zinc plays an important role in protein synthesis, and high zinc levels can increase protein synthesis. It enhances insulin activity by contributing to the structure of insulin, and high zinc levels can increase insulin secretion (12).

Zinc affects immune system functions, and high zinc levels can enhance immune system functions (13). Zinc can regulate Cholesterol levels, and high zinc levels can lower Cholesterol levels. Zinc can increase antioxidant activity and high zinc levels can enhance antioxidant defense. Zinc can affect the absorption and metabolism of many vitamins, including vitamins A, E, and C (14). Therefore, blood zinc levels interact with many biochemical parameters, and these interactions are important for health and disease risk. Adolescence is a period where many factors can affect zinc levels (15, 16). When reviewing the literature, it is seen that the zinc requirement of children increases during adolescence, with boys requiring more zinc than girls (17,18).

This period is a rapid growth phase, and deficiencies in zinc intake can lead to serious problems. It is stated that there is an increase in negative health behaviors, especially smoking and alcohol use, which are also related to zinc, during adolescence, and this can also lead to a decrease in zinc levels (17-20). In addition, unbalanced nutrition during this period can also have a negative effect on zinc intake. High-intensity exercise and inappropriate intake of other electrolytes can also affect zinc levels during this period (17-20).

Insufficient zinc intake can cause anemia, immune deficiency, growth and developmental problems, skin problems, and depression (17-20). Therefore, it is highly important for Adolescents are advised to consume adequate amounts of zinc and to use recommended supplements. However, a review of the literature reveals that factors affecting zinc levels in the 10-18 age group are not adequately addressed.

MATERIAL and METHODS

Sample and Setting

This is a retrospective, descriptive, correlational, and cross-sectional study conducted with children and adolescents between the ages of 10-18 to determine zinc levels. The study was conducted at Dr. Behçet Uz Children's Hospital between 2019-2021. The necessary sample size was determined using the GPOWER statistical program, and a total of 542 patients who presented to the pediatric outpatient clinics and had their zinc levels tested were included in the study. Chi-square analysis was used to determine the necessary sample size based on a two-tailed hypothesis, a 0.01 significance level, and 99% power, and a sample size of 301 children was determined. Patients were identified by searching the electronic record system for the years 2019, 2020, and 2021. As a result of the search, 150 patients in 2019, 218 patients in 2020, and 174 patients in 2021 were found to have had their plasma zinc concentration tested in the morning hours non-fasting and were included in the study. Plasma zinc concentrations for girls under 66 μg/dL and for boys under 70 μg/dL were considered zinc deficiency (low level of zinc) and values above 120 μg/dL were considered high levels of zinc.

Measures

The data was collected using a socio-demographic data form and a zinc information form. The socio-demographic form includes the age and gender of the children. The zinc information form includes the children's zinc values, vitamin D level, LDL Cholesterol level, iron, ferritin, CRP, calcium, and sodium levels. The researchers prepared this form based on expert opinions and the literature.

Data Collection Process

To prevent bias, the researchers searched the archives separately for each year for two months. Then, they discussed and decided together on the patients to be included in the study. The agreement among the researchers was determined to be 99.9%.

Ethical Consideration

Permission was obtained from the relevant university ethics committee for the study to be conducted. Then, written permission was obtained from the hospital management for the study to be conducted. The data was provided to us in compliance with the personal data protection law by removing patients' identification numbers, names, file numbers, and protocol numbers. The Helsinki Declaration rules were followed at every stage of the study.

Statistical Analysis

The IBM SPSS 24.0 software was used for data analysis. Number, percentage, and mean were used for descriptive data analysis. Independent samples t-test was used to compare zinc...
levels by gender, chi-square analysis was used to compare zinc levels by children’s ages, and multiple linear regression analysis was used to evaluate the predictive power of the identified variables on zinc levels. Whether there was multicollinearity was examined with VIF and tolerance values, and it was found that the VIF value was less than 10 and the tolerance value was greater than 0.2, indicating that there was no multicollinearity and regression analysis could be performed. The Durban Watson value was examined for autocorrelation, and it was determined to be between 1.5 and 2.5. As there was no autocorrelation, it was decided to perform regression analysis. The significance level was set at 0.05.

**RESULTS**

The average age of the patients is 13.64±2.63. Of the children participating in the study, 60.1% (n=326) are female and 39.9% (n=216) are male. It was determined that 12.7% (n=69) of the children had low zinc levels (Table 1).

When the average zinc levels of the patients were examined according to gender, the zinc average of girls was found to be 90.58±22.47 µg/dL (min=11.30-max=188.40) and that of boys was 91.85±18.09 µg/dL (min=52.5-max=167.30). There was no significant difference found between the zinc values of children according to gender (p>0.05) (Table 2).

When the zinc levels of patients were examined according to age groups, 11.1% (n = 24) of children in the 10–12 age group, 12% (n = 20) of children in the 13–15 age group, and 15.7% (n = 25) of children in the 16–18 age group had low levels of zinc. Although the percentage of children with low zinc levels increased as their age increased, this increase was not statistically significant (p> 0.05).

When the descriptive data of zinc were examined according to age groups, the zinc average of children in the 10–12 age group was 92.59±19.77 µg/dL (min=42.9-max=167.30) and the median was 92.25 µg/dL; the zinc average of children in the 13–15 age group was 90.06±19.91 µg/dL (min=11.90-max=162.40) and the median was 90.80 µg/dL; and the zinc average of children in the 16–18 age group was 90.12±23.03 µg/dL (min=11.30-max=188.40) and the median was 91.60 µg/dL (Table 3).

A regression analysis was conducted with eight variables included in the model. The results showed that zinc level was significantly predicted by the combination of the eight variables (p 0.001). The eight variables included in the model were found to explain 5.6% of the variance in zinc level. When examining which variables significantly predicted zinc levels on their own, LDL Cholesterol (β*=0.136) and iron (β*=0.123) levels were found to be significant predictors (Table 4).

### Table I. Descriptive Characteristics

<table>
<thead>
<tr>
<th>Variables</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>13.64±2.63</td>
</tr>
<tr>
<td>Gender (n) (%)</td>
<td></td>
</tr>
<tr>
<td>Girl</td>
<td>326 (60.1)</td>
</tr>
<tr>
<td>Boy</td>
<td>216 (39.9)</td>
</tr>
<tr>
<td>Zinc Level (µg/dL)</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>69 (12.7)</td>
</tr>
<tr>
<td>High</td>
<td>473 (87.3)</td>
</tr>
</tbody>
</table>

### Table II. Comparison of Zinc Values in Children According to their Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>M±SD</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girl (n=325)</td>
<td>90.58±22.47</td>
<td>0.722</td>
<td>0.471</td>
</tr>
<tr>
<td>Boy (n=216)</td>
<td>91.85±18.09</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

M= Mean, SD= Standart Deviation

### Table III. Comparison of Zinc Levels in Children According to Age Groups

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Low Level of Zinc</th>
<th>High Level of Zinc</th>
<th>X²</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>10-12 Age</td>
<td>24</td>
<td>11.1</td>
<td>193</td>
<td>88.9</td>
</tr>
<tr>
<td>13-15 Age</td>
<td>20</td>
<td>12.0</td>
<td>146</td>
<td>88.0</td>
</tr>
<tr>
<td>16-18 Age</td>
<td>25</td>
<td>15.7</td>
<td>134</td>
<td>84.3</td>
</tr>
</tbody>
</table>
In this study, factors influencing the zinc levels of children aged 10–18 years were examined. The parameters that were analyzed together with the zinc levels of the children were used to determine the influencing factors in this study. Zinc is a vital mineral for the body and is involved in many enzyme reactions. Zinc deficiency can cause many health problems.

It is important for children and adolescents, especially during the growth and development process, to consume sufficient amounts of zinc (21-36). Plasma zinc concentrations for girls under 66 μg/dL and for boys under 70 μg/dL considered as zinc deficiency (37) and values above 120 μg/dL were considered high level of zinc (38).

In this study, a difference of approximately one point was observed in the zinc levels of children according to their gender. Although this difference was not statistically significant, it is consistent with the information in the literature that there may be a difference in zinc levels between genders (21–24). It is believed that, especially during adolescence, the increased metabolism and greater body mass (weight gain) in boys may increase the need for zinc and elevate zinc levels (21-26). In our study, it was observed that the percentage of children with low zinc levels increases as age increases, but this increase was not statistically significant (p > 0.05). There was approximately a 3% increase in the number of children with low zinc levels between age groups. When the mean zinc levels of children were compared, a decrease of approximately 2 points was observed in the 16–18 age group. According to the literature, the increase in growth rate increases the zinc requirement, and inadequate nutrition, excessive physical activity, and other metabolic problems can lead to changes in zinc levels, especially during adolescence (21,22). Although there was no statistically significant difference between age groups in this study, it was observed that zinc levels decreased and the number of children with low zinc levels increased with age. This situation can lead to growth and development problems, a weakened immune system, and other health issues (21,22). Therefore, regular monitoring of zinc deficiency in children of all age groups is important.

In this study, it was determined that LDL Cholesterol, iron, ferritin, CRP, hydrovitamin D, calcium, sodium, and phosphorus explain about 5.6% of the variation in zinc levels. A literature review shows that zinc is an important mineral for maintaining metabolic functions (23). Zinc requires other minerals to be present at adequate levels to maintain its functions properly. As our findings suggest, there is a significant interaction between zinc and other minerals (24, 25). In our study, it was observed that the combined effect of these minerals with zinc accounted for approximately 6% of the variation in zinc levels. Although this value may seem relatively low, it is thought to have good explanatory power for zinc, which is influenced by many factors. In this study, when examining which variables significantly predicted zinc levels alone, it was found that LDL Cholesterol (β=0.136) and iron (β=0.123) levels significantly predicted zinc levels on their own. It was observed that LDL Cholesterol had the greatest impact on zinc levels in this study. In the literature, it is also seen that LDL Cholesterol significantly affects zinc levels. In this study, it was found that LDL Cholesterol and iron levels were significant predictors of zinc levels, with LDL Cholesterol having the strongest effect. The literature also suggests a significant relationship between zinc and LDL Cholesterol levels, with a decrease in zinc levels being associated with an increase in LDL Cholesterol levels and an increased risk of cardiovascular disease in children (26, 31, 32). However, the effects of zinc supplementation on LDL Cholesterol levels are mixed, and the exact mechanisms of these interactions are not yet fully understood (27,28). Therefore, it is crucial to monitor and maintain zinc levels within the established limits for the respective age group to reduce the risk of heart disease in children. In this study, iron level was found to be an important factor affecting zinc level. However, ferritin level, which indicates stored iron level, did not affect zinc level. It was observed that as the iron level increased, the zinc level also increased. In the literature, it is stated that iron and zinc sources are similar products, and therefore, children who consume one adequately can also consume the other in similar proportions (27-33). In this study, iron levels were found to be an important factor that affects zinc levels. However, ferritin levels, which indicate stored iron levels, did not affect zinc levels.

### DISCUSSION

#### Tablo IV. Level of Predicting Zinc Value by Some Variables

<table>
<thead>
<tr>
<th>Zinc</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>95% Confidence Interval for B</th>
<th>ANOVA Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>49.011</td>
<td>23.728</td>
<td>2.066</td>
<td>0.040</td>
</tr>
<tr>
<td>Hydro-Vitamin D</td>
<td>0.254</td>
<td>0.134</td>
<td>0.019</td>
<td>0.059</td>
</tr>
<tr>
<td>LDL- Cholesterol</td>
<td>0.057</td>
<td>0.023</td>
<td>0.036</td>
<td>0.016</td>
</tr>
<tr>
<td>Iron</td>
<td>0.067</td>
<td>0.031</td>
<td>0.123</td>
<td>0.030</td>
</tr>
<tr>
<td>Ferritin</td>
<td>-0.041</td>
<td>0.024</td>
<td>-0.100</td>
<td>-1.719</td>
</tr>
<tr>
<td>CRP</td>
<td>0.202</td>
<td>0.492</td>
<td>0.023</td>
<td>0.410</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.346</td>
<td>0.568</td>
<td>0.039</td>
<td>0.610</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.179</td>
<td>0.159</td>
<td>0.075</td>
<td>1.123</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>-0.630</td>
<td>1.409</td>
<td>-0.027</td>
<td>-0.447</td>
</tr>
</tbody>
</table>

**R***=0.237, **R****=0.056, F****=2.260, p=0.023

Abbreviations: *β, Standardized Beta; ** t, t-test value; ***R, correlation co-efficient; **** R2, R Square; *****F, Anova Value
Our study showed that zinc levels increased with an increase in iron levels, which is consistent with the literature indicating that iron and zinc sources are similar and children can consume them in similar amounts (27-33). However, some sources indicate that elevated iron levels can hinder zinc uptake and accumulation and that zinc can also reduce iron absorption (34,35). Despite this, our study found a positive correlation between zinc and iron levels, which may be attributed to children consuming similar amounts of both minerals from the same food sources (36). Several studies have shown that high zinc levels are associated with high ferritin levels, indicating that zinc can enhance iron absorption and lead to iron accumulation in the body (30).

CONCLUSION

In conclusion, in this study, it was found that zinc levels were significantly affected by LDL Cholesterol and iron. Although other variables were not significant on their own, they were found to have an impact on zinc levels when combined with LDL Cholesterol and iron. To obtain more conclusive results, it is recommended to expand the study by including a broader sample of individuals from different regions, particularly focusing on those with inadequate levels of variables that were not found to be effective in this study. The close monitoring of zinc levels and their neurodevelopmental importance and impact on growth in children and adolescents has encouraged further research in this area. More advanced studies are needed to generate practical outcomes for clinical applications.

Limitations

Although this study has strong points, such as using a large sample from various regions of Turkey, there are also a few limitations. Firstly, the study was conducted using a convenience sample, which should be considered when interpreting the results. Secondly, a portion of the sample was evaluated during the pandemic period, which may have affected outpatient clinic visits and could potentially impact the generalizability of the study’s findings.

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Conflict of interest: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors’ Contribution

Conceptualization: ZIPB, DO
Data curation: ZIPB, DO, MB
Formal analysis: ZIPB, DA, HÇ, FD, MB
Funding acquisition: ZIPB
Investigation: ZIPB, DO
Methodology: ZIPB, DO, DA
Project administration: DO, DA, MB
Resources: ZIPB, FD
Software: ZIPB, DO, DA
Supervision: DO, HÇ, MB
Validation: DO, MB, FD
Visualization: HÇ, FD
Writing–original draft: ZIPB, DO, DA, HÇ, FD, MB
Writing–review & editing: ZIPB, DO, DA, HÇ, FD, MB

Ethical approval: The present study was conducted in strict accordance with the principles outlined in the Declaration of Helsinki. Informed consent was obtained from the participant of this study. Ethics committee approval was received at Izmir Bakırçay University. Decision no: 1038, Research no: 1018, Date: 11.05.2023

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