The Effect of Low-Fat Diet on Absorption of Fat-Soluble Vitamins in Dyslipidemic Children (Age From 6-12 Years)

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تقييم النظام الغذائي قليل الدهون على امتصاص الفيتامينات التي تذوب في الدهون لدي الأطفال المصابين بعسر شحيمات الدم (من ٦ إلى ١٢ سنة)

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مستخلص البحث:

يرتبط خلل الدهون في الدم لدى الأطفال باضطرابات في التمثيل الغذائي للدهون وزيادة خطر الإصابة بأمراض القلب والأوعية الدموية. تهدف هذه الدراسة إلى التحقيق في مستويات الفيتامينات الذوابة في الدهون (أ، هـ ، د) في مصل الدم، وتحديد مدى انتشار النقص لدى الأطفال المصابين بخلل دهون الدم الذين يتبعون نظامًا غذائيًا منخفض الدهون. **الطرق:** أجريت الدراسة في مستشفى الأطفال بجامعة القاهرة بين سبتمبر ٢٠٢٢ وأكتوبر ٢٠٢٣، وشملت ٣٥ طفلاً تتراوح أعمارهم بين ٦-١٢ عامًا تم تشخيصهم بخلل في دهون الدم. التزم هؤلاء الأطفال بنظام غذائي CHILD-2-LDLلأكثر من ٦ أشهر. تم جمع البيانات الديموغرافية والقياسات الجسمانية وتناول الطعام وصورة الدهون في المصل. تم قياس مستويات الفيتامينات أ و هـ و د في المصل باستخدام طرق التحليل المناعي. **النتائج:** شملت مجموعة خلل دهون الدم ١٦ ذكراً (٤٥,٧٪) و ١٩ أنثى (٥٤,٣٪)، بمتوسط عمر ١٠ سنوات. أظهرت نتائج تحليل الدهون أن متوسط الكوليسترول الكلي كان (٣٦٤,١ ± ١٩٨ ملجم/ديسيليتر)، ومتوسط الكوليسترول الضار LDL كان (٢٢٥,٦ ملجم/ديسيليتر)، ومستويات الدهون الثلاثية كانت (٣٦٨,١ ملجم/ديسيليتر)، والكوليسترول الجيد HDL كان (٣٦,٨ ± ٢٥,٢ ملجم/ديسيليتر). كانت مستويات فيتامين د منخفضة بشكل ملحوظ (١٥,٧ ± ٥,٧ نانوجرام/مللي)، مما يشير إلى وجود نقص. بينما كانت مستويات فيتامين أ و هـ ضمن المستويات الطبيعية، أظهر مرضى خلل دهون الدم اتجاهاً نحو انخفاض مستويات فيتامين أ. **الاستنتاج:** أظهر الأطفال المصابون بخلل دهون الدم اضطرابات كبيرة في مستويات الدهون ونقص في فيتامين د مع نقص لفيتامين أ بنسبة ٢٠ % من عدد المشتركين. تؤكد هذه النتائج على أهمية التدخلات الغذائية والمكملات لمعالجة النقص الغذائي وتحسين ملفات الدهون، وبالتالي تقليل مخاطر الإصابة بأمراض القلب والأوعية الدموية لدى مرضى خلل الدهون من الأطفال.

الكلمات الدلالية : نظام غذائي منخفض الدهون، اضطراب شحميات الدم، الفيتامينات الذائبة في الدهون، الدهون، فيتامين أ، فيتامين د، فيتامين هـ، طب الأطفال

Abstract:

Background: Dyslipidemia in children is associated with abnormal lipid metabolism and an increased risk of cardiovascular disease. This study investigates the serum levels of fat-soluble vitamins A, E, and D, and determines the prevalence of deficiencies in children with dyslipidemia following a low-fat diet. **Methods:** The study, conducted at Cairo University Children Hospital between September 2022 and October 2023, included 35 children aged 6-12 years diagnosed with dyslipidemia. These children adhered to the CHILD-2-LDL diet for over 6 months. Demographic data, anthropometric measurements, dietary intake, and serum lipid profiles were collected. Serum levels of vitamins A, E, and D were measured using HPLC and immunoassay methods. **Results:** The dyslipidemia group included 16 males (45.7%) and 19 females (54.3%), with a mean age of 10 years. The lipid profile showed total cholesterol (364.1 ± 198 mg/dl), LDL cholesterol (225.6 mg/dl), and triglycerides (368.1 mg/dl), and HDL cholesterol (36.8 ± 25.2 mg/dl). Vitamin D levels were significantly low (15.7 ± 5.7 ng/ml), indicating a deficiency. While vitamin A and E levels were within normal ranges, dyslipidemia patients exhibited a trend toward low vitamin A levels. Conclusion: Children with dyslipidemia demonstrated significant lipid abnormalities and vitamin D deficiency. These findings

underscore the importance of dietary interventions and supplementation to address nutritional deficiencies and improve lipid profiles, thereby reducing cardiovascular risks in pediatric dyslipidemia patients.

Key Words: low Fat Diet, Dyslipidemia, Fat Soluble Vitamins, Lipids, Vit. A, Vit. D, Vit. E, Pediatrics

Introduction

Dyslipidemia refers to the abnormal levels of lipids (cholesterol and/or fatty acids) or lipoproteins in the blood **(Bibiloni, 2015).** It is characterized by disorders of lipid metabolism, which, although essential for health, can become dangerous when concentrations are abnormal **(National Heart, Lung, and Blood Institute, 2011).** The prevalence of dyslipidemia in children is significant, with conditions like familial hypercholesterolemia (FH) affecting approximately 1 in every 250 children, and around 1 in 5 children meeting criteria for childhood overweight or obesity, often associated with lipid abnormalities **(De Ferranti et al., 2016; Garrido-Miguel et al., 2019).**

The National Lipid Association (NLA), American Heart Association (AHA), and American College of Cardiology

(ACC) emphasize lifestyle therapies as crucial for reducing premature cardiovascular disease risk, either alone or alongside pharmacotherapies **(Jacobson et al., 2015; Arnett et al., 2019; Williams et al., 2022).** Research has demonstrated that improper diets, especially those with excess energy intake, are major contributors to hypercholesterolemia and obesity in children and adolescents **(Williams et al., 2022; Arnett et al., 2019).**

The pathologic process of atherosclerosis begins in youth and increases the risk of cardiac events such as heart disease, myocardial infarction, and stroke later in life. Risk factors for atherosclerotic cardiovascular disease (ASCVD) in childhood include lifestyle factors, medical conditions (e.g., obesity, diabetes), and genetic conditions **(Schefelker & Peterson, 2022).**

The mainstay of clinical management for pediatric dyslipidemias, including FH in very young ages, involves lifestyle changes such as diet modifications and exercise, with drug therapy considered if diet modifications fail to lower low-density lipoprotein cholesterol levels (LDL-c) adequately **(Gidding et al., 2012).**

Fat-soluble vitamins, including vitamins A, D, E, and K, play critical roles in maintaining overall health, immune function, muscle and heart function, blood clotting, and eye health **(chumarthy et al., 2015).** They are absorbed along with dietary fat, transported via chylomicrons in circulation, and stored in peripheral tissues **(Modern Nutrition, 2014).**

Vitamin A is known to influence lipid metabolism and can regulate key lipogenic enzymes and gene expressions involved in lipid metabolism **(Bonet et al., 2012; Chen & Chen, 2014; Blaner, 2019).** Epidemiological and mechanistic studies suggest that vitamin A may promote lipid catabolism and reduce obesity and ASCVD risk **(Miller et al., 2020; Rissanen et al., 2003; Dwyer et al., 2004; Huang et al., 2018)**. However, excessive intake of Vit. A through supplements or retinoid drugs has been associated with hypercholesterolemia and other lipid abnormalities **(Dwyer et al., 2004).**

Vitamin E, primarily alpha tocopherol, acts as an antioxidant by scavenging peroxyl radicals and protecting membrane lipids from oxidation **(Niki et al., 2014).** Deficiencies in fat-soluble vitamins have been linked to fat deposition, chronic inflammation, and obesity in young populations **(Sarni et al.,**

2005; Wei et al., 2016; Gunanti et al., 2014), while other studies show positive associations between fat-soluble vitamin levels and obesity measures **(García et al., 2013).**

The study aims to elucidate how dietary interventions may influence fat-soluble vitamin levels in children with dyslipidemia.

Patients and Methods

Patients: The study took place at Cairo University Children Hospital between September 2022 and October 2023. Its objective was to evaluate serum levels of fat-soluble vitamins and determine the prevalence of deficiencies in children with dyslipidemia following a low-fat diet. A total of 35 children, aged 6 to 12 years and diagnosed with dyslipidemia, were enrolled in the study. These children were receiving treatment and dietary counselling at the Clinical Nutrition Outpatient Clinic of the Department of Pediatrics, Cairo University .

Study Design: This was a cross-sectional observational trial involving children with dyslipidemia who had been following the CHILD-2-LDL diet for more than 6 months. The CHILD-2-

LDL diet, based on the recommendations of the 2011 Expert el on Cardiovascular Health and Risk Reduction in Children and Adolescents, emphasizes specific macronutrient distributions, with 50-55% of energy from carbohydrates, 15-20% from protein, and a restriction of total fat intake to 25-30% of total energy intake.

Assessments:

1.Initial Assessment:

including age and sex were collected from medical records.

- Anthropometric measurements such as weight, height, and body mass index (BMI) were obtained and plotted against WHO z-scores using WHO Anthro software (version 3.2.2, January 2011).
- Dietary intake was assessed using the 24-hour recall method, averaging data from three different days for each child. Nutrient analysis was conducted using the food composition tables of the National Nutrition Institute based on the recommended dietary allowance (RDA) of the National Academy of Science, Egypt.

- Food Frequency Questionnaires (FFQ) were administered to assess the frequency of food consumption patterns.

2.Serum Lipid Profile (Baseline) :

- The assessment of lipid profiles involves measuring total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides through a blood sample, typically obtained after fasting. The Particits were instructed to fast for 8-12 hours prior to venous blood sample collection. **(Schaefer et al., 2016)**

3.Fat-Soluble Vitamins Tests:

- Serum levels of fat-soluble vitamins, particularly vitamin D, were assessed using an immunoassay method. The vitamin D assay involved a sequential competitive assay utilizing 25-hydroxyvitamin D2 and 25-hydroxyvitamin D3, with results expressed in ng/ml. Standard curves and calibration were performed according to established protocols. **(Zerwekh, 2008)**

- Vitamins A and E were assessed using a high-performance liquid chromatography (HPLC) method involving liquid-liquid extraction, sample preparation with internal standards, and detection at specific wavelengths, ensuring high accuracy and sensitivity **(Pan et al., 2020)**

Inclusion Criteria:

- Children aged 6-12 years of both sexes.
- Established diagnosis of dyslipidemia based on NHLBI guidelines. **(National Heart, Lung, and Blood Institute, 2011).**
- Adherence to the recommended dietary modifications of the CHILD-2-LDL diet for at least 6 months. **(Schefelker& Peterson,2022).**

Exclusion Criteria:

- Presence of intestinal malabsorption disorders.
- History of liver or renal diseases.
- The duration of fat-restricted diet is less than 6 months.

Data Analysis: Data from anthropometric assessments, dietary intake assessments, and serum lipid profiles were analyzed using appropriate statistical methods. Descriptive statistics, t-tests, and correlation analyses were performed to evaluate relationships between variables and assess the prevalence of fat-soluble vitamin deficiencies.

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Results:

The study investigated serum levels of vitamins A, E, and D among(n=35) children and adolescents with dyslipidemia, including 16 males (45.7%) and 19 females (54.3%), with a mean age of 10 years. **Fig (1)**

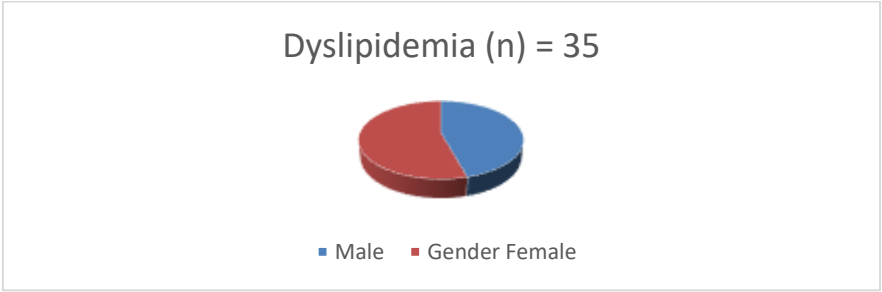

Figure (1)

Based on the detailed analysis of children and adolescents with dyslipidemia, several key findings emerge:

Ages and BMI Differences:

- Dyslipidemia patients had a mean age of 10 years.
- Dyslipidemia patients body weight (32.3 kg) and height (130.9 cm). **Fig (2)**

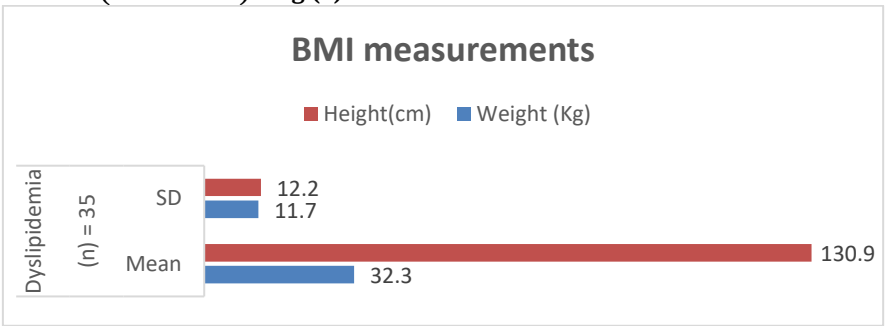

Figure (2)

Lipid Profile:

- Patients with dyslipidemia exhibited total cholesterol levels of (364.1 ± 198 mg/dl), LDL cholesterol levels of

(225.6 mg/dl), and triglyceride levels of (368.1 mg/dl). **Table (1)**

- HDL cholesterol levels were low at 36.8 ± 25.2 mg/dl. **Table (1)**

Dyslipidemia

	Mean	**SD**
TC	364.1	198.0
HDL	36.8	25.2
LDL	225.6	194.4
VLDL	25.3	57.9
TG	368.1	594.1

Table (1)

Vitamin Status:

- The study investigated serum levels of vitamins A, E, and D among these patients, shedding light on potential vitamin deficiencies and their relationship with lipid metabolism.
- Dyslipidemia patients had significantly low serum vitamin D levels (15.7 ± 5.7 mg/mL), indicating potential deficiency. **Table (2), Fig (3)**

- Vitamin A concentrations were within normal limits in our patients; However, these patients exhibited a trend toward low vitamin A levels (20% of the patients have deficiency), with mean values of 40.7 ± 23.3 IU/L. **Fig.4**
- Similarly, serum vitamin E levels were within the normal range, with mean values of 11.41 mg/mL in dyslipidemia patients.

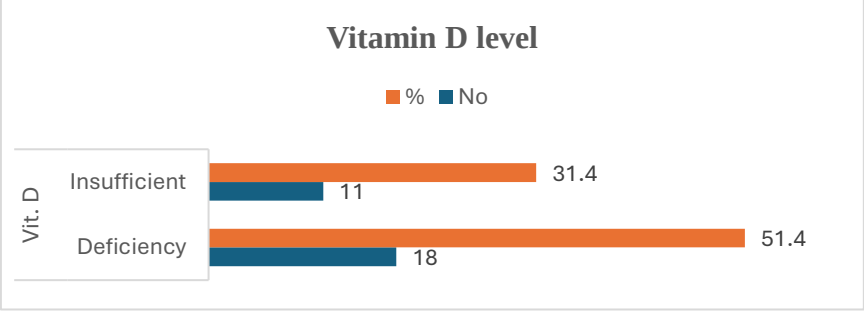

Figure (3)

		Dyslipidemia		*P value*
		No	**%**	
*Vit. A**	**Low**	7	20.0	0.020
	Normal	22	62.9	
	High	6	17.1	
*Vit. E***	**Low**	3	8.6	0.330
	Normal	32	91.4	
	High	-	-	
*Vit. D****	**Deficiency**	18	51.4	0.000
	Insufficient	11	31.4	
	Normal	6	17.1	

Table (2)

***Normal Value range of Vitamin A (from 20 to 60 mcg/dL) (Markell and Siddiqui, 2022)**

****Normal Value range of Vitamin E (from 5.7 to 19.9 mg/L) (Le et al., 2020)**

*****Ranges of Vitamin D (sever deficiency <5 / Moderate deficiency 5-15 / Insufficiency 16-20 / Sufficiency 21-100) ng/mL (Lee et al., 2013)**

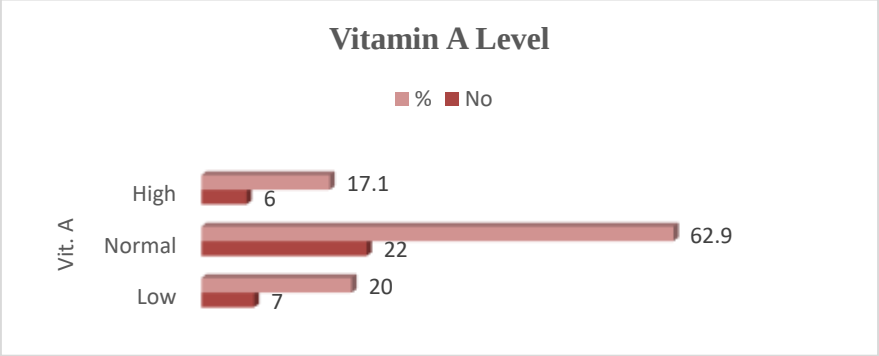

Figure (4)

Vitamin Intake Relative to Recommended Levels:

- **Vitamin A Intake:** Dyslipidemia patients consumed vitamin A below recommended levels, with 22.4% of RDA. This deficiency underscores the need for dietary interventions to improve vitamin A intake, particularly from rich food sources such as fruits and vegetables as a Provitamin.
- **Vitamin E Intake:** The study revealed suboptimal vitamin E intake among dyslipidemia patients, who consumed only 22.6% of the recommended dietary allowance (RDA). Enhancing dietary diversity and incorporating vitamin E-rich foods such as nuts, seeds, and getting more sunlight may help bridge this gap.

- **Vitamin D Intake:** Dyslipidemia patients exhibited inadequate vitamin D intake, likely contributing to low serum levels. The study emphasizes the importance of dietary sources (e.g., fortified foods, fatty fish) and supplementation strategies to address vitamin D insufficiency and support overall metabolic health.

Discussion:

The result within our study reveals significant insights into the lipid profiles and vitamin levels among children and adolescents with dyslipidemia. The study involved 35 participants with dyslipidemia, who followed the CHILD 2-LDL dietary recommendations aimed at managing their condition through reduced fat intake and balanced macronutrients. The lipid profile analysis showed marked deviations from normal levels. According to the ***National Heart, Lung, and Blood Institute (2011),*** childhood dyslipidemia, which is classified into primary and secondary forms, carries significant implications for the early onset of atherosclerosis and premature cardiovascular disease (CVD). The study corroborates these concerns. Dyslipidemia participants exhibited notable abnormalities in their lipid profiles. Their mean Total Cholesterol (TC) level

stood at 364.1 ± 198 mg/dl, well above the usual ranges. Alarmingly, their High-Density Lipoprotein Cholesterol (HDL) levels were markedly low, averaging 36.8 ± 25.2 mg/dl, a troubling sign given HDL's role in protecting against heart disease. Conversely, Low-Density Lipoprotein Cholesterol (LDL) levels were significantly elevated, with an average of 225.6 mg/dl, indicating an increased risk for atherosclerosis development. Triglycerides (TG) also showed heightened levels, averaging 368.1 mg/dl, further compounding the cardiovascular risk factors in these children. This underscores the critical importance of addressing dyslipidemia in childhood to mitigate future cardiovascular risks. As emphasized by ***(Sarah & Jane, 2023),*** lifestyle modifications and medical management are imperative to effectively lower LDL-C levels and mitigate these risks.

Vitamin deficiencies were observed, particularly vitamin D insufficiency/deficiency, aligning with previous research ***(AlQuaiz et al., 2020; Liu et al., 2022).*** Our findings were particularly alarming, with 51.4% of the dyslipidemia group showing deficiency, and 31.4% showing insufficient levels, which is crucial for bone health and overall metabolic functions.

The data underscores the critical need for early and effective intervention in children with dyslipidemia.

The assessment of vitamin A revealed significant deficiencies among our patients. Within 20% of participants had deficiencies, and 62.9% maintained normal levels, while 17.1% had high levels. Our findings suggest a relationship between obesity, dyslipidemia, and vitamin status, warranting further investigation ***(Ismail et al., 2014; Yu et al., 2022; Liu et al., 2022).*** For Vitamin E, a majority (91.4%) of the dyslipidemia participants maintained normal levels, with only a small percentage showing deficiencies.

Dietary analysis revealed discrepancies between recommended and actual intake levels, with our participants consuming below recommended levels for various nutrients **(Song et al., 2017).** Protein intake was below the RDA, contrasting with suggestions for its potential benefits on lipid profiles **(Bahadoran et al., 2013).** Fat intake, particularly from dairy sources, and carbohydrate intake were also below recommendations **(Kelishadi et al., 2004).**

(Zalaket et al., 2018) Reported that calcium and vitamin A intake were insufficient, despite their potential benefits on lipid

profiles**.** Consumption of fish, nuts, and fiber-rich foods was low, while lean meats and poultry were favored **(Kameyama et al., 2020).** Clinical analysis revealed elevated lipid levels among our participants, consistent with previous studies **(Oliosa et al., 2019; Kavey, 2023; Gujral & Gupta, 2024).**

Moreover, regular monitoring and individualized treatment plans are crucial in managing dyslipidemia and preventing its progression to more severe cardiovascular conditions. In conclusion, the findings from this study emphasize the importance of comprehensive care and management strategies for children with dyslipidemia. By addressing both lipid abnormalities and vitamin deficiencies, healthcare providers can better mitigate the long-term health risks associated with this condition. Future research should focus on refining dietary guidelines and exploring additional therapeutic options to improve the health outcomes of pediatric patients with dyslipidemia.

Conclusion:

This study aimed to provide insights into the nutritional status and fat-soluble vitamin levels among children with dyslipidemia following a low-fat diet. The findings contribute

to the development of effective dietary interventions and nutritional strategies for managing dyslipidemia in pediatric populations.

Recommendations:

1. **Balanced Diet**:
    - Focus on eating plenty of fruits, vegetables, whole grains, and lean proteins like chicken or fish.
    - Limit sugary drinks, processed foods, and high-fat snacks.
2. **Nutrient-Rich Foods**:
    - Include foods rich in calcium (like dairy), magnesium (like nuts and seeds), vitamin D (like fortified milk or fatty fish), exposure to direct sunlight and vitamin A (like carrots or sweet potatoes) in meals as a Provitamin.
3. **Team Approach**:
    - Work together with doctors, nutritionists, and other healthcare providers to create a plan that fits each child's needs and goals.

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