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Nedeljko Radlović¹, Zoran Leković^{2,3}, Jovana Janković³, Siniša Dučić^{2,3}, Petar Rosić²,
Iva Čevrljaković⁴, Vladimir Radlović^{2,3,*}

Lipids in the diet of children and adolescents

Липиди у исхрани деце и адолесцената

¹Serbian Medical Society, Academy of Medical Sciences of the Serbian Medical Society, Belgrade, Serbia;

²University of Belgrade, Faculty of Medicine, Belgrade, Serbia;

³University Children's Hospital, Belgrade, Serbia;

⁴Kruševac General Hospital, Pediatric Department, Kruševac, Serbia

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***Correspondence to:**

Vladimir RADLOVIĆ

University Children's Hospital, Tiršova 10, 11000 Belgrade, Serbia

e-mail: vladar@beotel.net

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SUMMARY

Lipids are a macronutrient of multiple importance for adequate growth and development, as well as maintaining health in other phases of life. In addition to being, along with carbohydrates, the main source of calories, lipids are an indispensable structural and functional constituent of the human body. Their intake must be complete and adjusted to optimal needs, which differ in quantitative terms during different phases of growth and development. Of particular importance is the coverage of the needs for essential and semi-essential fatty acids, as well as strict adherence to the upper limit of the permissible intake of saturated fatty acids, cholesterol and trans fatty acids.

Keywords: lipids; physiological role; optimal needs; children and adolescents

САЖЕТАК

Липиди су макронутријент од вишеструког значаја за адекватан раст и развој, као и очување здравља у осталим фазама живота. Сем што су, уз угљене хидрате, основни извор калорија, липиди су неизоставан структурни и функционални конституент организма. Њихов унос мора бити комплетан и прилагођен оптималним потребама, које се у квантитативном погледу разликују током различитих фаза раста и развоја. Посебан значај има покриће потреба у есенцијалним и семиесенцијалним масним киселинама, као и стриктно поштовање горње границе дозвољеног уноса засићених масних киселина, холестерола и транс масних киселина.

Кључне речи: липиди; физиолошка улога; оптималне потребе; деца и адолесценти

INTRODUCTION

Lipids, along with proteins and carbohydrates, are among the macronutrients of the human diet. In addition to being an important source and reservoir of energy, lipids are essential structural and functional factors of the human body and, as such, are responsible for numerous physiological processes [1–5]. Inadequate fat balance during the developmental period has numerous consequences, such as energy deprivation and essential fatty acid deficiency in celiac disease, cystic fibrosis and cholestatic syndrome, or obesity, secondary hyperlipidemia and a tendency to cholelithiasis in conditions of excessive intake [6–13].

This article, along with a review of the dietary content, digestion and absorption, and basic physiological roles of lipids, provides current guidelines for their optimal intake in childhood and adolescence.

LIPIDS IN THE HUMAN DIET

About 90–95% of the lipids present in the standard human diet are triglycerides, with the remainder being phospholipids and cholesterol [1]. Triglycerides are esters of glycerol and fatty acids. According to chain length, fatty acids are classified as short-chain ($\leq C6$), medium-chain ($C8–14$), or long-chain ($\geq C16$); they may also be classified according to whether they contain an even or odd number of carbon atoms [1, 14]. The human diet is dominated by long-chain fatty acids with an even number of carbon atoms. Long-chain fatty acids are further differentiated into saturated and mono- and polyunsaturated. The monounsaturated fatty acids, palmitoleic ($C16:1$, $\omega-7$) and oleic ($C18:1$, $\omega-9$), can be synthesized in our body, while the essential fatty acids, linoleic ($C18:2$, $\omega-6$) and alpha-linolenic ($C18:3$, $\omega-3$) must be ingested through food [15]. The basic source of essential fatty acids is foods of plant origin, because

plants, unlike animals, possess Δ 12-desaturase in their chloroplasts, which converts oleic acid into linoleic acid, as well as Δ 15-desaturase, which transforms linoleic acid into alpha-linolenic acid [16, 17]. Although plant foods are, in general, low in fat, there are certain plant varieties from which oils rich in linoleic and alpha-linolenic acid, as well as other unsaturated fatty acids, are obtained by appropriate technological procedures. During the process of successive elongation and desaturation of essential fatty acids, which is almost completely carried out in the liver, long chain polyunsaturated fatty acids (LCPUFA) are formed, which have ≥ 20 C atoms and ≥ 2 double bonds [1]. However, the capacity for endogenous synthesis of the final components of ω -3 LCPUFA, i.e. docosahexaenoic (DHA, C22:6, ω -3) and eicosapentaenoic (EPA, C20:5, ω -3), is insufficient, not only in infants, but also in other ages, so the intake of preformed EPA and DHA with food or in the form of supplements is necessary to meet physiological needs [15, 18–22]. This also applies to arachidonic acid (C20:4, ω -6), which is also a semi-essential nutrient within the first few months after birth [23]. According to the spatial arrangement of hydrogen atoms around the double bond of the carbon chain, cis and trans unsaturated fatty acids are further distinguished. Trans fatty acids, identical to saturated ones, are characterized by a rigid linear structure, high melting point and high atherogenic potential [24–27]. In addition, some studies suggest that excessive intake of trans fatty acids ($> 1\%$ of total energy intake) is a risk factor in developing insulin resistance and breast, prostate, and colon cancers [24, 25]. In milk, dairy products and ruminant meat, trans fatty acids make up 4–6% of all fatty acids [28]. However, during the thermal processing of food, and especially during the hydrogenation of vegetable oils into margarine, a large part of cis fatty acids, sometimes as much as 60%, is converted to trans isomers [28]. Due to transplacental and transmammary transfer and possible damage to the developing brain, pregnant and breastfeeding women, as well as children, especially within the first 2–3 years, should be maximally spared from the intake of trans fatty acids [24, 28].

Phospholipids are a complex of diacylglycerol and inositol, choline, serine or ethanolamine linked by a phosphate group. The exception is sphingomyelin, which contains sphingosine instead of glycerol. As key components of the cell and subcellular membranes of all eukaryotes, phospholipids are present in foods of plant and animal origin.

Cholesterol is the main animal sterol, while the main sterol in fungi is ergosterol, and in plants sitosterol. It is synthesized in the body from acetyl-CoA, primarily in the liver, and partly ingested with animal food. From food it is primarily (85–90%) absorbed in free form, and to a lesser extent in ester compounds with fatty acids.

Tables 1–3 show the quantitative and qualitative fat content of some foods [29–34].

Plant foods are characterized by the absence of cholesterol, with the exception of palm and coconut oil, the predominant content of unsaturated fatty acids and, except for algal oil, a complete lack of LCPUFA. Also, the level of EPA and DHA in animal food from land is much lower than in food of the same species from water, especially marine [35].

DIGESTION AND ABSORPTION OF LIPIDS

Digestion and absorption of fat occurs primarily in the small intestine. Triglycerides are hydrolyzed by pancreatic lipase, phospholipids by phospholipase 2, and cholesterol esters by cholesterol esterase. Under the action of sublingual and gastric lipase, most of the short- and medium-chain triglycerides are hydrolyzed and absorbed in the stomach [36–38]. In breast-feeding infants, lactic lipase also makes an important contribution to the digestion of triglycerides [36]. After hydrolysis, fatty acids and cholesterol are reabsorbed and transported into the bloodstream via the lymphatic system as part of chylomicrons [37, 38]. In addition to pancreatic lipase, colipase and optimal pH, the condition for normal digestion and absorption of fats is the optimal presence of bile acids and salts [37, 38]. The exception is short-chain and medium-chain triglycerides, which are water-soluble and, independent of bile acids and salts, either in hydrolyzed or intact form, pass directly into the bloodstream [36, 38].

PHYSIOLOGICAL ROLE OF LIPIDS

Lipids are essential structural and functional factors of the human body. Triglycerides, along with carbohydrates, are the main source of energy. In addition, they are the main reservoir of energy and indispensable carriers of numerous physiological functions. The role of phospholipids and cholesterol lies in their universal presence in the cellular and subcellular membranes of all eukaryotes [39, 40]. Cholesterol is a precursor of steroid hormones and bile acids and a basic component of myelin [41, 42]. Essential fatty acids have a special and multiple significance. Unlike other fatty acids, their primary role is related to the synthesis of LCPUFA, mostly DHA and arachidonic (C20:4, ω -6), which are part of the membrane phospholipids of cells of the central nervous system and retina [15, 20, 23]. With their adequate presence, which is highest in the neurocytes of the gray matter of the frontal lobe of the brain, photoreceptor cells of the macula and interneural synapses, these LCPUFA fractions, especially DHA, ensure an optimal level of mental and visual functions [22, 23, 43]. In addition, LCPUFA are precursors of tissue hormones (eicosanoids), prostanoids, leukotrienes, lipoxins and others, which play an irreplaceable role in numerous processes at the cellular and tissue level [22, 23]. DHA is also a precursor of the anti-inflammatory neuroprotectors, protectins, resolvins and maresins [20, 44].

PHYSIOLOGICAL NEED FOR LIPIDS

Recommendations from the Institute of Medicine of the United States, the American Heart Association, and the United States Department of Health and Human Services regarding the proportion of fat in the diet are given in Table 4 [45, 46, 47]. Both the World Health Organization and the Food and Agriculture Organization of the United Nations recommend consuming less than 10% saturated fatty acids and less than 1% trans fatty acids of the total caloric value of food [47, 48, 49]. Considering the limited capacity of endogenous conversion of alpha-linolenic acid into EPA and DHA, recommendations are given

regarding their optimal intake (Table 5) [49]. Identical or similar positions are followed by other relevant international and national institutions and associations [15, 50].

CONCLUSION

Lipids are among the three basic components of the human diet. They are an important source of energy and an essential structural and functional constituent of our body. Their intake must be adapted to optimal needs, which differ quantitatively during different stages of growth and development. Of particular importance is meeting the needs for essential and semi-essential fatty acids, as well as strictly adhering to the permitted intake of saturated fatty acids, cholesterol and trans fatty acids.

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Table 1. Triglyceride and cholesterol content in certain types of food [29, 30]

Type of food	Triglycerides (g/100 g)	Ratio of saturated to unsaturated fatty acids	Cholesterol (mg/100 g)
Human milk*	3.5–4.5	0.34–0.47:1	9–15
Cow's milk	3.6–3.88	1.7–2.3:1	5–15
Cheese ("full fat")	23–32	1.8–2.1:1	70–100
Chicken yolks	31–33	1.8–1.1:1	1070–1700
Chicken liver	4–6.2	0.93:1	429–555
Chicken meat (with skin)	6.2–11.2	0.55–0.62:1	60–91
Beef (brisket)	1.55–3	2.32:1	70
Pork (lean)	1–2.8	0.34:1	65–77
Sardine	1.2–9.81	0.43:1	142
Salmon	12.5–16.5	0.28:1	35–52
Catfish	1.58–4.3	0.1:1	33

*According to reference 29

Table 2. Linoleic and α -linolenic acid content in vegetable and animal fats (mg/100 g) [31, 32]

Dietary source	Linoleic acid	α -linolenic acid	Ratio
Linseed oil	24,000	47,000	1:2
Soybean oil	53,400	7600	7:1
Olive oil	8000	950	8:1
Corn oil	50,000	900	55:1
Sunflower oil	60,200	500	120:1
Pork fat	8600	1000	8.6:1
Tallow	2580	190	13.6:1

Table 3. Content of basic ω -3 long chain polyunsaturated fatty acids in food (mg/100 g) [33, 34]

Dietary source	EPA	DHA
Sardine	763	1292
Herring	909	1105
Salmon	862	1104
Tuna	91	328
Catfish	20	69
Fish oil	27,050	900
Microalgae oil	15,000	30,000
Human milk	0.47–0.53	3.51–5.52
Infant formula	0.45–0.55	6.81–6.88
Egg	0	58
Chicken	10	20
Beef	2	3
Pork	0	2

DHA – docosahexaenoic; EPA – eicosapentaenoic

Table 4. Basic guidelines regarding the presence of fat in the diet of children and adolescents [45, 46, 47]

Component	Recommended intake
Total fat (share of total caloric value of food)	0–1 year: 40–50% 2–3 years: 30–35% 4–18 years: 25–35%
Essential fatty acids	7–10% (ω -6: ω -3 ~ 5–10:1)
Saturated fatty acids	< 10%
Trans fatty acids	< 1%
Cholesterol	< 300 mg daily

Table 5. Recommended daily requirements in ω -3 long chain polyunsaturated fatty acids in food (WHO/FAO, 2008) [49]

Age	DHA	EPA+DHA
0–6 months	0.1–0.18% total cal	
6–24 months	10–12 mg/kg	
2–4 years		100–150 mg
4–6 years		150–200 mg
> 6 years		200–250 mg

DHA – docosahexaenoic; EPA – eicosapentaenoic