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Research Article

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Dietary intake and food sources of essential fatty acids among Korean adolescents: a cross-sectional study based on the 2016–2021 KNHANES data

Enkhgerel Erdenetsetseg [1], **Hye Ran Shin** [2], **SuJin Song** [3]†

[1]Graduate Student, Department of Food and Nutrition, Hannam University, Daejeon, Korea
[2]Researcher, Department of Food and Nutrition, Hannam University, Daejeon, Korea
[3]Associate Professor, Department of Food and Nutrition, Hannam University, Daejeon, Korea

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†**Corresponding author:**
SuJin Song
Department of Food and Nutrition, Hannam University, 1646 Yuseong-daero, Yuseong-gu, Daejeon 34054, Korea.
Tel: +82-42-629-8791
Fax: +82-42-629-8789
Email: sjsong@hnu.kr

ORCID iDs
Enkhgerel Erdenetsetseg
https://orcid.org/0009-0008-0830-2173
Hye Ran Shin
https://orcid.org/0000-0001-9434-7379
SuJin Song
https://orcid.org/0000-0003-1871-4346

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ABSTRACT

Objectives: This study evaluated dietary intake and food sources of essential fatty acids in Korean adolescents.
Methods: This study was comprised of 3,932 adolescents (9–18 years) who participated in the 2016–2021 Korea National Health and Nutrition Examination Surveys. Dietary intake and food sources of essential fatty acids, including alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and linoleic acid (LA) were evaluated using data obtained from one-day 24-hour dietary recall. The proportions of adolescents consuming ALA, EPA + DHA, and LA above or below the adequate intake (AI) of the 2020 Dietary Reference Intakes for Koreans were calculated. All statistical analyses accounted for the complex sampling design effect and appropriate sample weights.
Results: The mean intakes of ALA, EPA, DHA, and LA among Korean adolescents were 1.29 g/day, 69.6 mg/day, 166.0 mg/day, and 11.1 g/day, respectively. Boys had higher intakes of all essential fatty acids compared to girls. By age group, adolescents aged 15–18 years showed lower intakes of EPA and DHA compared to adolescents in younger age groups. The 9–11-year-old adolescents had lower intakes of ALA and LA than older adolescents. The proportions of adolescents who consumed more than AI were 35.7% for ALA, 30.4% for EPA + DHA, and 41.5% for LA. Adherence to the AI for ALA did not differ by sex or age group, although boys showed a lower adherence to the AI for EPA + DHA than girls. Major food sources for ALA and LA were plant-based oils, mayonnaise, pork, and eggs. Mackerel was the most significant contributor to EPA and DHA intake (EPA, 22.6%; DHA, 22.2%), followed by laver, squid, and anchovy.
Conclusions: The proportion of Korean adolescents who consumed EPA + DHA more than AI was low. Our findings highlight that nutrition education emphasizing an intake of essential fatty acids from healthy food sources is needed among Korean adolescents.

Keywords: essential fatty acids; eicosapentaenoic acid; docosahexaenoic acid; Korea; adolescents

INTRODUCTION

Dietary fatty acids play an essential role in energy provision in humans, in addition to regulating various physiological functions and supplying essential fatty acids [1,2]. Alpha-

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Data Availability
The data that support the findings of this study are openly available in KNHANES at https://knhanes.kdca.go.kr/.

linolenic acid (ALA), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and linoleic acid (LA) cannot be synthesized (or are synthesized in insufficient quantities) in the human body, and hence need to be obtained through food. These essential fatty acids are necessary for healthy development of the body as well as various physiological processes, and thus an adequate intake (AI) of essential fatty acids is particularly important for adolescents [1,2].

A recent study analyzing trends in the intake of dietary fats among Korean adolescents aged 12–18 years reported an increase of about 7.5 g/day in the total fat intake from 2007 to 2017. The intake of saturated fatty acid (SFA) and monounsaturated fatty acid (MUFA) markedly increased, while omega-3 fatty acid (n-3 FA) intake showed no significant change [3]. Accordingly, the same study noted an increase from 13.7% in 2007–2009 to 27.5% in 2016–2017 in the proportion of adolescents consuming total fat above the acceptable macronutrient distribution range (AMDR), with 49.7% of adolescents consuming SFA above the AMDR in 2016–2017 [3].

Due to the different effects on physiological function, health status, and metabolic diseases of dietary fatty acids, consuming a balanced and adequate amount of dietary fatty acids is crucial. Previous studies on adolescents have shown that a higher SFA intake can have adverse effects on serum triglycerides and HDL-cholesterol levels [4], whereas n-3 FA intake, particularly ALA, EPA, and DHA, have been found to exert favorable effects on waist circumference, insulin resistance, and HDL-cholesterol levels [5,6]. Additionally, the intake of EPA and DHA have been reported to be closely related to improving cognitive function and learning capabilities, as well as preventing immune-related diseases [7,8].

Previous studies of adolescents in other countries have consistently reported that the intake of essential fatty acids does not meet the recommended levels [9-11]. In addition, a study analyzing trends in essential fatty acids intake among Korean adults showed an increasing trend in the intake of ALA and LA, whereas the intake of EPA and DHA decreased, with a shift in major dietary sources of essential fatty acids from fish and plant-based foods to animal-based foods [12]. However, there is a lack of research evaluating the intake of essential fatty acids and their food sources among Korean adolescents. Therefore, this study aimed to evaluate the dietary intake of essential fatty acids and their food sources among Korean adolescents and assess them against the 2020 Dietary Reference Intakes for Koreans (KDRIs) using data from the 2016–2021 Korea National Health and Nutrition Examination Surveys (KNHANES). In this study, through detailed monitoring of the essential fatty acids intake among Korean adolescents, the findings can be used to identify related nutritional health issues and provide foundational information necessary for developing nutrition education and dietary guidelines for aimed at adolescents.

METHODS

Ethics statement

Informed written consent was obtained from each participant. The KNHANES data used in this study were collected with the approval of the Institutional Review Board of Korea Disease Control and Prevention Agency (approval No. 2018-01-03-P-A, 2018-01-03-C-A, 2018-01-03-2C-A, and 2018-01-03-5C-A).

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1. Data and study subjects

This study used data from the 2016–2021 KNHANES, a nationwide survey performed annually by the Korea Disease Control and Prevention Agency to assess the nutritional and health status of Koreans. It employs a stratified cluster sampling design to select a nationally representative survey sample aged one year and above and is mainly comprised of health interviews, health examinations, and nutrition surveys [13]. In the present study, eligible study subjects included adolescents aged 9–18 years who participated in the 2016–2021 KNHANES. Out of 4,711 adolescents, those without dietary data (n = 698) and those whose energy intake was below 1st percentile or above 99th percentile (n = 81) were excluded. A total of 3,932 adolescents were included in the final data analysis. The study subjects were classified into 3 age groups according to the age classification for Korean adolescents in the 2020 KDRIs: 9–11 years, 12–14 years, and 15–18 years [14]. The distribution of the study subjects by sex and age group is shown in **Table 1**.

2. Evaluation of essential fatty acids intake

In this study, dietary intake data obtained through a one-day 24-hour dietary recall were used. The 24-hour recall was conducted approximately one week after the health examinations by the nutrition survey team. Information on the energy (kcal/day) and dietary fatty acids intake (g/day or mg/day) included in the dietary intake data were used to calculate the percentage of energy intake from each type of fatty acid (%kcal).

The intake of essential fatty acids (ALA, EPA + DHA, and LA) was compared with the AI of the 2020 KDRIs, and the proportion of adolescents consuming above or less than the AI was calculated for each essential fatty acid. The AI of essential fatty acids according to the 2020 KDRIs is as follows: for boys, 1) 9–11 years of age: ALA 1.3 g/day, EPA + DHA 220 mg/day, and LA 9.5 g/day; 2) 12–14 years of age: ALA 1.5 g/day, EPA + DHA 230 mg/day, and LA 12.0 g/day; 3) 15–18 years of age: ALA 1.7 g/day, EPA + DHA 230 mg/day, and LA 14.0 g/day; for girls, 1) 9–11 years of age: ALA 1.1 g/day, EPA + DHA 150 mg/day, and LA 9.0 g/day; 2) 12–14 years of age: ALA 1.2 g/day, EPA + DHA 210 mg/day, and LA 9.0 g/day; 3) 15–18 years of age: ALA 1.1 g/day, EPA + DHA 100 mg/day, and LA 10.0 g/day [14]. To identify the food sources of essential fatty acids, this study utilized the 3rd food code provided by the KNHANES to calculate the contribution percentage (%) of each food item to the total intake of each essential fatty acid and presented a list of the top 10 food sources based on their contribution percentage.

3. Statistical analyses

All statistical analyses in this study were performed using the SAS 9.4 (SAS Institute, Cary, NC, USA). According to the stratified cluster sampling design of the KNHANES, data analyses considered stratification variables, cluster variables, and appropriate weights. The mean and 95% confidence interval for energy and dietary fatty acids intake were presented according to sex and age group. The proportion of adolescents consuming essential fatty acids below or above the AI, as specified in the 2020 KDRIs, was presented by sex and age

Table 1. Study subject by sex and age group

Age group	All	Boys	Girls
Total	3,932 (100.0)	2,052 (52.2)	1,880 (47.8)
9–11 years	1,420 (28.0)	739 (26.9)	681 (29.2)
12–14 years	1,191 (27.4)	643 (27.4)	548 (27.4)
15–18 years	1,321 (44.6)	670 (45.7)	651 (43.4)

n (%).
The statistical analysis accounted for the complex sampling design effect and included an appropriate sample weight.

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group, and a χ^2 test was performed to examine differences in proportions by sex and age group. $P < 0.05$ was considered statistically significant.

RESULTS

1. Total fat and fatty acids intake of study subjects

The energy and fatty acids intake of the study subjects are presented in **Table 2**. The total fat intake of adolescents was 56.8 g (25.1%kcal), with 62.7 g (25.2%kcal) for boys and 50.2 g (25.1%kcal) for girls. The mean intake of SFA, MUFA, polyunsaturated fatty acid (PUFA), n-3 FA, and omega-6 fatty acid (n-6 FA) was 19.8 g/day, 18.5 g/day, 12.9 g/day, 1.6 g/day, and 11.2 g/day, respectively. The intakes of all fatty acids were higher in boys than in girls. However, the percentage of energy intake from each fatty acid did not differ by sex. The total fat, MUFA, PUFA, and n-6 FA intakes were lower in the 9–11 years age group compared to the other age groups, while the intake of other fatty acids did not significantly differ across age groups.

2. Essential fatty acids intake according to sex and age group

Table 3 shows the intake of essential fatty acids among adolescents by sex and age groups. The intake of essential fatty acids was 1.29 g/day of ALA, 69.6 mg/day of EPA, 166.0 mg/day of DHA, and 11.1 g/day of LA. Boys showed a higher intake of all essential fatty acids than girls. The intakes of EPA and DHA were lower in the 15–18 years age group, while ALA and LA intake was lower in the 9–11 years age group compared to the other age groups. The percentage of energy intake from each essential fatty acid was 0.57%kcal for ALA, 0.03%kcal for EPA, 0.08%kcal for DHA, and 4.89%kcal for LA. The percentage of energy intake from ALA, EPA, and DHA did not show significant differences depending on the age group.

3. Evaluation of essential fatty acids intake compared to AI

The evaluation of essential fatty acids intake compared to the AI of the KDRIs are presented in **Table 4**. The proportions of subjects consuming above the AI for ALA, EPA + DHA, and LA were 35.7%, 30.4%, and 41.5%, respectively. There were no significant differences in the distribution of adolescents consuming below or above the AI for ALA according to sex or age group. For the evaluation of EPA + DHA, the proportion of boys consuming above AI was lower than that of girls ($P < 0.001$) and different distributions in the proportion of adolescents consuming above AI were shown across age groups for both boys and girls ($P < 0.05$). Although no significant differences were observed in the proportion of adolescents consuming above AI for LA between boys and girls, the proportion was lowest in the age group of 15–18 years for both sexes ($P < 0.05$).

4. Food sources of essential fatty acids according to sex and age group

A list of the top 10 food sources of essential fatty acids according to sex and age group is provided in **Table 5**. In this study population, the main food sources of ALA were soybean oil (22.9%), perilla oil (9.8%), mayonnaise (9.2%), canola oil (4.9%), and pork (4.7%). The major contributors to EPA and DHA intake were primarily fish and shellfish, with mackerel showing the highest contribution (EPA 22.6% and DHA 22.2%). The main food sources of LA were soybean oil (20.6%), mayonnaise (7.5%), pork (7.3%), snacks, biscuits and cookies (6.6%), and eggs (5.3%). There were no considerable differences in the food sources of essential fatty acids by sex or age group, although the contribution percentage of snacks, biscuits and cookies to EPA and DHA intake was higher in girls compared to boys.

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Table 2. Dietary intake of total fat and fatty acids among Korean adolescents

Total fat and fatty acids	All	Boys	Girls
Total			
Energy (kcal/day)	2,011 (1,980–2,042)	2,222 (2,177–2,268)	1,780 (1,745–1,815)
Total fat (g/day)	56.8 (55.5–58.0)	62.7 (60.8–64.6)	50.2 (48.7–51.8)
SFA (g/day)	19.8 (19.3–20.3)	21.5 (20.8–22.2)	18.0 (17.3–18.6)
MUFA (g/day)	18.5 (18.1–19.0)	20.6 (19.9–21.4)	16.3 (15.7–16.9)
PUFA (g/day)	12.9 (12.5–13.2)	14.5 (14.0–15.0)	11.1 (10.7–11.5)
n-3 FA (g/day)	1.6 (1.5–1.6)	1.8 (1.7–1.8)	1.4 (1.3–1.4)
n-6 FA (g/day)	11.2 (11.0–11.5)	12.6 (12.2–13.1)	9.7 (9.4–10.0)
Total fat (%kcal)	25.1 (24.8–25.5)	25.2 (24.8–25.7)	25.1 (24.6–25.6)
SFA (%kcal)	8.8 (8.6–8.9)	8.6 (8.5–8.8)	8.9 (8.7–9.2)
MUFA (%kcal)	8.2 (8.0–8.3)	8.3 (8.1–8.5)	8.1 (7.9–8.3)
PUFA (%kcal)	5.7 (5.6–5.8)	5.8 (5.7–5.9)	5.6 (5.4–5.7)
n-3 FA (%kcal)	0.71 (0.69–0.73)	0.72 (0.69–0.74)	0.70 (0.67–0.73)
n-6 FA (%kcal)	4.97 (4.88–5.05)	5.07 (4.95–5.19)	4.86 (4.73–4.98)
9–11 years			
Energy (kcal/day)	1,885 (1,844–1,926)	1,999 (1,937–2,061)	1,769 (1,722–1,817)
Total fat (g/day)	52.9 (51.3–54.6)	56.9 (54.6–59.3)	48.9 (46.8–51.0)
SFA (g/day)	18.9 (18.3–19.6)	20.0 (19.1–20.9)	17.8 (16.9–18.7)
MUFA (g/day)	17.3 (16.7–17.9)	18.8 (17.9–19.7)	15.8 (15.0–16.5)
PUFA (g/day)	11.6 (11.2–12.0)	12.6 (11.9–13.2)	10.6 (10.0–11.1)
n-3 FA (g/day)	1.5 (1.4–1.5)	1.6 (1.5–1.7)	1.4 (1.3–1.5)
n-6 FA (g/day)	10.1 (9.7–10.4)	10.9 (10.4–11.5)	9.1 (8.7–9.6)
Total fat (%kcal)	25.1 (24.6–25.6)	25.5 (24.8–26.2)	24.7 (24.1–25.4)
SFA (%kcal)	9.0 (8.8–9.2)	9.0 (8.7–9.3)	9.0 (8.7–9.3)
MUFA (%kcal)	8.2 (8.0–8.4)	8.4 (8.1–8.7)	8.0 (7.7–8.3)
PUFA (%kcal)	5.5 (5.3–5.6)	5.6 (5.4–5.8)	5.4 (5.2–5.6)
n-3 FA (%kcal)	0.70 (0.67–0.73)	0.70 (0.66–0.74)	0.70 (0.66–0.74)
n-6 FA (%kcal)	4.76 (4.63–4.88)	4.87 (4.70–5.04)	4.65 (4.46–4.84)
12–14 years			
Energy (kcal/day)	2,043 (1,997–2,088)	2,246 (2,181–2,312)	1,821 (1,763–1,878)
Total fat (g/day)	57.7 (55.8–59.7)	63.9 (61.1–66.7)	51.1 (48.5–53.6)
SFA (g/day)	19.8 (19.1–20.6)	21.9 (20.8–23.0)	17.6 (16.6–18.6)
MUFA (g/day)	18.9 (18.2–19.6)	20.9 (19.8–21.9)	16.7 (15.8–17.7)
PUFA (g/day)	13.4 (12.8–13.9)	14.9 (14.1–15.7)	11.7 (11.0–12.4)
n-3 FA (g/day)	1.7 (1.6–1.8)	1.9 (1.8–2.0)	1.5 (1.4–1.6)
n-6 FA (g/day)	11.6 (11.1–12.1)	12.9 (12.2–13.6)	10.2 (9.6–10.8)
Total fat (%kcal)	25.0 (24.5–25.6)	25.2 (24.5–25.9)	24.8 (24.0–25.6)
SFA (%kcal)	8.6 (8.4–8.8)	8.6 (8.3–8.9)	8.6 (8.2–8.9)
MUFA (%kcal)	8.2 (7.9–8.4)	8.2 (7.9–8.5)	8.1 (7.8–8.4)
PUFA (%kcal)	5.8 (5.6–6.0)	5.9 (5.7–6.2)	5.7 (5.5–6.0)
n-3 FA (%kcal)	0.75 (0.70–0.79)	0.76 (0.71–0.82)	0.73 (0.66–0.80)
n-6 FA (%kcal)	5.05 (4.89–5.20)	5.12 (4.91–5.34)	4.96 (4.74–5.19)
15–18 years			
Energy (kcal/day)	2,071 (2,019–2,122)	2,339 (2,265–2,414)	1,762 (1,702–1,822)
Total fat (g/day)	58.6 (56.5–60.7)	65.5 (62.4–68.6)	50.6 (47.8–53.5)
SFA (g/day)	20.4 (19.5–21.2)	22.1 (21.0–23.3)	18.3 (17.1–19.5)
MUFA (g/day)	19.1 (18.3–19.9)	21.6 (20.4–22.8)	16.3 (15.3–17.3)
PUFA (g/day)	13.3 (12.8–13.9)	15.3 (14.5–16.1)	11.1 (10.5–11.7)
n-3 FA (g/day)	1.6 (1.5–1.6)	1.8 (1.7–1.9)	1.3 (1.2–1.4)
n-6 FA (g/day)	11.7 (11.3–12.2)	13.5 (12.7–14.2)	9.7 (9.2–10.3)
Total fat (%kcal)	25.2 (24.6–25.8)	25.0 (24.3–25.8)	25.4 (24.5–26.3)
SFA (%kcal)	8.8 (8.5–9.0)	8.5 (8.1–8.8)	9.1 (8.7–9.5)
MUFA (%kcal)	8.2 (8.0–8.5)	8.2 (7.9–8.6)	8.2 (7.8–8.6)
PUFA (%kcal)	5.8 (5.6–5.9)	5.9 (5.7–6.1)	5.6 (5.4–5.9)
n-3 FA (%kcal)	0.69 (0.66–0.71)	0.70 (0.66–0.74)	0.67 (0.64–0.71)
n-6 FA (%kcal)	5.05 (4.92–5.19)	5.16 (4.96–5.36)	4.93 (4.73–5.13)

Mean (95% confidence interval).
The statistical analysis accounted for the complex sampling design effect and included an appropriate sample weight.
SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; n-3 FA, omega-3 fatty acid; n-6 FA, omega-6 fatty acid.

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Table 3. Dietary intake of essential fatty acids among Korean adolescents

Essential fatty acids	All	Boys	Girls
Total			
ALA (g/day)	1.29 (1.24–1.33)	1.44 (1.37–1.51)	1.12 (1.07–1.17)
EPA (mg/day)	69.6 (64.5–74.8)	79.1 (71.5–86.6)	59.4 (53.6–65.1)
DHA (mg/day)	166.0 (154.5–177.6)	183.3 (166.2–200.3)	147.3 (134.0–160.5)
LA (g/day)	11.1 (10.8–11.3)	12.4 (12.0–12.9)	9.5 (9.2–9.9)
ALA (%kcal)	0.57 (0.55–0.59)	0.58 (0.56–0.61)	0.56 (0.54–0.59)
EPA (%kcal)	0.03 (0.03–0.04)	0.03 (0.03–0.04)	0.03 (0.03–0.03)
DHA (%kcal)	0.08 (0.07–0.08)	0.08 (0.07–0.09)	0.08 (0.07–0.09)
LA (%kcal)	4.89 (4.81–4.98)	4.99 (4.88–5.11)	4.78 (4.66–4.91)
9–11 years			
ALA (g/day)	1.15 (1.10–1.21)	1.24 (1.15–1.32)	1.07 (1.00–1.14)
EPA (mg/day)	75.9 (66.3–85.4)	79.5 (66.4–92.7)	72.2 (60.0–84.4)
DHA (mg/day)	183.1 (160.2–205.9)	188.0 (155.2–220.8)	178.1 (148.8–207.3)
LA (g/day)	9.9 (9.5–10.3)	10.8 (10.2–11.3)	9.0 (8.5–9.5)
ALA (%kcal)	0.55 (0.53–0.57)	0.55 (0.52–0.59)	0.54 (0.51–0.58)
EPA (%kcal)	0.04 (0.03–0.04)	0.04 (0.03–0.04)	0.04 (0.03–0.05)
DHA (%kcal)	0.09 (0.08–0.10)	0.09 (0.07–0.10)	0.09 (0.08–0.11)
LA (%kcal)	4.68 (4.55–4.80)	4.79 (4.62–4.96)	4.57 (4.38–4.76)
12–14 years			
ALA (g/day)	1.38 (1.29–1.47)	1.52 (1.39–1.64)	1.23 (1.12–1.33)
EPA (mg/day)	77.6 (68.0–87.1)	97.4 (81.5–113.3)	56.0 (46.8–65.3)
DHA (mg/day)	183.1 (162.0–204.2)	223.3 (188.2–258.4)	139.3 (117.7–160.9)
LA (g/day)	11.4 (11.0–11.9)	12.7 (12.1–13.4)	10.0 (9.4–10.6)
ALA (%kcal)	0.61 (0.56–0.65)	0.60 (0.55–0.65)	0.61 (0.55–0.67)
EPA (%kcal)	0.04 (0.03–0.04)	0.04 (0.03–0.05)	0.03 (0.02–0.03)
DHA (%kcal)	0.08 (0.07–0.09)	0.10 (0.08–0.11)	0.07 (0.06–0.08)
LA (%kcal)	4.98 (4.82–5.13)	5.05 (4.83–5.27)	4.89 (4.67–5.12)
15–18 years			
ALA (g/day)	1.31 (1.24–1.38)	1.51 (1.40–1.63)	1.08 (1.01–1.15)
EPA (mg/day)	60.8 (54.0–67.6)	67.8 (57.3–78.3)	52.8 (44.9–60.8)
DHA (mg/day)	144.9 (129.7–160.0)	156.4 (133.3–179.6)	131.6 (113.0–150.1)
LA (g/day)	11.5 (11.1–12.0)	13.3 (12.5–14.0)	9.6 (9.0–10.1)
ALA (%kcal)	0.57 (0.54–0.59)	0.58 (0.55–0.62)	0.55 (0.52–0.58)
EPA (%kcal)	0.03 (0.03–0.03)	0.03 (0.02–0.03)	0.03 (0.02–0.03)
DHA (%kcal)	0.07 (0.06–0.07)	0.06 (0.05–0.07)	0.07 (0.06–0.08)
LA (%kcal)	4.97 (4.83–5.11)	5.08 (4.88–5.28)	4.85 (4.65–5.05)

Mean (95% confidence interval).
The statistical analysis accounted for the complex sampling design effect and included an appropriate sample weight.
ALA, alpha-linolenic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; LA, linoleic acid.

5. Essential fatty acids intake of adolescents in other countries

A summary of the recent literature on the essential fatty acids intake of adolescents from other countries is provided in **Table 6**. The ALA intake of Korean adolescents in this study was similar to that reported in Australia (1.4 g/day for boys and 1.2 g/day for girls) [15] and Brazil (1.55 g/day for boys and 1.32 g/day for girls) [6], but lower than that in the US (1.74 g/day for boys and 1.57 g/day for girls) [16] and Costa Rica (2.55 g/day) [17]. However, it was higher than that in Iran [18] and Mozambique [2]. EPA intake among Korean adolescents was similar to that in Iran [18] and the US [16]. The DHA intake of this study population was similar to that of adolescents in Iran [18] and Costa Rica [17], but higher than that of adolescents in the US (0.02–0.04 g/day) [16]. In the case of LA intake, Korean and Brazilian adolescents showed similar levels [6], while adolescents from the US [16], Iran [18], and Costa Rica [17] showed a higher intake.

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Table 4. Proportion of study subjects adhering to an adequate intake of essential fatty acids among Korean adolescents

Sex and age group	ALA			EPA + DHA			LA		
	< AI	≥ AI	*P*-value	< AI	≥ AI	*P*-value	< AI	≥ AI	*P*-value
All	64.3	35.7		69.6	30.4		58.5	41.5	
Sex			0.090			< 0.001			0.175
Boys	65.8	34.2		73.7	26.3		57.2	42.8	
Girls	62.6	37.4		65.2	34.8		59.9	40.1	
Age group			0.722			0.048			< 0.001
9–11 years	64.4	35.6		68.4	31.6		55.6	44.4	
12–14 years	63.2	36.8		73.0	27.0		55.4	44.6	
15–18 years	64.8	35.2		68.3	31.7		62.3	37.7	
Sex × age group									
Boys × 9–11 years	65.0	35.0	0.323	72.3	27.7	0.013	50.6	49.4	0.001
Boys × 12–14 years	63.5	36.5		69.4	30.6		57.0	43.0	
Boys × 15–18 years	67.6	32.4		77.1	22.9		61.2	38.8	
Girls × 9–11 years	63.7	36.3	0.766	64.6	35.4	< 0.001	60.6	39.4	0.008
Girls × 12–14 years	62.9	37.1		76.9	23.1		53.7	46.3	
Girls × 15–18 years	61.6	38.4		58.1	41.9		63.5	36.5	

%.
The statistical analysis accounted for the complex sampling design effect and included an appropriate sample weight. *P*-values were obtained from the χ^2 test.
The AI for essential fatty acids was from the 2020 Dietary Reference Intakes for Koreans.
ALA, alpha-linolenic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; LA, linoleic acid; AI, adequate intake.

DISCUSSION

In this study, the dietary intake and food sources of essential fatty acids among Korean adolescents aged 9–18 years were evaluated using data collected from the 2016–2021 KNHANES. As a result, the intake of essential fatty acids among Korean adolescents was found to be 1.29 g/day for ALA, 69.6 mg/day for EPA, 166.0 mg/day for DHA, and 11.1 g/day for LA. Compared to the AI of the 2020 KDRIs, the proportion of subjects consuming above the AI for each of these essential fatty acids was 35.7% for ALA, 30.4% for EPA + DHA, and 41.5% for LA, indicating that the intake of EPA + DHA had the highest percentage of adolescents below the AI.

In recent years, the total fat intake among Korean adolescents has shown an increasing trend, with a significant increase in the intake of SFA and MUFA, while no significant change has been observed in the intake of n-3 FA [3]. In addition, the n-6 FA intake showed a slight increase in boys, and no significant change in girls [3]. Particularly, it was reported that the proportion of Korean adolescents and young adults consuming SFA above the AMDR was higher compared to the other age groups [3,19]. In a previous study analyzing changes in essential fatty acids intake among Korean adults between 2007 and 2018, an increase in the intake of ALA by 0.3 g/day and LA by 1.4 g/day was observed, while the intake of EPA showed a tendency to decrease [12]. Among the Korean adolescents evaluated in the present study, the ALA and LA intake increased with age. Furthermore, boys showed higher intakes than girls in all of the age groups evaluated. However, no significant differences were observed in the intake of EPA and DHA depending on sex or age group, with the age group of 15–18 years showing the lowest intake of EPA and DHA. In a recent study that evaluated fatty acids intake in Koreans aged 1 year or older using data from the 2019–2021 KNHANES, usual daily intake of fatty acids was estimated based on dietary data obtained from one-day 24-hour dietary recall [20]. As a result, the usual dietary intake of ALA for Koreans was reported to be 1.399 g/day, EPA 0.099 mg/day, DHA 0.217 mg/day, and LA 9.88 g/day [20].

When comparing the intake levels of essential fatty acids among Korean adolescents with those in other countries, the ALA and LA intake among the US adolescents (12–19 years old)

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Table 5. Contribution percentage of main food sources to essential fatty acids intake among Korean adolescents

Essential fatty acids	Rank	All		Boys		Girls		9–11 years		12–14 years		15–18 years	
ALA	1	Soybean oil	22.9	Soybean oil	23.3	Soybean oil	22.3	Soybean oil	22.1	Soybean oil	22.1	Soybean oil	24.4
	2	Perilla oil	9.8	Perilla oil	9.7	Perilla oil	10.0	Perilla oil	9.9	Perilla oil	11.3	Mayonnaise	10.2
	3	Mayonnaise	9.2	Mayonnaise	8.6	Mayonnaise	9.9	Mayonnaise	7.0	Mayonnaise	10.2	Perilla oil	8.4
	4	Canola oil	4.9	Pork	4.9	Canola oil	5.0	Canola oil	4.8	Canola oil	4.7	Canola oil	5.2
	5	Pork	4.7	Canola oil	4.9	Pork	4.4	Tofu	4.7	Tofu	4.3	Pork	5.2
	6	Tofu	4.3	Tofu	4.6	Tofu	3.9	Pork	4.5	Pork	4.3	Tofu	3.8
	7	Bread	3.0	Bread	2.8	Bread	3.3	Bread	3.2	Bread	3.1	Bread	2.7
	8	Egg	2.6	Perilla seed	2.6	Egg	2.7	Egg	2.8	Egg	2.7	Perilla seed	2.7
	9	Perilla seed	2.5	Egg	2.5	Perilla seed	2.3	Laver	2.5	Perilla seed	2.4	Egg	2.2
	10	Snacks, biscuits & cookies	2.1	Laver	2.1	Snacks, biscuits & cookies	2.1	Snacks, biscuits & cookies	2.4	Sandwiches	1.9	Snacks, biscuits & cookies	2.0
EPA	1	Mackerel	22.6	Mackerel	23.1	Mackerel	21.9	Mackerel	30.3	Mackerel	23.2	Laver	12.7
	2	Laver	12.7	Laver	13.1	Laver	12.1	Laver	12.9	Laver	12.4	Mackerel	11.5
	3	Squid	8.2	Squid	7.6	Squid	9.0	Squid	7.4	Squid	7.5	Squid	10.0
	4	Anchovy	4.8	Anchovy	4.9	Snacks, biscuits & cookies	5.4	Anchovy	4.4	Anchovy	4.6	Croaker	6.3
	5	Snacks, biscuits & cookies	3.9	Atka Mackerel	4.4	Anchovy	4.5	Eel	3.7	Atka Mackerel	4.4	Anchovy	5.5
	6	Croaker	3.5	Croaker	3.8	Shrimp	3.6	Shrimp	3.3	Snacks, biscuits & cookies	3.9	Snacks, biscuits & cookies	4.8
	7	Shrimp	3.0	Eel	3.3	Croaker	3.1	Snacks, biscuits & cookies	3.2	Croaker	3.1	Saury	4.4
	8	Eel	2.9	Saury	2.9	Saury	2.7	Fish cake	2.4	Shrimp	2.8	Hairtail	3.8
	9	Atka Mackerel	2.9	Snacks, biscuits & cookies	2.8	Hairtail	2.5	Atka Mackerel	2.4	Fish cake	2.6	Fish cake	2.8
	10	Saury	2.8	Fish cake	2.7	Pollack	2.5	Spanish Mackerel	2.1	Eel	2.5	Shrimp	2.7
DHA	1	Mackerel	22.2	Mackerel	23.1	Mackerel	21.0	Mackerel	30.9	Mackerel	22.7	Squid	16.1
	2	Egg	14.2	Egg	13.5	Egg	15.0	Egg	13.1	Egg	14.1	Egg	15.9
	3	Squid	13.3	Squid	12.8	Squid	14.1	Squid	12.0	Squid	12.5	Mackerel	9.6
	4	Fish cake	5.6	Fish cake	6.1	Snacks, biscuits & cookies	5.7	Fish cake	5.3	Fish cake	5.7	Fish cake	6.1
	5	Anchovy	4.3	Anchovy	4.7	Fish cake	5.0	Anchovy	4.0	Anchovy	4.3	Croaker	5.9
	6	Snacks, biscuits & cookies	4.1	Croaker	3.5	Anchovy	3.8	Spanish Mackerel	3.9	Snacks, biscuits & cookies	4.2	Snacks, biscuits & cookies	5.0
	7	Tuna	3.3	Spanish Mackerel	3.2	Tuna	3.5	Eel	3.8	Tuna	3.4	Anchovy	4.8
	8	Croaker	3.2	Tuna	3.1	Spanish Mackerel	2.7	Snacks, biscuits & cookies	3.3	Croaker	2.8	Hairtail	4.1
	9	Spanish Mackerel	3.0	Eel	3.0	Croaker	2.6	Tuna	2.7	Spanish Mackerel	2.6	Tuna	4.0
	10	Eel	2.8	Snacks, biscuits & cookies	2.8	Hairtail	2.6	Hairtail	1.7	Hairtail	2.5	Saury	3.6
LA	1	Soybean oil	20.6	Soybean oil	20.8	Soybean oil	20.4	Soybean oil	19.9	Soybean oil	20.2	Soybean oil	21.7
	2	Mayonnaise	7.5	Pork	7.7	Mayonnaise	8.2	Pork	7.0	Mayonnaise	8.5	Mayonnaise	8.3
	3	Pork	7.3	Mayonnaise	7.1	Pork	6.8	Snacks, biscuits & cookies	7.0	Pork	6.8	Pork	8.0
	4	Snacks, biscuits & cookies	6.6	Snacks, biscuits & cookies	6.9	Snacks, biscuits & cookies	6.1	Egg	5.9	Snacks, biscuits & cookies	6.3	Snacks, biscuits & cookies	6.5
	5	Egg	5.3	Egg	5.0	Egg	5.7	Mayonnaise	5.8	Egg	5.4	Egg	4.7
	6	Sesame oil	4.5	Sesame oil	4.4	Sesame oil	4.6	Sesame oil	4.9	Sesame oil	4.6	Sesame oil	4.0
	7	Bread	3.9	Bread	3.8	Bread	4.1	Bread	4.0	Chicken	3.9	Bread	3.8
	8	Chicken	3.8	*Ramyeon*	3.7	Chicken	3.8	Chicken	3.8	Bread	3.9	*Ramyeon*	3.8
	9	*Ramyeon*	3.5	Chicken	3.7	*Ramyeon*	3.1	Tofu	3.4	*Ramyeon*	3.8	Chicken	3.6
	10	Tofu	3.1	Tofu	3.3	White rice	3.0	White rice	3.2	Tofu	3.2	White rice	2.9

Food and %.
Ramyeon, instant noodles; ALA, alpha-linolenic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; LA, linoleic acid.

based on the one-day 24-hour dietary recall data from the 2017–2020 National Health and Nutrition Examination Surveys was higher than that of Korean adolescents, but EPA and DHA intake was lower [16]. Based on dietary data from 2 non-consecutive days of 24-hour dietary recall conducted in 2006–2007, 1,804 European adolescents (12.5–17.5 years old)

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Table 6. Intake of essential fatty acids among adolescents across different countries

First author (publication year)	Country	Subjects	Data and study period	Dietary assessment	ALA	EPA	DHA	LA
Freese *et al.* (2015) [2]	Mozambique	Girls 14–19 years	2010	1-day 24-hour dietary recall		Median (g/day)		
		Study area 1 (n = 82)			0.35			4.15
		Study area 2 (n = 18)			0.41			2.82
		Study area 3 (n = 71)			0.24			1.22
		Study area 4 (n = 22)			0.40			3.61
		Study area 5 (n = 66)			0.23			3.24
Meyer (2016) [15]	Australia	12–18 years	National Nutrition and Physical Activity Survey, 2011–2012	2-day 24-hour dietary recall		Mean ± SE (g/day)		
		Boys (n = 566)			1.4 ± 0.03			9.6 ± 0.22
		Girls (n = 535)			1.2 ± 0.03			8.1 ± 0.22
Monge-Rojas *et al.* (2020) [17]	Costa Rica	13–18 years	2017	3-day food records		Mean ± SD (g/day)		
		Total (n = 818)			2.55 ± 0.11	1.40 ± 0.29	0.16 ± 0.04	20.2 ± 7.41
Mozafarinia *et al.* (2022) [18]	Iran	6–18 years	Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable disease, 2011–2012	FFQ		Mean ± SD (g/day)		
		Total (n = 4,323)			0.30 ± 0.37	0.06 ± 0.13	0.10 ± 0.16	17.54 ± 9.32
		Boys (n = 2,270)			0.28 ± 0.25	0.06 ± 0.14	0.10 ± 0.17	17.16 ± 8.66
		Girls (n = 2,053)			0.32 ± 0.46	0.06 ± 0.12	0.10 ± 0.15	17.96 ± 9.99
Takey *et al.* (2023) [6]	Brazil	12–17 years (n = 37,023)	ERICA study, 2013–2014	1-day 24-hour dietary recall		Median (g/day)		
		Total			1.42			10.85
		Boys			1.55			12.01
		Girls			1.32			10.09
		12–13 years			1.37			10.25
		14–17 years			1.44			11.09
		Boys 12–13 years			1.47			11.04
		Boys 14–17 years			1.60			12.40
		Girls 12–13 years			1.30			9.69
		Girls 14–17 years			1.33			10.23
USDA (2022) [16]	USA	6–19 years	National Health and Nutrition Examination Survey, 2017–2020 (March)	1-day 24-hour dietary recall		Mean ± SE (g/day)		
		Boys 6–11 years (n = 701)			1.44 ± 0.062	0.02 ± 0.002	0.02 ± 0.003	15.72 ± 0.681
		Girls 6–11 years (n = 710)			1.49 ± 0.051	0.02 ± 0.004	0.02 ± 0.005	15.49 ± 0.458
		Boys 12–19 years (n = 899)			1.74 ± 0.073	0.02 ± 0.003	0.03 ± 0.005	18.71 ± 0.628
		Girls 12–19 years (n = 841)			1.57 ± 0.081	0.03 ± 0.007	0.04 ± 0.009	16.64 ± 1.212

ALA, alpha-linolenic acid; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; LA, linoleic acid; FFQ, food frequency questionnaire.

showed a similar intake level of essential fatty acids as the subjects in the present study [21]. Australian and Brazilian adolescents also showed ALA and LA intake levels similar to those of Korean adolescents [5,15]. The results of dietary assessment in Iranian adolescents using a food frequency questionnaire in 2011–2012 showed an intake level of EPA and DHA that was similar to Korean adolescents, but the ALA and LA intakes were 0.3 g/day and 17.54 g/day, respectively, which showed a significant difference [18]. The ALA intake of Costa Rican adolescents (13–18 years old) was reported to be as high as 2.55 g/day, while the EPA and LA intakes were also higher compared to adolescents in other countries [17]. Due to variations in sex and age composition among the study subjects, dietary assessment methods, and survey period across studies, a direct comparison of the results on the intake of essential fatty acids represented a challenge. Nonetheless, it was possible to identify a significant variation in the intake patterns of essential fatty acids in adolescents across different countries.

The current study found that the proportion of Korean adolescents consuming each essential fatty acid above AI did not exceed 50% in all sex and age groups. In particular, only 30% of Korean adolescents consumed EPA + DHA above AI. Previous studies in other countries have consistently reported that essential fatty acids intake in adolescents fail to meet the recommended levels [1,9-11]. A systematic review on the intake of essential fatty acids in European countries revealed that the majority failed to meet the recommended levels for EPA + DHA intake, with only 2 out of 10 countries reaching the recommended intake levels [11].

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When evaluating the intake of essential fatty acids among children and adolescents aged 4–12 years in Indonesia, the proportion of subjects with an intake below the reference level from Food and Agriculture Organization/World Health Organization criteria for ALA, EPA + DHA, and LA was reported as 84%, 80.9%, and 31%, respectively [1]. In a study of 822 Australian adolescents, the proportion of subjects who consumed above AI did not exceed 50% for each essential fatty acid, with less than 10% of the participants meeting the recommended intake criteria for EPA + DHA [10]. In French adolescents, it was reported that fewer than 10% achieved the recommended intake level for ALA and EPA + DHA, respectively [9]. Although essential fatty acids play an important role in the nutritional status and development of adolescents, the results showed that the intake levels of ALA and EPA + DHA did not meet the recommended levels in adolescents from various countries, including Korea. This highlights the need for the provision of dietary strategies for improving the intake of EPA + DHA, along with the periodic monitoring of essential fatty acids intake.

The main sources of essential fatty acids for Korean adolescents in this study were similar to those of Korean adults [12]. The main sources of ALA and LA were plant oils, mayonnaise, pork, and eggs, while fish contributed significantly to EPA and DHA. For Korean adults, beans and walnuts were among the top food sources of ALA. For Korean adolescents, snacks, biscuits and cookies were included in the list of main food sources of ALA, EPA, and DHA. In particular, the proportion of snacks, biscuits and cookies, from which adolescents derived their EPA and DHA intake was higher in girls compared to boys. Among Australian adolescents, the highest proportion of essential fatty acids were derived from the food sources as follows: 1) dairy products, margarine, potato and potato chips, and red meat for ALA; 2) fish and red meat for EPA and DHA; 3) margarine, bread, vegetable oils, cereals, potato chips, and poultry for LA [10,22]. Similar reports found that Indonesian adolescents mainly derived their ALA intake from plant-based dishes, beans, nuts, and seeds, while the intakes of EPA and DHA were mainly derived from fish, which contributed to 91.2% of the intake of these essential fatty acids [1]. Among adolescents from European countries, the main dietary sources of ALA were meat, bread and cake, snacks, seasonings, and sauces. In addition, the main food sources of EPA and DHA were fish, meat, and eggs, while the main sources of LA were plant oils, meat, bread and snacks, seasonings, and sauces [9,21].

The main food sources of essential fatty acids among adolescents in each country appear to differ due to differences in various factors, including the eating habits of adolescents, the food environment of households and communities, and the food culture of each country. However, a significant proportion of the intake of essential fatty acids has been attributed to animal-based food sources and processed foods across previous studies of adolescents, and these food sources also tend to be high in SFA and trans fatty acid. According to the KDRIs, foods rich in ALA include perilla oil, nuts, seeds, and beans, while EPA and DHA are predominantly found in oily fish [14]. This suggests that adolescents should be encouraged to choose healthy food sources that are rich in essential fatty acids while reducing their intake of animal-based and processed foods.

A limitation of this study is the challenge of reflecting the usual dietary intake of essential fatty acids in the study subjects based solely on an analysis of the dietary intake data obtained through a single 24-hour dietary recall. This method could underestimate the proportion of subjects meeting the KDRIs [20]. However, despite this limitation, given the lack of research on the evaluation of essential fatty acids intake in adolescents, it is worth highlighting the fact that this study analyzed essential fatty acids intake and food sources from a

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representative sample of Korean adolescents based on national-level nutritional survey data. The findings of this study can therefore be used as a basis from which to develop dietary guidelines and nutrition education for Korean adolescents, and are expected to contribute to improving the dietary practices and health status of adolescents across the world.

CONCLUSIONS

This study evaluated the dietary intake and food sources of essential fatty acids among Korean adolescents aged 9–18 years based on data obtained from the 2016–2021 KNHANES. We also evaluated essential fatty acids intake by comparing it with the AI levels of KDRIs. Our findings revealed that the proportion of Korean adolescents consuming essential fatty acids above the AI of KDRIs was relatively low, with 35.7% for ALA and 30.4% for EPA + DHA. As the nutritional status of adolescents has a significant impact on their growth and development, as well as their health and disease status in adulthood, detailed monitoring of nutrient intake during adolescence is necessary. In particular, this study is significant in that it is among the first to evaluate the intake patterns of essential fatty acids in Korean adolescents, which is lacking research. Based on the results of this study, an appropriate intake of essential fatty acids and a selection of healthy food sources should be emphasized through dietary guidelines and nutrition education aimed at adolescents. Future studies will need to examine trends in essential fatty acids intake among Korean adolescents, as well as determine the relationship between their essential fatty acids intake and health status.

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