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Secular trends in dietary energy, carbohydrate, protein, and fat intake among Korean children and adolescents

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Authorship: YJK, SJH, and JWL conceived and designed the study. SJH contributed to statistical analysis and interpretation of the data. YJK and JWL contributed to the acquisition and interpretation of data. DIS, YJK, and JWL contributed to the investigation of the results and the drafting of the manuscript. All authors critically revised the manuscript, provided final approval, and agreed to be accountable for all aspects of the work, ensuring its integrity and accuracy.

Ethical Standards Disclosure: This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the Institutional Review Board of Severance Hospital (IRB number: 4-2022-0796). **Written informed consent was obtained from all subjects.**

Abstract

Objective: We aimed to analyze the evolving trends in macronutrient intake and dietary composition among Korean children and adolescents over a 10-year period.

Design: We utilized cross-sectional data from the Korean National Health and Nutrition Examination Survey (KNHANES) spanning the years 2010–2020. Overall, the study included 11,861 participants aged 6–18 years who completed the 24-h dietary recall survey. Subsequently, we assessed trends in energy consumption and macronutrient intake across population subgroups, including age, sex, and obesity status. Survey-weighted linear regression was employed to determine the beta coefficient and p-value for trends in dietary nutrient consumption, treating the survey year as a continuous variable.

Setting: KNHANES from 2010 to 2020.

Participants: 11,861 children and adolescents aged 6–18 years.

Results: Total energy intake significantly decreased across the 10-year survey period, with a corresponding decline in the percentage of energy intake from carbohydrates. Conversely, the proportion of energy intake from fat increased during the same period. Subgroup analysis revealed changes in the composition of energy intake across age, sex, and obesity status, with a consistent increase in total fat intake observed across all subgroups. Upon analyzing data on dietary fibers, total sugars, and fat subtypes intake, we found insufficient dietary fiber intake and increased intake of all fat subtypes.

Conclusions: This study underscores the gradually changing dietary intake patterns among Korean children and adolescents. Our findings revealed that these transitions in dietary nutrient consumption may pose potential risks of diet-related diseases in the future.

Keywords: Children; Adolescents; Total calorie; Macronutrients; Korean national survey

INTRODUCTION

Suboptimal diet is one of the leading risk factors for poor health outcomes, particularly contributing to a high risk of obesity, type 2 diabetes mellitus, cardiovascular diseases (CVD), and specific diet-related cancers [1,2]. Dietary risk factors, including excessive intake of saturated fats, refined carbohydrates, and sweets, alongside inadequate intake of whole grains, fruits, vegetables, and seafood, significantly contribute to the global burden of non-communicable diseases [3,4]. Thus, understanding the overall population trends in diet is crucial for recognizing challenges and opportunities for improving nutritional status and reducing diet-related illnesses [1,2].

The formative years of childhood and adolescence are pivotal for shaping dietary preferences and behaviors, exerting lasting effects on dietary patterns in adulthood and life-long susceptibility to chronic diseases[3,5]. During this developmental phase, dietary intake must meet energy demands and provide essential macronutrients to support vital processes in growth and development [6]. Recently, pediatric obesity has become a public concern owing to its association with various comorbidities in childhood as well as obesity and related diseases in adulthood [7]. Globally, and particularly in Korea, there has been a surge in the prevalence of pediatric obesity [8]. According to the data from the National School Health Examination (NSHE) in Korea, the prevalence of obesity in children aged 6–18 years increased from 8.7% in 2007 to 15.0% in 2017 [9]. Additionally, findings from a 30-year longitudinal cohort study in Korea (1986–2017) showed a significant rise in obesity rates, particularly among individuals aged 12 years and older [10]. This trend correlates with increased consumption of fast foods accompanied by sugary beverages and reduced intake of vegetables [6,11].

Asian countries, including Korea, have witnessed substantial shifts in food consumption and dietary habits in the recent decades [12]. Traditional Asian dietary patterns characterized by low-fat and high-fiber foods have been supplanted by the consumption of foods rich in fat, sugar, and salt, and these changes have had a profound impact on nutritional status and public health[13,14] Specifically, these changes in dietary habits have resulted in nutritional imbalances among Korean children and adolescents, posing a significant concern during the growth period [15]. Therefore, it is necessary to identify recent changes in dietary consumption trends to develop strategies that can improve dietary patterns and alleviate disease burden. Despite this significance, studies examining secular trends in macronutrient consumption

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among children and adolescents at the population level in Korea are lacking.

Therefore, this study aimed to perform a comprehensive investigation of trends in dietary macronutrient intake among Korean children and adolescents over a 10-year period. Our major goal was to provide a more nuanced understanding of contemporary dietary trends by utilizing data from the most recent decade. We also analyzed the trends in macronutrient intake according to subgroups stratified by age, sex, and obesity status. Furthermore, we examined the trends in the intake of dietary fiber, total sugars and fat subtypes to offer insights into the changes in dietary composition and highlight specific areas for nutrition interventions.

METHODS

Study design and study population

Data for this study were sourced from the Korean National Health and Nutrition Examination Survey (KNHANES) performed from 2010 to 2020 to assess dietary nutrient intake. KNHANES is an annual nationwide cross-sectional survey conducted with nationally representative samples of Korea, consisting of non-institutionalized Korean citizens [(16)]. The KNHANES protocol received approval from the Institutional Review Board of the Korea Centres for Disease Control and Prevention, which has been detailed in a previous publication [(16)].The study population included children and adolescents aged 6–18 years voluntarily participating in the survey. All participants provided informed consent, and the institutional review board of Severance Hospital approved the study protocol (IRB number: 4-2022-0796). Finally, a total of 11,861 participants were included in the analysis.

Assessment of dietary intake

In the KNHANES, dietary intake was assessed using a standardized 24-h dietary recall method. During the survey, participants reported all food and beverage consumed in the preceding 24 hours through face-to-face interviews conducted by trained staff members at the participants' households. Various measuring aids including food models and pictures were utilized to help participants recall detailed information on food and beverage consumption. Notably, the survey staff had undergone intensive training and participated in retraining sessions five to six times per year. In cases where the children could not respond independently, the primary respondents were permitted to request assistance from their main

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caregivers. Previous research on dietary assessment methodology has demonstrated the value of data collected through self-reporting methods in understanding dietary intake in children[17]. Subsequently, using the National Standard Food Composition Table from the Rural Development Administration, total energy, carbohydrates (g), dietary fiber (g), total sugars (g), proteins (g), and fatty acids (total fat, saturated fatty acids [SFA], monounsaturated fatty acids [MUFA], polyunsaturated fatty acids [PUFA], omega-3 fatty acids [N3], and omega-6 fatty acids [N6]) (g) were calculated [18].

The percentage of energy intake from carbohydrates, total sugars, and proteins were calculated using the following formula: carbohydrate (g), sugar (g), or protein (g) × 4 kcal/total energy intake (kcal) × 100. For fatty acids, the formula was as follows: fat (g) × 9 kcal/total energy intake (kcal) × 100. Notably, during the KNHANES from 2010 to 2015, information regarding the intake of total sugars was not collected. In addition, the intake of dietary fiber and fat subtypes (SFA, MUFA, PUFA, N3, and N6) was not evaluated during the 2010–2012 KNHANES. Detailed nutritional assessment information is available on the KNHANES website (https://knhanes.kdca.go.kr/knhanes).

Covariates

Anthropometric measurements were collected during health examinations at mobile centers by trained medical personnel following standardized protocols. To ensure data accuracy, a quality control project was implemented through on-site inspections. The detailed measurement protocol has been previously documented [19].

Obesity was defined using age- and sex-specific body mass index (BMI) reference values from the 2017 Korean National Growth Charts [20]. It was classified into two categories: obesity (based on weight) and obesity (based on BMI), which were defined as weight and BMI at or above the 95th percentile for age and sex, respectively [20]. Abdominal obesity was defined as a waist circumference (WC) at or above the 90th percentile of sex-specific WC for age [21]. Socioeconomic status was investigated via a self-reported questionnaire and included household income, education level, and residence. Household income was divided into quartiles, graded from the lowest to the highest. The level of education was classified as less than elementary school, middle school, and high school. The residence area was determined based on participants' living location, categorized as either "dong" for urban areas or a "eup"/"myeon" for rural areas according to the administrative divisions of Korea.

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Study outcomes

The main outcome was energy intake from macronutrients, specifically carbohydrates, protein, and fat. Subgroup analysis were conducted across various population subgroups, including age categories (6–8, 9–11, 12–14, and 15–18 years), sex, obesity (based on weight), obesity (based on BMI), and abdominal obesity. Additionally, trends in the intake of total sugars and fat subtypes were examined.

Statistical analysis

Statistical analysis were conducted for data from 1 January 2010 to 31 December 2020. The sampling plan in the KNHANES follows a multi-stage clustered probability design. To address the complex sampling design, all survey statistics were evaluated utilizing sample weights allocated to the sample participants. By incorporating sample weights into the analysis, parameters for the study population could be estimated accurately. Continuous variables are presented as mean ± standard error, whereas categorical variables are expressed as counts (percentages). Differences in variables between years were compared using one-way analysis of variance and Pearson's chi-squared test. We employed survey-weighted linear regression to calculate the beta coefficient and p-value for linearly increasing or decreasing trends in dietary nutrient consumption, treating the survey year as a continuous variable. Additionally, the statistical significance of overall and trend differences in dietary intake was assessed using the Rao–Scott chi-square test for subgroups including age, sex, obesity (based on weight), obesity (based on BMI), and abdominal obesity.

All statistical tests were conducted using R software (version 4.1.2; www.r-project.org; R Foundation for Statistical Computing, Vienna). The statistical significance level was set at $p < 0.05$. We used the survey R package to perform the analysis with a complex sampling design.

RESULTS

Participant characteristics

A total of 11,861 children and adolescents aged 6–18 years (6,189 boys [52.2%] and 5,672 girls [47.8%]) were included in this study (Table 1). The percentage of adolescents aged 9–11 years declined from 28% in 2010 to 25% in 2020. Additionally, the proportion of participants with the lowest household income decreased from 14.1% in 2010 to 6.1% in 2020, whereas

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those with the highest household income increased from 25.5% to 31.6%. The number of participants living in rural areas decreased from 19% to 9.3% over the 10-year period. Regarding anthropometric measurements, the mean BMI and WC increased from 19.6 kg/m^2 to 20.1 kg/m^2 and from 65.7 cm to 67.9 cm, respectively, over the 10-year span. The proportion of participants with general obesity (a combination of two types of obesity: weight and BMI) increased from 5.6% to 6.5% over 10 years, while the proportion of participants with abdominal obesity rose from 5.5% to 6.5%.

Trends in carbohydrate, protein, and fat intake

A total of 11,861 participants who completed the 24-h dietary recall survey were included in the nutrient analysis. As shown in Figure 1, from 2010 to 2020, the total energy intake per day decreased from 2065.3 kcal/day in 2010 to 1842.7 kcal/day in 2020 (β coefficient = -17.25, $p < 0.001$). Similarly, the percentage of energy intake from carbohydrates decreased from 61.9% to 58.8% (β coefficient = -0.38, $p < 0.001$). Conversely, the percentage of energy intake from protein and fat increased from 14.1% to 15.0% (β coefficient = 0.08, $p < 0.001$) and 24.0% to 26.2% (β coefficient = 0.30, $p < 0.001$), respectively (Table S1 in the Supplement).

Subgroup analysis

Trends in total energy intake and intake of carbohydrates (%), protein (%), and fat (%) across the population subgroups were examined (Figures 2 and 3). Figure 2 shows the trends in energy intake and the percentage of macronutrient intake by age group and sex. Generally, energy intake increased with age, excluding the years 2014, 2019, and 2020, during which the energy intake of the 12–14-year age group exceeded that of the 15–18-year age group. Significant decreasing trends were observed in total energy intake in all age groups, excluding participants aged 6–8 years (9–11-year age group; $p = 0.012$, 12–14-year age group; $p = 0.016$, and 15–18-year age group; $p < 0.001$). These decreasing trends were consistent with the carbohydrate intake (%) in all age groups (all $p < 0.001$). Conversely, the intake of protein (%) and fat (%) increased in all age groups (all $p < 0.01$). Notably, the increase in fat intake (%) in the 15–18-year age group was 19% ($p = 0.004$), whereas it was approximately half of that in other age groups (all $p < 0.001$, p for interaction = 0.031). Compared with girls, boys consumed more total energy and protein (%) (both $p < 0.001$) and less carbohydrates (%) ($p = 0.008$). However, no significant difference was observed in fat intake (%) between the

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sexes (p = 0.354). In both sexes, total energy intake and the proportion of carbohydrate intake (%) declined, whereas the intake of protein (%) and fat (%) increased over the 10-year period (all p < 0.001). Changes in total calorie, carbohydrate (%), protein (%), and fat (%) intake were not significantly different between the sexes (p = 0.590, p = 0.666, p = 0.235, p = 0.982, respectively) (Table S2 in the Supplement).

Figure 3 shows the trends in the total energy intake and dietary macronutrient composition according to the presence of general obesity (defined as weight and BMI for age) and abdominal obesity. Participants with obesity (weight) consumed higher total calories and protein (%) (p < 0.001 and p = 0.010, respectively), with no interaction noted. However, this trend of significantly higher consumption of total calories and protein (%) was not observed in participants with obesity (based on BMI). Nonetheless, similar trends were observed in participants with obesity (based on weight) and those with abdominal obesity (p = 0.009 and p = 0.026, respectively). Regardless of the presence of general or abdominal obesity, there was a significant increasing trend in fat intake (%) across all participants (abdominal obesity, p = 0.002; others, p < 0.001).

Participants with missing data on the intake of total sugars (2010–2015) and dietary fiber and fat subtypes (2010–2012) were excluded from the analysis. Figure 4 presents the overall trends in the percentage of energy intake from the total sugars between 2016 and 2020 and fat subtypes (SFA, MUFA, PUFA, N3, and N6) between 2013 and 2020. Energy intake from total sugars significantly decreased from 14.5% in 2016 to 13.5% in 2020 (β coefficient = -0.23, p = 0.030). However, there were significant increasing trends in the consumption of all fat subtypes over the 5 years (all p < 0.001). Trends in intake of total sugars (%) and fat (%) are delineated by age group and sex (Figures 5 and 6). When analyzed by age group, similar increasing trends in fat intake (%) were observed (all p < 0.05); however, the decreasing trend in total sugars intake (%) was only found in participants aged 6–8 years (β coefficient = -0.42, p = 0.010). Moreover, an increasing trend in dietary fiber intake was only observed in participants aged 12–14 years (β coefficient = 0.30, p = 0.019) (Figure S1 in the Supplement). There were no significant interactions between the intake of total sugars (%) and fat (%) according to age group. In terms of sex, there were increasing trends in fat intake (%) in both boys and girls (all p<0.001). However, the result was significant, excluding the percentage of N3 intake in girls (β coefficient = 0.01, p = 0.056). Changes in the consumption of N3 (%) were greater in boys than in girls (p = 0.046). There were no significant interactions between

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the intake of total sugars (%) and other fats (%) and sex. Furthermore, dietary fiber intake between 2013 and 2020 was 18.1–21.6 g/day in boys and 15.6–18.4 g/day in girls (Table S3 in the Supplement).

DISCUSSION

Utilizing nationally representative data from 2010 to 2020, this study represents the first attempt to describe the secular trends in dietary energy and macronutrient intake among Korean children and adolescents, examining differences across subgroups defined by age, sex, and obesity status. We observed decreasing trends in total energy intake alongside a greater proportion of fat in dietary nutrient intake. Additionally, the increase in total fat intake corresponded to increasing trends in the consumption of five fat subtypes (SFA, MUFA, PUFA, N3, and N6). These findings indicate a dietary nutrient transition among Korean children and adolescents over the 10-year period, highlighting the need for continuous monitoring and public health consideration.

This study revealed a decrease in daily total energy intake between 2010 and 2020. First, the observed decline in total energy intake among Korean children and adolescents may be associated with their dietary environment, as childhood dietary habits are predominantly influenced by parental dietary lifestyle factors [(22)]. Moreover, the significant decrease in total energy intake aligns with a recent analysis of dietary macronutrient intake trends in Korean adults [(19)], suggesting a potential correlation among family members' consumption patterns[(23)]. Second, this finding may be related to the pattern of skipping breakfast, which has recently appeared more prevalent among Korean children and adolescents [(6)]. Despite the fundamental role of breakfast consumption in ensuring adequate total energy daily intake, the prevalence of skipping breakfast in Korea has increased over the past decade, mirroring similar trends observed in the US [(24)]. Additionally, in the era of globalization, economic growth may also impact dietary transitions in countries, leading to changes in the overall food environment and eating patterns [(25)].

Our analysis revealed a significant increase in total fat intake across all age, sex, and obesity status subgroups. Notably, participants in the younger age groups exhibited a more rapid increase in fat consumption compared with those in the older age group (15–18 years). Previous studies examining dietary fat intake in children identified lower levels of total fat and SFA intake in children from Asian countries than in those from Western countries [(26-28)].

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However, Asian children have shown increasing trends in dietary fat consumption over time, reflecting transitions in dietary patterns from a traditional plant-based diet to a higher intake of meat and dairy products [3]. According to the dietary reference intake for Koreans in 2020, the proportion of fat intake (%) in Korean children and adolescents did not exceed 15–30%, which corresponds to the findings of this study [29]. However, compared with the reference level of SFA intake (%), the study population's consumption of SFA exceeded the upper limit of 7–8% in all age and sex subgroups [29], which is concerning as high intake of SFA is associated with increased CVD risk [30]. Therefore, appropriate fat consumption should be emphasized based on the dietary reference to prevent long-term complications.

Despite the increasing trends in energy intake from the five different fat subtypes during 2016–2020, the results varied when analyzed by sex. Notably, N3 consumption increased more rapidly in boys than in girls, and the observed findings were not significant in girls. These findings align with recent reviews where children from different countries consistently have N3 intake levels below the dietary recommendations[31,32]. Many health benefits of N3 have been demonstrated, and their positive effects on CVD are widely recognized in adults[33]. In addition, a recent study on the role of daily N3 supplementation reported that it is likely to contribute to improved cognitive functioning in children and adolescents [34,35]. Our findings suggest that efforts to raise awareness of healthy fat choices, particularly among Korean girls, are essential to achieve a more balanced approach to the consumption of fat and reduce the burden of chronic disease.

While the overall energy intake from carbohydrates (%) declined, the proportion of energy from fat (%) increased, indicating a need for proportional adjustments in dietary macronutrient consumption. Future studies are warranted to determine the optimal dietary macronutrient ratio among Korean children and adolescents. Additionally, although total sugar intake (%) appeared to be declining overall, subgroup analysis revealed that this decreasing trend was limited to the 6–8-year age group. Given the adverse health effects of excessive sugar consumption, including obesity, type 2 diabetes, CVD, and cancer [36], efforts to reduce sugar intake should be emphasized through nutritional education, particularly among Korean children and adolescents aged 9–18 years. Furthermore, dietary fiber consumption in this study (18.1–21.6 g/day in boys and 15.6–18.4 g/day in girls) was below the recommended levels based on the 2020 dietary reference intake for Koreans, in which 25–30 g/day for boys and 20–25 g/day for girls are recommended [29]. Research has shown

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sufficient dietary fiber intake facilitates better bowel movement and prevents a rapid increase in blood glucose after meals [37,38], highlighting the need for nutrition interventions to encourage a diet rich in fiber.

Anthropometric measurements in our study showed increasing trends in BMI, WC, and the percentage of general obesity (defined by weight and BMI) as well as abdominal obesity over the 10-year period. Despite the observed decrease in total energy intake, the prevalence of obesity has continued to rise in line with the increasing consumption of fat. A notable finding in this study is that all participants with obesity consumed a higher percentage of fat (%) compared with those without obesity. While providing children with adequate dietary fat is essential for healthy growth and development, excessive consumption of SFA is suspected to be a contributing factor to childhood obesity[34,39]. These findings may be related to the increased consumption of fast foods in recent decades. Previous research based on a US national survey indicated that children and adolescents with frequent fast food intake consumed more total energy and fat [6]. Excessive intake of SFA is also associated with hypercholesterolemia, increasing the risk of CVD[40]. Given that fast foods are rich sources of SFA, their consumption can negatively impact the body composition and nutritional status of children and adolescents, contributing to the rising prevalence of childhood obesity[40].

This study has certain limitations. First, the reliance on participants' self-reported 24-h dietary recall may introduce recall bias. Additionally, dietary surveys completed by primary caregivers at home, without a specific age limit, might not accurately represent the dietary intake occurring outside the home environment. Future studies could benefit from incorporating school meal plans to collect more comprehensive daily intake data, particularly for school-age children and adolescents. Second, as this study specifically focused on Korean children and adolescents, our findings might not be generalizable to populations with different cultural contexts and dietary patterns. Third, the increasing trends in BMI and obesity were observed despite the decline in total energy intake. This might be due to poor diet quality characterized by excessive SFA intake and changes in lifestyle factors such as decreased physcial activity and increased skipping of breakfast among Korean youth[41,42]. Lastly, the utilization of dietary nutrient intake data without considering food intake in practice may limit the comprehensive understanding of people’s eating habits. Future research could explore trend analysis according to the food groups to provide a more holistic view.

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Despite these limitations, our study has certain strengths. By using data from the KNHANES, a large-scale nationally representative survey in Korea, our findings can be more broadly applied to the young Korean population. Furthermore, the analysis covered a decade's worth of data, which facilitated the evaluation of changes in macronutrient intake patterns over time. This cross-sectional approach yields critical insights into the dietary nutrient consumption trends among Korean children and adolescents. Finally, conducting subgroup analysis by age, sex, and obesity status allowed for a deeper understanding of the factors influencing consumption trends. This enables pediatric nutritionists and health care practitioners to explore group-specific variations and to develop strategies targeted for the subgroups.

In conclusion, this population-based study, utilizing the KNHANES data, provided valuable insights into the dietary macronutrient intake trends among Korean children and adolescents over a decade. The observed trends in dietary macronutrient consumption may have implications for future increases in adulthood obesity and related comorbid conditions over the long term. Therefore, our findings underscore the importance of continuously monitoring dietary changes and developing health strategies to prevent the potential risk of diet-related non-communicable diseases. Considering the practicality of nutrition education, adopting food-based educational approaches to improve current nutrient intake may prove more effective in real-world settings. Efforts to facilitate more balanced dietary choices are warranted to support Korean children and adolescents' healthier growth and development.

REFERENCES

1. Rehm CD, Peñalvo JL, Afshin A *et al.* (2016) Dietary Intake Among US Adults, 1999-2012. *Jama* **315**, 2542-2553.
2. Liu J, Micha R, Li Y *et al.* (2021) Trends in Food Sources and Diet Quality Among US Children and Adults, 2003-2018. *JAMA Netw Open* **4**, e215262.
3. Jo G, Park D, Lee J *et al.* (2022) Trends in Diet Quality and Cardiometabolic Risk Factors Among Korean Adults, 2007-2018. *JAMA Netw Open* **5**, e2218297.
4. Kant AK (2004) Dietary patterns and health outcomes. *J Am Diet Assoc* **104**, 615-635.
5. Gu X & Tucker KL (2017) Dietary quality of the US child and adolescent population: trends from 1999 to 2012 and associations with the use of federal nutrition assistance programs. *Am J Clin Nutr* **105**, 194-202.

https://doi.org/10.1017/S1368980024002180 Published online by Cambridge University Press

6. Kang M, Choi SY & Jung M (2021) Dietary intake and nutritional status of Korean children and adolescents: a review of national survey data. *Clin Exp Pediatr* **64**, 443-458.

7. Llewellyn A, Simmonds M, Owen CG *et al.* (2016) Childhood obesity as a predictor of morbidity in adulthood: a systematic review and meta-analysis. *Obes Rev* **17**, 56-67.

8. Kim JH & Moon JS (2020) Secular Trends in Pediatric Overweight and Obesity in Korea. *J Obes Metab Syndr* **29**, 12-17.

9. Park HK, Seo JY, Jung HW *et al.* (2023) Prevalence and trends in obesity and severe obesity in Korean children and adolescents, 2007-2020: A population-based study. *Pediatr Int* **65**, e15472.

10. Suh J, Jeon YW, Lee JH *et al.* (2021) Annual incidence and prevalence of obesity in childhood and young adulthood based on a 30-year longitudinal population-based cohort study in Korea: the Kangwha study. *Ann Epidemiol* **62**, 1-6.

11. Yang YS, Han BD, Han K *et al.* (2022) Obesity Fact Sheet in Korea, 2021: Trends in Obesity Prevalence and Obesity-Related Comorbidity Incidence Stratified by Age from 2009 to 2019. *J Obes Metab Syndr* **31**, 169-177.

12. Kelly M (2016) The nutrition transition in developing Asia: dietary change, drivers and health impacts. *Eating, drinking: surviving: the international year of global understanding-IYGU*, 83-90.

13. Popkin BM (2006) Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *Am J Clin Nutr* **84**, 289-298.

14. Popkin BM, Adair LS & Ng SW (2012) Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev* **70**, 3-21.

15. Yim HR, Yun HJ & Lee JH (2021) An Investigation on Korean Adolescents' Dietary Consumption: Focused on Sociodemographic Characteristics, Physical Health, and Mental Health. *Int J Environ Res Public Health* **18**.

16. Kweon S, Kim Y, Jang MJ *et al.* (2014) Data resource profile: the Korea National Health and Nutrition Examination Survey (KNHANES). *Int J Epidemiol* **43**, 69-77.

17. Foster E & Bradley J (2018) Methodological considerations and future insights for 24-hour dietary recall assessment in children. *Nutr Res* **51**, 1-11.

18. Lim S-H, Kim J-B, Cho Y-S *et al.* (2013) National standard food composition tables provide the infrastructure for food and nutrition research according to policy and industry. *The Korean Journal of Food And Nutrition* **26**, 886-894.

https://doi.org/10.1017/S1368980024002180 Published online by Cambridge University Press

19. Chun DW, Kwon YJ, Heo SJ *et al.* (2024) Secular trends in dietary energy, carbohydrate, fat, and protein intake among Korean adults, 2010-2020 KHANES. *Nutrition* **121**, 112360.

20. Kim JH, Yun S, Hwang SS *et al.* (2018) The 2017 Korean National Growth Charts for children and adolescents: development, improvement, and prospects. *Korean J Pediatr* **61**, 135-149.

21. Lee J, Kang SC, Kwon O *et al.* (2022) Reference Values for Waist Circumference and Waist-Height Ratio in Korean Children and Adolescents. *J Obes Metab Syndr* **31**, 263-271.

22. Yu SY & Yang YJ (2019) Nutritional status and related parental factors according to the breakfast frequency of elementary school students: based on the 2013~ 2015 Korea National Health and Nutrition Examination Survey. *Journal of Nutrition and Health* **52**, 73-89.

23. Lee HA & Park H (2015) Correlations between Poor Micronutrition in Family Members and Potential Risk Factors for Poor Diet in Children and Adolescents Using Korean National Health and Nutrition Examination Survey Data. *Nutrients* **7**, 6346-6361.

24. Ramsay SA, Bloch TD, Marriage B *et al.* (2018) Skipping breakfast is associated with lower diet quality in young US children. *Eur J Clin Nutr* **72**, 548-556.

25. Czarnocinska J, Wadolowska L, Lonnie M *et al.* (2020) Regional and socioeconomic variations in dietary patterns in a representative sample of young polish females: a cross-sectional study (GEBaHealth project). *Nutr J* **19**, 26.

26. Song S & Shim JE (2022) Increasing trends in dietary total fat and fatty acid intake among Korean children: using the 2007-2017 national data. *Nutr Res Pract* **16**, 260-271.

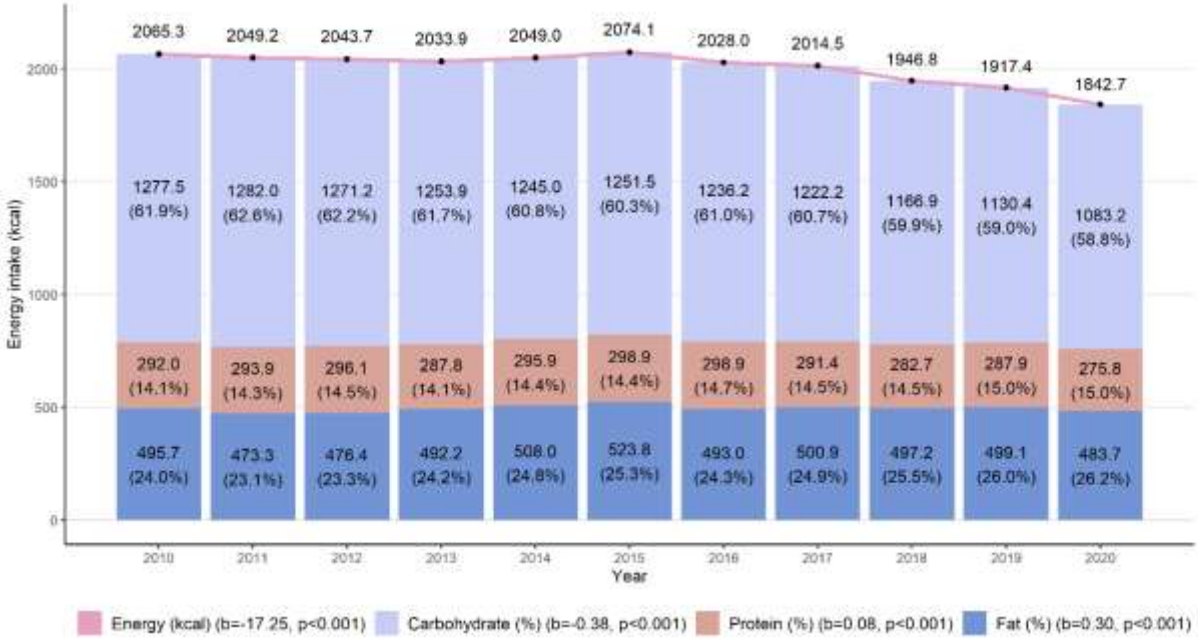
27. Cui Z & Dibley MJ (2012) Trends in dietary energy, fat, carbohydrate and protein intake in Chinese children and adolescents from 1991 to 2009. *Br J Nutr* **108**, 1292-1299.

28. Libuda L, Alexy U & Kersting M (2014) Time trends in dietary fat intake in a sample of German children and adolescents between 2000 and 2010: not quantity, but quality is the issue. *Br J Nutr* **111**, 141-150.

29. Hwang J-Y, Kim Y, Lee HS *et al.* (2022) The development of resources for the application of 2020 Dietary Reference Intakes for Koreans. *Journal of Nutrition and*

Health **55**, 21-35.
30. Maki KC, Dicklin MR & Kirkpatrick CF (2021) Saturated fats and cardiovascular health: Current evidence and controversies. *J Clin Lipidol* **15**, 765-772.
31. Harika RK, Cosgrove MC, Osendarp SJ *et al.* (2011) Fatty acid intakes of children and adolescents are not in line with the dietary intake recommendations for future cardiovascular health: a systematic review of dietary intake data from thirty countries. *British journal of nutrition* **106**, 307-316.
32. Rippin HL, Hutchinson J, Jewell J *et al.* (2019) Child and adolescent nutrient intakes from current national dietary surveys of European populations. *Nutr Res Rev* **32**, 38-69.
33. Shahidi F & Ambigaipalan P (2018) Omega-3 Polyunsaturated Fatty Acids and Their Health Benefits. *Annu Rev Food Sci Technol* **9**, 345-381.
34. Monnard C & Fleith M (2021) Total Fat and Fatty Acid Intake among 1-7-Year-Old Children from 33 Countries: Comparison with International Recommendations. *Nutrients* **13**.
35. van der Wurff ISM, Meyer BJ & de Groot RHM (2020) Effect of Omega-3 Long Chain Polyunsaturated Fatty Acids (n-3 LCPUFA) Supplementation on Cognition in Children and Adolescents: A Systematic Literature Review with a Focus on n-3 LCPUFA Blood Values and Dose of DHA and EPA. *Nutrients* **12**.
36. Prinz P (2019) The role of dietary sugars in health: molecular composition or just calories? *Eur J Clin Nutr* **73**, 1216-1223.
37. Korczak R, Kamil A, Fleige L *et al.* (2017) Dietary fiber and digestive health in children. *Nutr Rev* **75**, 241-259.
38. Fuller S, Beck E, Salman H *et al.* (2016) New Horizons for the Study of Dietary Fiber and Health: A Review. *Plant Foods Hum Nutr* **71**, 1-12.
39. Uauy R & Dangour AD (2009) Fat and fatty acid requirements and recommendations for infants of 0-2 years and children of 2-18 years. *Ann Nutr Metab* **55**, 76-96.
40. Guasch-Ferré M, Babio N, Martínez-González MA *et al.* (2015) Dietary fat intake and risk of cardiovascular disease and all-cause mortality in a population at high risk of cardiovascular disease. *Am J Clin Nutr* **102**, 1563-1573.
41. Seo YB, Oh YH & Yang YJ (2022) Current Status of Physical Activity in South Korea. *Korean J Fam Med* **43**, 209-219.
42. Chang SH, Hong SW, Suh YS *et al.* (2021) Association between Skipping Breakfast and Overweight in Korean Adolescents: Analysis of the 13th Korea Youth Risk Behavior Web-based Survey. *Keimyung Medical Journal* **40**, 98-107.

Figure 1. Total energy intake per day and trends in carbohydrate, protein, and fat intake from 2010 to 2020 (n = 11,816) *



*Survey-weighted linear regression was used to obtain beta coefficients and p-values.

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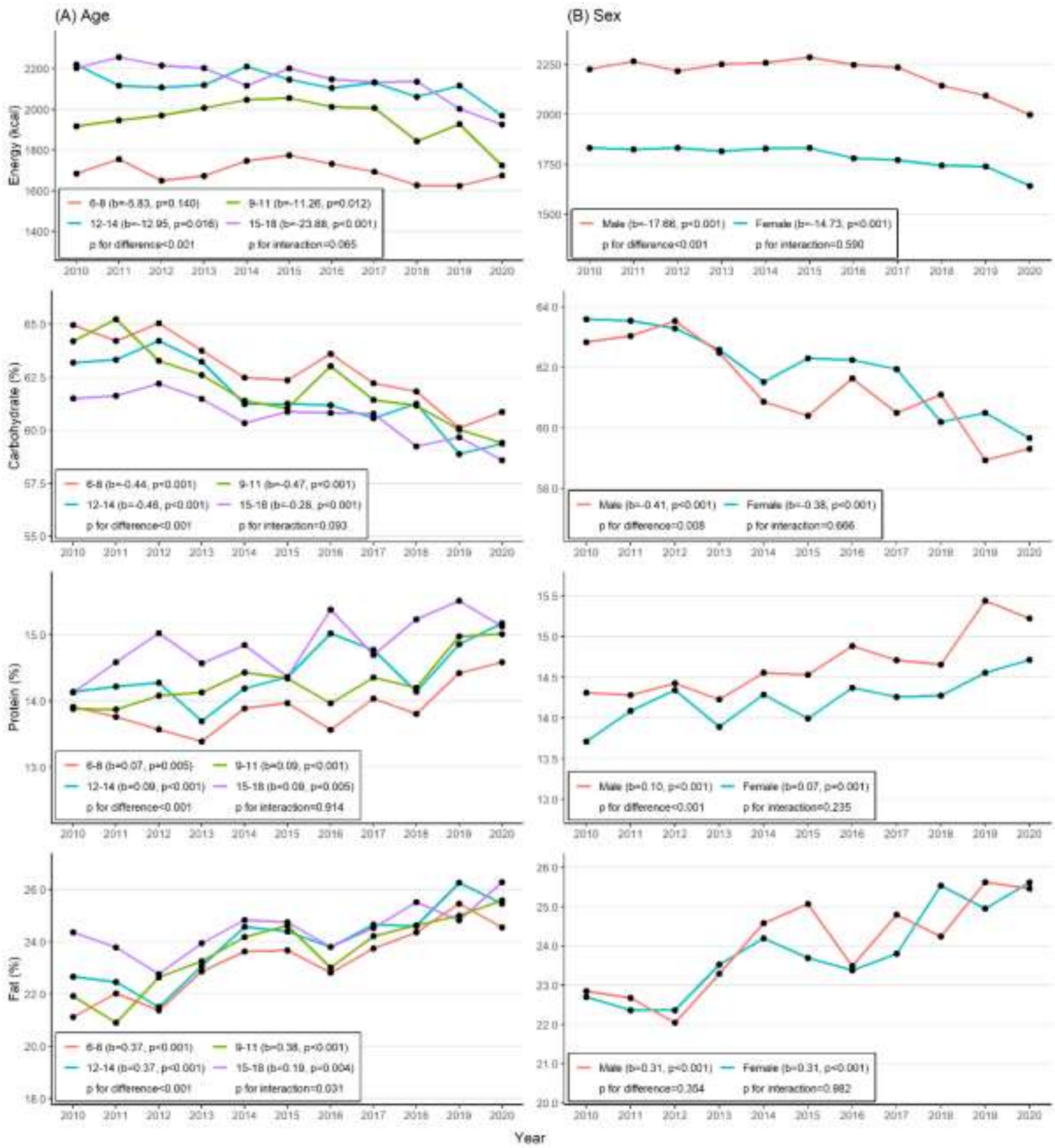
Figure 2. Trends in total energy and macronutrient intake according to (A) age and (B) sex (n = 11,816) *



*Survey-weighted linear regression was used to obtain beta coefficients and p-values. Rao-Scott chi-square test was used to obtain p-values for difference and interaction between groups.

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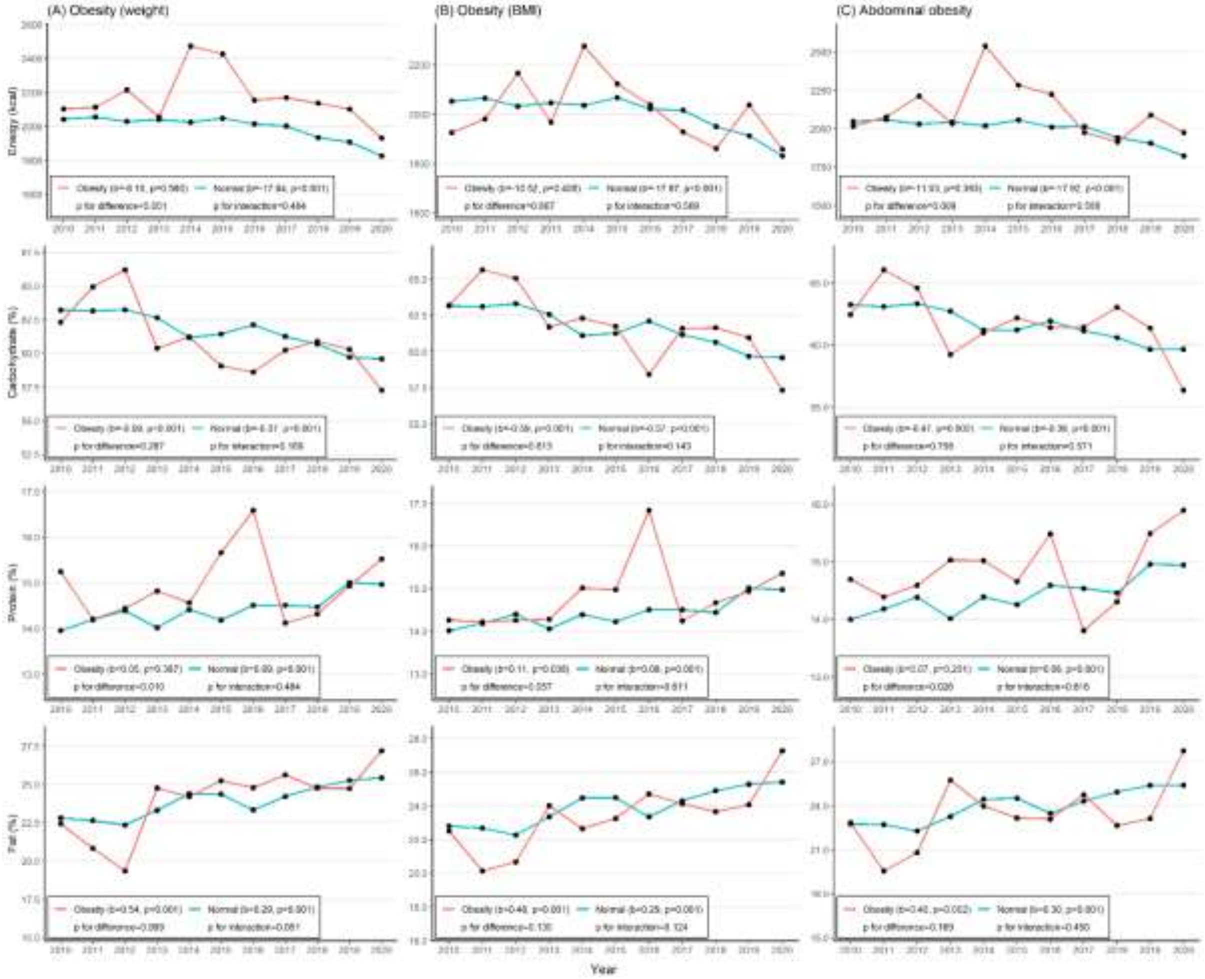
Figure 3. Trends in total energy and macronutrient intake according to the presence of (A, B) general or (C) abdominal obesity (n (A) = 11,065, n (B) = 11,063 and n (C) = 11,047) *†



*Survey-weighted linear regression was used to obtain beta coefficients and p-values. Rao-Scott chi-square test was used to obtain p-values for difference and interaction between groups.

†General obesity was classified into two categories: obesity (weight) and obesity (BMI), which were defined as weight and BMI at or above the 95th percentile for age and sex, respectively. Abdominal obesity was defined as a waist circumference (WC) at or above the 90th percentile of sex-specific WC for age.

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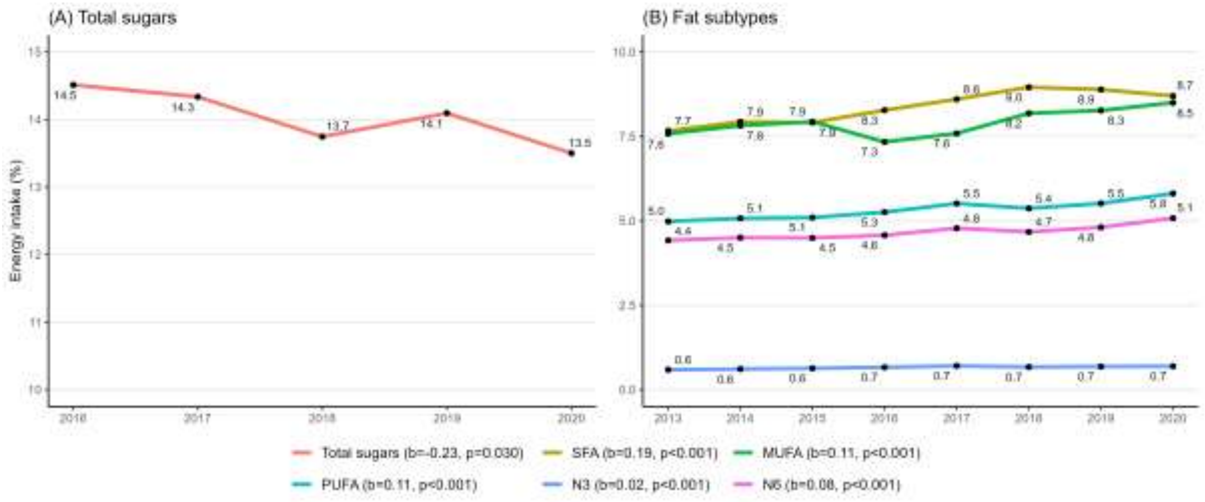
Figure 4. Overall trends in energy intake from total sugars and fat subtypes from 2016 to 2020 (n (A) = 4,738 and n (B) = 7,972) *



*Survey-weighted linear regression was used to obtain beta coefficients and p-values.

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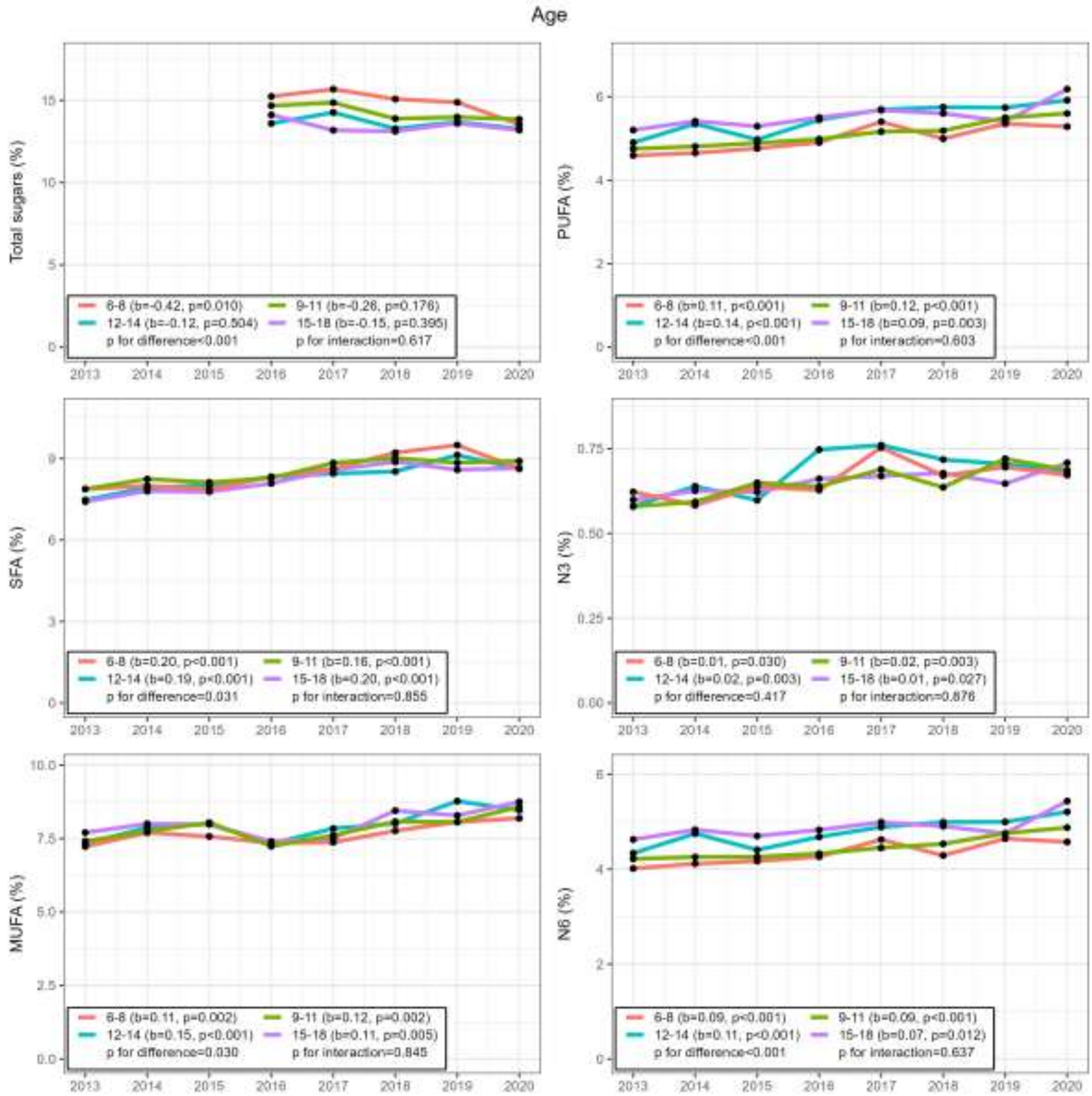
Figure 5. Trends in energy intake from total sugars and fat subtypes according to age group (n 4,738 for sugar and 7,972 for fat subtypes) *



SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; N3, omega-3 fatty acids; N6, omega-6 fatty acids

*Survey-weighted linear regression was used to obtain beta coefficients and p-values. Rao-Scott chi-square test was used to obtain p-values for difference and interaction between groups.

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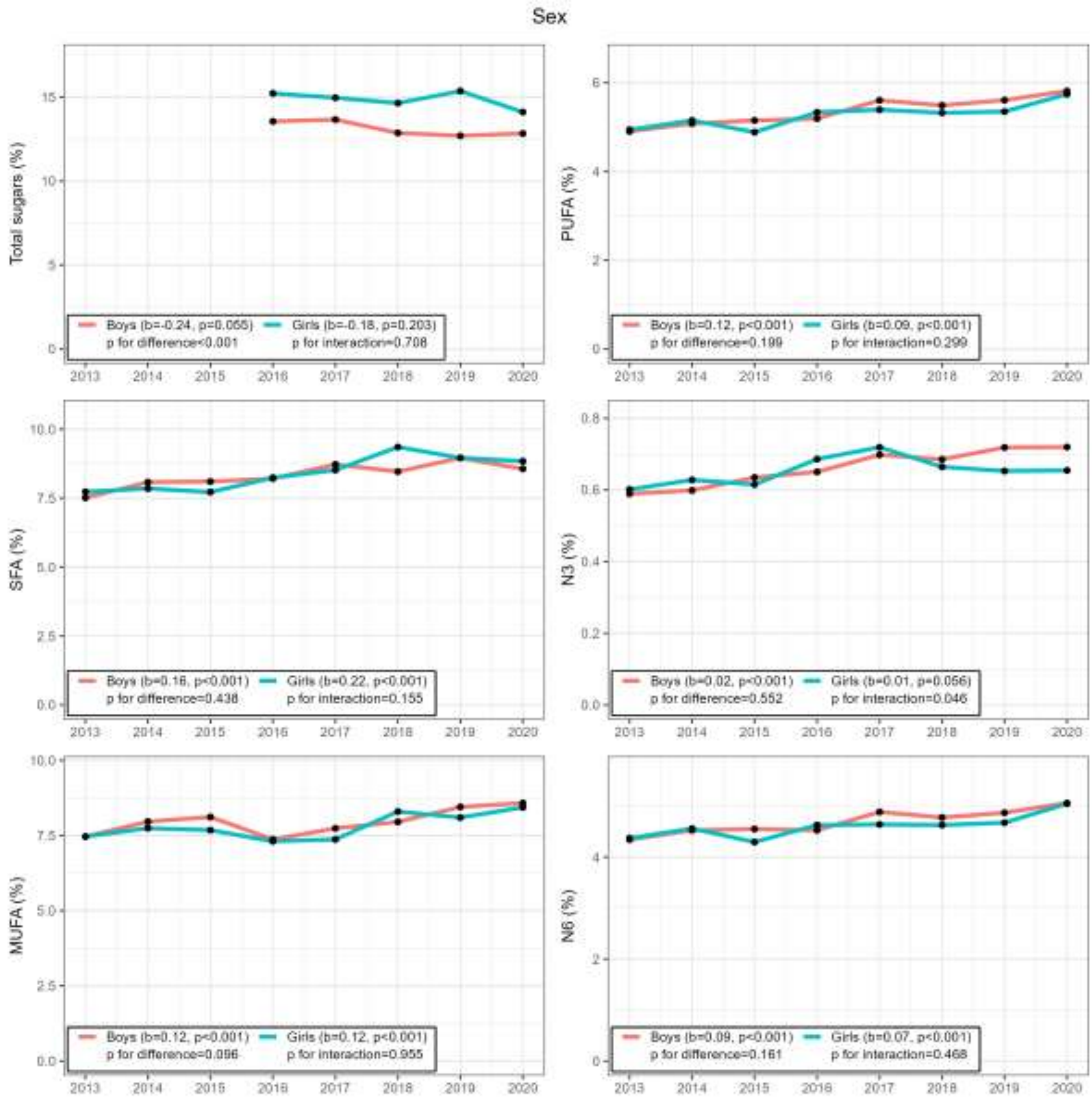
Figure 6. Trends in energy intake from total sugars and fat subtypes according to sex (n 4,738 for sugar and 7,972 for fat subtypes) *



SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; N3, omega-3 fatty acids; N6, omega-6 fatty acids

*Survey-weighted linear regression was used to obtain beta coefficients and p-values. Rao-Scott chi-square test was used to obtain p-values for difference and interaction between groups.

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Table 1. Demographic and clinical characteristics of the study population (n = 11,816) from 2010 to 2020 †

Characteristic	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	p-value*
Total No. (n=11,816)	1,460	1,269	1,160	1,278	992	964	1,073	1,005	929	1,010	721	
Sex, n (%)												0.914
Male	776 (53%)	663 (52%)	618 (53%)	666 (52%)	514 (52%)	509 (53%)	553 (52%)	505 (50%)	477 (51%)	518 (51%)	390 (54%)	
Female	684 (47%)	606 (48%)	542 (47%)	612 (48%)	478 (48%)	455 (47%)	520 (48%)	500 (50%)	452 (49%)	492 (49%)	331 (46%)	
Age, n (%) (years)												<0.001
6–8	368 (25%)	344 (27%)	255 (22%)	297 (23%)	258 (26%)	224 (23%)	315 (29%)	275 (27%)	247 (27%)	281 (28%)	195 (27%)	
9–11	408 (28%)	302 (24%)	301 (26%)	338 (26%)	247 (25%)	221 (23%)	249 (23%)	271 (27%)	260 (28%)	272 (27%)	183 (25%)	
12–14	374 (26%)	311 (25%)	318 (27%)	298 (23%)	226 (23%)	247 (26%)	240 (22%)	209 (21%)	203 (22%)	212 (21%)	164 (23%)	
15–18	310 (21%)	312 (25%)	286 (25%)	345 (27%)	261 (26%)	272 (28%)	269 (25%)	250 (25%)	219 (24%)	245 (24%)	179 (25%)	

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Household income (quartile), n (%)												<0.001
Quartile 1	147 (10%)	140 (11%)	99 (8.6%)	133 (10%)	93 (9.5%)	120 (12%)	98 (9.2%)	86 (8.6%)	77 (8.3%)	93 (9.2%)	48 (6.7%)	
Quartile 2	394 (27%)	353 (28%)	282 (25%)	375 (30%)	240 (24%)	224 (23%)	273 (26%)	253 (25%)	236 (25%)	299 (30%)	198 (28%)	
Quartile 3	442 (31%)	432 (34%)	399 (35%)	386 (30%)	392 (40%)	320 (33%)	336 (31%)	337 (34%)	340 (37%)	317 (31%)	256 (36%)	
Quartile 4	457 (32%)	329 (26%)	367 (32%)	374 (29%)	259 (26%)	296 (31%)	363 (34%)	329 (33%)	275 (30%)	299 (30%)	218 (30%)	
Education, n (%)												0.225
< Elementary school	1,148 (83%)	935 (80%)	848 (80%)	924 (79%)	714 (79%)	695 (78%)	800 (79%)	748 (80%)	697 (81%)	758 (81%)	544 (80%)	
Middle school	197 (14%)	209 (18%)	185 (17%)	218 (19%)	171 (19%)	170 (19%)	180 (18%)	167 (18%)	138 (16%)	156 (17%)	111 (16%)	
High school	31	31	25	32	23	24	27	23	26	25	29	

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	(2.3%)	(2.6%)	(2.4%)	(2.7%)	(2.5%)	(2.7%)	(2.7%)	(2.5%)	(3.0%)	(2.7%)	(4.2%)	
Residence, n (%)												<0.001
Urban	1,243 (85%)	1,099 (87%)	998 (86%)	1,032 (81%)	824 (83%)	825 (86%)	896 (84%)	891 (89%)	787 (85%)	833 (82%)	621 (86%)	
Rural	217 (15%)	170 (13%)	162 (14%)	246 (19%)	168 (17%)	139 (14%)	177 (16%)	114 (11%)	142 (15%)	177 (18%)	100 (14%)	
Total no. excluding missing values of WC (n = 11,047)	1,365	1,177	1,070	1,189	923	894	1,008	938	861	937	685	
Waist circumference, mean (SE)	64.1 (10.7)	64.3 (10.9)	64.5 (10.2)	64.3 (10.8)	64.5 (11.1)	67.4 (11.9)	65.0 (11.6)	64.4 (11.3)	65.4 (11.3)	65.7 (12.2)	67.6 (12.9)	<0.001
Abdominal obesity	35 (2.4%)	37 (2.9%)	19 (1.6%)	27 (2.1%)	28 (2.8%)	45 (4.7%)	43 (4.0%)	40 (4.0%)	33 (3.6%)	50 (5.0%)	46 (6.4%)	>0.999
Total no. excluding missing values of weight (n = 11,065)	1371	1178	1070	1191	923	894	1010	938	862	943	685	
Weight, mean (SE)	43.7 (16.2)	43.9 (16.7)	45.0 (15.8)	44.7 (16.6)	44.1 (17.0)	46.7 (17.9)	43.7 (17.4)	43.6 (16.9)	44.6 (17.7)	44.4 (18.1)	46.6 (19.0)	<0.001
Obesity	57	56	39	40	41	51	50	58	58	62	63	>0.999

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	(4.2%)	(4.8%)	(3.6%)	(3.4%)	(4.4%)	(5.7%)	(5.0%)	(6.2%)	(6.7%)	(6.6%)	(9.2%)	
Total no. excluding missing values of BMI (n = 11,063)	1371	1178	1070	1191	923	894	1010	938	861	942	685	
BMI, mean (SE)	19.2 (3.6)	19.2 (3.8)	19.2 (3.5)	19.3 (3.7)	19.3 (3.9)	19.8 (4.2)	19.1 (4.0)	19.2 (3.9)	19.4 (4.1)	19.5 (4.3)	20.1 (4.5)	<0.001
Obesity	64 (4.7%)	56 (4.8%)	34 (3.2%)	48 (4.0%)	37 (4.0%)	52 (5.8%)	51 (5.0%)	48 (5.1%)	55 (6.4%)	61 (6.5%)	63 (9.2%)	>0.999

BMI, body mass index; SE, standard error; WC, waist circumference

*p-values were calculated using one-way analysis of variance or Pearson's chi-squared test.

†General obesity was classified into two categories: obesity (weight) and obesity (BMI), defined as weight and BMI at or above the 95th percentile for age and sex, respectively. Abdominal obesity was defined as a waist circumference (WC) at or above the 90th percentile of sex-specific WC for age.

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