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The proportion of differently processed foods in the diet of Croatian school-aged children and its impact on daily energy and nutrient intake

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ABSTRACT

In countries around the world, a dietary shift is observed in which the consumption of highly processed foods increases over unprocessed or minimally processed foods. The objective of this study was to observe the proportion of processed foods in the diet of school-aged children and to assess how this relates to sex, weight status and school meal consumption. The aim was to assess the impact of processed foods on overall diet quality in terms of ultra-processed foods contribution to total daily energy intake. Dietary intake was observed from dietary records for three non-consecutive days of 168 children (50.6% boys) aged 8.3 ± 0.5 years. All foods and beverages were classified into four groups according to NOVA food classification system. The contribution of each NOVA food group to total daily energy intake was calculated and the mean nutrient intake of children divided into terciles according to total daily energy intake from ultra-processed foods was compared. Anthropometric measurements were performed according to standard protocols, while sex and age z-scores were obtained using AnthroPlus software. Results show that unprocessed or minimally processed foods (38.1% kcal) and ultra-processed foods (38.1% kcal) had the highest proportion of dietary intake. There was no difference in NOVA food groups intake by sex or weight status, while number of school meals may contribute to the intake of processed culinary ingredients. Children who had higher energy intake from ultra-processed foods had lower intake of animal proteins (p=0.009), polyunsaturated fatty acids (p=0.014), vitamin A (p=0.027) and most minerals, but higher intake of carbohydrates (p=0.014) and copper (p=0.014) compared to children with lower energy intake from ultra-processed foods. In conclusion, school-aged children had equal share of energy from unprocessed or minimally processed foods and from ultra-processed foods. Higher share of energy from ultra-process foods may contribute to poor overall nutrition.

Introduction

Recently, a higher consumption of highly processed foods over unprocessed or minimally processed foods has been observed worldwide. This is mainly because highly processed foods are available, cheap to produce and distribute, as well as tastier and more durable, and can be consumed anytime, anywhere. (Monteiro et al. 2013; Monteiro et al., 2018a). Therefore, these mass-produced foods are becoming a key determinant of dietary patterns in the current global food system (Monteiro 2009; Monteiro et al. 2013; Stuckler et al. 2012; Popkin, 2006a; Popkin, 2006b). According to this global trend, in order to identify foods on the

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nature, extent and propose of food processing Monteiro et al. (2018b; 2019a) propose the NOVA food classification system, which classifies foods into four groups: unprocessed or minimally processed foods (UMPFs), processed culinary ingredients (PCIs), processed foods (PFs), and ultra-processed foods (UPFs). According to NOVA food classification, UPFs are formulations of ingredients that are mostly industrial and produced through a range of industrial processes. Most of these products are ready-to-eat products, pre-prepared and ready-to-heat products (Monteiro et al. 2019a; Monteiro et al. 2019b).

Due to their availability and organoleptic properties, UPFs are associated with addictive eating behaviours (Filgueiras et al., 2019). Therefore, it is not surprising that several studies have estimated that the consumption of UPFs represents from 18.5% to 65.9% of the total energy intake in children (Rauber et al., 2015; Sparrenberger et al., 2015; Moubarac et al., 2017; Balardi et al. 2018; Cediel et al., 2018; Marrón-Ponce et al., 2018; Setyowati et al., 2018; Neri et al., 2019; Rauber et al. 2019; Vandevijvere et al., 2019; Khandpur et al., 2020; de Lacerda et al., 2020; Machado et al., 2020; Oliveira et al. 2020; Costa et al., 2021; Onita et al., 2021; Shim et al., 2021; Vedovato et al., 2021). One of the consequences of the excessive UPFs consumption is the deterioration of the quality of children's diet. It was observed that children who frequently consumed UPFs had a lower intake of n-3-polyunsaturated fatty acids, vitamins A, B12, C and E, calcium and zinc, but higher intake of sodium, sugar and trans-fatty acids, total lipid (Sparrenberger et al., 2015; Cornwell et al., 2018; Setyowati et al., 2018; Vandevijvere et al., 2019; Neri et al., 2019; Rauber et al., 2019; Machado et al., 2020). Although inappropriate eating behaviours in childhood may increase the risk of developing obesity (Wijnhoven et al., 2015), evidence linking UPFs consumption to anthropometric measures is inconsistent (Sparrenberger et al., 2015; Mais et al., 2018; Costa et al., 2019; de Lacerda et al., 2020; Oliveira et al., 2020; Costa et al., 2021). In Brazil, two study results suggest that there is no association between UPFs consumption and body mass index (Sparrenberger et al., 2015; Oliveira et al., 2020) nor waist circumference or waist-to-hip ratio in school-aged children (7-10 years) (Oliveira et al., 2020). On the other hand, a higher body mass index demonstrated greater risk of high UPFs consumption among children in Brazil aged 2-9 years (Mais et al., 2018) and children aged 8-12 years (de Lacerda et al., 2020). A longitudinal study suggests that excessive UPFs consumption in early childhood (4 years) may play a role in childhood obesity at the age 8 years (Costa et al., 2019) and that excessive UPFs consumption at school age is associated with adiposity in adolescence (Costa et al., 2021) and early adulthood (Chang et al., 2021). In addition, the results of a systematic review showed that there is a positive association between the UPFs consumption and body fat during childhood (Costa et al., 2018). These longitudinal studies confirm that eating behaviours in childhood can continue into adolescence and adulthood and increase the risk of developing obesity and other non-communicable diseases (Singh et al., 2008).

Since the results of recent studies that have observed the health consequences of consuming UPFs are inconclusive and limited, further research in this area is needed. In view of this, the objective of this study was to observe the proportion of processed foods in a diet of school-aged children and how it is related to sex, weight status and school meals consumption. It is also aimed to evaluate the impact of processed foods to overall diet quality with respect to the contribution of UPFs to total daily energy intake of school-aged children in Croatia.

Materials and methods

Participants and settings

This study was a cross-sectional observational study within “Pilot Project: School meals and fruit and vegetable intake in schools with and without a garden”, part of the Horizon 2020 project “Strengthening European Food Chain Sustainability by Quality and Procurement” (Strength2Food, H2020-SFS-2015-2, contract no. 678024). Permissions to conduct the pilot project in primary schools were obtained from Ethics Committee of the Institute for Medical Research and Occupational Health (100-21/16-8) and the Croatian Ministry of Science and Education and the Education and Teacher Training Agency (602-01/16-01/00388). The selection of schools was made according to the project protocol and is explained elsewhere (Colić Barić et al., 2021).

The study was designed according to the Declaration of Helsinki and approved by Ethics Committee of the School of Medicine, University of Zagreb (380-59-10106-19-11/307). All parents/caregivers were informed about the protocols of the study and gave their written consent. The study was conducted (2019/2020 school year) on a total of 681 children from 13 primary schools in Zagreb City and 1 school in Zagreb County. Out of 681 participants, who provided written informed consent, the study was based on 168 children (50.6% boys) aged 8.3 ± 0.5 years whose anthropometric characteristics were measured and who completed 3-day dietary records.

Anthropometric measurements

Anthropometric assessment was performed during Physical Education and Health classes and children wore light sportswear. Anthropometric assessment was carried out by a trained person and it included measurements of body weight and height. Body height was measured to the nearest 0.1 cm and body weight was measured to the nearest 0.1 kg using a combined medical digital scale and stadiometer (Seca, Type 877-217, Vogel & Halke Gmbh & Co., Germany). Body mass index (kg/m^2) was used to assess weight status and was calculated from height and body weight data. Age- and sex-standardised World Health Organisation z-scores for each child were obtained using AnthroPlus software (Blössner et al., 2009).

Dietary assessment

Food and beverage consumption as well as energy and nutrient intake were observed from dietary records on 3 non-consecutive days, 2 weekdays and 1 weekend day. Parents kept dietary records for their children and expressed the amount of foods and beverages consumed in grams by weighing or using standard kitchen measurements.

To estimate energy and nutrient intake, dietary records were analysed using the *Prehrana* software (Infosistem d.d, Zagreb, Croatia), which is based on Croatian food composition tables (Kaić-Rak and Antonić, 1990). For products that were not included in the food composition tables, the energy and nutrient content was taken from the nutrition information on the product labels or from the manufacturers.

All reported foods and beverages were classified into subgroups within the four groups according to the NOVA food classification system, based on the type, extent and purpose of industrial food processing (Monteiro et al., 2018b; Monteiro et al., 2019a; Monteiro et al., 2019b). The first NOVA food group, unprocessed or minimally processed foods (UMPFs), includes natural edible parts of plants (fresh, chilled, frozen, or dried fruits and vegetables; grains and pasta, groats, flakes and flour from grains; legumes; nuts and seeds; herbs and species) and animals (meat; poultry; fish), eggs (fresh, chilled or powdered), fungi, algae, drinking water (spring and tap water), fresh or pasteurised milk, yoghurt, and other minimally processed foods. The second NOVA food group, processed culinary ingredients (PCIs), includes salt, vegetable oils, lard, butter, sugar, molasses, honey and starch. The third NOVA food group, processed foods (PFs), includes products made by adding ingredients from the 2nd group, as well as products preserved by non-alcoholic fermentation, canning and bottling (e.g. canned or bottled fruits and vegetables; salted and sweet nuts and seeds; canned dried or smoked meats and fish; chesses; and freshly unpacked breads). The fourth NOVA food group, ultra-processed foods (UPFs), includes the formulations of ingredients that are mostly industrial, produced by a range of industrial processes. This group includes ready-to-eat products, pre-prepared and ready-to-heat products (e.g. carbonated, energy and soft drinks; confectionery, biscuits, pastries, cakes, packaged snacks and energy bars; milk-based sweet products; spreads and margarine; pre-packaged bread and rolls, breakfast cereals; instant soups and sauces; sausages, burgers, reconstituted meat products; mixed dishes such as pies, pizza and pasta dishes; infant formula, follow-on milk; meal replacement shakes). For each child, the relative energy intake of the groups and subgroups was calculated as a percentage of total daily energy intake (Monteiro et al., 2018b; Monteiro et al., 2019a; Monteiro et al., 2019b).

Statistical analysis

Data analysis was performed using IBM SPSS Statistics v. 23.0, released in 2015 (IBM SPSS Statistics for Windows, Armonk, NY, USA: IBM Corp.). The distribution of the data was tested using the Shapiro-Wilk normality test. Continuous data were expressed as a mean and standard deviation or median and interquartile range for normally distributed and non-normally distributed variables, respectively. All categorical variables were reported as percentages. Initially, differences in relative energy intake from four NOVA food groups were tested between boys and girls using an independent Student's T-test. Also, differences in relative energy intake from four NOVA food groups were tested between z-scores BMI-for-age categories and the number of consumed school meals using a one-way analysis of variance with post hoc Scheffe's test, while differences in proportion of energy from school meals were tested using Kruskal-Wallis test with post hoc Dunnett's test. For further analysis, all enrolled children were first divided into terciles according to total daily energy intake from UPFs with visual binning method, and then compared in their daily energy and nutrient intake using the Kruskal-Wallis test with post hoc Dunnett's test. For all analyses, the significance level was set at $p<0.05$.

Results

This study involved 168 school-aged children (8.3 ± 0.5 years) from the city of Zagreb and Zagreb Municipality. The children were almost equally boys (50.6%) or girls (49.4%).

Table 1. Basic characteristics of children in a sample[1]

Characteristic	Total of 168 children
Age (yr.)	8.3 ± 0.5
Sex:	
Male (%)	50.6
Female (%)	49.4
Body height (cm)	134.9 ± 5.6
z-score body height-for-age	0.84 ± 0.95
Body weight (kg)	30.6 ± 6.0
z-score body weight-for-age	0.68 ± 1.05
Body mass index (kgm^{-2})	16.7 ± 2.5
z-score body mass index-for-age	0.26 ± 1.14
Body mass index categories according to z-score body mass index-for-age:	
< - 1 (%)	12.8
- 1 – 1 (%)	65.4
> 1 (%)	21.8
The number of meals consumed by children at school:	
0 meal (%)	25.0
1 meal (%)	32.1
2 meals (%)	13.1
3 meals (%)	29.8

[1]All continuous variables are presented as mean ± standard deviation and categorical variables as percentages.

Table 1 shows the anthropometric characteristics of the children, which indicate that most of the children have an adequate weight status.

The results presented in Table 2 show that most of the daily energy intake came from UMPFs (38.1% kcal) and UPFs (38.1% kcal), followed by PFs (15.3% kcal) and PCIs (7.1% kcal). Within UMPFs, the major contributors of energy were milk and yoghurt, meat and poultry, and cereals, grains and flour. PCIs predominantly included plant oil and animal fats. PFs were dominated by fresh bread, cheese, and salted, smoked or canned meat and fish. Top three subgroups sources of daily energy from UPFs were biscuits, cakes and sweet bakery goods, confectionery, and milk-based products. The children consumed all the groups and subgroups listed in Table 2, but some of the subgroups such as fish, legumes, nuts and seeds, other PCIs, other PFs, bakery products, and other salty snacks and ultra-processed breads were consumed less frequently and in smaller quantities. Considering this and the statistical analysis used (median with interquartile range), it appears that these subgroups did not contribute to the daily energy intake, i.e. the median energy intake from these subgroups is 0 kcal.

In this study population, there was no difference in the consumption of NOVA food groups between the sexes (Table 3). Also, the results of this study show that children, regardless of their weight status (Table 3), had the same energy intake from all 4 food groups according to the NOVA food classification. In terms of the number of school meals (Table 4), children had similar energy intake from UMPFs, PFs, and UPFs.

However, children who ate 1 school meal had significantly ($p = 0.017$) lower energy intake (6.3 ± 3.3% kcal) from PCI compared with children who did not eat school meals (8.7 ± 4.3% kcal) and the same as children who ate 2 or 3 meals (7.4 ± 2.8% kcal, 7.9 ± 3.5% kcal, respectively).

From the results presented in Table 4 it is clearly seen that the children who ate 2 and 3 meals at school had a higher proportion of energy from all four NOVA food groups through school meals than students who ate only 1 meal or did not eat school meals.

Table 2. Average proportion of absolute and relative energy intake according to NOVA food groups and subgroups in sample (n=168)[1]

NOVA food groups and subgroups	kcal	% of total energy
UNPROCESSED OR MINIMALLY PROCESSED FOODS (UMPF)	**616 (501 – 765)**	**38.1 (31.7 – 45.9)**
Meat and poultry	129 (77 – 193)	7.9 (5.1 – 11.2)
Fish	0 (0 – 0)	0.0 (0.0 – 0.0)
Eggs	20 (0 – 60)	1.4 (0.0 – 3.4)
Fruits	69 (34 – 105)	4.2 (2.3 – 6.1)
Vegetables	12 (6 – 19)	0.7 (0.4 – 1.2)
Roots and tubers	36 (21 – 58)	2.1 (1.3 – 3.6)
Legumes	0 (0 – 12)	0.0 (0.0 – 0.7)
Nuts and seeds	0 (0 – 0)	0.0 (0.0 – 0.0)
Cereals, grains and flours	81 (39 – 123)	4.7 (2.5 – 7.6)
Pasta	57 (9 – 112)	3.7 (0.6 – 6.1)
Milk and yoghurt	133 (83 – 197)	8.1 (4.9 – 11.0)
Other[2]	2 (0 – 4)	0.1 (0.0 – 0.2)
PROCESSED CULINARY INGRIDIENTS (PCI)	**117 (83 – 159)**	**7.1 (4.8 – 9.5)**
Animal fat	20 (0 – 44)	1.0 (0.0 – 0.2)
Plant oil	80 (52 – 109)	4.6 (3.0 – 6.5)
Sugars	2 (0 – 11)	0.0 (0.0 – 0.7)
Other[3]	0 (0 – 0)	0.0 (0.0 – 0.0)
PROCESSED FOODS (PF)	**259 (198 – 369)**	**15.3 (11.9 – 21.6)**
Fresh bread	195 (127 – 269)	12.5 (7.7 – 15.4)
Plant food preserved in brine	2 (0 – 9)	0.1 (0.0 – 0.5)
Salted, smoked or canned meat and fish	8 (0 – 43)	0.4 (0.0 – 2.8)
Cheese	26 (0 – 59)	1.6 (0.0 – 3.3)
Other[4]	0 (0 – 0)	0.0 (0.0 – 0.0)
ULTRA-PROCESSED FOODS (UPF)	**616 (455 – 829)**	**38.1 (29.0 – 44.7)**
Bakery products	0 (0 – 104)	0.0 (0.0 – 6.7)
Biscuits, cakes and sweet bakery goods	88 (0 – 173)	5.0 (0.0 – 9.5)
Breakfast cereals	49 (0 – 98)	3.0 (0.0 – 5.8)
Chips cracker and other salty snacks	0 (0 – 54)	0.0 (0.0 – 3.2)
Confectionary	62 (0 – 122)	3.6 (0.0 – 7.2)
Milk-based products	60 (0 – 128)	3.4 (0.0 – 7.9)
Reconstituted meat and fish products	50 (19 – 101)	3.0 (1.3 – 5.5)
Spread and margarines	23 (0 – 54)	1.4 (0.0 – 3.3)
Ultra-processed bread	0 (0 – 0)	0.0 (0.0 – 0.0)
Frozen, canned and ready to eat meals	6 (0 – 51)	0.3 (0.0 – 3.1)
Soft drinks	13 (0 – 48)	0.8 (0.0 – 2.4)
Other[5]	9 (0 – 24)	0.6 (0.0 – 1.5)

[1]All continuous variables are presented as median (interquartile range).
[2]Including sea foods, yeasts, spring and tap water, teas, dried herbs and spices.
[3]Including salt, seasoning mixes with salt, vinegar and unsweetened cocoa powder.
[4]Including dried fruits, peanut butter, salted and roasted nuts and seeds.
[5]Including instant soups, read-to-eat sauces and wine.

Table 3. Differences in relative energy intake according to NOVA food groups between sex and body mass index categories[1]

Characteristics	Unprocessed or minimally processed foods - UMPF (% kcal)	Processed culinary ingredients - PCI (% kcal)	Processed foods - PF (% kcal)	Ultra-processed foods - UPF (% kcal)
Sex				
Male (n=85)	37.7 ± 10.4	7.0 ± 3.2	17.4 ± 7.4	37.9 ± 11.7
Female (n=83)	39.1 ± 9.7	8.0 ± 4.1	15.4 ± 7.0	37.5 ± 11.9
p value[*]	0.373	0.077	0.074	0.825
Body mass index categories according to z-score body mass index-for-age				
< - 1 (n=22)	37.9 ± 9.8	7.2 ± 3.7	15.8 ± 9.3	39.0 ± 12.1
- 1 – 1 (n=110)	38.6 ± 9.3	7.5 ± 3.8	16.7 ± 7.2	37.3 ± 11.5
> 1 (n=36)	38.4 ± 10.9	7.2 ± 3.7	16.2 ± 6.4	38.3 ± 11.3
p value[†]	0.963	0.885	0.137	0.245

[1]All continuous variables are presented as mean ± standard deviation.
[*]Difference between boys and girls was tested using an independent Student's T-test ($p<0.05$).
[†]Difference between z-scores BMI-for-age categories was tested using an one-way analysis of variance with post hoc Scheffe test ($p<0.05$).

Table 4. Differences in relative energy intake and proportion of energy from school meals according to NOVA food processing groups between the number of consumed school meals[1]

Number of consumed school meals	Unprocessed or minimally processed foods - UMPF (% kcal)	Processed culinary ingredients - PCI (% kcal)	Processed foods - PF (% kcal)	Ultra-processed foods - UPF (% kcal)
The relative daily energy intake				
0 meal (n=42)	39.9 ± 9.6	8.7 ± 4.3[a]	15.5 ± 7.2	35.8 ± 12.2
1 meal (n=54)	39.1 ± 11.5	6.3 ± 3.3[b]	15.0 ± 6.9	39.6 ± 12.6
2 meals (n=22)	36.7 ± 9.1	7.4 ± 2.8[ab]	17.9 ± 9.1	38.1 ± 12.9
3 meals (n=50)	37.1 ± 9.2	7.9 ± 3.5 [ab]	17.9 ± 6.3	37.1 ± 9.9
p value[*]	0.425	0.017	0.118	0.452
The proportion of energy from school meals				
0 meal (n=42)	0.0 (0.0 – 0.0)[a]	0.0 (0.0 – 0.0)[a]	0.0 (0.0 – 0.0)[a]	0.0 (0.0 – 0.0)[a]
1 meal (n=54)	2.2 (0.0 – 10.4)[a]	0.0 (0.0 – 11.9)[a]	6.2 (0.0 – 26.2)[b]	7.0 (0.0 – 14.9)[b]
2 meals (n=22)	31.5 (9.6 – 41.0)[b]	35.1 (5.0 – 46.7)[b]	37.1 (16.9 – 63.0)[c]	14.7 (4.4 – 38.1)[bc]
3 meals (n=50)	30.1 (17 – 41.0)[b]	32.6 (17.6 – 50.3)[b]	50.4 (33.9 – 64.5)[c]	29.9 (16.3 – 42.8)[c]
p value[†]	< 0.001	< 0.001	< 0.001	< 0.001

[1]Continuous data were presented as mean and standard deviation or median and interquartile range according to the normality distribution.
[*]Difference in relative daily energy intake between number of consumed school meals was tested using an one-way analysis of variance with post hoc Scheffe test ($p<0.05$). [a,b] Different superscript in the column indicate a difference between groups.
[†]Difference in proportion of energy from school meals between number of consumed school meals was tested using a Kruskal-Wallis test with post hoc Dunnett's test ($p<0.05$). [a,b,c] Different superscript in the column indicate a difference between groups.

Table 5. Difference in average daily energy and nutrient intake between children divided into terciles according to daily energy share of ultra-processed foods[1]

Dietary parameters	Tercile 1 (n=56) (10.2 – 32.0% kcal)	Tercile 2 (n=56) (32.1 – 41.7% kcal)	Tercile 3 (n=56) (41.7 – 70.9% kcal)	p value*
Energy (kcal)	1632 (1407 – 1835)	1712 (1360 – 2006)	1817 (1537 – 1980)	0.074
Macronutrients				
Proteins (g)	68.3 (59.4 – 80.3)	67.6 (55.7 – 82.9)	62.5 (56.0 – 72.4)	0.171
Plant protein (g)	21.5 (17.5 – 25.6)	23.3 (17.2 – 27.3)	23.4 (20.0 – 28.8)	0.318
Animal protein (g)	47.5[a] (41.2 – 53.8)	43.1[ab] (34.8 – 52.9)	40.5[b] (31.7 – 49.8)	0.009
Carbohydrates (g)	193.6[a] (157.6 – 221.0)	208.3[ab] (168.0 – 233.1)	233.8[b] (190.4 – 262.1)	0.003
Monosaccharides (g)	63.4 (47.6 – 72.1)	67.0 (51.5 – 81.4)	71.8 (54.8 – 90.9)	0.089
Polysaccharides (g)	92.0[a] (72.7 – 115.2)	82.6[ab] (62.8 – 99.3)	76.7[b] (54.3 – 93.0)	0.014
Dietary fibre (g)	15.1 (13.3 – 17.4)	15.9 (11.5 – 18.5)	14.6 (11.4 – 17.7)	0.686
Fat (g)	65.8 (53.6 – 82.6)	67.5 (52.3 – 79.8)	71.7 (59.4 – 91.3)	0.389
Saturated fatty acids (g)	27.0 (22.0 – 33.4)	28.0 (22.0 – 32.9)	28.6 (24.4 – 34.5)	0.586
Monounsaturated fatty acids (g)	20.3[a] (15.2 – 25.5)	16.8[ab] (12.7 – 22.5)	15.5[b] (11.3 – 18.4)	< 0.001
Polyunsaturated fatty acids (g)	12.3[a] (9.9 – 16.1)	11.5[ab] (8.1 – 13.6)	10.7[b] (8.4 – 13.2)	0.043
Cholesterol (g)	292.1[a] (157.6 – 441.0)	187.2[ab] (133.1 – 351.9)	160.7[b] (97.7 – 284.2)	< 0.001
Minerals				
Sodium (mg)	3261.02 (2672.36 – 3890.86)	29991.53 (2523.56 – 3660.30)	3229.56 (2552.52 – 3857.24)	0.376
Potassium (mg)	2282.03[a] (2000.90 – 2666.57)	1985.80[ab] (1629.83 – 2428.39)	1793.65[b] (1451.15 – 2211.12)	< 0.001
Calcium (mg)	684.33 (609.89 – 813.93)	632.07 (520.87 – 815.89)	630.22 (483.14 – 754.58)	0.054
Magnesium (mg)	121.66[a] (106.34 – 148.63)	121.32[a] (100.61 – 158.69)	109.43[b] (81.71 – 134.07)	0.006
Phosphorous (mg)	1015.40[a] (826.53 – 1167.40)	905.59[ab] (738.59 – 1092.93)	784.22[b] (621.61 – 971.86)	< 0.001
Iron (mg)	8.15 (6.42 – 10.30)	7.44 (5.99 – 9.39)	6.57 (5.41 – 8.60)	0.363
Zinc (mg)	3.10 (2.53 – 3.53)	2.72 (2.05 – 3.31)	2.72 (2.03 – 3.14)	0.225
Copper (mg)	1.91[a] (0.99 – 2.89)	2.41[b] (1.79 – 3.61)	2.03[ab] (1.09 – 3.16)	0.014
Vitamins				
Vitamin A (µg RE)	578.23[a] (382.49 – 727.54)	594.21[a] (420.28 – 783.42)	442.07[b] (289.62 – 638.01)	0.027
Thiamine (mg)	0.79 (0.67 – 1.03)	0.76 (0.59 – 0.93)	0.78 (0.53 – 1.13)	0.443
Riboflavin (mg)	1.09 (0.93 – 1.36)	1.10 (0.76 – 1.27)	1.00 (0.72 – 1.35)	0.200
Niacin (mg)	12.45 (10.33 – 14.95)	12.37 (10.89 – 14.29)	10.81 (7.14 – 14.45)	0.079
Pyridoxine (mg)	1.11 (0.84 – 1.41)	1.09 (0.82 – 1.31)	0.91 (0.64 – 1.27)	0.152
Vitamin C (mg)	78.74 (52.06 – 107.48)	71.77 (46.75 – 112.33)	71.60 (43.74 – 89.96)	0.529

[1]*All continuous variables are presented as median (interquartile range).*
[*]*Differences between categories were tested using an Kruskal-Wallis test (p<0.05).* [a,b] *Different superscript in row indicate difference among groups teste using Dunnett's test (p<0.05)*

Table 5 shows the comparison of daily energy and nutrient intake in children, divided into terciles according to the energy share of the UPFs. From the results, the minimum daily energy share from UPFs was 10.2% kcal and the maximum was 70.9% kcal. Although the daily energy intake was the same in all terciles of children, most of the nutrient intake decreased as the energy share of UPFs increased. The results show that children in the 1st tercile had significantly higher intake of animal protein ($p=0.032$), polysaccharides ($p=0.014$), monounsaturated fatty acids ($p<0.001$), polyunsaturated fatty acids ($p=0.049$), cholesterol ($p<0.001$), potassium ($p<0.001$) and phosphorus ($p=0.001$), compared to children in the 3rd tercile. On the contrary, children from the 1st terciles had lower intake of carbohydrates ($p=0.002$) than children from the 3rd tercile and less copper ($p=0.033$) than children from the 2nd tercile. Magnesium and vitamin A intake were significantly higher in children from the 1st ($p=0.007$ and $p=0.046$, respectively) and the 2nd tercile ($p=0.005$ and $p=0.036$, respectively), compared to the children from the 3rd tercile.

Discussion

This is the first study to observe the food consumption of Croatian school-aged children according to the NOVA food classification. The main findings were that nearly 40% of the energy intake of school-aged children comes through the consumption of UMPFs as well as UPFs. The consumption of foods according to NOVA food classification was not influenced by sex and weight status, which complements existing studies on this topic. According to the available literature, this is the first study to observe differences in energy intake from NOVA food classification in relation to the number of school meals consumed in children. The present study provides additional insight into the effects of UPFs consumption on overall nutrition.

In this study, the average daily energy intake of the children (n=168; 8.3 ± 0.5 years) was 1706 kcal (IQ 1428 - 1920 kcal). UMPFs (38.1% kcal) and UPFs (38.1% kcal) contributed the most to daily energy intake, followed by PFs (15.3% kcal) and PCIs (7.1% kcal). Although in most previous studies the energy content of UPFs in children was more than 30%, differences in the energy share of UPFs were found between middle- and high-income countries. Accordingly, the children from middle-income countries and countries with traditional dietary patterns such as Brazil (Sparrenberger et al., 2015; Oliveira et al. 2020; de Lacerda et al., 2020; Costa et al., 2021), Mexico (Marrón-Ponce et al., 2018), Chile (Cediel et al., 2018), Portugal (Vedovato et al., 2021), Colombia (Khandpur et al., 2020), Indonesia (Khandpur et al., 2020), Belgium (Vandevijvere et al., 2019), and Korea (Shim et al., 2021) have a diet based on UMPFs, and UPFs contribute between 15.9% and 47% to their daily energy intake. However, the children from high-income countries (United Statas of America, United Kingdom, Australia and Canada) have Western dietary patterns, dominated by mass-produced foods with UPFs, contributing 53.1% to 66.2% to their total energy intake (Rauber et al., 2015; Moubarac et al., 2017; Balardi et al. 2018; Neri et al., 2019; Rauber et al. 2019; Machado et al., 2020; Onita et al., 2021). The results of this study, indicating the daily energy intake of a specific subgroups, show that in UMPFs the main sources of energy were milk and yoghurt (8.1% kcal), meat and poultry (7.9% kcal) and cereals, grains and flour (4.2% kcal). These findings are consistent with previous studies (Setyowati et al., 2018; Neri et al., 2019; Machado et al., 2020; Oliveira et al., 2020), while Vandevijvere et al. (2019) found that children in Belgium had higher consumption of fruits (23.5 - 25.2% kcal) and pasta, rice and other grains (20.8 - 23.7% kcal). As shown by the results of this study, plant oils (4.6% kcal) and animal fats (1.0% kcal) were the main contributors to daily energy intake from PCIs, as in the studies of Neri et al. (2019) and Machado et al. (2020). According to Oliveira et al. (2020), the main energy sources were bread, cheese and sugar, but the authors observed the categories of PCIs and PFs together. In recent studies, it was observed that cheese and fresh bread were the subgroups of PCs with the highest energy share (Setyowati et al., 2018; Neri et al., 2019; Macahdo et al., 2020), which is also the case in this study. The three main subgroups contributing to the daily energy from UPFs were biscuits, cakes and sweet bakery products (5.0% kcal), confectionery (3.6% kcal) and milk-based products (3.4% kcal). According to the existing literature, one of the three main contributors to daily energy intake were sweet biscuits and cakes, but other contributors to this group depend on the eating habits of the study population. In the United States of America (Neri et al., 2019) and Australia (Macahdo et al., 2020), the dominant source of daily energy intake were mass-produced breads (10.0% kcal and 5.2% kcal, respectively), while in Brazil (Oliveira et al., 2020) and Belgium (Vandevijvere et al., 2019) those were reconstituted meat products (4.42% kcal and 12.0 - 12.9% kcal, respectively) among other consumed foods from UPFs. It should be noted that these studies used different methodology to collect food and beverage consumption data when assessing the energy contribution of UPFs in children of different age groups and socioeconomic characteristics. The differences could also be due to the fact that the foods were divided into subgroups that differed according to the dietary habits of the study population. According to the World Bank country classification, Croatia was classified as a high-income country in the year the study was conducted (Hamadeh et al., 2021; Eorld Bank Group, 2021). However, the results of the present study suggest that the children had similar dietary habits to the children from middle-income countries and countries with traditional dietary patterns. The reason could be that in Croatia the consumption of "cooked meals" in the family or in the school canteen still prevails over the consumption of "fast food concepts" (Čačić Kenjerić and Sokolić, 2021). Nevertheless, national action in the form of a reduction in energy intake from UPFs is needed, especially because an increase in energy intake from UPFs and a decrease from UMPFs have been observed in children and adolescents in America over 19 years (Wang et al., 2021).

In this study, sex, weight status, and the number of consumed school meals were hypothesized as potential risk factors that could influence processed foods consumption. However, no differences were found according to sex in the consumption of all four NOVA food groups, which is consistent with previous studies in Brazilian children in different age groups: 6-11 years old (Azeredo et al., 2020); aged 2 to 9 years (Mais et al., 2018) and aged 8 to 12 years (de Lacerda et al., 2020). Furthermore, children with different weight status had the same energy intake from all 4 groups according to the NOVA food classification. The results of previous studies that observed an association between anthropometric measurements and UPFs consumption are inconclusive. Two studies in Brazilian population aged 2-10 years (Sparrenberger et al. 2015) and 6-10 years (Oliveira et al. 2020) found no association between consumption of UPFs and body mass index, while higher body mass index was a risk factor for higher consumption of UPFs in children in Brazil aged 2-9 years (Mais et al., 2018) and 8-12 years (de Lacerda et al., 2020). Accordingly, further research is needed in this area, as longitudinal studies show that higher energy intake from UPFs in childhood can lead to obesity in adolescence and early adulthood (Costa et al., 2019; Costa et al., 2019; Chang et al., 2021). In terms of the number of school meals, it was hypothesised that children who ate more school meals had higher energy intake from UMPFs and lower energy intake from UPFs compared to the children who had no school meals or had only 1 meal. However, in this study population, energy intake from UMPFs, PFs, and UPFs was similar, but the children who had 1 school meal had significantly lower energy intake (6.28 ± 3.31% kcal) from PCIs compared with children who had no school meals (8.66 ± 4.29% kcal), while it was the same with the children who had 2 or 3 meals (7.41 ± 2.82% kcal and 7.90 ± 3.52% kcal, respectively). It is interesting to highlight that the children who had 2 and 3 school meals had a higher proportion of energy intake from UPFs (14.7% and 29.9%, respectively) from school meals than children who ate no school meals or only 1 meal, but it should be noted that this proportion was lower compared to UMPFs, PCIs, and PFs. These results suggest that meals in Croatian schools were mostly prepared with less processed foods and children consumed more energy from UPFs from other meals than from school meals. According to the available literature, this is the first study to observe differences in energy intake from foods according NOVA food classification in relation to the number of school meals consumed in children. This information is important because it indicates the quality of the school meals and 75% of children consume at least one of the school meals in Zagreb City and Zagreb municipality. The results of this study may be due to the fact that the consumption of processed foods is observed in relation to the number of school meals consumed, but not to the type of meals. Namely, the children who ate 1 school meal could eat breakfast or lunch. Different types of meals (breakfast *vs.* lunch) require different types of processed foods used in meal preparation. Therefore, it is suggested that future studies consider the intake of energy from processed foods in relation to the type of school meals.

When the children from this study were divided into terciles according to the proportion of total energy intake from UPFs, it was found out that the most nutrient intake decreased as the proportion of energy from UPFs increased, although total daily energy intake remained the same in all terciles. Children in the 3rd tercile had lower intake of animal protein, polysaccharides, monounsaturated fatty acids, polyunsaturated fatty acids, cholesterol, potassium, and phosphorus than children in the 1st tercile. In addition, children in the 3rd tercile had lower magnesium and vitamin A intake compared to children in the 1st and 2nd terciles. In contrast, children from the 3rd tercile had higher carbohydrates intake than children from the 1st tercile and lower copper intake (p=0.033) than children from the 2nd tercile. Similarly, in Columbian children (5-12 years) it was estimated that higher consumption of UPFs is associated with lower intake of n-3 polyunsaturated fatty acids, vitamins A, B12, C and E, calcium and zinc, but higher intake of sodium, sugar and trans fatty acids (Cornwell et al., 2018). The results of a Brazilian study (children aged 2-10 years) suggest that higher consumption of UPFs contributes to higher intake of fats, carbohydrates, sodium and trans fatty acids and lower intake of proteins, fibres and monounsaturated fatty acids (Sparrenberger et al., 2015). In Jakarta (children aged 5-12 years), higher consumption of UPFs may lead to higher intake of energy, fat, sodium and sucrose (Setyowati et al., 2018), while in Belgium (children aged 6-9 years), it leads to higher intake of saturated fat and fat. Few studies have found a positive association between higher consumption of UPFs and added sugars (Neri et al., 2019; Rauber et al., 2019; Machado et al., 2020).

This is the first study to describe the consumption of NOVA food groups among children in Croatia, namely in the City of Zagreb. To our knowledge, it is also the first study to observe differences in energy intake from NOVA food groups between children who ate school meals. The study included a smaller sample of children, which implies caution in the generalisation of the results. Due to the cross-sectional design of the study, a causal relationship between UPFs consumption and socio-demographic, anthropometric or lifestyle factors cannot be established. A limitation in the data analysis is the use of the national food composition tables and nutrition declaration to assess dietary intake, as data are not available for several vitamins and minerals, which may lead to the underestimation of nutrients. However, the strength of this study is that food and beverage consumption data were collected based on 3-day dietary records that included both school meals and meals at home.

Conclusions

This study shows that the energy intake of school-aged children comes equally from the unprocessed or minimally processed food group and the ultra-processed food group. The consumption of all four NOVA food groups did not differ neither between boys and girls nor between children of different weight status. The consumption of school meals may encourage the consumption of unprocessed or minimally processed foods and processed culinary ingredients. However, there is a need to reduce the intake of processed and ultra-processed foods through school meals. The children had the same daily energy intake regardless of the proportion of daily energy from ultra-processed foods. Meanwhile, the children with the highest daily energy intake from ultra-processed foods had lower intake of certain nutrients, which may contribute to poor overall nutrition. Further research is needed to establish the factors which may contribute to the consumption of ultra-processed foods in order to take action for reducing the intake of these foods.

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