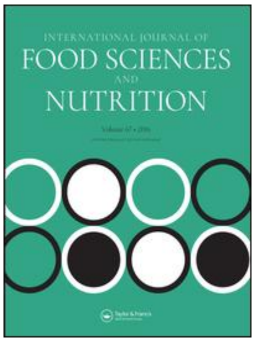

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RESEARCH ARTICLE

Comprehensive dietary evaluation of Italian primary school children: food consumption and intake of energy, nutrients and phenolic compounds

Alice Rosi[a], Pedro Mena[a], Fabio Castello[a], Daniele Del Rio[b,c] and Francesca Scazzina[a,c]

[a]Human Nutrition Unit, Department of Food and Drugs, University of Parma, Parma, Italy; [b]Human Nutrition Unit, Department of Veterinary Science, University of Parma, Parma, Italy; [c]Giocampus Scientific Committee, Parma, Italy

ABSTRACT

Information on children's diet including bioactive compounds is quite scarce. This observational study investigated the composition of the diet of children living in Parma (Italy; $n = 172$, 8–10 years) using 3-day food records completed in winter and spring. Mean daily intakes of food groups, energy and nutrients were obtained using the national food database, while (poly)phenol contents were estimated from Phenol-Explorer or by specific literature searches. Food consumption, energy and nutrient intakes decreased in spring and were partially in line with national data. Adherence to the nutritional recommendations was not satisfied for the majority of nutrients. Main contributors to the phenolic intake were flavonoids (flavan-3-ols) and phenolic acids (hydroxycinnamic acids), while main dietary sources were fruit, chocolate-based products, vegetables, and tea & coffee (decaffeinated). This study provided the first comprehensive analysis of the nutritional composition of children's diet. Future research should look at the health implications of dietary choices in children.

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Primary school students; dietary intake; food source; vitamin; mineral; polyphenol

Introduction

Worldwide, children and adolescents are at high risk of being overweight or obese, as well as underweight, all conditions associated with unfavourable health consequences during their entire life (Abarca-Gómez et al. 2017). The latest data from the Health Behaviour in School-aged Children study reported 11–33% prevalence of overweight and obesity for children aged 11 years (Currie et al. 2014). Similarly, 16–48% of overweight and obesity prevalence has been reported for 6–9 years old European children enrolled in the WHO European Childhood Obesity Surveillance Initiative, with the highest rates in Southern European countries (Greece, Spain and Italy) (Spinelli et al. 2019). In addition to overweight and obesity, Europe faces a double burden of malnutrition with a concurrent high prevalence of nutrient deficiencies (WHO 2015). Environmental factors, in particular unhealthy diets, have been recognized as paramount to lead to malnutrition in Europe, in terms of both overnutrition and nutrient deficiencies (Afshin et al. 2019). Therefore, besides monitoring the body composition of children and adolescents, carefully evaluating diet and food habits is an essential part of health surveillance (Wilkinson et al. 2007).

Although dietary intakes are difficult to measure accurately in free-living young populations, there is a need for epidemiological data on food habits to better investigate the relationship between diet and health, to define evidence-based nutritional guidelines, and to plan health promotion preventive programmes (WHO 2015). Several surveillance programmes have been carried out during the last decades in European children and adolescents. Among all, the Health Behaviour in School-aged Children survey (HBSC), the WHO European Childhood Obesity Surveillance Initiative (COSI), and the Healthy Lifestyle in Europe by Nutrition in Adolescence study (HELENA) are likely those having the greatest relevance. Italy was involved in all these surveys, but the last national food consumption survey was carried out in 2005–2006 (Leclercq et al. 2009; Sette et al. 2011). This and previous Italian surveys (Saba et al. 1990; Turrini et al. 2001) have been essential to describe food consumption patterns and to monitor the nutritional status of

CONTACT Francesca Scazzina francesca.scazzina@unipr.it Department of Food and Drugs, University of Parma, Via Volturno 39, 43125 Parma, Italy.
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the Italian population. However, in Italy, the food consumption pattern has been transformed quickly during the past decade, due to several economic, social and environmental changes able to affect dietary habits, especially in the young population (Leclercq et al. 2009).

Moreover, the link between human health and dietary choices involves other non-nutritive compounds present mostly in plant foods. Among these, it looks like (poly)phenols might be good candidates to describe some of the preventive properties of a diet rich in fruits and vegetables (Del Rio et al. 2013; Rodriguez-Mateos et al. 2014; Potì et al. 2019). Unlike nutrients, (poly)phenols are not considered essential for reaching the full genetically determined lifespan, since they do not cause classical deficiencies (Williamson and Holst 2008). However, (poly)phenols have been recognised to have beneficial effects on human health, protecting against several chronic diseases such as cardiovascular diseases, type 2 diabetes, neurodegeneration, and some types of cancer (Vauzour et al. 2010; Del Rio et al. 2013; Rodriguez-Mateos et al. 2014; Tresserra-Rimbau et al. 2014; Zanotti et al. 2015; Vitale et al. 2017; García-Conesa et al. 2018; Potì et al. 2019). To date, the evidence linking major health outcomes and (poly)phenol intake in a context of habitual diet is limited if considering only prospective epidemiological studies. Despite some epidemiological data on the intake of (poly)phenols are available in adults (Pérez-Jiménez et al. 2011; Grosso et al. 2014; Zamora-Ros et al. 2016), habitual consumption among children and adolescents has been scarcely investigated worldwide (Rossi et al. 2018; Ziauddeen et al. 2019). Therefore, the collection of additional population data along different life stages is needed to further explore the prospects of (poly)phenols on human health. Despite some recent studies trying to fill the gap by assessing energy and nutrient intake in some Italian school age healthy child cohorts (Hebestreit et al. 2017; Verduci et al. 2019; Ruggiero et al. 2019), there is a fundamental lack of works investigating the (poly)phenol contents of Italian children's diet.

In keeping all these considerations, this is the first survey aimed at describing the diet of Italian primary school children during the entire school year, considering both food consumption and daily intakes of energy, macronutrients, vitamins, minerals and (poly)phenols. To the best of our knowledge, there are no studies reporting Italian children's diet in such a comprehensive way.

Materials and methods

Study population and design

This observational study was carried out involving 220 third and fourth grade primary school children (8–10 years old) participating in the Giocampus school programme (Rosi et al. 2016) in Parma (North Italy). Data were collected during two different weeks, one in winter (December–January) and one in spring (April–May).

Before acceptance, both teachers and parents were informed about the study procedures and methods. Participants' parents/legal tutors provided a written informed consent, while children provided their oral informed assent. The study was performed in compliance with the Helsinki declaration and was approved by the Ethical Committee of the University of Parma (Prot. 5351).

Dietary assessment and energy, nutrients and (poly)phenol intakes

Dietary intakes were assessed using a 3-day weighed dietary record adapted for children. Each child completed the food diary twice during three consecutive days (2 weekdays and a weekend day), with the help of parents and teachers. They were asked to record all food and beverages consumed (excluded water) with portion sizes in grams/millilitres or using household measures (e.g. spoon, glass, cup) or, as in the case of food consumed at school, reporting the entire or submultiples of the standard portion served during lunch. Recipes or complex foods including various ingredients were broke up into individual raw foods considering the corresponding proportion in the dish.

Mean daily intakes of food groups, energy and nutrients were obtained matching the raw food univocally to those contained in the Food Composition Database for Epidemiological Studies in Italy (Gnagnarella et al. 2015). The food groups are described in Supplementary Table 1. Only vitamins (A, B1, B2, B3, B6, B9, C, D and E) and minerals (calcium, sodium, potassium, phosphorus, zinc, and iron) with complete data for all the food items consumed were considered, to avoid underestimation of those not well represented in the Italian database.

Mean daily intakes of (poly)phenolic compounds belonging to the flavonoid and phenolic acid classes (anthocyanins, flavan-3-ols—both monomers and proanthocyanidins—, flavanones, flavones, flavonols, isoflavones, theaflavins, chalcones, hydroxybenzoic acids, hydroxycinnamic acids, and hydroxyphenylpropanoic acids), as well as stilbenes and total phenol content through the Folin assay method were estimated from the Phenol-Explorer database on polyphenol content in foods (Neveu et al. 2010). As for energy and nutrients, raw foods were matched univocally to those included in the Phenol-Explorer database. In the case of foods missing in Phenol-Explorer, values were obtained from the most similar food or by specific literature searches. Weight changes during cooking and/or processing were taken into account by applying yield factors obtained from Bognar's tables (Bognar 2002) or from Phenol-Explorer (Rothwell et al. 2013). Moreover, the mean daily total (poly)phenol intake was calculated as the sum of all individual (poly)phenolic compounds.

Anthropometric measurements

Anthropometrics were measured at the beginning of each assessment period, according to the WHO guidelines (WHO 1995). Height was measured to the nearest 100 mm using a portable stadiometer, while body weight was measured to the nearest 100 g by using an electronic scale in order to calculate the BMI and define the weight status through the International Obesity Task Force sex- and age-specific cut-offs for children BMI (Cole and Lobstein 2012).

Statistical analysis

Since primary school students in Parma aged 8–10 years are around 2500–3000, we estimated that the study population should be composed of at least 130 children (90% level of confidence and 7% marginal error) to be representative of the entire study population.

Data are expressed as mean ± standard deviation (SD) or as median (interquartile range) for continuous variables or as absolute frequencies/percentages for categorical variables. Descriptive statistics were performed to explain participants' diet and compare data to the national nutritional recommendations (SINU 2014). The normality of data distribution was checked through the Kolmogorov–Smirnov test. Between season differences were investigated using the paired sample *t*-Test for normally distributed variables (energy and nutrients) or the non-parametric Wilcoxon Signed Ranks Test for paired samples for non-normally distributed variables (anthropometrics, food groups and (poly)phenolic compounds). The Statistical Package for Social Science SPSS 25.0 (SPSS Inc, Chicago, IL) was used to perform all the statistical analyses, keeping the significance at $p < 0.05$.

Results

Participants' characteristics

Of the 220 eligible students, 204 produced the parents' written informed consent to participate and were enrolled in the study (response rate 93%). Thirty-two children did not fill both diaries or had missing dietary data so they were excluded from the analysis. A final sample of 172 children (52% females, 48% males, 8–10 years old) completed the study. Anthropometric measurements remained similar between the two seasons, with the mean BMI corresponding to a normal weight status (78% under-normal weight, 15% overweight and 7% obese).

Food group, energy and nutrient intakes

Food consumption data are presented in Table 1, by seasons. A decrease in food consumption was reported during spring for juices ($p = 0.010$), fruit ($p < 0.001$), vegetables ($p = 0.006$), bread and substitutes ($p < 0.001$), fish and shellfish ($p < 0.001$) and cocoa-based products ($p = 0.008$). On the contrary, an increased intake during spring was observed only for meat ($p < 0.001$) and legumes ($p = 0.001$).

In line with these results, a lower intake of energy and nutrients was observed during spring (Table 2). The mean daily energy intake decreased from 1575 kcal in winter to 1435 in spring ($p < 0.001$). This lower energy intake was due to a small but significant decrease in protein ($p = 0.032$), total fat ($p = 0.007$) and total carbohydrate ($p < 0.001$) intakes. The mean contribution to total energy were 14, 29 and 59% during winter and 15, 30 and 57% during spring for proteins, total fats and available carbohydrates, respectively. When nutrient intakes were compared to the national recommendations for 7–10 years old children (Figure 1), more than 90% of participants were found to have a mean daily protein intake above the recommended intake in both seasons. On the contrary, the majority of children had an adequate intake for total fats (92% in winter and 86% in spring) and polyunsaturated fatty acids (61 and 56% for winter and spring, respectively), but more than 50% consumed saturated fatty acids above the recommendation levels. Similarly, 60 and 67% of participants reached the recommended intake of carbohydrates during winter and spring, respectively, but sugar intake was above the recommended amount for more than 80% of children in both seasons. The daily intake of fibre was found to be below the recommendations

Table 1. Food group intakes (g/day) by seasons.

Food group (g/day)	Winter	Spring	*p* Value
Non-alcoholic beverages	0.0 (0.0–110.0)	0.0 (0.0–38.6)	0.092
Juices	66.7 (0.0–133.3)	0.0 (0.0–66.7)	0.010
Fruit	112.6 (59.2–189.5)	81.9 (36.7–143.5)	0.000
Nuts	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.064
Vegetables	90.0 (48.8–136.2)	77.8 (42.6–125.5)	0.006
Spices and aromatic herbs	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.100
Potatoes	26.7 (0.0–46.0)	17.5 (0.0–55.7)	0.885
Pasta and cereals	90.3 (72.8–109.1)	86.1 (63.5–107.8)	0.066
Bread, substitutes and pizza	102.2 (46.6–153.5)	73.0 (36.7–119.2)	0.000
Breakfast cereals	0.0 (0.0–10.0)	0.0 (0.0–10.0)	0.630
Legumes	0.0 (0.0–0.0)	0.0 (0.0–10.0)	0.001
Fish and shellfish	30.0 (0.0–45.8)	0.0 (0.0–30.0)	0.000
Meat	30.3 (13.3–53.3)	46.7 (23.3–76.7)	0.000
Cured meat	16.7 (4.3–31.3)	16.2 (0.0–26.7)	0.193
Eggs	3.3 (1.2–16.4)	2.3 (0.0–18.3)	0.791
Milk and yogurt	125.0 (84.6–166.7)	125.0 (82.1–154.2)	0.151
Dairies	14.3 (6.7–28.0)	14.3 (7.7–27.6)	0.506
Animal fats	0.0 (0.0–1.3)	0.0 (0.0–1.0)	0.048
Vegetable oils and fats	13.0 (9.7–16.6)	13.0 (9.6–15.8)	0.430
Desserts	52.7 (38.8–82.5)	52.0 (31.7–76.2)	0.071
Cocoa-based products	3.3 (0.0–10.9)	1.9 (0.0–8.3)	0.008
Tea and coffee (decaffeinated)	0.0 (0.0–3.7)	0.0 (0.0–0.0)	0.019
Others	55.0 (0.0–91.7)	33.3 (0.0–74.2)	0.023

Values are presented as median (interquartile range). *P* value was calculated by using the Wilcoxon Signed Ranks test for paired samples.

Table 2. Intake of energy (kcal/day) and nutrients (mg/day or µg/day) by seasons.

Food group	Winter	Spring	*p* Value
Energy (kcal/day)	1575.0 ± 307.5	1434.6 ± 277.6	0.000
Protein (g/day)	55.3 ± 12.6	53.0 ± 12.7	0.032
Total fat (g/day)	50.6 ± 13.0	47.9 ± 12.6	0.007
Cholesterol (mg/day)	188.8 ± 74.8	180.4 ± 76.7	0.253
SFA (g/day)	18.2 ± 5.2	17.1 ± 5.3	0.016
MUFA (g/day)	22.9 ± 5.8	21.8 ± 5.6	0.015
PUFA (g/day)	5.8 ± 2.0	5.5 ± 1.7	0.036
Available carbohydrate (g/day)	232.2 ± 49.5	204.9 ± 44.3	0.000
Sugars (g/day)	79.8 ± 24.1	67.9 ± 22.9	0.000
Fibre (g/day)	13.8 ± 4.1	11.9 ± 3.5	0.000
Vitamin B1 (mg/day)	0.8 ± 0.3	0.8 ± 0.2	0.001
Vitamin B2 (mg/day)	1.0 ± 0.3	0.9 ± 0.2	0.000
Vitamin B3 (mg/day)	10.9 ± 3.5	11.0 ± 3.9	0.766
Vitamin B6 (mg/day)	1.3 ± 0.3	1.2 ± 0.3	0.002
Vitamin B9 (µg/day)	205.5 ± 65.5	169.0 ± 53.0	0.000
Vitamin C (mg/day)	93.1 ± 47.3	70.9 ± 45.3	0.000
Vitamin A - Ret eq. (µg/day)	599.2 ± 371.0	554.2 ± 379.8	0.226
Vitamin E - ATE (mg/day)	6.9 ± 1.9	6.4 ± 1.8	0.002
Vitamin D (µg/day)	1.3 ± 0.9	1.1 ± 0.9	0.205
Calcium (mg/day)	503.2 ± 171.6	481.2 ± 172.8	0.135
Sodium (mg/day)	1844.0 ± 809.7	1543.6 ± 630.2	0.000
Potassium (mg/day)	1966.9 ± 509.1	1743.6 ± 458.2	0.000
Phosphorus (mg/day)	864.1 ± 199.0	804.9 ± 191.1	0.001
Zinc (mg/day)	7.3 ± 1.6	6.9 ± 1.6	0.002
Iron (mg/day)	6.8 ± 1.8	6.3 ± 1.8	0.001

Values are presented as mean ± SD. *P* value was calculated by using the *t*-test for paired samples. MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; SFA: saturated fatty acids.

for the 40% of participants in winter and up to 55% in spring.

As a consequence of the lower food consumption during spring than in winter, vitamin and mineral intakes significantly decreased over time, except for vitamin B3, vitamin A, vitamin D and calcium, which remained unchanged (Table 2). The recommended intake for 7–10 years old Italian children was not reached for vitamin B3, vitamin B9, vitamin E and vitamin D in both seasons, while for minerals, children had an intake above the recommendations for sodium (Figure 2).

(Poly)phenolic compound intakes

The intake of total (poly)phenols, total flavonoids, total phenolic acids and (poly)phenol subclasses is presented in Table 3. The median daily intake of total

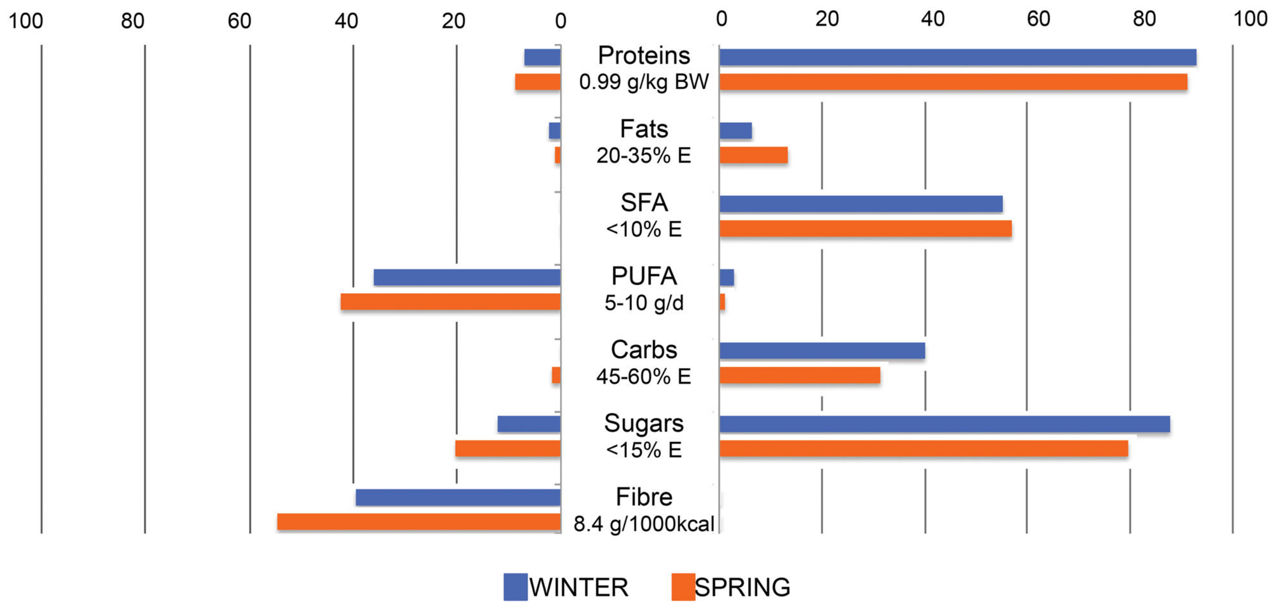

Figure 1. Nutrient intakes compared to the Italian nutritional recommendations for children aged 8–10 years (SINU 2014). Left: percentage of children below the recommended intake; right: percentage of children above the recommended intake. The percentage of children within the recommended intake is the difference between 100% and the sum of children below or above the recommendations. Carbs: available carbohydrates; PUFA: polyunsaturated fatty acids; SFA: saturated fatty acids.

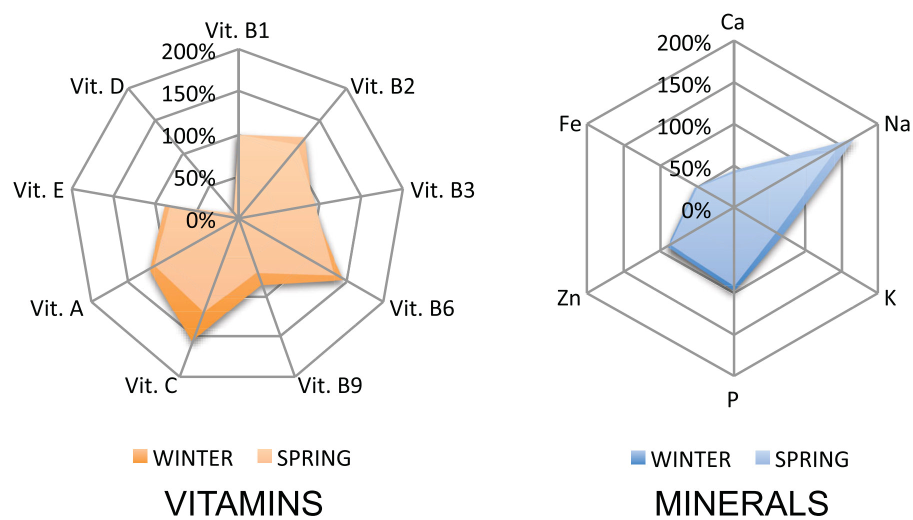

Figure 2. Vitamin and mineral relative intakes compared to the recommended values (centre line corresponding to the 100%) for Italian children aged 8–10 years (SINU 2014).

phenol estimated by the Folin assay was 777 mg/day in winter and 621 mg/day in spring ($p < 0.001$). Similarly, the median daily intake of total (poly)phenols was lower in spring than in winter (192 and 226 mg/day, respectively, $p = 0.009$). Total flavonoids contributed to the total (poly)phenol intake by 80% in winter and 76% in spring, while the total phenolic acids for 20 and 24%, respectively (Figure 3). The total flavonoid intake decreased significantly in spring ($p = 0.001$), while total phenolic acid consumption remained similar between the two seasons. Flavonoid subclasses decreased over time, except for minor dietary flavonoids like isoflavones and chalcones. The main contributors to total flavonoids were flavan-3-ols in both seasons (Figure 3), which accounted for around 77% of mean total flavonoids and up to 60% of the mean total (poly)phenol intake. The second most important (poly)phenol subclass was hydroxycinnamic acids, accounting for around 89% of mean total phenolic acids and 20% of mean total (poly)phenol intake. On the contrary, the intake of isoflavones, chalcones, hydroxyphenylpropanoic acids and

Table 3. Intake of total (poly)phenols and (poly)phenol subclasses (mg/day) by seasons.

Compounds (mg/day)	Winter	Spring	*p* Value
Total phenols (Folin assay)	776.7 (563.1–945.6)	621.0 (441.6–820.0)	0.000
Total (poly)phenols[a]	226.3 (145.2–315.6)	192.3 (110.4–285.5)	0.009
Total flavonoids[b]	182.1 (112.7–257.3)	145.6 (78–229.3)	0.001
Flavan-3-ols	137.7 (66.9–210.6)	104.2 (50.2–179.7)	0.013
Flavanones	1.9 (0.8–25.2)	1.2 (0.7–3.3)	0.004
Flavones	6.4 (4.2–10)	5.3 (3.6–7.8)	0.006
Flavonols	7.8 (2.3–24.6)	3.8 (1.6–8.7)	0.000
Isoflavones	0.0 (0.0–0.4)	0.0 (0.0–0.3)	0.065
Anthocyanins	0.0 (0.0–4.4)	1.1 (0–18.5)	0.000
Chalcones	0.0 (0.0–1.4)	0.0 (0.0–1.4)	0.513
Total phenolic acids[c]	42.3 (28.4–56.7)	40.0 (26.2–61.6)	0.452
Hydroxybenzoic acids	3.7 (1.6–6.9)	3.7 (1.2–6.4)	0.388
Hydroxycinnamic acids	37.8 (24.4–50.4)	35.1 (20.7–55.5)	0.568
Hydroxyphenylpropanoic acids	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.025
Stilbenes	0.0 (0.0–0.0)	0.0 (0.0–0.1)	0.001

Values are presented as median (interquartile range).
[a]Total (poly)phenol were calculated as the sum of total flavonoids, total phenolic acids and stilbenes.
[b]Total flavonoids as the sum of flavan-3-ols, flavonols, flavanones, flavones, isoflavones, anthocyanins, theaflavins and chalcones.
[c]Total phenolic acids as the sum of hydroxybenzoic, hydroxycinnamic and hydroxyphenylpropanoic acids.
p Value was calculated by using the Wilcoxon Signed Ranks test for paired samples.

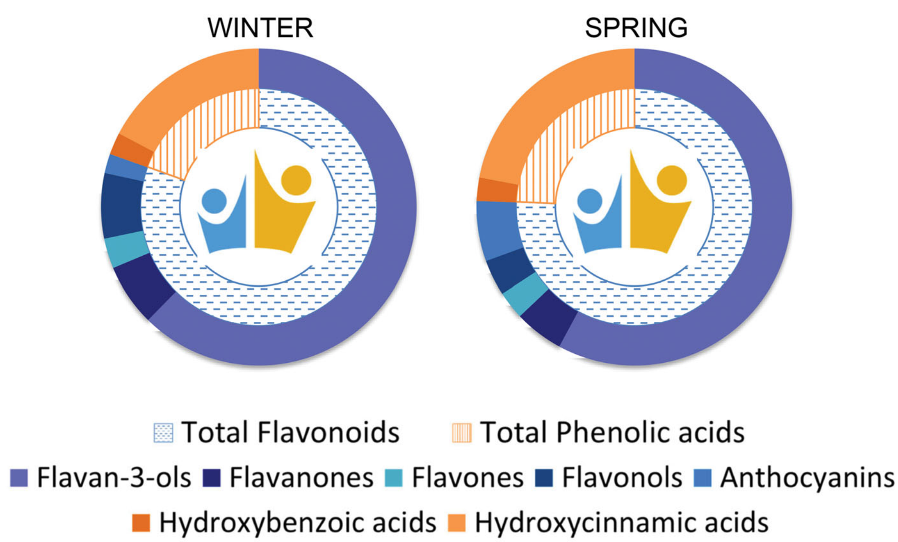

Figure 3. Relative contribution of classes and subclasses of phenolic compounds to the total (poly)phenol intake. The internal circle accounts for the percentage of flavonoids and phenolic acids in the diet, while the external circle for the contribution to the phenolic intake of each phenolic subclass. Isoflavonoids, chalcones, hydroxyphenylpropanoic acids and stilbenes were not included since they contributed less than 0.5% of the total intake.

stilbenes was very low and each contribution to total (poly)phenol intake was lower than 0.5%.

Major food groups and food item sources of total (poly)phenols and (poly)phenol subclasses are listed in Table 4. Fruit and chocolate-based products were the two main dietary contributors to total (poly)phenol intake in both seasons. Among fruit, (poly)phenols came mostly from apples and strawberries, while cocoa powder and milk chocolate bars were the main contributors among chocolate-based products. Vegetables were the third main dietary source of total (poly)phenols in winter and tea and coffee (decaffeinated) in spring. Other important food sources, accounting for more than 5% of total (poly)phenol intakes, were fruit juices and tea and coffee (decaffeinated) during winter, and fruit juices and vegetables in spring. Similar results were observed for the main sources of flavan-3-ols (Table 4). Regarding the dietary intake of main phenolic acids, hydroxycinnamates, main contributors were fruits and potatoes, with vegetables and tea and coffee (decaffeinated) changing depending on the season. When it comes to the main single food items, apples were the main sources of total (poly)phenols, flavan-3-ols and chalcones, as well as some other (poly)phenol subclasses seasonally. Orange juice and spinach were the main food items

Table 4. The three highest food group sources (% contribution to phenolic intake) and the highest food item source (% contribution to phenolic intake) of total (poly)phenols and (poly)phenol subclasses.

	Food groups		Food items	
Compounds	Winter	Spring	Winter	Spring
Total (poly)phenols	1. Fruit 32% 2. Cocoa-based products 32% 3. Vegetables 9%	1. Fruit 43% 2. Cocoa-based products 24% 3. Tea and coffee (decaffeinated) 9%	Apple 25%	Apple 24%
Flavan-3-ols	1. Cocoa-based products 50% 2. Fruit 40% 3. Tea and coffee (decaffeinated) 7%	1. Fruit 49% 2. Cocoa-based products 41% 3. Tea and coffee (decaffeinated) 7%	Apple 33%	Apple 35%
Flavanones	1. Juices 92% 2. Vegetables 4% 3. Fruit 2%	1. Juices 89% 2. Vegetables 7% 3. Fruit 2%	Orange pure juice 92%	Orange pure juice 89%
Flavones	1. Cereal-based products 42% 2. Juices 22% 3. Others 16%	1. Cereal-based products 52% 2. Juices 19% 3. Others 16%	Orange pure juice 22%	Wheat 25%
Flavonols	1. Vegetables 77% 2. Tea and coffee (decaffeinated) 9% 3. Fruit 4%	1. Vegetables 56% 2. Fruit 14% 3. Tea and coffee (decaffeinated) 12%	Spinach 60%	Spinach 17%
Isoflavones	1. Others 100%	1. Others 53% 2. Legumes 47%	Vegetable broth 100%	Vegetable broth 53%
Anthocyanins	1. Fruit 80% 2. Cereal-based products 11% 3. Olives 9%	1. Fruit 96% 2. Cereal-based products 3% 3. Olives 1%	Strawberry 74%	Strawberry 61%
Chalcones	1. Fruit 97% 2. Juices 3%	1. Fruit 98% 2. Juices 2%	Apple 97%	Apple 98%
Hydroxybenzoic acids	1. Tea and coffee (decaffeinated) 36% 2. Fruit 21% 3. Cereal-based products 15%	1. Fruit 38% 2. Tea and coffee (decaffeinated) 25% 3. Cereal-based products 16%	Tea 19%	Strawberry 30%
Hydroxycinnamic acids	1. Fruit 30% 2. Potatoes 20% 3. Vegetables 16%	1. Fruit 30% 2. Tea and coffee (decaffeinated) 21% 3. Potatoes 18%	Apple 23%	Coffee decaffeinated 21%
Hydroxyphenylpropanoic acids	1. Olives 89% 2. Vegetable oils and fats 9% 3. Others 1%	1. Olives 89% 2. Vegetable oils and fats 9% 3. Others 1%	Olive black 67%	Olive green 71%
Stilbenes	1. Fruit 66% 2. Cocoa-based products 22% 3. Cereal-based products 5%	1. Fruit 87% 2. Cocoa-based products 9% 3. Legumes 2%	Strawberry 66%	Strawberry 86%

contributing to the intake of flavanones and flavonols, respectively, regardless of the season. Strawberries were the main sources of anthocyanins and stilbenes, and olives were the most representative food items for the intake of hydroxyphenylpropanoic acids (Table 4).

Discussion

This study provided the first comprehensive overview of the food consumption and the nutritional composition of the diet, including the intake of phenolic compounds, of primary school children living in Parma (North Italy) during the whole school year (winter and spring periods).

Children's diet was similar between the two seasons, despite the subjects tended to eat less during spring than winter. In general, food intake was lower in our population in comparison to the most recent national data for pre-school and school age children (3–10 years old), derived from the Italian National Food Consumption Survey (Leclercq et al. 2009). However, median daily intake of pasta and cereals as well as bread, substitutes and pizza were higher than at national level. Similar consumptions among national populations were found for sweet and dessert, cured meat, breakfast cereal, nut and legume food groups (Leclercq et al. 2009). It should be noted that the consumption of certain food groups (e.g., nuts and legumes) in primary school Italian children are generally below the recommended amount (Leclercq et al. 2009), in line with our results. Moreover, the national recommendation for fruit and vegetable consumption was not met in both winter and spring periods, in line with both national and European data on children and adolescents (Yngve et al. 2005; Leclercq et al. 2009; Verzeletti et al. 2010; Currie et al. 2014; Vereecken et al. 2015; Albani et al. 2017; Rosi et al. 2019). Similarly, the consumption of fish and of milk and dairy products did not meet the nutritional goals and, thus, their consumption should be increased in primary school Italian children. This is of particular relevance in children living in the north of Italy, where this investigation was carried out, which generally have a lower adherence to the Mediterranean Diet than their peers living in the south of the country (Grosso and Galvano 2016; Iaccarino Idelson et al. 2017).

The general lower food intake during spring than winter resulted in a decreased intake of energy and nutrients. The average energy intake was very similar to the one reported in a group of 7–11 years Italian children (Verduci et al. 2019), but it was lower than the energy intake reported in the Italian national data for pre-school and school age children (Sette et al. 2011). This lower amount could be expected as energy intake in Italy has decreased over time and the most recent representative data at national level are referred to 10 years ago (Saba et al. 1990; Turrini et al. 2001; Sette et al. 2011). This decrease in energy intake over time is consistent with other European surveys reporting that the energy intake of children has declined in the last decades (Adamson et al. 1992; Stahl et al. 2009; Gibson 2010; Smpokos et al. 2014). Besides energy, nutrient intakes were similar to those reported in a very recent publication on a similar sample (Verduci et al. 2019). Protein and fat intakes were lower than the Italian children's average consumption, while data comparable to the national one was found for carbohydrate, sugars and fibres (Sette et al. 2011). Nevertheless, average macronutrient contributions to the total energy intake were in line with national (SINU 2014) and international recommendations (WHO 2003; WHO and FAO 2003). Contrariwise, protein and fat contributions to the total energy intake have found to be above the nutritional recommendations for Italian as well as European children (Elmadfa 2009; Elmadfa and Freisling 2009; Rippin et al. 2019). Sugars and saturated fatty acids intakes were above the nutritional goals (SINU 2014; WHO 2003; WHO and FAO 2003), according to national and European data (Elmadfa 2009; Elmadfa and Freisling 2009; Sette et al. 2011; Rippin et al. 2019; Verduci et al. 2019; Graffe et al. 2020).

Regarding micronutrients, a point worth mentioning is the very low intake of vitamin D registered, almost half of the intake reported in the last Italian National Food Consumption Survey (Sette et al. 2011) but in line with the recent national study aforementioned (Verduci et al. 2019). Vitamin D intake is generally low in European children, in particular in Southern regions (Elmadfa 2009; Elmadfa and Freisling 2009), and vitamin D deficiency in paediatric age has been extensively documented, also in Italian children (Antonucci et al. 2018; Saggese et al. 2018). Even if the nutritional goal is far to be reached, since foods containing vitamin D (e.g. fatty fish) were scarcely eaten in our population, Italian children are generally able to synthesize it in the skin if sufficiently exposed to sunlight. Despite this, vitamin D intake should be increased taking into account its key role in the regulation of calcium and phosphorus metabolism. Indeed, we also recorded a low calcium intake, although it was likely underestimated since we did not consider the consumption of water, one of the major dietary sources of calcium (Vannucci et al. 2018). Another important aspect of the children's diet in this study was the extremely high intake of sodium, more than 1.5 times above the recommendations (WHO 2003; WHO and FAO 2003; SINU 2014) and consistent with previous national and European data (Elmadfa 2009; Elmadfa and Freisling 2009; Campanozzi et al. 2015). This point is even more alarming if considering that some participants could have underestimated the discretional salt adding during food preparation and/or consumption.

An innovative aspect of this study was considering the daily intake of phenolic compounds and their major food sources since, to the best of our knowledge, the data for these bioactives in children is quite limited. The total (poly)phenol intake was almost half of the intake registered for children enrolled in the UK National Diet and Nutrition Survey (NDNS) Rolling Programme (Ziauddeen et al. 2019) and for school age children from Argentine (Rossi et al. 2018). The lower intake in Italian children could be due to the differences among diets between Italian—closer to a Mediterranean diet—and Argentinian and British children. In fact, higher (poly)phenol intakes have been previously observed in non-Mediterranean European countries with respect to Mediterranean ones in both adolescents and adults (Zamora-Ros et al. 2016; Wisnuwardani et al. 2020).

Flavonoids were the most consumed (poly)phenol group, contributing for 76–80% to the mean total intake, while the total phenolic acids for 20–24%. Our results were consistent with those reported for the UK NDNS children, for which the relative contribution was around 80% for flavonoids and around 20% for phenolic acids (Ziauddeen et al. 2019). Conversely, an inverse situation was observed in Argentinian children, for which the total (poly)phenol intake derived mainly from phenolic acids (around 76%), while flavonoids contributed for around 23–24% (Rossi et al. 2018). This could be easily explained taking into account the widely different diet of Argentinian children, being caffeinated beverages (60% mate, 19% tea and 5% coffee) the major contributors to their total (poly)phenol intake (Rossi et al. 2018). The average total (poly)phenol intake of European adolescents from the cross-sectional multi-centre HELENA study (Wisnuwardani et al. 2019) was slightly higher than the one registered in our population, but they were similar to the data reported for UK children (Ziauddeen et al. 2019). According to Italian and UK data for children, flavonoids were the main (poly)phenol classes in adolescents, accounting for around 75% of the total intake, while phenolic acids contribution was 17–19% in both Mediterranean and non-Mediterranean countries (Wisnuwardani et al. 2019). As in our study, the main food contributors for the HELENA study were fruit, chocolate products and juices, even if fruit and vegetable consumption was lower than the recommended daily amount (Wisnuwardani et al. 2019). Besides differences among countries, the total (poly)phenol intake has been found to increase with age (Ziauddeen et al. 2019; Wisnuwardani et al. 2020). In adult populations, the total (poly)phenol intake reached up to 1 gram per day in the European EPIC cohort (Zamora-Ros et al. 2016) and in the French SU.VI.MAX. population (Pérez-Jiménez et al. 2011). Higher daily intakes were reported for adults enrolled in the Polish arm of the HAPIEE study (Grosso et al. 2014), while slightly lower amounts have been observed in the UK NDNS adult cohort (Ziauddeen et al. 2019), in Italian diabetic adults enrolled in the TOSCA.IT study (Vitale et al. 2018), in a Spanish population at high risk of cardiovascular diseases enrolled in the PREDIMED study (Tresserra-Rimbau et al. 2013), and in another Spanish population of young adults enrolled in the SUN cohort study (Mendonça et al. 2019).

Despite its novel results, this study presents some limitations. The small sample size and the geographically limited recruitment area may not make the results generalizable to the whole Italian paediatric population. Moreover, the intake of some minerals and vitamins may be underestimated since supplements and water consumption was not considered. On the contrary, the use of two repeated 3-day dietary records in different seasons along with the use of comprehensive nutritional databases, represents strength of this study. Indeed, the 3-day dietary record is a reliable and valid method to collect dietary data and to estimate food and nutrient intakes, and the used nutritional database was also specific for epidemiological surveys in the Italian population. Moreover, in order to ensure accuracy and data completeness, only those vitamins and minerals with complete data for all the food items consumed were analysed. Finally, the (poly)phenol results were obtained by combining data from Phenol-Explorer, the most comprehensive dataset available, with ad hoc literature searches for some foods missing a Phenol-Explorer value, but habitually consumed in Italy. All these methodological aspects (e.g. various dietary assessment tools, length of the reporting period, food composition databases) are important points to be kept into account when comparing different populations since they may contribute to the differences in intake of nutrients and (poly)phenols.

Conclusions

This work provides the first comprehensive assessment of dietary intake, including vitamins, minerals and (poly)phenols, of school age children living in Parma (North Italy). Overall, these results confirm the need for promoting healthier food choices in children, aiming at increasing the consumption of fruit, vegetables, nuts, fish and whole-grain cereals. Future research should be producing more accurate data on these key aspects to better understand the impact of diet on children healthy development and on the prevention of diseases. The implementation of this kind of study with larger sample sizes may also support the development of further health policies and nutritional guidelines, including (poly)phenolic compounds and, in case, other classes of food bioactives.

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No potential conflict of interest was reported by the author(s).

ORCID

Alice Rosi http://orcid.org/0000-0001-8533-797X
Pedro Mena http://orcid.org/0000-0003-2150-2977
Daniele Del Rio http://orcid.org/0000-0001-5394-1259
Francesca Scazzina http://orcid.org/0000-0002-5372-8658

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