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Association of heart rate and blood pressure among European adolescents with usual food consumption: The HELENA study

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Abstract *Background and aim:* In adults, there is some evidence that improving diet reduces blood pressure (BP) and the subsequent risk of cardiovascular diseases (CVDs). However, studies that analyse this association in adolescents are still scarce. The objective of the present study was to examine the associations between heart rate, systolic (SBP), diastolic (DBP) and mean arterial blood pressure (MAP) among European adolescents and usual intake of vegetables, fruits, dairy products, meat, fish, high-sugar foods and savoury snacks.

Methods and results: In total, 2283 adolescents from the HELENA-study (12.5–17.5 years old; 1253 girls) were included. Dietary intake was assessed using two computerized 24-hour dietary recalls. Age, sex, body mass index, maternal educational level, physical activity and Tanner stage were considered as confounders. Associations were examined by mixed model analysis stratified by sex. Tests for trend were assessed by tertiles of intake while controlling for the aforementioned confounders. Dairy products and fish intake were negatively associated with BP and heart rate. Significant decreasing trends were observed for heart rate and BP across tertiles of dairy products, fish intake and high-sugar foods intake ($p < 0.05$). Significant increasing trends were observed for SBP and MAP across tertiles of savoury snack intake ($p < 0.05$).

Conclusion: Significant but small inverse associations between fish and dairy products consumption with blood pressure and heart rate have been found in European adolescents. Dietary intervention studies are needed to explore these associations in the context of the modification of several risk factors for the prevention of cardiovascular diseases.

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Introduction

Increased heart rate is a risk factor for sudden death [1]. It predicts subsequent elevated blood pressure (BP) which is linked with cardiovascular disease (CVD) risk [2]. Heart rate progressively increases along with both systolic (SBP) and diastolic (DBP) blood pressure [3]. This association between heart rate and SBP is linear and has been confirmed not only in adults but also in children on the basis of a small number of studies [4]. BP during childhood has a significant association with BP during adulthood, meaning that children with increased BP are at higher risk for hypertension and its related morbidities as adults [5].

Much of the human and social impact caused each year by CVD could be averted through cost-effective and feasible diet interventions [5]. Decreased sodium intake in the population is a public health diet intervention that could possibly lead to reduce CVDs [6]. Evidence suggests that reducing sodium intake is beneficial as it significantly reduces SBP and DBP in children. Only an estimated 11% of sodium consumption results from adding salt while cooking or eating a meal [7], so attention should be paid on contribution of sodium intake from food categories, like savoury snacks that highly contribute to daily sodium consumption [8]. Higher compared with lower intake of sugars has also been associated with BP. Although effects of dietary sugars on BP seem to be modest, there is convincing evidence to support the idea that reducing sugar intake may reduce BP in adults [9].

There has also been growing evidence that fruit and vegetable consumption is negatively related with mortality from cardiovascular disease [10]. There is some evidence that improving diet, including higher consumption of fruit, vegetables and oily fish, is an important strategy to reduce the risk of CVD and that increased fish and vegetable intake is inversely associated with BP [11].

The objective of the present study was to assess the associations between heart rate, SBP, DBP and mean arterial blood pressure (MAP) among European adolescents with their usual intake of vegetables, fruits, dairy products, meat, fish, high-sugar foods and savoury snacks.

Methods

Study sample

The Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study (HELENA-CSS) is a multi-center study for the assessment of the nutritional and lifestyle status of adolescents in 10 European cities [12]. A random cluster sampling of 3528 European adolescents (target number) aged 12.5–17.5 years, stratified for geographical location, age and socioeconomic status, was carried out. Adolescents were excluded from the analysis a posteriori; if participating simultaneously in another clinical trial, if aged $<$12.5 or $\geq$17.5 years or if they suffered from an acute infection less than 1 week before the inclusion. All data were collected via standardized procedures. Details on the sampling and recruitment process and quality control procedures can be found elsewhere [13]. Ethical issues and respect for good clinical procedures have also been discussed previously [14]. Informed consent was obtained from all participating adolescents and their parents.

Sensitivity analyses were performed in the sample by comparing the levels of BP and HR among adolescents who had complete dietary data ($n = 2283$) and those who did not ($n = 1148$). We found no significant differences in both levels of BP and in heart rate between the two aforementioned subgroups ($p > 0.05$) and finally 2283 subjects were included in the current study.

Dietary assessment

Dietary intake was assessed using a computerized 24-hour recall on 2 non-consecutive days, excluding weekend days, and within a time-span of 2 weeks. The 24-hour recall was performed using a validated computer-based tool for self-reported 24-hour recalls, HELENA-DIAT (Dietary Assessment Tool), based on a previous version developed for Flemish adolescents, called Young Adolescents' Nutrition Assessment on Computer (YANA-C) [15]. Difficulties in obtaining comparable estimates of the energy and nutrient content of foods across countries precluded the use of country specific food composition tables to calculate energy and nutrient intakes. For pragmatic reasons, the data of the HELENA-DIAT were linked to the German Food Code and Nutrient Date Base (BLS (Bundeslebensmittelschlüssel), version II.3.1, 2005), as this food composition database contained the largest number of nutrients and food items in Europe: approximately 12,000 coded foods and it has been demonstrated good accuracy in estimating nutrient intake in European adolescents [16]. If a food item was missing in the German food composition table, calculations were made via recipes or a local food composition table for the specific country. All food groups were estimated in grams per day. Dairy products included milk, yoghurt, cottage cheese and milk and yoghurt beverages. High-sugar foods included sugar, honey, jam, cakes, pies, biscuits, confectionery and carbonated drinks. Savoury snacks included chips, salty biscuits, crackers and pop corns.

Measurement of blood pressure and heart rate

SBP, DBP and heart rate were measured in all centres using the same type of automated digital BP device for clinical use (OMRON MODEL hem 7001) approved by the European Hypertension Society [17]. These data collection procedures have been previously described [18]. Briefly, participants were seated in a separate, quiet room for 10 min with their backs supported and feet on the ground. The between-device coefficient of variation was <5% for measurements of SBP, DBP and heart rate. Two BP and heart rate readings were taken with a 10 min interval between; the lowest reading was recorded. MAP was calculated as ((2*DBP) + SBP)/3. Interobserver coefficients of variation were 2.1% and 3.6% for SBP and DBP, respectively.

Physical examination

Weight and height of the adolescents were measured by trained researchers in a standardized way. Weight was recorded in underwear and without shoes to the nearest 0.1 kg, using an electronic scale. Height was measured barefoot in the Frankfort horizontal plane to the nearest 0.1 cm, using a telescopic height measuring instrument. Body Mass Index (BMI) was calculated as body weight in kg divided by the square of height in meters.

Identification of sexual maturation was evaluated by a physical examination performed by a physician who visually assessed each adolescent and classified him/her into the appropriate Tanner stage in one of the five stages (stages I–V) of pubertal maturity according to Tanner and Whitehouse [19].

Socioeconomic status and physical activity questionnaires

A self-reported socio-demographic, economic and lifestyle questionnaire about the adolescent and its family was collected [18]. Parental educational level was defined as one of four levels (elementary, lower secondary, higher secondary or tertiary education).

To assess physical activity of the last 7 days, an adolescent-adapted version of the International Physical Activity Questionnaire (IPAQ) was used, namely the IPAQ-A [20], assessing the different domains of physical activity (school, transport, housework and leisure time). For each of the four domains, total physical activity, moderate, vigorous and moderate to vigorous physical activity (MVPA) (expressed as minutes per week) were computed and summed to be used in the analyses, based on the guidelines for data processing and analyses of the IPAQ.

Statistical analyses

The Statistical Package for the Social Sciences for Windows version 20 (SPSS Inc, Chicago, IL, USA) was used to carry out all statistical analyses. Only adolescents with complete two 24-hour recalls, BP and heart rate data were included in the study (n = 2283). Underreporters of energy intake were calculated using Goldberg's cut-offs, 15% of the final sample were categorized as underreporters and finally included since the results from descriptive and correlation analyses were very similar when including or excluding the underreporters ($p < 0.05$). Individual usual food and nutrient intakes, resulting from the two 24-hour recalls were estimated using the Multiple Source Method (MSM) [21]. This method removes the effect of day-to-day variability and random error in both 24-hour recalls.

In a first instance, crude spearman rank correlations were calculated by sex to evaluate associations between heart rate/DBP/SBP/MAP and usual vegetable intake, usual fruit intake, usual dairy products intake, usual meat intake, usual fish intake, usual high-sugar foods intake and usual savoury snack intake. Linear mixed model analyses stratified by sex were then used to verify associations between heart rate/DBP/SBP/MAP and usual vegetable intake, usual fruit intake, usual dairy products intake, usual meat intake, usual fish intake, usual high-sugar foods intake and usual savoury snack intake. Study centre was included as the random intercept. Age, body mass index, maternal educational level, physical activity and Tanner stage were entered as covariates. The Jonckheere trend test was used

Table 1 General characteristics, blood pressure (mm Hg), heart rate and usual food intakes of the Healthy Lifestyle in Europe by Nutrition in Adolescence study sample (n = 2283).

	Boys (n = 1052)	Girls (n = 1231)	p
Age	14.8 ± 1.3	14.7 ± 1.2	0.367
BMI (kg/m^2)	21.3 ± 3.9	21.2 ± 3.5	0.651
Tanner stage			**< 0.001**
Tanner I	1	0	
Tanner II	9.5	4.6	
Tanner III	24.2	24.4	
Tanner IV	41.1	44.7	
Tanner V	24.3	26.4	
Maternal education			0.551
Lower education	6.4	6.7	
Secondary education	27	25.6	
Higher secondary education	29.4	32	
Higher education	37.3	35.7	
MVPA (min/wk)	811.2 ± 609	631.8 ± 514.2	**< 0.001**
Diastolic BP (mm Hg)	67.6 ± 9.1	67.9 ± 8.9	0.333
Systolic BP (mm Hg)	124.7 ± 14.5	115.9 ± 11.4	**< 0.001**
MAP (mm Hg)	86.6 ± 9.7	83.9 ± 8.9	**< 0.001**
Heart rate (bpm)	77.4 ± 13.5	81.1 ± 13.7	**< 0.001**
Vegetable intake (g/d)	89.9 ± 60.7	91.7 ± 55.7	0.458
Fruit intake (g/d)	125.2 ± 103.9	129.1 ± 92.2	0.337
Dairy products (g/d)	277.4 ± 235.9	207.4 ± 168.3	**< 0.001**
Meat intake (g/d)	162.7 ± 82.4	129.7 ± 63.7	**< 0.001**
Fish intake (g/d)	20.5 ± 22.7	19.8 ± 22.4	0.504
High-sugar foods intake (g/d)	290.1 ± 293.2	270.8 ± 306.8	0.126
Snack intake (g/d)	9.9 ± 18.1	6.4 ± 12.1	**< 0.001**

BP, blood pressure; MVPA, moderate and vigorous physical activity; CI, Confidence interval.
Values are percentages for categorical variables; means ± SD for continuous variables.
Significant differences between gender in bold letters ($p < 0.05$).

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for tertiles of intake while controlling for the aforementioned confounders.

Results

Median heart rate and DBP was lower in boys than girls. SBP was higher in boys than in girls ($p < 0.05$) (Table 1). In total, 17.3% of adolescents had an average SBP and 4.3% an average DBP greater than or equal to the 95th percentile for sex, age, and height [22]. The significance of these results in terms of health effects have already been discussed elsewhere [23] and is not the major focus of this article.

For girls, significant negative correlations were found between heart rate, DBP, SBP, MAP and usual consumption of dairy products and fish. A significant

Table 2 Crude spearman rank correlations between heart rate (bpm), diastolic blood pressure (mm Hg), systolic blood pressure (mm Hg), arterial blood pressure (mm Hg) and usual food intake among European adolescents by sex (n = 2283).

	Heart rate		Diastolic blood pressure, mm Hg		Systolic blood pressure, mm Hg		Arterial blood pressure, mm Hg	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Vegetable intake (g/d)	−0.00	0.03	0.01	−0.02	−0.02	−0.01	−0.00	−0.01
Fruit intake (g/d)	−0.02	**−0.10**	0.05	−0.00	0.00	0.02	0.04	0.01
Dairy products (g/d)	**−0.12**	**−0.10**	**−0.14**	**−0.16**	**−0.13**	**−0.13**	**−0.15**	**−0.16**
Meat intake (g/d)	**−0.06**	**−0.06**	0.03	−0.02	−0.01	−0.04	0.01	−0.02
Fish intake (g/d)	**−0.14**	**−0.10**	−0.04	**−0.06**	**−0.13**	**−0.12**	**−0.09**	**−0.10**
High-sugar foods intake (g/d)	−0.04	−0.04	**0.08**	0,03	0,06	0,05	**0,08**	0,04
Snack intake (g/d)	0.00	0.01	**0.11**	0.00	**0.10**	−0.02	**0.12**	−0.01

Significant values ($p < 0.05$) in bold letters.

Table 3 Mixed model analyses between heart rate (bpm), diastolic blood pressure (mm Hg), systolic blood pressure (mm Hg), arterial blood pressure (mm Hg) and usual food intake among European adolescents, adjusted for age, body mass index, Tanner stage, education of the mother and physical activity (n = 2283).

	Boys				Girls			
	α	SE	95% CI	p	α	SE	95% CI	p
Heart rate								
Vegetable intake (g/d)	−0.006	0.007	−0.020−0.009	0.454	0.004	0.007	−0.010, 0.017	0.580
Fruit intake (g/d)	0.004	0.004	−0.004, 0.012	0.349	−0.003	0.004	−0.012, 0.005	0.443
Dairy products (g/d)	−0.006	0.002	−0.010, 0.002	**0.002**	−0.000	0.002	−0.005, 0.004	0.858
Meat intake (g/d)	−0.004	0.005	−0.014, 0.006	0.453	−0.003	0.006	−0.015, 0.009	0.642
Fish intake (g/d)	−0.047	0.019	−0.084, −0.009	0.014	−0.027	0.018	−0.061, 0.008	0.128
High-sugar foods intake (g/d)	−0.001	0.001	−0.004, 0.001	0.371	0.000	0.001	−0.002, 0.003	0.940
Snack intake (g/d)	0.056	0.024	0.008, 0.103	0.023	−0.001	0.032	−0.064, 0.061	0.969
Diastolic blood pressure								
Vegetable intake (g/d)	−0.002	0.005	−0.012, 0.007	0.656	−0.008	0.004	−0.016, 0.001	0.100
Fruit intake (g/d)	0.003	0.003	−0.003, 0.008	0.306	0.002	0.003	−0.004, 0.007	0.587
Dairy products (g/d)	−0.001	0.001	−0.003, 0.002	0.607	−0.004	0.002	−0.007, −0.001	**0.008**
Meat intake (g/d)	−0.001	0.003	−0.007, 0.006	0.858	−0.003	0.004	−0.011, 0.005	0.473
Fish intake (g/d)	−0.012	0.013	−0.036, 0.013	0.349	−0.016	0.011	−0.039, 0.006	0.157
High-sugar foods intake (g/d)	0.001	0.001	−0.001, 0.003	0.186	0.001	0.001	0.001, 0.002	0.499
Snack intake (g/d)	0.037	0.016	0.006, 0.067	0.020	0.011	0.021	−0.030, 0.051	0.607
Systolic blood pressure								
Vegetable intake (g/d)	−0.005	0.007	−0.019, 0.009	0.483	−0.001	0.005	−0.011, 0.010	0.913
Fruit intake (g/d)	0.002	0.004	−0.006, 0.009	0.693	0.003	0.003	−0.003, 0.010	0.323
Dairy products (g/d)	−0.000	0.002	−0.004, 0.003	0.910	−0.002	0.000	−0.005, 0.002	0.433
Meat intake (g/d)	0.001	0.010	−0.009, 0.010	0.914	0.000	0.005	−0.009, 0.010	0.926
Fish intake (g/d)	−0.018	0.018	−0.054, 0.018	0.324	−0.039	−0.014	−0.066, −0.012	**0.005**
High-sugar foods intake (g/d)	0.002	0.001	−0.000, 0.005	0.070	0.001	0.001	−0.001, 0.003	0.244
Snack intake (g/d)	0.032	0.023	−0.013, 0.077	0.161	0.000	0.025	−0.049, 0.049	0.999
Arterial blood pressure								
Vegetable intake (g/d)	−0.003	0.005	−0.013, 0.006	0.511	−0.005	0.004	−0.014, 0.003	0.231
Fruit intake (g/d)	0.002	0.003	−0.003, 0.008	0.394	0.002	0.003	−0.003, 0.007	0.440
Dairy products (g/d)	−0.000	0.001	−0.003, 0.002	0.739	−0.003	−0.002	−0.006, −0.000	0.041
Meat intake (g/d)	−0.000	0.003	−0.007, 0.007	0.942	−0.002	0.004	−0.009, 0.006	0.676
Fish intake (g/d)	−0.014	0.013	−0.038, 0.011	0.271	−0.023	0.011	−0.045, −0.002	0.034
High-sugar foods intake (g/d)	0.001	0.001	−0.000, 0.003	0.083	0.001	0.001	−0.001, 0.002	0.353
Snack intake (g/d)	0.035	0.016	0.004, 0.066	0.025	0.007	0.020	−0.032, 0.046	0.737

Significant values ($p < 0.01$) in bold letters.

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negative correlation was also found between heart rate and usual fruit and meat intake among girls ($p < 0.05$) (Table 2). For boys, significant positive correlations were found between DBP, SBP, MAP and usual savoury snack intake, as well as between DBP, MAP and usual high-sugar foods intake ($p < 0.05$). Significant negative correlations for boys were found between heart rate, SBP, DBP, MAP and usual dairy product intake, as well as between heart rate, SBP, MAP and usual fish intake and also between heart rate and usual meat intake ($p < 0.05$). However, all correlations were low and below 0.200 (Table 2).

After controlling for age, body mass index, maternal educational level, physical activity and Tanner stage, intake of dairy products (g/d) was negatively associated with heart rate (−0.01; CI −0.01, −0.00) in boys and with DBP (−0.00; CI −0.01, −0.00) in girls. Fish intake (g/d) was negatively associated with SBP (−0.01; CI −0.07, −0.01) in girls (Table 3).

Across tertiles of dairy products intake, statistically significant decreasing trends were observed for heart rate, SBP, DBP and MAP ($p < 0.001$). Across tertiles of fish intake, statistically significant decreasing trends were observed for heart rate, SBP and MAP ($p < 0.001$). Across tertiles of meat

Table 4 Tertiles of vegetable, fruit, dairy products, meat, fish, sweets and savoury snack across BP and heart rate values adjusted by age, sex, body mass index, education level of the mother, physical activity and Tanner stage (n = 2283).

	Mean	95% CI	Mean	95% CI	Mean	95% CI	p
	Vegetable intake ≤ 58.8 g/day (N = 753)		Vegetable intake >58.8 & <104 g/day (N = 754)		Vegetable intake ≥ 104 g/day (N = 776)		
Heart rate, bpm	79.3	78.3–80.3	79.4	78.5–80.4	79.5	78.6–80.5	0.592
Diastolic BP, mm Hg	68.3	67.6–69	67.3	66.7–67.9	67.8	67.2–68.4	0.733
Systolic BP, mm Hg	121.3	120.2–122.3	118.9	118–119.8	119.8	118.8–120.7	0.227
MAP	86	85.2–86.7	84.5	83.8–85.1	85.1	84.5–85.7	0.438
	Fruit intake ≤ 68.4 g/day (N = 753)		Fruit intake >68.4 & <150.3 g/day (N = 754)		Fruit intake ≥ 150.3 g/day (N = 776)		
Heart rate, bpm	80	79.1–81	79.5	78.5–80.5	78.7	77.7–79.7	0.021
Diastolic BP, mm Hg	67.5	66.8–68.1	67.9	67.3–68.5	67.9	67.3–68.6	0.263
Systolic BP, mm Hg	120.3	119.3–121.3	119.3	118.3–120.3	120.2	119.3–121.2	0.732
MAP	85.1	84.4–85.7	85	84.4–85.7	85.4	84.7–86.1	0.328
	Dairy products ≤ 125.7 g/day (N = 753)		Dairy products >125.7 & <276.9 g/day (N = 754)		Dairy products ≥ 276.9 g/day (N = 776)		
Heart rate, bpm	80.8	79.8–81.7	80.2	79.2–81.2	77.3	76.4–78.3	**<0.001**
Diastolic BP, mm Hg	69	68.3–69.6	68.2	67.6–68.9	66.2	65.6–66.8	**<0.001**
Systolic BP, mm Hg	121.3	120.4–122.4	119.5	118.5–120.4	119.1	118.2–120.1	**<0.001**
MAP	86.4	85.8–87.1	85.3	84.7–86	83.8	83.2–84.5	**<0.001**
	Meat intake ≤ 107.2 g/day (N = 753)		Meat intake >107.2 & <167.5 g/day (N = 754)		Meat intake ≥ 167.5 g/day (N = 776)		
Heart rate, bpm	80.4	79.4–81.4	80	79.1–81	77.9	76.9–78.9	**<0.001**
Diastolic BP, mm Hg	67.8	67.2–68.5	68.1	67.4–68.7	67.4	66.8–68.1	0.750
Systolic BP, mm Hg	119.1	118.1–120	120.3	119.3–121.3	120.4	119.5–121.4	0.093
MAP	84.9	84.3–85.6	85.5	84.8–86.2	85.1	84.5–85.8	0.555
	Fish intake ≤ 7.6 g/day (N = 753)		Fish intake >7.6 & <17.0 g/day (N = 754)		Fish intake ≥ 17.0 g/day (N = 776)		
Heart rate, bpm	81.4	80.4–82.4	79.5	78.5–80.4	77.5	76.5–78.4	**<0.001**
Diastolic BP, mm Hg	68.2	67.6–68.9	67.9	67.2–68.5	67.3	66.6–67.9	0.078
Systolic BP, mm Hg	122.1	121.1–123.1	119.4	118.5–120.4	118.4	117.5–119.4	**<0.001**
MAP	86.2	85.5–86.8	85.1	84.4–85.7	84.3	83.7–85	**<0.001**
	High-sugar foods intake 174.6 ≤ g/day (N = 753)		High-sugar foods intake > 174.6 & <396.9 g/day (N = 754)		High-sugar foods intake ≥ 396.9 g/day (N = 776)		
Heart rate, bpm	80	79–81	79.7	78.8–80.7	78.5	77.5–79.5	**<0.001**
Diastolic BP, mm Hg	68.4	67.7–69	67.6	66.9–68.2	67.4	66.8–68	0.736
Systolic BP, mm Hg	121.3	120.3–122.2	118.8	117.8–119.7	119.9	118.9–120.8	**<0.001**
MAP	86	85.3–86.7	84.6	84–85.3	84.9	84.2–85.6	0.004
	Snack intake ≤ 1.3 g/day (N = 753)		Snack intake >1.3 & <2.7 g/day (N = 754)		Snack intake ≥ 2.7 g/day (N = 776)		
Heart rate, bpm	80.6	79.6–81.6	78.3	77.3–79.3	79.3	78.4–80.3	0.100
Diastolic BP, mm Hg	67.5	66.9–68.1	67.5	66.8–68.1	68.3	67.7–69	0.076
Systolic BP, mm Hg	117.2	116.4–118.1	121	120–122	121.7	120.6–122.7	**<0.001**
MAP	84.1	83.4–84.7	85.3	84.6–86	86.1	85.4–86.8	**<0.001**

BP, blood pressure; MAP, mean arterial blood pressure.
Significant values ($p < 0.01$) across tertiles of food intake in bold letters.

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intake, statistically significant decreasing trends were observed for heart rate ($p < 0.001$). Across tertiles of high-sugar foods intake, significant decreasing trends were observed for heart rate and SBP ($p < 0.001$). Across tertiles of snack intake, significant increasing trends were observed for SBP and MAP ($p < 0.001$) (Table 4) (Fig. 1).

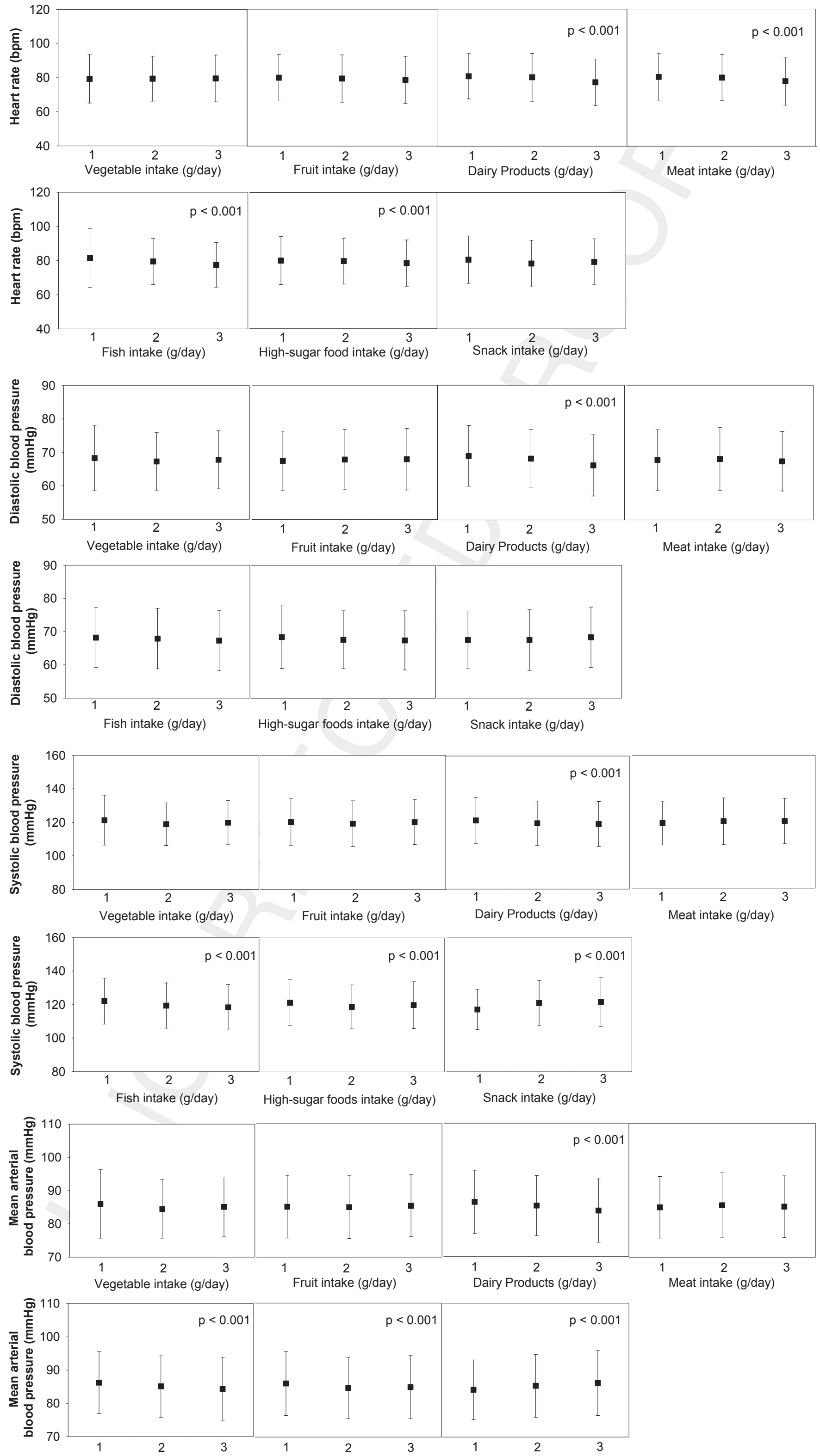

Figure 1 Levels of mean heart rate and blood pressure across tertiles of usual food intake.

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Discussion

In agreement with the current literature, most of our results seem to be biologically plausible. The present study showed that dairy products were inversely associated with heart rate and BP. An increase in dairy products of 10 g/d was associated with a decrease of −0.10 beats/min of heart rate in boys. There would be a reduction of 1.4 beats/min in heart rate for an increase of a glass of milk per day. Although this effect appears somewhat limited in absolute terms, it might still be important at the population level for the prevention of cardiovascular diseases further in life. The effects of milk protein-derived peptides isoleucine-proline-proline and valine-proline-proline on BP have long been studied. The mechanism of the antihypertensive effect of the tripeptides by inhibition of angiotensin-converting enzyme type 1 has been accepted [24].

The inverse association between fish intake and heart rate was found in a study among adult men without coronary heart disease. Moreover, in the same study an inverse association between fish intake and both diastolic and systolic BP was also observed [25]. A meta-analysis of the effects of fish oil on heart rate indicates that fish oil reduces heart rate, particularly in those with higher baseline heart rate or in patients with longer treatment duration [26]. In our study we observed a decreasing trend in SBP, DBP, MAP and heart rate when increasing the fish intake. An increase in fish intake of 10 g/d was associated with a decrease of SBP of −0.40 mmHg in girls. This seems clinically relevant, because for each increase in fish consumption of one portion per week, there was an average reduction of 4 mmHg of SBP.

Limited data have been published regarding the association between fruit intake and BP [27]. Inverse associations between concentrations of antioxidant vitamins and BP levels have recently been reported in the adolescents involved in the HELENA study [28]. Plausible biological explanations for such associations are the antioxidant activity of several fruits and vegetables components (i.e. folate, vitamin C) supporting the prevention of the formation of atherosclerotic plaques by increasing serum HDL-cholesterol [29]. We failed in finding any association between fruit and vegetable intake and BP and/or heart rate. Only a decreasing trend of heart rate was observed when increasing fruit intake.

In agreement with existing literature, the current findings indicate that SBP and MAP tend to increase when savoury snack intake increases [30]. Savoury snacks are high-sodium processed foods and an increase in savoury snack consumption could lead to fatal cardiac events during adulthood. In a recent study, sodium intake from snacks was almost half of the average daily sodium consumption and was significantly associated with BP in adolescents [31]. In contrast and disagreement with existing literature, our results showed that heart rate and SBP tended to decrease when high-sugar foods intake increased. Associations between higher intakes of sugar and increased BP have also been reported [9]. Dietary sugar has also been attributed to increased BP. Excessive intake of dietary fructose, particularly from sugar-sweetened beverages, has been shown to increase hepatic fat synthesis, which results in increased concentrations of circulating triglycerides and cholesterol and urate synthesis that may directly stimulate the rennin-angiotensin system to increase BP [32].

The present study has several limitations as well as strengths. Regarding limitations, firstly, the temporality of the associations observed cannot be examined because of the cross-sectional design of the study, so no causal effects can be drawn. Secondly, even if we found significant associations between usual food intake and blood pressure and heart rate, these associations were small and their causal effect should be confirmed in intervention studies. Thirdly, the use of physical activity questionnaires instead of accelerometer data which is considered “the gold standard” for measuring energy expenditure can be seen as a limitation. However, non-wear activity diaries were not analysed in combination with the accelerometers in our study sample and consequently, some activities such as swimming could not be registered and some individuals could be misclassified as non-active [33]. On the other hand, the main strengths are the large sample size and the complete set of potential confounders used in our analyses. Also the in depth dietary intake information obtained via repeated 24-h recalls corrected for within person variability is a strength in this study.

Conclusions

We found significant but small inverse associations between fish and dairy products consumption with blood pressure and heart rate in European adolescents.

Our results should be interpreted cautiously as causal effects should not be drawn due to the cross-sectional design of the study. Dietary intervention studies are needed to explore these associations in the context of the modification of several risk factors for the prevention of cardiovascular diseases.

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