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Breakfast consumption and CVD risk factors in European adolescents: the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study

Lena Hallström[1,2,*], Idoia Labayen[2,3], Jonatan R Ruiz[2], Emma Patterson[2], Carine A Vereecken[4,5], Christina Breidenassel[6], Frédéric Gottrand[7], Inge Huybrechts[5], Yannis Manios[8], Lorenza Mistura[9], Kurt Widhalm[10], Katerina Kondaki[8] Luis A Moreno[11] and Michael Sjöström[2], on behalf of the HELENA Study Group

[1]School of Health, Care and Social Welfare, Box 883, Mälardalens University, 72123 Västerås, Sweden: [2]Unit for Preventive Nutrition, Department of Biosciences and Nutrition, Karolinska Institute, Huddinge, Sweden: [3]Department of Nutrition and Food Science, University of the Basque Country, Vitoria, Spain: [4]Research Foundation – Flanders, Brussels, Belgium: [5]Department of Public Health, Ghent University, Ghent, Belgium: [6]Institut für Ernährungs- und Lebensmittelwissenschaften-Humanernährung, Rheinische Friedrich-Wilhelms Universität, Bonn, Germany: [7]Faculté de Médecine, Université de Lille 2, Lille, France: [8]Department of Nutrition and Dietetics, Harokopio University, Athens, Greece: [9]National Research Institute on Food and Nutrition, Rome, Italy: [10]Division of Clinical Nutrition and Prevention, Department of Pediatrics, Medical University of Vienna, Vienna, Austria: [11]Escuela Universitaria de Ciencias de la Salud, Universidad de Zaragoza, Zaragoza, Spain

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Abstract

Objective: To examine the association between breakfast consumption and CVD risk factors in European adolescents.

Design: Cross-sectional. Breakfast consumption was assessed by the statement 'I often skip breakfast' and categorized into 'consumer', 'occasional consumer' and 'skipper'. Blood pressure, weight, height, waist circumference, skinfold thickness, total cholesterol (TC), HDL cholesterol (HDL-C), LDL cholesterol (LDL-C), TAG, insulin and glucose were measured and BMI, TC:HDL-C, LDL-C:HDL-C and homeostasis model assessment–insulin resistance index (HOMA-IR) were calculated.

Setting: The European Union-funded HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study.

Subjects: European adolescents, aged 12·50–17·49 years, from ten cities within the HELENA study (*n* 2929, *n* 925 with blood sample, 53 % females).

Results: In males, significant differences across breakfast consumption category ('consumer', 'occasional consumer' and 'skipper') were seen for age, BMI, skinfold thickness, waist circumference, cardiorespiratory fitness, systolic and diastolic blood pressures, TC:HDL-C, LDL-C:HDL-C, glucose, insulin, HOMA-IR and LDL-C; in females, for cardiorespiratory fitness, skinfold thickness, BMI, insulin and HOMA-IR. In overweight/obese males significant differences were also seen for TC and LDL-C, whereas no differences were observed in non-overweight males or in females regardless of weight status.

Conclusions: Our findings among European adolescents confirm previous data indicating that adolescents who regularly consume breakfast have lower body fat content. The results also show that regular breakfast consumption is associated with higher cardiorespiratory fitness in adolescents, and with a healthier cardiovascular profile, especially in males. Eating breakfast regularly may also negate somewhat the effect of excess adiposity on TC and LDL-C, especially in male adolescents.

Keywords
Diet surveys
Physical fitness
Body composition
Blood
Adolescents

The prevalence of overweight and obesity in adolescence has increased dramatically in developed countries over the past two decades[1]. In addition to genetic and environmental factors, the breakfast meal and the frequency with which it is consumed may influence appetite, dietary intake and composition. These mechanisms may have important implications for body weight regulation. Indeed, several studies have shown a positive association between breakfast skipping and overweight/obesity in adolescents[2–5].

*Corresponding author: Email lena.hallstrom@mdh.se

Breakfast is commonly considered a key component of a healthy diet contributing to whole-diet nutrient adequacy[6,7]. Adolescents who rarely have breakfast are more likely to smoke, drink alcohol and are less likely to exercise than regular breakfast consumers[8]. Breakfast consumption may reduce the risk of chronic diseases due to its potential impact on overall diet quality[6,9–11]. Although breakfast is widely promoted as essential for the nutritional well-being of young people, breakfast skipping is relatively common among adolescents in Western countries[3,12].

Overweight and obesity in childhood are associated with CVD risk factors (adverse levels of lipids, insulin and blood pressure)[13–15]. CVD events occur more frequently during or after the fifth decade of life; however, there is evidence indicating that the precursors of CVD have their origin in early childhood[16]. Adverse CVD risk factors during childhood have been shown to track later into adulthood[17,18]. We hypothesized that if breakfast can be considered a marker of a healthy lifestyle in young people, adolescents who regularly consume breakfast should also have a healthier cardiovascular profile than their peers who skip breakfast.

The purpose of the present study was to examine the association between different patterns of breakfast consumption (skipping, occasional consumption and regular consumption) and CVD risk factors, including BMI, skinfold thickness, waist circumference, cardiorespiratory fitness, blood pressure, blood lipids and insulin resistance, in European adolescents from nine different countries. We also studied the interaction between breakfast consumption and weight status on CVD risk factors.

Methods

Study design and sampling

Adolescents were part of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study[19]. HELENA is a multi-centre, cross-sectional study performed in ten European cities (Athens and Heraklion in Greece; Dortmund in Germany; Ghent in Belgium; Lille in France; Pecs in Hungary; Rome in Italy; Stockholm in Sweden; Vienna in Austria; Zaragoza in Spain) that was designed to obtain reliable and comparable data on nutrition- and health-related parameters of a sample of European adolescents[19].

A total of 3528 (52 % females) adolescents, aged 12·50–17·49 years (mean 14·7 (SD) 1·2 years), were recruited between October 2006 and December 2007. Adolescents were randomly selected from schools using proportional cluster sampling taking into account the geographical distribution in each city, the ratio of private to public schools and the number of classes per school. One-third of the classes were randomly selected for blood collection, resulting in a total of 1089 (53 % females) blood samples for the subsequent clinical biochemistry assays. Eighty-three per cent of the total sample (*n* 3528) responded to a question concerning breakfast consumption, resulting in a final sample of 2929 adolescents (53 % females), for whom blood analyses were available for 925 (53 % females). The response frequencies to the breakfast question differed between centres, ranging from 60 % (in Pecs) to 98 % (in Lille and Vienna). Age and BMI were similar between responders and non-responders to the breakfast question ($P > 0{\cdot}1$).

After receiving complete information about the aims and methods of the study, all adolescents and their parents or guardians signed an informed written consent. All participants met the general HELENA inclusion criteria: they were not participating simultaneously in another clinical trial and had not had an acute infection less than 1 week before the study[19]. The study was performed following the ethical guidelines of the Declaration of Helsinki 1961 (revision of Edinburgh 2000), Good Clinical Practice and the legislation concerning clinical research in human subjects in each of the participating countries. The protocol was approved by the corresponding local Human Research Review Committees of the centres involved[19,20].

Breakfast assessment

Adolescents reported their breakfast habits by responding to the following statement: 'I often skip breakfast'. There were seven possible answers ranging from strongly disagree (1) to strongly agree (7). Adolescents were categorized into three groups: (i) 'consumers' (answered '1' or '2'); (ii) 'occasional consumers' (answered '3', '4' or '5'); and (iii) 'skippers' (answered '6' or '7'). The term 'breakfast' was left open to interpretation by the adolescents themselves.

Physical examination

Weight and height were measured following standard procedures[21], and BMI (kg/m^2) was calculated as body mass (in kilograms) divided by the square of height (in metres). Adolescents were classified according to the international BMI cut-off values as non-overweight or overweight/obese[22]. Waist circumference was used as a surrogate of central body fat, and was measured to the nearest 0·1 cm in triplicate at the midpoint between the superior iliac spine and the costal edge in the midaxillary line with an anthropometric non-elastic tape (Seca 200; Belgium). Skinfold thickness was measured to the nearest 0·2 mm in triplicate on the left side at the following sites: biceps, triceps, subscapular, suprailiac, thigh and medial calf, with a Holtain calliper (Crymych, UK)[21]. The same trained investigators made all measurements and the inter-rater reliability was greater than 95 %.

Assessment of pubertal status

Overweight/obese adolescents tend to mature earlier than non-overweight[23]. Pubertal stage was therefore recorded and adjusted for in the analysis. A trained researcher of the same sex as the child assessed the developmental stage according to the scale proposed by Tanner and Whitehouse[24], as described elsewhere[25].

Cardiorespiratory fitness

Cardiorespiratory fitness was assessed by means of the 20 m shuttle run test[26]. Participants were required to run between two lines 20 m apart, while keeping pace with audio signals emitted from a pre-recorded compact disk. The initial speed was 8·5 km/h, which was increased by 0·5 km/h each minute (1 min equals one stage). All measurements were carried out under standardized conditions in an indoor gymnasium, during ordinary classes in physical education and simultaneously by ten to twenty adolescents. The participants were encouraged to keep running as long as possible. The last completed stage or half-stage at which the participant dropped out was scored. Cardiorespiratory fitness (i.e. V_{O2max} in ml/kg per min) was estimated from the last half-stage completed, sex, age, weight and height[27]. All participants received comprehensive instructions about the test. This test has shown to be valid[28], reliable[29] and feasible for use in population-based studies and in the school setting[30].

Physical activity

We measured physical activity with accelerometry over 7 d (Actigraph™ GT1M; Pensacola, FL, USA) and expressed it as total counts/min[31].

Blood pressure

Blood pressure was measured (in the morning) with an automatic oscillometric device (OMRON M6; Omron Healthcare Europe). The adolescent first sat quietly for 5 min, with his/her back supported, feet on the floor and right arm supported with the cubital fossa at heart level. Two recordings of systolic and diastolic measurements (in mmHg), 5 min apart, were made and the lowest value of the two recordings was retained[25].

Blood analysis

A detailed description of blood sampling and procedures has been published elsewhere[32]. Blood samples were drawn after an overnight fast of 10 h. Serum TAG, total cholesterol (TC), HDL cholesterol (HDL-C), LDL cholesterol (LDL-C) and glucose were measured, in single, on the Dimension RxL clinical chemistry system (Dade Behring, Schwalbach, Germany) with enzymatic methods following the manufacturer's reagents and instructions. The intra- and inter-assay CV for all parameters was <4 %. Insulin concentrations were measured by a solid-phase two-site chemiluminescent immunometric assay with an Immulite 2000 analyser (DPC Biermann GmbH, Bad Nauheim, Germany) using the manufacturer's reagents and instructions. The sensitivity of the insulin assay was 2 mU/l. The inter-assay CV was 5·2 %. The homeostasis model assessment–insulin resistance index (HOMA-IR) was calculated as [fasting insulin (mU/l) × fasting glucose (mg/dl) × 0·0555]/22·5[33]. Five adolescents with an insulin value >70 mU/l were excluded from the analysis of insulin and HOMA-IR.

Sociodemographic status

Parents' education level was assessed via questionnaire by the adolescent and was categorized as elementary, lower secondary, higher secondary and university level education. We obtained information about family structure through the aforementioned questionnaire. Family structure was defined as 'traditional family' when the adolescent was living at home with two parents (parents and/or step-parents) or 'single/shared-care' when the adolescent was living in a single-parent family or had 'shared care' between parents. Those living in other family structures (e.g. in a foster home or with grandparents) were categorized into the 'single/shared-care' family structure.

Statistical analysis

Associations between sex and breakfast consumption categories (consumer, occasional consumer and skipper) were assessed by the χ^2 test. We compared mean levels of CVD risk factors across breakfast consumption categories using one-way analysis of covariance with breakfast consumption category as the fixed factor, CVD risk factors as dependent variables and age, centre (random variable), mother's and father's education and family structure entered as covariates. Analyses including waist circumference were additionally adjusted for height. All analyses were performed in males and females separately. Variables with skewed distribution (i.e. the sum of six skinfolds, V_{O2max}, TAG, TC:HDL-C and HOMA-IR) were logarithmically transformed to obtain a more symmetric distribution.

To study the interaction between breakfast consumption and weight status (i.e. non-overweight and overweight/obese) on CVD risk factors, we performed a two-way analysis of covariance (with breakfast consumption and weight status as fixed factors) adjusting for the covariates mentioned above. A possible breakfast consumption/weight status interaction effect on CVD risk factors was studied by inserting the product term (breakfast consumption × weight status) into the model. All analyses were performed using the SPSS for Windows statistical software package version 16·0 (SPSS Inc., Chicago, IL, USA), and the level of significance was set at 5 %.

Results

The percentage of breakfast consumers was significantly higher in males than in females, in both the total study sample as well as in the subgroup with blood analysis (Table 1, $P < 0·001$). In the whole study sample, the percentage of breakfast consumers was significantly higher in females from northern/central Europe than in females from southern Europe (Table 2, $P < 0·01$). In contrast, among

Table 1 Breakfast consumption, weight status, mother's/father's education level and family structure by sex: adolescents (n 2929), aged 12–17 years, from ten European cities participating in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study

	Total sample					Sub-sample*				
	Males		Females			Males		Females		
	Frequency	%	Frequency	%	P†	Frequency	%	Frequency	%	P†
Age										
<15 years	760	56	924	59	0·038	252	58	309	63	0·152
≥15 years	610	44	635	41		181	42	183	37	
Breakfast consumption										
Consumer	694	51	699	45	<0·001	244	56	213	43	<0·001
Occasional consumer	344	25	342	22		80	18	109	22	
Skipper	332	24	518	33		109	25	170	35	
BMI (kg/m^2)										
Non-overweight	1007	74	1243	80	<0·001	322	75	396	81	0·047
Overweight	260	19	253	16		78	18	76	15	
Obese	103	7	63	4		33	7	20	4	
Mother's education										
Elementary	101	8	111	7	0·768	33	8	41	9	0·550
Lower secondary	328	25	367	25		104	26	116	25	
Higher secondary	405	31	497	33		127	32	168	36	
University	453	35	518	35		139	34	146	31	
Father's education										
Elementary	83	7	111	9	0·643	31	8	32	7	0·885
Lower secondary	358	28	409	29		108	28	132	29	
Higher secondary	369	29	403	28		119	30	145	32	
University	454	36	504	35		134	34	149	33	
Family structure										
Traditional	1035	78	1191	79	0·383	335	79	393	83	0·225
Single/shared-care	291	22	309	21		87	21	83	17	

*Sub-sample with blood analysis.
†P value from χ^2 test; $P<0·05$ indicates statistical significance.

Table 2 Breakfast consumption by sex and European region: adolescents (n 2929), aged 12–17 years, from ten European cities participating in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study

	Total sample					Sub-sample*				
	Southern		Northern/central			Southern		Northern/central		
	Frequency	%	Frequency	%	P†	Frequency	%	Frequency	%	P†
Males										
Consumer	289	58	504	58	<0·001	95	58	169	63	0·056
Occasional consumer	65	13	60	7		16	10	11	4	
Skipper	146	29	306	35		52	32	90	33	
Female										
Consumer	271	45	521	55	<0·01	84	42	152	52	0·106
Occasional consumer	51	8	59	6		16	8	21	7	
Skipper	283	47	374	39		99	50	120	41	

*Sub-sample with blood analysis.
†P value from χ^2 test; $P<0·05$ indicates statistical significance.

males from northern/central Europe the percentage of breakfast skippers was significantly higher compared with those from southern Europe (Table 2, $P<0·001$). No regional differences were seen in the percentage of breakfast consumers/skippers among the subgroup of adolescents with blood analysis. No association was observed between sex and either maternal/paternal education level or family structure (Table 1). Table 3 shows the mean age and values of the studied CVD risk factors by breakfast consumption category and sex. In males, significant differences across breakfast consumption category were seen for age, BMI, skinfold thickness, waist circumference, systolic and diastolic blood pressures (all $P<0·001$), as well as for TC:HDL-C, LDL-C:HDL-C, glucose, insulin and HOMA-IR (all $P<0·01$) and LDL-C ($P<0·05$). No association was observed between breakfast and TAG, TC or HDL-C (Table 3). In females, significant differences across breakfast consumption category were seen for skinfold thickness ($P<0·01$) BMI, insulin and HOMA-IR (all $P<0·05$), whereas no association was observed between breakfast consumption category and age or the other studied CVD risk factors. Cardiorespiratory fitness differed significantly by breakfast consumption category in both males and females (both $P<0·001$).

Table 3 CVD risk factors by breakfast consumption and sex: adolescents (*n* 2929), aged 12–17 years, from ten European cities participating in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study

	Males (*n* 1370)				Females (*n* 1559)			
	Mean	SE	P^*	R^2	Mean	SE	P^*	R^2
Age (years)								
Consumer	14·9	0·1			14·9	0·1		
Occasional consumer	15·0	0·1	0·001	0·046	14·8	0·1	0·198	0·035
Skipper	15·2	0·1			15·0	0·1		
BMI (kg/m^2)								
Consumer	20·9	0·2			21·2	0·1		
Occasional consumer	21·8	0·2	<0·001	0·072	21·4	0·2	0·015	0·049
Skipper	22·6	0·2			21·8	0·2		
Sum of six skinfolds (mm)†								
Consumer	70·4	1·5			100·6	1·4		
Occasional consumer	77·6	2·1	<0·001	0·050	101·6	2·1	0·003	0·019
Skipper	80·6	2·2			107·0	1·7		
WC (cm)								
Consumer	73·3	0·4			70·2	0·3		
Occasional consumer	75·0	0·5	<0·001	0·129	70·5	0·5	0·083	0·068
Skipper	76·5	0·5			71·3	0·4		
V_{O2max} (ml/kg per min)†								
Consumer	52·4	0·4			36·8	0·3		
Occasional consumer	50·1	0·5	<0·001	0·071	36·3	0·4	<0·001	0·096
Skipper	48·5	0·5			34·9	0·3		
SBP (mmHg)								
Consumer	124	0·5			116	0·5		
Occasional consumer	124	0·8	<0·001	0·112	116	0·7	0·822	0·036
Skipper	129	0·8			116	0·5		
DBP (mmHg)								
Consumer	67	0·4			68	0·4		
Occasional consumer	67	0·5	<0·001	0·056	68	0·5	0·636	0·011
Skipper	70	0·5			69	0·4		
Blood markers		(*n* 433)				(*n* 492)		
TAG (mg/dl)†								
Consumer	64·2	2·1			76·1	2·9		
Occasional consumer	62·2	3·9	0·138	0·024	71·6	4·2	0·835	0·001
Skipper	70·7	3·2			71·0	3·2		
TC (mg/dl)								
Consumer	152·5	1·8			168·3	2·1		
Occasional consumer	154·2	3·3	0·216	0·018	166·5	3·0	0·889	0·005
Skipper	158·2	2·7			167·9	2·3		
HDL-C (mg/dl)								
Consumer	53·8	0·7			57·9	0·8		
Occasional consumer	54·0	1·2	0·082	0·036	57·2	1·2	0·797	0·007
Skipper	51·2	1·0			57·2	0·9		
LDL-C (mg/dl)								
Consumer	88·7	1·7			97·9	1·8		
Occasional consumer	89·2	3·1	0·030	0·019	96·9	2·7	0·923	0·007
Skipper	96·6	2·5			98·2	2·1		
TC:HDL-C†								
Consumer	2·91	0·05			2·96	0·04		
Occasional consumer	2·94	0·09	0·007	0·015	2·98	0·06	0·842	0·005
Skipper	3·19	0·07			3·02	0·05		
LDL-C:HDL-C								
Consumer	1·72	0·05			1·74	0·04		
Occasional consumer	1·73	0·08	0·008	0·016	1·77	0·06	0·686	0·004
Skipper	1·98	0·07			1·79	0·05		
Insulin (μIU/ml)								
Consumer	8·3	0·4			9·3	0·4		
Occasional consumer	11·1	0·8	0·001	0·048	9·2	0·5	0·025	0·093
Skipper	10·6	0·6			10·6	0·4		
Glucose (mg/dl)								
Consumer	91·6	0·5			88·3	0·5		
Occasional consumer	92·2	0·9	0·004	0·012	89·1	0·7	0·182	0·075
Skipper	94·6	0·8			89·6	0·5		
HOMA-IR†								
Consumer	1·9	0·1			2·0	0·1		
Occasional consumer	2·5	0·2	0·001	0·050	2·0	0·1	0·038	0·103
Skipper	2·5	0·1			2·4	0·1		

WC, waist circumference; V_{O2max}, cardiorespiratory fitness; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, HDL cholesterol; LDL-C, LDL cholesterol; HOMA-IR, homeostasis model assessment–insulin resistance index.
All analyses were adjusted for centre (random variable), age, mother's education, father's education and family structure.
**P* value from one-way analysis of covariance; $P < 0·05$ indicates statistical significance.
†Analysis was performed on log-transformed data, but non-transformed data are presented as mean and SE.

Table 4 CVD risk factors by breakfast consumption, sex and weight status: adolescents (*n* 2929), aged 12–17 years, from ten European cities participating in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study

	Males								Females							
	Non-overweight (*n* 1007)		Overweight/obese (*n* 363)						Non-overweight (*n* 1243)		Overweight/obese (*n* 316)					
	Mean	SE	Mean	SE	*P**	*P*†	*P*‡	R^2	Mean	SE	Mean	SE	*P**	*P*†	*P*‡	R^2
V_{O2max} (ml/kg per min)§																
Consumer	54·6	0·3	43·6	0·7					37·7	0·3	32·3	0·7				
Occasional consumer	53·0	0·5	41·5	0·9	<0·001	0·001	0·651	0·361	36·5	0·4	33·6	0·8	<0·001	0·003	0·083	0·182
Skipper	51.8	0·6	41·7	0·8					35·4	0·4	31·6	0·7				
SBP (mmHg)																
Consumer	122	0·6	131	1·1					115	0·5	122	1·1				
Occasional consumer	122	0·9	130	1·4	<0·001	<0·001	0·211	0·186	115	0·7	123	1·4	<0·001	0·861	0·834	0·100
Skipper	125	0·9	136	1·3					115	0·6	122	1·1				
DBP (mmHg)																
Consumer	66	0·4	69	0·8					68	0·4	72	0·9				
Occasional consumer	66	0·6	70	1·0	<0·001	<0·001	0·664	0·080	67	0·6	73	1·1	<0·001	0·884	0·300	0·052
Skipper	69	0·6	72	0·8					68	0·5	72	0·9				
Blood parameters	(*n* 322)		(*n* 111)						(*n* 396)		(*n* 96)					
TAG (mg/dl)§																
Consumer	60·5	2·4	76·5	4·4					71·4	3·1	99·2	7·0				
Occasional consumer	59·2	4·3	74·2	8·6	<0·001	0·410	0·924	0·066	70·9	4·5	75·1	10·1	0·006	0·393	0·465	0·017
Skipper	65·3	3·9	79·8	5·0					68·2	3·6	80·0	6·4				
TC (mg/dl)																
Consumer	153·9	2·0	147·9	3·8					168·3	2·3	168·1	5·2				
Occasional consumer	151·5	3·6	165·3	7·4	0·109	0·034	0·025	0·037	165·7	3·3	170·9	7·5	0·413	0·980	0·812	0·010
Skipper	154·5	3·3	164·0	4·3					166·9	2·7	171·0	4·7				
HDL-C (mg/dl)																
Consumer	55·5	0·7	47·9	1·4					59·1	0·9	52·0	2·0				
Occasional consumer	54·7	1·3	50·8	2·7	<0·001	0·377	0·526	0·108	57·6	1·3	55·2	2·8	0·002	0·990	0·413	0·022
Skipper	53·3	1·2	47·5	1·6					58·2	1·0	53·9	1·8				
LDL-C (mg/dl)																
Consumer	88·3	1·8	90·0	3·5					97·1	2·0	101·6	4·5				
Occasional consumer	85·9	3·4	102·7	6·8	0·001	0·015	0·049	0·048	95·6	2·9	103·3	6·6	0·057	0·982	0·914	0·009
Skipper	90·6	3·1	106·2	4·0					96·5	2·4	103·5	4·2				
TC:HDL-C§																
Consumer	2·85	0·05	3·14	0·10					2·89	0·05	3·31	0·11				
Occasional consumer	2·83	0·10	3·36	0·19	<0·001	0·024	0·414	0·078	2·94	0·07	3·21	0·16	<0·001	0·962	0·775	0·039
Skipper	3·00	0·09	3·49	0·11					2·95	0·06	3·27	0·10				
LDL-C:HDL-C																
Consumer	1·66	0·05	1·92	0·09					1·68	0·04	2·01	0·10				
Occasional consumer	1·63	0·09	2·12	0·18	<0·001	0·023	0·354	0·067	1·72	0·06	1·99	0·15	<0·001	0·979	0·909	0·036
Skipper	1·79	0·08	2·27	0·11					1·73	0·05	1·99	0·09				
Insulin (μIU/ml)																
Consumer	7·4	0·4	11·5	0·8					8·6	0·4	12·9	0·8				
Occasional consumer	10·7	0·8	12·5	1·6	<0·001	0·039	0·489	0·103	9·1	0·5	9·6	1·2	<0·001	0·031	0·061	0·160
Skipper	9·5	0·7	12·5	1·0					9·9	0·4	13·1	0·8				

Table 4 *Continued*

	Males								Females							
	Non-overweight (*n* 1007)		Overweight/obese (*n* 363)						Non-overweight (*n* 1243)		Overweight/obese (*n* 316)					
	Mean	SE	Mean	SE	P*	P†	P‡	R^2	Mean	SE	Mean	SE	P*	P†	P‡	R^2
Glucose (mg/dl)																
Consumer	91·3	0·5	92·7	1·1					88·2	0·5	88·5	1·1				
Occasional consumer	92·0	1·0	93·1	2·1	0·293	0·021	0·949	0·009	89·8	0·7	85·5	1·6	0·563	0·022	0·005	0·092
Skipper	94·3	0·9	95·1	1·2					88·9	0·6	91·6	1·0				
HOMA-IR§																
Consumer	1·7	0·1	2·7	0·2					1·9	0·1	2·8	0·2				
Occasional consumer	2·4	0·2	2·8	0·4	<0·001	0·064	0·329	0·130	2·0	0·1	2·0	0·3	<0·001	0·109	0·057	0·161
Skipper	2·3	0·2	3·0	0·2					2·2	0·1	3·0	0·2				

V_{O2max}, cardiorespiratory fitness; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL-C, HDL cholesterol; LDL-C, LDL cholesterol; HOMA-IR, homeostasis model assessment–insulin resistance index.
All analyses were adjusted for centre (random variable), age, mother's education, father's education and family structure.
*Main effect of weight status by two-way analysis of covariance (ANCOVA); $P<0·05$ indicates statistical significance.
†Main effect of breakfast consumption by two-way ANCOVA; $P<0·05$ indicates statistical significance.
‡Interaction effect between breakfast consumption and weight status by two-way ANCOVA; $P<0·05$ indicates statistical significance.
§Analysis was performed on log-transformed data, but non-transformed data are presented as mean and SE.

Interactions between breakfast consumption categories and weight status

Table 4 presents the means of the CVD risk factors by breakfast consumption category, sex and weight status. In male adolescents, an interaction effect on TC and LDL-C was observed between breakfast consumption and weight status. Males who were breakfast consumers and overweight/obese had lower TC and LDL-C compared with the skipper group ($P<0·001$), whereas no association was observed in the non-overweight group. In females, an interaction between breakfast consumption and weight status was observed for glucose. These results persisted after excluding the underweight adolescents from the analysis (data not shown) and when the analyses were additionally adjusted for pubertal status (data not shown). The analyses were repeated after further adjusting for objectively measured physical activity, and the results did not change (data not shown).

Discussion

The present study, conducted in a relatively large sample of adolescents from nine different European countries, confirmed previous data indicating that adolescents who regularly consume breakfast have lower body fat content. The results also showed that regular breakfast consumption is associated with higher cardiorespiratory fitness in both males and females, and with a healthier cardiovascular profile, especially in males.

The frequency of regular breakfast consumption in our study sample was similar to that reported in other Western populations[3,4]. Our study showed that more males than females reported to be regular breakfast consumers. We also observed that older male adolescents were more likely to be breakfast skippers than younger male adolescents. Previous studies from large epidemiological and cross-sectional surveys have observed marked declines in the frequency of breakfast consumption from childhood to adolescence[12,34,35].

In the present study, regular breakfast consumers had lower total adiposity (estimated by BMI or skinfold thickness). Two systematic reviews have examined the association between breakfast consumption and body weight[3,4]. Rampersaud *et al.* concluded that although breakfast eaters consumed more energy daily, they were less likely to be obese; yet they noted that not all studies reported significant relationships between breakfast skipping and overweight/obesity[3]. In a recent review Szajewska and Ruszczynski concluded that in European children and adolescents consuming breakfast is associated with a lower BMI and with a reduced risk of becoming overweight or obese[4], which concurs with our results. Our results showed differences in breakfast consumption, according to sex, between the two regions of Europe (southern *v.* northern/central). To the best of our knowledge, there are no studies investigating differences in breakfast consumption among adolescents from southern and northern/central Europe. Vereecken *et al.* have shown differences among countries in Europe: in the southern region daily breakfast consumption ranges from 33 % (Greek girls) to 72 % (Spanish boys) and in the northern/central region it ranges from 42 % (Hungarian girls) to 73 % (Swedish boys)[36]. Further research is needed on a regional and/or national level to better understand the breakfast consumption among adolescents living in different parts of Europe.

Breakfast is, for adolescents, one of the most important meals of the day and its consumption is associated with favourable diet quality (i.e. favourable nutrient and energy intakes) and improved food choice[6] and exercise patterns[8]. Thus, skipping breakfast has been proposed to influence weight status indirectly by leading to hunger in the morning and resulting in increased snacking and consumption of empty calories[6]. On the other hand, it could be the food and nutrient content of breakfast itself that influences body weight[34,37,38]. Indeed, several studies have shown that the consumption of high-fibre or wholegrain cereals at breakfast is associated with lower BMI[34,39,40].

We observed that regular breakfast consumption was associated with higher cardiorespiratory fitness in both males and females. These findings confirm the results of a recent report conducted in large sample of schoolchildren[41]. Our study showed that boys and girls who never ate breakfast had lower mean cardiorespiratory fitness. A possible link between breakfast consumption and fitness could be due to a clustering of healthy behaviours[8,42,43]. Breakfast consumers seem to have a more active lifestyle than breakfast skippers[44]. In a previous study[8], the authors showed that breakfast skippers were much more likely to exercise infrequently than regular breakfast consumers.

Regular breakfast consumption was associated with a healthier cardiovascular profile (i.e. waist circumference, blood pressure, TC:HDL-C, LDL-C:HDL-C and insulin resistance) in male adolescents in the present study. Waist circumference is a surrogate measure of abdominal adiposity and is considered an important contributor to metabolic complications in children and adolescents[45]. Studies investigating the relationship between breakfast consumption and body fat distribution in adolescents are scarce. Deshmukh-Taskar *et al.* showed that mean waist circumference was higher in breakfast skippers[37], which concurs with our results. Moreover, a previous study conducted in a well-characterized sample of ninety-three overweight youths (aged 10–17 years) reported that eating breakfast was associated with lower visceral adiposity as measured by dual-energy X-ray absorptiometry[46].

Male breakfast consumers in the present study had lower systolic and diastolic blood pressures regardless of BMI, whereas no association was found in females. Youths who usually consume breakfast are more likely to be frequent consumers of fruit, cereals and milk[47], which, in turn, are central foods in the recommended dietary pattern for lowering blood pressure[48,49]. Therefore, the intake of milk products during breakfast supports total daily intakes of milk and Ca[6,10,50], which have been associated with a lower risk of hypertension in adults[51]. In agreement with our findings, a sex-specific association (observed in males only) between breakfast and blood pressure was reported in a previous study performed in Greek adolescents[52].

We did not find any significant effect of breakfast consumption on most of the CVD risk factors, such as blood lipid levels, blood pressure or insulin resistance, in females. Regular breakfast consumption was significantly related to a healthier blood lipid profile in males. Breakfast consumers had lower TC, LDL-C and lower TC:HDL-C and LDL-C:HDL-C ratios. Moreover, our results suggested that consuming breakfast regularly may influence the negative effects of being overweight in males. To our knowledge, there are no previous studies examining the relationship between breakfast consumption and blood metabolic variables. Albertson *et al.* examined possible sex-related differences in the association between the consumption of ready-to-eat cereals at breakfast and cardiovascular health indicators, showing that ready-to-eat cereals were significantly associated with lower blood lipid levels only in males[34]. Other studies have also documented a lack of significant associations between food group consumption and cholesterol among females, suggesting a complex association between dietary patterns, blood lipids and sex.

The use of the self-reported statement 'I often skip breakfast' to gauge habitual breakfast consumption could be a limitation of our study. The term 'breakfast consumers' in the literature includes a variety of definitions, such as consuming breakfast every day, every week day, on the dietary survey day, or usual or habitual consumption[3], which makes comparisons difficult. In addition, there is no consensus regarding how to define breakfast consumption. A recent study found that the percentage of breakfast skippers varied greatly according to how breakfast was categorized[53]. Furthermore, because of the cross-sectional nature of the study design, no conclusion can be drawn about the directionality and causality of the associations seen between breakfast consumption and CVD risk factors. The large sample of adolescents in the study population and the standardized and harmonized methodology are notable strengths of the present study. In addition, previous studies have predominantly used BMI as a measure of body composition. Recent systematic reviews indicated that skinfold thicknesses and waist circumference are valid makers of total and central fatness in young people[28] and are strong predictors of future health status[54]. The inclusion of these two surrogates of fatness, and the consistency of the results observed, strengthen our study's conclusions.

Conclusions

Our findings in European adolescents confirm previous data indicating that those who regularly consume breakfast have lower body fat. The results also indicate that regular breakfast consumption is associated with higher cardiorespiratory fitness in both males and females, and with a healthier cardiovascular profile, especially in males. Eating breakfast regularly may also negate somewhat the effect of excess adiposity on TC and LDL-C in male adolescents.

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