British Journal of Nutrition (2012), **107**, 1850–1859 doi:10.1017/S0007114511005149

British Journal of Nutrition

Cardiorespiratory fitness and dietary intake in European adolescents: the Healthy Lifestyle in Europe by Nutrition in Adolescence study

M. Cuenca-García[1]*, F. B. Ortega[1,2], I. Huybrechts[3], J. R. Ruiz[2,4], M. González-Gross[5], C. Ottevaere[3], M. Sjöström[2], L. E. Dìaz[6], D. Ciarapica[7], D. Molnar[8], F. Gottrand[9], M. Plada[10], Y. Manios[11], L. A. Moreno[12], S. De Henauw[3], M. Kersting[13] and M. J. Castillo[1] on behalf of the HELENA study group

[1]*Department of Medical Physiology, School of Medicine, Granada University, Avenida de Madrid s/n, 18012 Granada, Spain*
[2]*Unit for Preventive Nutrition, Department of Biosciences and Nutrition, Karolinska Institutet, Huddinge, Sweden*
[3]*Department of Public Health, Ghent University, Ghent, Belgium*
[4]*Department of Physical Education and Sport, School of Physical Activity and Sport Sciences, Granada University, Granada, Spain*
[5]*Department of Health and Human Performance, Faculty of Physical Activity and Sport Sciences, Universidad Politécnica, Madrid, Spain*
[6]*Immunonutrition Research Group, Department of Metabolism and Nutrition, Institute of Food Science, Technology and Nutrition (ICTAN), Spanish National Research Council (CSIC), Madrid, Spain*
[7]*National Research Institute for Food and Nutrition, Rome, Italy*
[8]*Department of Pediatrics, Pécs University, Pécs, Hungary*
[9]*Inserm U995, University Lille2, Lille, France*
[10]*Department of Social Medicine, School of Medicine, Crete University, Crete, Greece*
[11]*Department of Nutrition and Dietetics, Harokopio University, Athens, Greece*
[12]*GENUD (Growth, Exercise, Nutrition and Development) Research Group, Escuela Universitaria de Ciencias de la Salud, Zaragoza University, Zaragoza, Spain*
[13]*Research Institute of Child Nutrition Dortmund, Rheinische Friedrich-Wilhelms-Universität Bonn, Germany*

(Submitted 12 April 2011 – Final revision received 27 July 2011 – Accepted 16 August 2011 – First published online 28 November 2011)

Abstract

The present study investigated the association between cardiorespiratory fitness (CRF) and dietary intake in European adolescents. The study comprised 1492 adolescents (770 females) from eight European cities participating in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. CRF was assessed by the 20 m shuttle run test. Adolescents were grouped into low and high CRF levels according to the FITNESSGRAM Standards. Dietary intake was self-registered by the adolescents using a computer-based tool for 24 h dietary recalls (HELENA-Dietary Assessment Tool) on two non-consecutive days. Weight and height were measured, and BMI was calculated. Higher CRF was associated with higher total energy intake in boys ($P=0{\cdot}003$). No association was found between CRF and macronutrient intake (as percentage of energy), yet some positive associations were found with daily intake of bread/cereals in boys and dairy products in both boys and girls (all $P<0{\cdot}003$), regardless of centre, age and BMI. CRF was inversely related to sweetened beverage consumption in girls. These findings were overall consistent when CRF was analysed according to the FITNESSGRAM categories (high/low CRF). A high CRF was not related to compliance with dietary recommendations, except for sweetened beverages in girls ($P=0{\cdot}002$). In conclusion, a high CRF is associated with a higher intake of dairy products and bread/cereals, and a lower consumption of sweetened beverages, regardless of centre, age and BMI. The present findings contribute to the understanding of the relationships between dietary factors and physiological health indicators such as CRF.

Key words: Physical fitness: Dietary recommendations: Diet: Food consumption

---

Abbreviations: CRF, cardiorespiratory fitness; CSS, Cross-Sectional Study; DIAT, Dietary Assessment Tool; FBDG, food-based dietary guidelines; HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence; YANA-C, Young Adolescents' Nutrition Assessment on Computer.

* **Corresponding author:** M. Cuenca-García, fax +34 958 246179, email mmcuenca@ugr.es

Both physical fitness and diet influence the risk of CVD[1–4]. Cardiorespiratory fitness (CRF) is one of the most important components of health-related fitness[3]. High levels of CRF are associated with a healthier cardiovascular risk profile already in children[5] and when they become adults[6]. In this context, FITNESSGRAM Standards (developed by the Cooper Institute) established sex- and sex-specific CRF cut-off values for adolescents known as Healthy Fitness Zones[7]. The Healthy Fitness Zones are designed to represent the level of CRF (expressed as VO_{2max}) that is associated with adequate functional and health-related outcomes in adolescents.

Healthier eating in early childhood may help to prevent the development of chronic diseases later in life[8]. Studies have suggested that most adolescents do not comply with dietary guidelines/recommendations and these behaviours may induce adverse metabolic effects[9–11]. Moreover, there are some reference dietary intake estimates for nutrient intakes (e.g. from the Institute of Medicine)[12] and food-based dietary guidelines (FBDG, e.g. food pyramids)[13,14].

The importance of the independent relationship of healthy CRF level and diet in the prevention and treatment of CVD is well established, but little is known about the interaction between these two factors. In fact, dietary patterns have been associated with the overall cause of mortality, but the diet–disease relationship was largely confounded by CRF[15]. Few studies have examined the association between CRF levels and dietary intake in young[16] and older adults[17]. The results observed in older adults showed that people with higher fitness levels are more likely to meet the dietary recommendations than their less fit peers[17]. However, this relationship is not clear in young adults[16] and data are lacking in adolescents.

Although physical fitness is in part genetically determined[18], it is also influenced by environmental factors, particularly physical activity, and it is unknown how it is associated with nutrition. The FITNESSGRAM Standards have been associated with CVD risk factors in children and adolescents[19,20], and identifying which dietary behaviours are related to or co-exist with high levels of CRF is of both clinical and public health relevance. The present study investigated the association between CRF and dietary intake in a large sample of European adolescents.

Methods

Study design

Data were derived from the HELENA-CSS (Healthy Lifestyle in Europe by Nutrition in Adolescence-Cross-Sectional Study), which is a multi-centre study conducted in ten European cities (Athens in Greece, Dortmund in Germany, Ghent in Belgium, Heraklion in Greece, Lille in France, Pecs in Hungary, Rome in Italy, Stockholm in Sweden, Vienna in Austria and Zaragoza in Spain). The main aim of the HELENA-CSS was to obtain reliable and comparable data on nutrition and health-related parameters such as physical activity, physical fitness, body composition, food choices and preferences, cardiovascular risk factors, vitamins and mineral status, immunological biomarkers and genetic markers. A total of 3528 adolescents (age range 12·5–17·5 years) were assessed at schools between 2006 and 2007, all fulfilling with the general HELENA-CSS inclusion criteria[21]. Details on sampling procedures and study design of the HELENA study have been reported elsewhere[21,22]. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the ethics committee of each city involved[23]. Written informed consent was obtained from both the adolescents and their parents.

Participants

Only eight study centres could be included for the 24 h dietary recall analyses (Stockholm, Dortmund, Ghent, Lille, Athens, Rome, Vienna and Zaragoza), because incomplete information was obtained from Heraklion and Pecs. Heraklion could not be included in the 24 h recall analyses since only a minority of the study population completed two 24 h recall days due to logistic problems. Pecs was also excluded from the 24 h recall analyses because no nutrient information was available and thus the standardised data cleaning procedures could not be performed. Finally, 2084 cases (54 % girls) remained eligible for the 24 h dietary recall analyses. The 20 m shuttle run test was assessed in 2814 cases, while weight and height were measured in the whole sample.

In the present study participants with complete and valid data on 20 m shuttle run test, weight and height measurement and a 2 d 24 h dietary recall were included. A total of 2018 participants (53 % girls) met these criteria. Under-reporters, following previously described definition[24], were excluded from all analysis (526 cases, 58 % girls). The final sample for the present study was 1492 cases (52 % girls). Differences between the included and excluded groups for age, sex, weight, height and BMI z-score were analysed. No differences (all $P > 0·1$) were found between the included and excluded groups for age, sex and height, while weight (difference 4 kg) and BMI z-score (difference 0·41) were higher in the excluded group, which might be explained by the fact that the under-reporters excluded from the analyses had a higher BMI than the rest of the sample (data not shown). The descriptive characteristics of this sample are presented in Table 1.

Measurements

Cardiorespiratory fitness assessment. CRF was measured with the 20 m shuttle run test[25]. 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 is 8·5 km/h, which is increased by 0·5 km/h per min (1 min equals one stage). Participants were instructed to run in a straight line, to pivot on completing a shuttle, and to pace themselves in accordance with the audio signals. The test was finished when the participant fails to reach the end lines concurrent with the audio signals on two consecutive occasions. The test was performed once, and the last half-stage fulfilled by the adolescent was recorded.

Table 1. Descriptive characteristics of the study sample and stratified by sex
(Mean values and standard deviations or standard errors)

	All (*n* 1492)		Boys (*n* 722)		Girls (*n* 770)		
	Mean	SD	Mean	SD	Mean	SD	*P**
Age (years)	14·7	1·2	14·7	1·3	14·6	1·2	0·159
Weight (kg)	56·7	11·4	59·3	12·7	54·2	7·0	< 0·001
Height (cm)	165·6	9·1	169·5	9·4	161·9	9·3	< 0·001
BMI (kg/m²)	20·6	3·2	20·5	3·3	20·7	3·2	0·369
20 m shuttle run (stage)	5·5	1·1	6·9	1·1	4·1	1·1	< 0·001
VO_{2max} (ml/kg per min)	42·2	7·4	46·2	7·1	38·4	5·5	< 0·001
	Mean	SE	Mean	SE	Mean	SE	
Energy (kJ)	10 281·1	16·5	11 666·2	102·3	8982·3	64·7	< 0·001
Macronutrients							
Carbohydrate (% E)	48·9	0·2	48·7	0·2	49·0	0·2	0·254
Saccharides (% E)	23·7	0·2	23·3	0·3	24·1	0·2	0·025
Polysaccharides (% E)	24·5	0·1	24·4	0·2	24·6	0·2	0·362
Protein (% E)	15·8	0·1	15·9	0·1	15·7	0·1	0·109
Total fat (% E)	33·7	0·1	33·5	0·2	34·0	0·2	0·022
Saturated fat (% E)	14·0	0·1	14·0	0·1	14·0	0·1	0·668
Cholesterol (mg)	372·1	3·2	415·7	5·0	331·1	3·6	< 0·001
Food group							
Bread/cereals (g)†	127·7	1·6	144·9	2·5	111·7	1·9	< 0·001
Grains/potatoes (g)‡	198·4	2·0	217·6	3·0	180·5	2·5	< 0·001
Fruit (g)	136·9	2·7	137·2	4·0	136·6	3·5	0·904
Vegetables (g)	144·0	2·3	142·3	3·5	145·6	3·1	0·469
Dairy products (g)	281·9	5·9	322·8	9·5	243·5	6·8	< 0·001
Cheese (g)	32·7	0·6	37·2	0·9	28·4	0·7	< 0·001
Protein food (g)§	205·8	2·2	233·9	3·4	179·4	2·5	< 0·001
Fat/sweet food (g)‖	170·4	1·9	185·5	2·9	156·2	2·3	< 0·001
Sweetened beverages (g)¶	482·7	9·2	575·0	14·5	396·2	10·1	< 0·001

% E, percentage of energy.
* Boys *v.* girls (*t* test).
† Bread, rolls and cereals.
‡ Starchy roots, potatoes, flour, pasta, rice and other grain products.
§ Meat, fish, pulses, eggs, meat substitute and protein from vegetarian products.
‖ Confectionery, chocolate, other sugar products, savoury snacks and butter–animal fat.
¶ Juices, carbonate, soft and isotonic drink.

The equations of Léger *et al.*[25], previously validated in young people[25,26], were used to estimate VO_{2max} (ml/kg per min) from the test score. Participants were classified into low and high CRF levels according to the FITNESSGRAM Standards for the Healthy Fitness Zones[7,27]. The thresholds proposed by the FITNESSGRAM have been consistently validated in relation to CVD risk in young people[20]. The FITNESSGRAM proposed one threshold for boys for the adolescence period and three thresholds for girls based on age, since VO_{2max} (expressed in relative terms) is stable across this period in boys, but progressively decreases in girls. Boys with a VO_{2max} of 42 ml/kg per min or higher were classified as having a high CRF level. Girls aged 12 and 13 years with a VO_{2max} of 37 and 36 ml/kg per min or higher, respectively, were classified as having a high CRF level. Girls aged 14 or older with a VO_{2max} of 35 ml/kg per min or higher were classified as having a healthy CRF level.

Healthy Lifestyle in Europe by Nutrition in Adolescence-Dietary Assessment Tool. Dietary intake assessment was performed by a computer-based tool for self-reported 24 h recalls, HELENA-DIAT (Dietary Assessment Tool), on two non-consecutive days. This tool was based on the Young Adolescents' Nutrition Assessment on Computer (YANA-C) software and has been proposed as a good method of collecting detailed dietary information from adolescents. Food and nutrient intakes assessed with YANA-C were compared with both food records and 24 h dietary recall interviews, proving a good inter-method agreement with both standard methods ($\kappa = 0·38–0·92$ and 0·38–0·90, respectively)[28]. We have recently conducted a feasibility and validity study in 236 adolescents (age 14·6 (SD 1·7) years) from eight European cities who completed the 24 h recall (YANA-C, now called HELENA-DIAT) twice (once by self-report and once by interview)[29]. We observed a good inter-method agreement, suggesting that the adaptation, translation and standardisation of the HELENA-DIAT allows to accurately assess dietary intake in European adolescents. Dietary intake was divided into six meal occasions and refers to the day before the interview. The adolescents completed the program autonomously in the computer classroom during school time while fieldworkers were present to give assistance if necessary[29]. Every participant was asked to fill in the HELENA-DIAT on arbitrary days, twice in a time span of 2 weeks. Since the questionnaire was filled in during school time, no data could be collected about the dietary intake on Fridays and Saturdays.

To calculate energy and nutrient intakes, data of the HELENA-DIAT were linked to the German Food Code and Nutrient Database (Bundeslebensmittelschlüssel, version II.3.1, 2005)[30]. The usual dietary intake of nutrients and foods was estimated by the multiple source method (https://nugo.-dife.de/msm/)[31]. The multiple source method calculates first dietary intake for individuals and then constructs the population distribution based on the individual data. This method takes into account the between- and within-person variability of the dietary intake data.

Average energy intake was estimated in kJ and the intake of carbohydrates, saccharides (monosaccharides and disaccharides), polysaccharides, proteins, total fat and saturated fat was adjusted for total energy intake (as percentage of energy). Cholesterol intake was expressed in mg. To compare the dietary intake of the adolescents with the FBDG in Europe[13], foods were grouped into aggregated food groups (g), such as bread/cereals (bread, rolls and cereals), grain/potatoes (starch roots, potatoes, flour, pasta, rice and other grain products), fruits, vegetables, dairy products (excluding cheese), cheese, protein food (meat, fish, pulses, eggs, meat substitute and protein from vegetarian products), fat/sweet food (confectionery, chocolate, other sugar products, savoury snacks and butter–animal fat) and sweetened beverages (juices, carbonate, soft and isotonic drink). Compliance with the Acceptable Macronutrient Distribution Ranges and Tolerable Upper Intake Levels according to the Institute of Medicine[12] and with the Acceptable Ranges of the Flemish FBDG[14] were calculated.

Under-reporting was considered when the ratio of energy intake over the estimated BMR was lower than 0·96, as proposed by Black[24]. BMR, used for estimating under-report, was calculated from age-specific FAO/WHO/UNU equations[32].

Anthropometric measurements. The protocol used to collect anthropometric data has been described previously[33]. All adolescents were measured by trained researchers in a standardised way. Weight was measured with an electronic scale (type SECA 861) to the nearest 0·1 kg. Height was measured in the Frankfort plane with a telescopic height-measuring instrument (type SECA 225) to the nearest 0·1 cm. BMI was calculated as body weight divided by the square of height (kg/m^2), and adjusted for age and sex to give a BMI standard deviation score (BMI z-score)[34].

Data analyses

Statistical analyses were performed using the statistical software PASW for Windows version 18 (PASW Inc., Chicago, IL, USA). Sex differences were tested with the t test. Statistical significance for t test was considered with $P \leq 0{\cdot}05$. All analyses were stratified by sex.

To examine the relationship between CRF and dietary intake, we used multilevel analysis[35]. Dietary intake was considered as the outcome variable and CRF as the independent variable, first, in the continuous form and, second, as the dichotomous variable (high/low CRF according to the FITNESSGRAM definition). For the multilevel analysis, the study centre was included as a random intercept and current

Table 2. Multilevel analysis examining the associations between cardiorespiratory fitness (VO_{2max}) and dietary intake
(Estimated values and 95 % confidence intervals)

	Boys				Girls			
	β	95 % CI	*P**	*P*†	β	95 % CI	*P**	*P*†
Energy (kJ)	42·739	14·258, 71·221	0·003	0·006	17·418	−7·960, 42·797	0·182	0·741
Macronutrients								
Carbohydrate (% E)	0·021	−0·042, 0·085	0·513	0·677	−0·011	−0·094, 0·072	0·790	0·624
Saccharides (% E)	0·012	−0·059, 0·082	0·744	0·717	−0·020	−0·107, 0·068	0·659	0·314
Polysaccharides (% E)	0·009	−0·041, 0·058	0·734	0·407	0·004	−0·060, 0·067	0·910	0·647
Protein (% E)	−0·008	−0·036, 0·020	0·565	0·787	0·021	−0·014, 0·056	0·247	0·150
Total fat (% E)	0·014	−0·037, 0·066	0·588	0·581	0·008	−0·060, 0·076	0·814	0·853
Saturated fat (% E)	0·028	0·001, 0·054	0·041	0·079	0·027	−0·007, 0·062	0·123	0·284
Cholesterol (mg)	1·854	0·444, 3·265	0·010	0·013	1·497	0·116, 2·877	0·034	0·204
Food group								
Bread/cereals (g)‡	1·313	0·623, 2·002	<0·001	<0·001	0·591	−0·110, 1·292	0·098	0·136
Grains/potatoes (g)§	−0·033	−0·840, 0·774	0·936	0·827	−0·645	−1·569, 0·279	0·171	0·041
Fruit (g)	1·337	0·168, 2·506	0·025	0·012	1·351	−0·013, 2·715	0·052	0·037
Vegetables (g)	0·765	−0·251, 1·782	0·140	0·250	0·976	−0·211, 2·164	0·107	0·139
Dairy products (g)	3·936	1·477, 6·396	0·002	<0·001	5·903	3·345, 8·461	<0·001	<0·001
Cheese (g)	−0·088	−0·344, 0·168	0·502	0·920	0·214	−0·067, 0·494	0·135	0·287
Protein food (g)‖	0·424	−0·478, 1·326	0·356	0·273	0·084	−0·786, 0·953	0·850	0·956
Fat/sweet food (g)¶	1·362	0·556, 2·169	0·001	0·009	0·590	−0·280, 1·460	0·183	0·872
Sweetened beverages (g)**	−4·931	−8·863, −0·999	0·014	0·007	−8·019	−11·680, −4·357	<0·001	<0·001

β, estimated value; % E, percentage of energy.
The level of significance is considered below the threshold after controlling for multiple testing ($P \leq 0{\cdot}003$).
* Model 1: after adjusting for centre and age.
† Model 2: after adjusting for centre, age and BMI z-score.
‡ Bread, rolls and cereals.
§ Starchy roots, potatoes, flour, pasta, rice and other grain products.
‖ Meat, fish, pulses, eggs, meat substitutes and protein from vegetarian products.
¶ Confectionery, chocolate, other sugar products, savoury snacks and butter–animal fat.
** Juices, carbonated, soft and isotonic drinks.

Table 3. Multilevel analysis examining dietary intake according to the FITNESSGRAM categories for cardiorespiratory fitness (CRF)
(Mean values with their standard errors)

	Boys						Girls					
	Low CRF (*n* 200)		High CRF (*n* 522)				Low CRF (*n* 261)		High CRF (*n* 509)			
	Mean	SE	Mean	SE	*P**	*P*†	Mean	SE	Mean	SE	*P**	*P*†
Energy (kJ)	11 177·2	258·9	11 712·4	210·5	0·017	0·026	8850·8	167·1	9021·8	146·3	0·230	0·602
Macronutrients												
Carbohydrate (% E)	48·3	1·1	48·8	1·1	0·310	0·394	49·0	1·1	48·9	1·1	0·847	0·735
Saccharides (% E)	22·7	1·2	23·2	1·1	0·353	0·643	23·8	1·3	24·4	1·3	0·180	0·316
Polysaccharides (% E)	24·4	0·7	24·6	0·6	0·657	0·434	24·9	0·8	24·2	0·8	0·045	0·070
Protein (% E)	16·3	0·6	16·1	0·5	0·288	0·391	15·6	0·5	15·8	0·5	0·518	0·415
Total fat (% E)	33·2	0·7	33·3	0·6	0·774	0·775	34·0	0·7	34·1	0·6	0·775	0·802
Saturated fat (% E)	13·6	0·7	14·0	0·6	0·075	0·119	13·9	0·2	14·1	0·2	0·188	0·326
Cholesterol (mg)	406·8	18·9	427·6	17·3	0·057	0·072	327·1	13·9	337·3	13·2	0·183	0·630
Food group												
Bread/cereals (g)‡	127·7	10·7	146·7	10·0	< 0·001	0·001	107·3	8·5	109·6	8·2	0·553	0·649
Grains/potatoes (g)§	224·5	15·9	220·5	15·3	0·521	0·656	189·0	10·8	173·1	10·4	0·002	< 0·001
Fruit (g)	129·3	10·6	142·7	8·6	0·142	0·103	129·0	10·1	141·7	9·1	0·094	0·080
Vegetables (g)	135·0	9·2	146·6	7·5	0·143	0·221	134·5	10·8	149·6	10·1	0·022	0·004
Dairy products (g)	311·5	51·6	345·7	49·9	0·003	0·003	222·8	26·6	257·5	25·3	0·001	0·004
Cheese (g)	36·6	3·3	36·2	3·0	0·844	0·833	28·5	2·2	26·1	2·4	0·116	0·201
Protein food (g)‖	241·7	18·3	239·8	17·6	0·784	0·855	181·6	16·2	183·4	16·0	0·713	0·835
Fat/sweet food (g)¶	168·7	10·3	187·0	9·4	0·004	0·016	149·9	7·6	159·9	7·1	0·038	0·189
Sweetened beverages (g)**	605·0	67·1	560·2	63·4	0·168	0·153	439·7	51·6	375·7	50·2	0·002	0·002

% E, percentage of energy.
The level of significance is considered below the threshold after controlling for multiple testing ($P \leq 0·003$).
* Model 1: after adjusting for centre and age.
† Model 2: after adjusting for centre, age and BMI z-score.
‡ Bread, rolls and cereals.
§ Starchy roots, potatoes, flour, pasta, rice and other grain products.
‖ Meat, fish, pulses, eggs, meat substitutes and protein from vegetarian products.
¶ Confectionery, chocolate, other sugar products, savoury snacks and butter–animal fat.
** Juices, carbonated, soft and isotonic drinks.

age (model 1) and BMI *z*-score (model 2) were entered as covariates. The level of statistical significance was controlled for multiple testing (0·05/number of tests = 0·05/17 = 0·003); therefore, statistical significance was only considered with $P \leq 0·003$. The effect-size statistics as Cohen's *d* (standardised mean differences) and 95 % CI were calculated[36]. Values of Cohen's *d* equal to 0·2, 0·5 and 0·8 were considered small, medium and large effects, respectively.

The associations between CRF and the compliance with dietary guidelines/recommendations were examined by binary logistic regression models (OR, 95 % CI), after controlling for centre and age. Statistical significance was also considered with $P \leq 0·003$.

Results

Descriptive characteristics of the study sample, and stratified by sex, can be found in Table 1. Weight, height and CRF levels were higher in boys ($P < 0·001$). Mean daily total energy intake, cholesterol intake and most food group consumption (all except fruit and vegetables) were also higher in boys ($P < 0·001$).

Table 2 shows the associations between CRF (VO_{2max}) and dietary intake. In boys, but not in girls, CRF was positively associated with mean daily energy intake ($P = 0·003$); this association was minimally attenuated when further adjusting for BMI *z*-score ($P = 0·006$). CRF was not related to the percentage of energy obtained from the different macronutrients or cholesterol intake, either in boys or in girls. CRF was positively related to mean daily intake of dairy products in both boys and girls. In boys, CRF was also positively associated with bread/cereals and fat/sweet food consumption. In girls, CRF was inversely associated with sweetened beverage consumption. In addition, whether the juices were added to the sweetened beverage groups (carbonated, soft and isotonic drinks) the results remained unchanged (data not shown). Overall, the results did not materially change after further adjustment for BMI *z*-score.

Table 3 shows the dietary intake according to the FITNESSGRAM levels. The only difference between the two categories was that boys with a low CRF reported to have consumed a lower amount of bread/cereals and dairy products than those with a high CRF ($P \leq 0·003$). In girls, those presenting low CRF also reported a lower consumption of dairy products but a higher consumption of grains/potatoes and sweetened beverages. The results did not materially change when BMI *z*-score was included as a covariate. The effect size, as estimated by Cohen's *d* statistics, was small (all $d \leq 0·2$).

Overall, CRF was not associated with compliance with dietary recommendations (Fig. 1). The binary logistic regression model showed that the only statistical significant associations were that girls complying with sweetened beverage recommendations (low consumption) had a higher probability of having high CRF levels (1·77, 95 % CI 1·24, 2·53).

Discussion

The results of the present study show the association between CRF and dietary intakes in a large sample of European adolescents controlling for centre, age and BMI. In both boys and girls, a high CRF is consistently associated with a higher consumption of dairy products, regardless of centre, age and BMI. A high CRF is also consistently associated with a higher intake of bread/cereals in boys, and a lower intake of sweetened beverages in girls. To the best of our knowledge, this is the first study reporting the association between CRF and dietary intakes in adolescents.

The association between CRF and dairy product intake observed in the present study is in accordance with a previous study in adults, showing that men and women in the higher fitness tertiles had higher Ca intakes[17]. The magnitude of the difference in dairy product intake between adolescents with a high *v.* low CRF was 11 and 9 % higher in boys and girls, respectively. Relatively small differences are expected since many factors influence dietary patterns. The potential benefit of milk consumption possibly due to the presence of many biologically active compounds[37] could be a possible explanation. In fact, combining consumption of high-quality

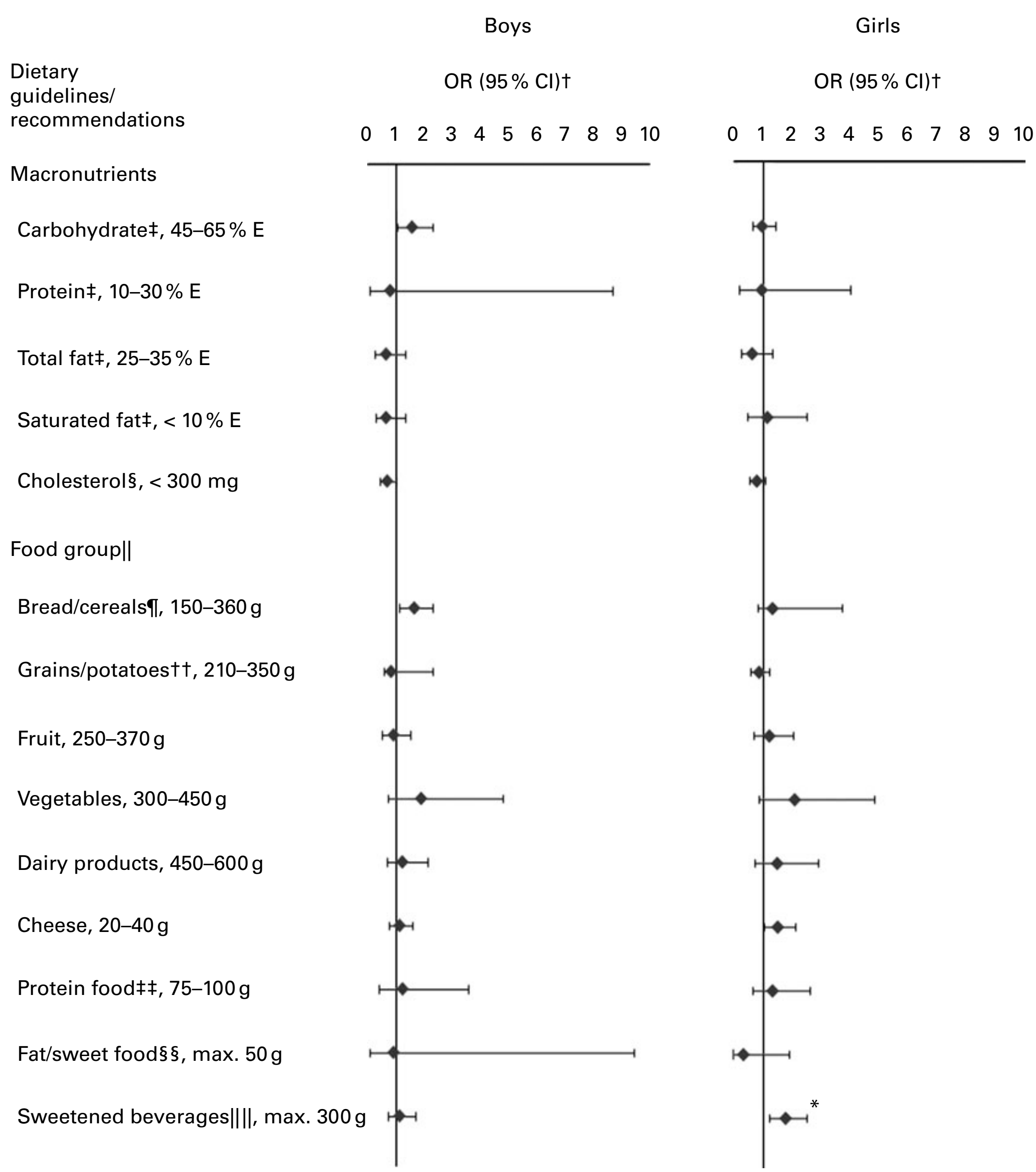

Fig. 1. OR and CI for presenting high cardiorespiratory fitness (CRF) and comply with dietary guidelines/recommendations. References present low CRF and comply with dietary recommendation (vertical lines indicate reference low CRF). † After adjusting for centre and age. ‡ Acceptable macronutrient distribution ranges. § Tolerable upper intake levels according to the Institute of Medicine[12]. || Acceptable ranges according to the Flemish food-based dietary guidelines[14]. ¶ Bread, rolls and cereals. †† Starchy roots, potatoes, flour, pasta, rice and other grain products. ‡‡ Meat, fish, pulses, eggs, meat substitutes and protein from vegetarian products. §§ Confectionery, chocolate, other sugar products, savoury snacks and butter–animal fat. |||| Juices, carbonated, soft and isotonic drinks. The level of significance is considered below the threshold after controlling for multiple testing ($P \leq 0{\cdot}003$). % E, percentage of energy; max., maximum.

(milk-based) proteins with resistance exercise[38,39] has been shown to induce higher gains in muscle mass in young, healthy, untrained men and women[40,41]. Dairy consumption is inversely associated with the metabolic syndrome[42,43], especially due to one of its components, i.e. Ca. In this line, observational studies have also shown an inverse association between the intake of Ca or dairy products and body weight, as well as total and abdominal fat[43–45]. Since body weight and adiposity are closely related to CRF, these findings could at least partially explain the association between CRF and dairy products observed in the present study.

The association of a high CRF with a higher intake of bread/cereals in boys is in accordance with previous studies in adults[16,17]. In these studies, a higher fitness was associated with a higher percentage of energy coming from carbohydrates[17] and a higher consumption of rye bread[16]. The higher intake of bread/cereals observed in boys with better CRF (13 % higher compared with those with a lower CRF) could be due to the need of carbohydrates to replenish glycogen stores.

The present study shows that girls with a lower CRF presented lower intakes of dairy products and higher intakes of sweetened beverages. This is in accordance with a previous study in young men and women[16], in which CRF was inversely related to the consumption of sweetened drinks. In both boys and girls, dairy product intake and the consumption of sweetened drinks are inversely related, although the association was not significant (data not shown). This can be interesting because the nutritional value of sweetened beverages compared with dairy products is very poor; in fact, it is considered as a source of energy of 'empty calories' (virtually no nutritional value). Sweetened beverages represent rapidly absorbed carbohydrates whose consumption has been shown to result in increases in blood glucose and insulin, and a high dietary glycaemic load, which are associated with the metabolic syndrome[46]. Thus, high added sugar consumption in the form of sweetened beverages is associated with a constellation of cardiovascular risk factors, both independently and through the development of obesity[47,48].

Overall, we did not observe associations between CRF and compliance with dietary recommendations neither in energy distribution among nutrients nor in food consumption in adolescents; only girls meeting the recommendations of sweetened beverage intakes were associated with a better CRF. These results are in contrast to those observed in adults[17]. Brodney *et al.*[17] reported that adults in the higher fitness tertiles consumed diets that more closely approached national dietary recommendations in terms of percentage of energy provided from fat and saturated fat, cholesterol intake or fruit and vegetable intakes. Results on sweetened beverage consumption have not been reported in that study. The lack of association found in the present study can be explained, at least in part, by the fact that food choices of adolescents do not match with the dietary recommendations[9–11]. We observed that most of the adolescents in the present study comply with recommendations in terms of percentage of energy from carbohydrate (73·5 % for boys, 76·8 % for girls), protein (99·6 % for boys, 98·7 % for girls) and total fat (58·4 % for boys, 56·2 % for girls). In contrast, a much lower proportion were compliant for energy derived from saturated fat (4·4 % for boys, 4·2 % for girls) and cholesterol intake (18·6 % for boys, 42·2 % for girls), with most of the people presenting higher intakes than recommended. Regarding food groups, a larger proportion of people (90 %) do not comply with recommendations particularly with regard to lower than recommended intakes of fruit and vegetables and higher intakes of protein food and fat food/sweet (data not shown).

The present study has some limitations. Self-report dietary data are prone to a variety of unintentional measurement errors. In addition, misreporting is a common problem in assessing dietary habits among adolescents[49]. According to Biro *et al.*[50], assessment of usual intakes on the individual level should be done by repeated short-term measurements (i.e. 24 h). In the present study, dietary intake was assessed on two self-administered, computer-assisted, non-consecutive 24 h recalls. Although more measurements would be desirable, this method has shown to be appropriate in collecting detailed dietary information from adolescents[28,29]. In order to decrease the influence that episodically consumed foods might have, dietary intake was corrected for within- and between-person variability according to the multiple source method[31]. For CRF, several methodological studies[20] and systematic reviews[5,6,51,52] were performed by our groups and concluded that the 20 m shuttle run test is currently the best field test available to assess CRF.

Conclusion

In conclusion, in a large sample of European adolescents, a high CRF is consistently associated with higher intakes of dairy products after controlling for centre, age and BMI. A high CRF is also associated with a higher intake of bread/cereals in boys, and with a lower consumption of sweetened beverages in girls. The present findings contribute to the understanding of the relationships between dietary factors and physiological health indicators, such as CRF.

Acknowledgements

The HELENA study took place with the financial support of the European Community Sixth RTD Framework Programme (Contract FOOD-CT: 2005-007034). The study was also partially supported by the European Union, in the framework of the Public Health Programme (ALPHA project, Ref: 2006120), the Swedish Council for Working Life and Social Research (FAS), the Spanish Ministry of Education (AP_2008-03 806, EX-2007-1124, EX-2008-0641, AGL2007-29 784-E/ALI, AP-2005-3827), the Spanish Ministry of Science and Innovation (RYC-2010-05 957), the Spanish Ministry of Health, Maternal, Child Health and Development Network (no. RD08/0072) (LAM), Universidad Politécnica of Madrid (CH/018/2008), and the Swedish Heart-Lung Foundation (20090635). The content of this article reflect only the authors' views and the rest of the HELENA study members and the European Community are not liable for any use that may be made of the information

British Journal of Nutrition

contained therein. All authors read and approved the final manuscript. The authors gratefully acknowledge all participating children and adolescents, and their parents and teachers, for their collaboration. They also acknowledge all the members involved in the fieldwork for their efforts and great enthusiasm. All authors contributed to the writing of the manuscript and provided comments on the drafts and approved the final version. M. C.-G. participated in the analysis, interpretation of the results and drafted the manuscript. F. B. O., I. H. and J. R. R. were involved in manuscript drafting and coordinated the statistical analysis. F. B. O., I. H., J. R. R. and M. J. C. contributed to the interpretation of the results and editing of the manuscript. L. A. M. coordinated the total HELENA study on the international level. M. G.-G., M. S., D. M., F. G., Y. M., L. A. M., S. D. H., M. K. and M. J. C. were involved in the design of the HELENA study and locally coordinated the project. C. O., M. P., L. E. D. and D. C. performed the data collection locally. The authors declare that they have no competing interests.

HELENA Study Group

Co-ordinator: Luis A. Moreno.

Core Group members: Luis A. Moreno, Fréderic Gottrand, Stefaan De Henauw, Marcela González-Gross, Chantal Gilbert.

Steering Committee: Anthony Kafatos (President), Luis A. Moreno, Christian Libersa, Stefaan De Henauw, Jackie Sánchez, Fréderic Gottrand, Mathilde Kersting, Michael Sjöstrom, Dénes Molnár, Marcela González-Gross, Jean Dallongeville, Chantal Gilbert, Gunnar Hall, Lea Maes, Luca Scalfi.

Project Manager: Pilar Meléndez.

Universidad de Zaragoza (Spain): Luis A. Moreno, Jesús Fleta, José A. Casajús, Gerardo Rodríguez, Concepción Tomás, María I. Mesana, Germán Vicente-Rodríguez, Adoración Villarroya, Carlos M. Gil, Ignacio Ara, Juan Revenga, Carmen Lachen, Juan Fernández Alvira, Gloria Bueno, Aurora Lázaro, Olga Bueno, Juan F. León, Jesús Mª Garagorri, Manuel Bueno, Juan Pablo Rey López, Iris Iglesia, Paula Velasco, Silvia Bel.

Consejo Superior de Investigaciones Científicas (Spain): Ascensión Marcos, Julia Wärnberg, Esther Nova, Sonia Gómez, Esperanza Ligia Díaz, Javier Romeo, Ana Veses, Mari Angeles Puertollano, Belén Zapatera, Tamara Pozo, David Martínez.

Université de Lille 2 (France): Laurent Beghin, Christian Libersa, Frédéric Gottrand, Catalina Iliescu, Juliana Von Berlepsch.

Research Institute of Child Nutrition Dortmund, Rheinische Friedrich-Wilhelms-Universität Bonn (Germany): Mathilde Kersting, Wolfgang Sichert-Hellert, Ellen Koeppen.

Pécsi Tudományegyetem (University of Pécs) (Hungary): Dénes Molnar, Eva Erhardt, Katalin Csernus, Katalin Török, Szilvia Bokor, Mrs Angster, Enikö Nagy, Orsolya Kovács, Judit Repásy.

University of Crete School of Medicine (Greece): Anthony Kafatos, Caroline Codrington, María Plada, Angeliki Papadaki, Katerina Sarri, Anna Viskadourou, Christos Hatzis, Michael Kiriakakis, George Tsibinos, Constantine Vardavas, Manolis Sbokos, Eva Protoyeraki, Maria Fasoulaki.

Institut für Ernährungs- und Lebensmittelwissenschaften – Ernährungphysiologie. Rheinische Friedrich Wilhelms Universität (Germany): Peter Stehle, Klaus Pietrzik, Marcela González-Gross, Christina Breidenassel, Andre Spinneker, Jasmin Al-Tahan, Miriam Segoviano, Anke Berchtold, Christine Bierschbach, Erika Blatzheim, Adelheid Schuch, Petra Pickert.

University of Granada (Spain): Manuel J. Castillo, Ángel Gutiérrez, Francisco B. Ortega, Jonatan R. Ruiz, Enrique G. Artero, Vanesa España-Romero, David Jiménez-Pavón, Palma Chillón, Magdalena Cuenca-García.

Istituto Nazionalen di Ricerca per gli Alimenti e la Nutrizione (Italy): Davide Arcella, Elena Azzini, Emma Barrison, Noemi Bevilacqua, Pasquale Buonocore, Giovina Catasta, Laura Censi, Donatella Ciarapica, Paola D'Acapito, Marika Ferrari, Myriam Galfo, Cinzia Le Donne, Catherine Leclercq, Giuseppe Maiani, Beatrice Mauro, Lorenza Mistura, Antonella Pasquali, Raffaela Piccinelli, Angela Polito, Raffaella Spada, Stefania Sette, Maria Zaccaria.

University of Napoli "Federico II" Dept of Food Science (Italy): Luca Scalfi, Paola Vitaglione, Concetta Montagnese.

Ghent University (Belgium): Ilse De Bourdeaudhuij, Stefaan De Henauw, Tineke De Vriendt, Lea Maes, Christophe Matthys, Carine Vereecken, Mieke de Maeyer, Charlene Ottevaere, Inge Huybrechts.

Medical University of Vienna (Austria): Kurt Widhalm, Katharina Phillipp, Sabine Dietrich, Birgit Kubelka, Marion Boriss-Riedl.

Harokopio University (Greece): Yannis Manios, Eva Grammatikaki, Zoi Bouloubasi, Tina Louisa Cook, Sofia Eleutheriou, Orsalia Consta, George Moschonis, Ioanna Katsaroli, George Kraniou, Stalo Papoutsou, Despoina Keke, Ioanna Petraki, Elena Bellou, Sofia Tanagra, Kostalenia Kallianoti, Dionysia Argyropoulou, Katerina Kondaki, Stamatoula Tsikrika, Christos Karaiskos.

Institut Pasteur de Lille (France): Jean Dallongeville, Aline Meirhaeghe.

Karolinska Institutet (Sweden): Michael Sjöstrom, Patrick Bergman, María Hagströmer, Lena Hallström, Mårten Hallberg, Eric Poortvliet, Julia Wärnberg, Nico Rizzo, Linda Beckman, Anita Hurtig Wennlöf, Emma Patterson, Lydia Kwak, Lars Cernerud, Per Tillgren, Stefaan Sörensen.

Asociación de Investigación de la Industria Agroalimentaria (Spain): Jackie Sánchez-Molero, Elena Picó, Maite Navarro, Blanca Viadel, José Enrique Carreres, Gema Merino, Rosa Sanjuán, María Lorente, María José Sánchez, Sara Castelló.

Campden & Chorleywood Food Research Association (UK): Chantal Gilbert, Sarah Thomas, Elaine Allchurch, Peter Burgess.

SIK – Institutet foer Livsmedel och Bioteknik (Sweden): Gunnar Hall, Annika Astrom, Anna Sverkén, Agneta Broberg.

Meurice Recherche & Development asbl (Belgium): Annick Masson, Claire Lehoux, Pascal Brabant, Philippe Pate, Laurence Fontaine.

Campden & Chorleywood Food Development Institute (Hungary): Andras Sebok, Tunde Kuti, Adrienn Hegyi.

Productos Aditivos SA (Spain): Cristina Maldonado, Ana Llorente.

Cárnicas Serrano SL (Spain): Emilio García.

Cederroth International AB (Sweden): Holger von Fircks, Marianne Lilja Hallberg, Maria Messerer.

Lantmännen Food R&D (Sweden): Mats Larsson, Helena Fredriksson, Viola Adamsson, Ingmar Börjesson.

European Food Information Council (Belgium): Laura Fernández, Laura Smillie, Josephine Wills.

Universidad Politécnica de Madrid (Spain): Marcela González-Gross, Jara Valtueña, David Jiménez-Pavón, Ulrike Albers, Raquel Pedrero, Agustín Meléndez, Pedro J. Benito, Juan José Gómez Lorente, David Cañada, Alejandro Urzanqui, Juan Carlos Ortiz, Francisco Fuentes, Rosa María Torres, Paloma Navarro.

References

1. Brunet M, Chaput JP & Tremblay A (2007) The association between low physical fitness and high body mass index or waist circumference is increasing with age in children: the 'Quebec en Forme' Project. *Int J Obes (Lond)* **31**, 637–643.
2. Steele RM, Brage S, Corder K, *et al.* (2008) Physical activity, cardiorespiratory fitness, and the metabolic syndrome in youth. *J Appl Physiol* **105**, 342–351.
3. Ortega FB, Ruiz JR, Castillo MJ, *et al.* (2008) Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond)* **32**, 1–11.
4. World Health Organization (2003) *Diet, Nutrition and the Prevention of Chronic Diseases. Joint WHO/FAO Expert Consultation. World Health Organ (WHO) Technical Report Series* no. 916. Geneva: WHO.
5. Ortega FB, Artero EG, Ruiz JR, *et al.* (2008) Reliability of health-related physical fitness tests in European adolescents. The HELENA Study. *Int J Obes (Lond)* **32**, Suppl. 5, S49–S57.
6. Ruiz JR, Castro-Pinero J, Artero EG, *et al.* (2009) Predictive validity of health-related fitness in youth: a systematic review. *Br J Sports Med* **43**, 909–923.
7. Cureton KJ & Warren GL (1990) Criterion-referenced standards for youth health-related fitness tests: a tutorial. *Res Q Exerc Sport* **61**, 7–19.
8. Bertheke Post G, de Vente W, Kemper HC, *et al.* (2001) Longitudinal trends in and tracking of energy and nutrient intake over 20 years in a Dutch cohort of men and women between 13 and 33 years of age: the Amsterdam growth and health longitudinal study. *Br J Nutr* **85**, 375–385.
9. Parizkova J (2000) Dietary habits and nutritional status in adolescents in Central and Eastern Europe. *Eur J Clin Nutr* **54**, Suppl. 1, S36–S40.
10. Cruz JA (2000) Dietary habits and nutritional status in adolescents over Europe-Southern Europe. *Eur J Clin Nutr* **54**, Suppl. 1, S29–S35.
11. Rolland-Cachera MF, Bellisle F & Deheeger M (2000) Nutritional status and food intake in adolescents living in Western Europe. *Eur J Clin Nutr* **54**, Suppl. 1, S41–S46.
12. IOM (2005) *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington, DC: National Academy Press, Food and Nutrition Board.
13. FAO/WHO (1996) *Preparation and Use of Food-Based Dietary Guidelines*. Geneva: WHO.
14. VIG (2006) *De actieve voedingsdriehoek: een praktische voedings-en beweeggids (The Active Food Triangle: A Practical Guide to Diet and Physical Activity)*. Brussels: Vlaams Instituut voor Gezondheidspromotie (VIG).
15. Heroux M, Janssen I, Lam M, *et al.* (2010) Dietary patterns and the risk of mortality: impact of cardiorespiratory fitness. *Int J Epidemiol* **39**, 197–209.
16. Haraldsdottir J & Andersen LB (1994) Dietary factors related to fitness in young men and women. *Prev Med* **23**, 490–497.
17. Brodney S, McPherson RS, Carpenter RS, *et al.* (2001) Nutrient intake of physically fit and unfit men and women. *Med Sci Sports Exerc* **33**, 459–467.
18. Bouchard C (1986) Genetics of aerobic power and capacity. In *Sports and Human Genetics* [RM Malina and RM Bouchard, editors]. Champaign, IL: Human Kinetics Publishers.
19. Ruiz JR, Ortega FB, Rizzo NS, *et al.* (2007) High cardiovascular fitness is associated with low metabolic risk score in children: the European Youth Heart Study. *Pediatr Res* **61**, 350–355.
20. Lobelo F, Pate RR, Dowda M, *et al.* (2009) Validity of cardiorespiratory fitness criterion-referenced standards for adolescents. *Med Sci Sports Exerc* **41**, 1222–1229.
21. Moreno LA, De Henauw S, Gonzalez-Gross M, *et al.* (2008) Design and implementation of the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study. *Int J Obes (Lond)* **32**, Suppl. 5, S4–S11.
22. Moreno LA, Gonzalez-Gross M, Kersting M, *et al.* (2008) Assessing, understanding and modifying nutritional status, eating habits and physical activity in European adolescents: the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. *Public Health Nutr* **11**, 288–299.
23. Beghin L, Castera M, Manios Y, *et al.* (2008) Quality assurance of ethical issues and regulatory aspects relating to good clinical practices in the HELENA Cross-Sectional Study. *Int J Obes (Lond)* **32**, Suppl. 5, S12–S18.
24. Black AE (2000) Critical evaluation of energy intake using the Goldberg cut-off for energy intake:basal metabolic rate. A practical guide to its calculation, use and limitations. *Int J Obes Relat Metab Disord* **24**, 1119–1130.
25. Léger LA, Mercier D, Gadoury C, *et al.* (1988) The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci* **6**, 93–101.
26. Liu NY, Plowman SA & Looney MA (1992) The reliability and validity of the 20-meter shuttle test in American students 12 to 15 years old. *Res Q Exerc Sport* **63**, 360–365.
27. TCI (2004) *FITNESSGRAM Test Administration Manual. The Cooper Institute (TCI)*. Champaign, IL: Human Kinetics.
28. Vereecken CA, Covents M, Matthys C, *et al.* (2005) Young adolescents' nutrition assessment on computer (YANA-C). *Eur J Clin Nutr* **59**, 658–667.
29. Vereecken CA, Covents M, Sichert-Hellert W, *et al.* (2008) Development and evaluation of a self-administered computerized 24-h dietary recall method for adolescents in Europe. *Int J Obes (Lond)* **32**, Suppl. 5, S26–S34.
30. Dehne LI, Klemm C, Henseler G, *et al.* (1999) The German Food Code and Nutrient Data Base (BLS II.2). *Eur J Epidemiol* **15**, 355–358.
31. Haubrock J, Harttig U, Souverein O, *et al.* (2010) An improved statistical tool for estimating usual intake distributions: the Multiple Source Method (MSM). *Arch Public Health* **68**, 14–15.
32. FAO/WHO/UNU (1985) *Energy and Protein Requirements. Report of a Joint FAO/WHO/UNU Expert Consultation*. Geneva: FAO/WHO/UNU.
33. Nagy E, Vicente-Rodriguez G, Manios Y, *et al.* (2008) Harmonization process and reliability assessment of anthropometric

measurements in a multicenter study in adolescents. *Int J Obes (Lond)* **32**, Suppl. 5, S58–S65.
34. Cole TJ, Freeman JV & Preece MA (1995) Body mass index reference curves for the UK, 1990. *Arch Dis Child* **73**, 25–29.
35. Pardo A, Ruiz MA & San Martin R (2007) How to fit and interpret multilevel models using SPSS. *Psicothema* **19**, 308–321.
36. Nakagawa S & Cuthill IC (2007) Effect size, confidence interval and statistical significance: a practical guide for biologists. *Biol Rev Camb Philos Soc* **82**, 591–605.
37. Baró L, Jiménez J, Martínez-Férez A, *et al.* (2001) Bioactive milk peptidos and proteins. *Ars Phamaceutica* **42**, 135–145.
38. Phillips SM, Hartman JW & Wilkinson SB (2005) Dietary protein to support anabolism with resistance exercise in young men. *J Am Coll Nutr* **24**, 134S–139S.
39. Moore DR, Robinson MJ, Fry JL, *et al.* (2009) Ingested protein dose response of muscle and albumin protein synthesis after resistance exercise in young men. *Am J Clin Nutr* **89**, 161–168.
40. Hartman JW, Tang JE, Wilkinson SB, *et al.* (2007) Consumption of fat-free fluid milk after resistance exercise promotes greater lean mass accretion than does consumption of soy or carbohydrate in young, novice, male weightlifters. *Am J Clin Nutr* **86**, 373–381.
41. Josse AR, Tang JE, Tarnopolsky MA, *et al.* (2009) Body composition and strength changes in women with milk and resistance exercise. *Med Sci Sports Exerc* **42**, 1122–1130.
42. Elwood PC, Pickering JE & Fehily AM (2007) Milk and dairy consumption, diabetes and the metabolic syndrome: the Caerphilly prospective study. *J Epidemiol Community Health* **61**, 695–698.
43. Pereira MA, Jacobs DR Jr, Van Horn L, *et al.* (2002) Dairy consumption, obesity, and the insulin resistance syndrome in young adults: the CARDIA Study. *JAMA* **287**, 2081–2089.
44. Brooks BM, Rajeshwari R, Nicklas TA, *et al.* (2006) Association of calcium intake, dairy product consumption with overweight status in young adults (1995–1996): the Bogalusa Heart Study. *J Am Coll Nutr* **25**, 523–532.
45. Lin YC, Lyle RM, McCabe LD, *et al.* (2000) Dairy calcium is related to changes in body composition during a two-year exercise intervention in young women. *J Am Coll Nutr* **19**, 754–760.
46. Ludwig DS (2002) The glycemic index: physiological mechanisms relating to obesity, diabetes, and cardiovascular disease. *JAMA* **287**, 2414–2423.
47. Dhingra R, Sullivan L, Jacques PF, *et al.* (2007) Soft drink consumption and risk of developing cardiometabolic risk factors and the metabolic syndrome in middle-aged adults in the community. *Circulation* **116**, 480–488.
48. Ludwig DS, Peterson KE & Gortmaker SL (2001) Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet* **357**, 505–508.
49. Moreno LA, Kersting M, de Henauw S, *et al.* (2005) How to measure dietary intake and food habits in adolescence: the European perspective. *Int J Obes (Lond)* **29**, Suppl. 2, S66–S77.
50. Biro G, Hulshof KF, Ovesen L, *et al.* (2002) Selection of methodology to assess food intake. *Eur J Clin Nutr* **56**, Suppl. 2, S25–S32.
51. Castro-Pinero J, Artero EG, Espana-Romero V, *et al.* (2010) Criterion-related validity of field-based fitness tests in youth: a systematic review. *Br J Sports Med* **44**, 934–943.
52. Artero EG, Espana-Romero V, Castro-Pinero J, *et al.* (2010) Reliability of field-based fitness tests in youth. *Int J Sports Med* **32**, 159–169.

British Journal of Nutrition