



Editor's choice  
Scan to access more  
free content

## ORIGINAL ARTICLE

# Cardiorespiratory fitness and ideal cardiovascular health in European adolescents

Jonatan R Ruiz,<sup>1,2</sup> Inge Huybrechts,<sup>3,4</sup> Magdalena Cuenca-García,<sup>5</sup> Enrique G Artero,<sup>6</sup> Idoia Labayen,<sup>7</sup> Aline Meirhaeghe,<sup>8</sup> German Vicente-Rodriguez,<sup>9,10</sup> Angela Polito,<sup>11</sup> Yannis Manios,<sup>12</sup> Marcela González-Gross,<sup>13,14</sup> Ascensión Marcos,<sup>15</sup> Kurt Widhalm,<sup>16</sup> Denes Molnar,<sup>17</sup> Anthony Kafatos,<sup>18</sup> Michael Sjöström,<sup>2</sup> Luis A Moreno,<sup>9,19</sup> Manuel J Castillo,<sup>5</sup> Francisco B Ortega,<sup>1,2</sup> on behalf of the HELENA study group

► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/heartjnl-2014-306750>).

For numbered affiliations see end of article.

## Correspondence to

Dr Jonatan R Ruiz, Department of Physical Education and Sport, Faculty of Sport Sciences, University of Granada, Ctra de Alfacar s/n CP, Granada 18011, Spain; [ruizj@ugr.es](mailto:ruizj@ugr.es)

Received 3 September 2014

Revised 24 October 2014

Accepted 14 November 2014

Published Online First

8 December 2014

## ABSTRACT

**Objective** We studied in European adolescents (i) the association between cardiorespiratory fitness and ideal cardiovascular health as defined by the American Heart Association and (ii) whether there is a cardiorespiratory fitness threshold associated with a more favourable cardiovascular health profile.

**Methods** Participants included 510 (n=259 girls) adolescents from 9 European countries. The 20 m shuttle run test was used to estimate cardiorespiratory fitness. Ideal cardiovascular health was defined as meeting ideal levels of the following components: four behaviours (smoking, body mass index, physical activity and diet) and three factors (total cholesterol, blood pressure and glucose).

**Results** Higher levels of cardiorespiratory fitness were associated with a higher number of ideal cardiovascular health components in both boys and girls (both  $p$  for trend  $\leq 0.001$ ). Levels of cardiorespiratory fitness were significantly higher in adolescents meeting at least four ideal components (13% higher in boys,  $p<0.001$ ; 6% higher in girls,  $p=0.008$ ). Receiver operating characteristic curve analyses showed a significant discriminating accuracy of cardiorespiratory fitness in identifying the presence of at least four ideal cardiovascular health components (43.8 mL/kg/min in boys and 34.6 mL/kg/min in girls, both  $p<0.001$ ).

**Conclusions** The results suggest a hypothetical cardiorespiratory fitness level associated with a healthier cardiovascular profile in adolescents. The fitness standards could be used in schools as part of surveillance and/or screening systems to identify youth with poor health behaviours who might benefit from intervention programmes.

health-related cardiorespiratory fitness standards for adolescents can be useful to identify the target population for primary CVD prevention as well as for health promotion policies.

Several attempts have been made in order to determine the cardiorespiratory fitness level associated with a healthier cardiovascular profile in children and adolescents.<sup>5–14</sup> However, it is rare for paediatricians, physical education teachers or other health agents to measure cardiorespiratory fitness when evaluating present and future cardiovascular health in youth.

The American Heart Association (AHA) released in 2010 a set of seven cardiovascular health components for youth and adults to describe ideal cardiovascular health.<sup>15</sup> Data from the Cardiovascular Risk in Young Finns Study showed that children with a higher number of ideal cardiovascular health components had a reduced risk for hypertension, metabolic syndrome, high levels of low-density lipoprotein cholesterol and high-risk carotid intima-media thickness 21 years later in adulthood.<sup>16</sup> The concept of ideal cardiovascular health has also been inversely associated with aortic intima-media thickness and the incidence of CVD,<sup>17</sup> and directly associated with aortic elasticity in adolescents.<sup>18</sup>

The Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study is a multicentre, cross-sectional study performed in nine European countries primarily designed to obtain reliable and comparable data on nutrition and health-related parameters of a relatively large sample of European adolescents aged 12.5–17.5 years.<sup>19</sup> The HELENA study collected data on the components included in the ideal cardiovascular health concept,<sup>15</sup> thus providing a great opportunity to (i) study the association between cardiorespiratory fitness and ideal cardiovascular health in European adolescents, and to (ii) examine whether there is a cardiorespiratory fitness threshold associated with a more favourable cardiovascular health profile.

## METHODS

### Study participants

The HELENA study was conducted from 2006 to 2007 in 10 European cities (hereafter called centres) from 9 countries.<sup>19</sup> The HELENA study sample comprised 3528 boys and girls aged 12.5–17.5 years with valid data for gender and body

## INTRODUCTION

Cardiorespiratory fitness is an important marker of cardiovascular health already in children and adolescents.<sup>1</sup> Longitudinal studies indicate that higher levels of cardiorespiratory fitness in childhood and adolescence are associated with a healthier cardiovascular profile<sup>2</sup> and with a reduced risk of myocardial infarction later in life.<sup>3</sup> Despite cardiovascular disease (CVD) events occurring most frequently during or after the fifth decade of life, the precursors of CVD seem to have their origin in childhood and adolescence.<sup>4</sup> Therefore, establishing



► <http://dx.doi.org/heartjnl-2014-307179>



CrossMark

**To cite:** Ruiz JR, Huybrechts I, Cuenca-García M, et al. *Heart* 2015;101:766–773.

mass index (BMI). Blood sampling was randomly performed in one-third of the recruited adolescents ( $n=1089$ ).

This study comprised adolescents who had complete data on (i) cardiorespiratory fitness and (ii) the components included in the ideal cardiovascular health concept.<sup>15</sup> A total of 510 ( $n=251$  and  $259$ , boys and girls, respectively) participants were finally included into the present study. There were no differences in the study key characteristics (ie, age, sex distribution, weight and height, and cardiorespiratory fitness) between the current study sample and the original HELENA sample ( $n=3528$ , all  $p>0.1$ ).

### Cardiorespiratory fitness

Cardiorespiratory fitness was assessed by the 20 m shuttle run test.<sup>20</sup> Participants were required to run between two lines 20 m apart, while keeping the pace with audio signals emitted from a pre-recorded CD. The initial speed was 8.5 km/h, which was increased by 0.5 km/h per minute (1 min equal 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 failed to reach the end lines concurrent with the audio signals on two consecutive occasions. Otherwise, the test ended when the subject stopped because of fatigue. We estimated the maximum oxygen consumption ( $VO_{2max}$ , mL/kg/min) from the 20 m shuttle run test scores using the equation reported by *Leger et al.*<sup>21</sup>

### Ideal cardiovascular health

The ideal cardiovascular health index and its different components were calculated as outlined by AHA<sup>15</sup> using the cut-off values for adolescents.

### Health behaviours

Data on smoking were collected via self-reported questionnaires. Adolescents who reported that they had never smoked were categorised as having an ideal smoking status and those who reported having smoked one or more cigarettes were categorised as presenting a non-ideal smoking status.

Height and weight were measured, and BMI calculated as weight (in kg) divided by height (in m<sup>2</sup>). BMI z-score and BMI categories were derived using British 1990 Growth Reference Data from the Child Growth Foundation.<sup>22 23</sup>

Physical activity was assessed by a self-report questionnaire.<sup>24</sup> Adolescents who did not reach 60 min of moderate to vigorous intensity physical activity every day were classified as having a non-ideal physical activity level.

**Diet:** The HELENA-Dietary Assessment Tool (HELENA-DIAT) was used to assess dietary intake and food consumption.<sup>25</sup> It is a self-reported 24 h dietary recall assessment tool based on six meal occasions. Participants completed the HELENA-DIAT in two non-consecutive days according to a standardised protocol. The German Nutrient Database was used to analyse the dietary data. The Multiple Source Method provided by the German Institute of Human Nutrition Potsdam-Rehbrücke as web-based programme package was used to account for within-person variation in the 24 h dietary recalls (<https://nugo.dife.de/msm/>). All dietary indicators described below have been scaled on a total daily energy intake of 2000 kcal as indicated in the ideal cardiovascular health calculations protocol.<sup>15</sup>

We classified adolescents as having an ideal fruit and vegetable consumption if they consumed at least 400 g of fruits and vegetables (sum of both) per day.<sup>26</sup> Adolescents who consumed at least 28 g of fish or fish products per day were classified as

having ideal fish consumption. Adolescents who consumed at least 1.1 g of fibre per 10 g of carbohydrates were classified as having ideal fibre consumption. Those who consumed <1500 mg of sodium per day were classified as having ideal sodium intakes. Adolescents who consumed 145 mL or less of soft drinks per day were classified as having ideal soft drink consumption. The calculation of the 145 mL sugar-sweetened beverages was obtained via the 'oz' unit that was included in the original recommendation: 450 kcal (36 oz) per week = 28.350 \* 36/7 g per day. Intake goals are expressed for a 2000 kcal diet and have been scaled accordingly for other levels of calorie intake. Adolescents who had at least four of these five ideal diet components were categorised as having an ideal healthy diet, and adolescents with 0–3 ideal diet components were classified as having a non-ideal healthy diet.

### Health factors

**Blood analysis:** For the determination of total cholesterol and glucose levels, venous blood samples were drawn after an overnight fast. In adolescence, levels of total cholesterol have been defined as ideal <4.40 mmol/L (<170 mg/dL) or non-ideal  $\geq 4.40$  mmol/L ( $\geq 170$  mg/dL).<sup>15</sup> Fasting serum glucose concentrations were analysed enzymatically and classified as ideal <5.6 mmol/L (<100 mg/dL) or non-ideal  $\geq 5.6$  mmol/L ( $\geq 100$  mg/dL).<sup>15</sup>

**Blood pressure:** It was measured twice after being seated in a quiet room for 10 min with their back supported and feet on the ground. Two blood pressure readings were taken with a 10 min interval of quiet rest. The lower value of the two measurements was used in the analysis to classify blood pressure status in adolescence as ideal (systolic blood pressure <90th centile and diastolic blood pressure <90th centile) or non-ideal (systolic blood pressure  $\geq 90$ th centile or diastolic blood pressure  $\geq 90$ th centile).<sup>15</sup> All centile-based threshold limits are sex-specific and age-specific from the entire HELENA study sample.

### Indices of the ideal cardiovascular health

From the individual health behaviours and factors described above, we generated the corresponding AHA indices (ie, ideal health behaviours index, ideal health factors index and the ideal cardiovascular health index). The ideal cardiovascular health index corresponds to the number of ideal health behaviours (0–4) and factors (0–3) achieved by the participant. In analyses, we used the ideal cardiovascular health index as a continuous variable (from 0 to 7) as done elsewhere,<sup>16 18</sup> as well as categorised as presence of at least four ideal components (ideal cardiovascular health vs non-ideal cardiovascular health).<sup>18</sup>

### Statistical analysis

The data are presented as means (SD) unless otherwise stated. Differences on cardiorespiratory fitness levels between ideal and non-ideal cardiovascular health components were assessed by analysis of covariance (ANCOVA) with cardiorespiratory fitness as a dependent variable, cardiovascular health component (ideal vs non-ideal) entered as a fixed factor, age as a covariate and centre as a random factor. The association of cardiorespiratory fitness with ideal cardiovascular health index, as well as with ideal health behaviours and factors separately, was assessed by ANCOVA as explained above.

We determined the cardiorespiratory fitness level associated with having at least four ideal components by receiver operating characteristic (ROC) curve.<sup>27</sup> The area under ROC curve (AUC) and 95% CI were calculated. Finally, binary logistic regression was used to study the relationship between cardiorespiratory fitness and ideal cardiovascular health score, adjusting for age

**Table 1** Characteristics of the study participants

	Boys (n=251)	Girls (n=259)
Age (years)	14.7±1.3	14.7±1.2
Body mass index (kg/m <sup>2</sup> )	21.1±4.1	21.2±3.5
Cardiorespiratory fitness (mL/kg/min)	46.1±7.4	37.6±5.6
Systolic blood pressure (mm Hg)	120.2±13.9	113.2±11.6
Diastolic blood pressure (mm Hg)	64.0±8.7	65.0±8.8
Glucose (mg/dL)	92.3±7.2	88.5±6.4
Total cholesterol (mg/dL)	153.7±26.7	166.9±27.6
Fruits and vegetables (g/day)	183.9±116.1	229.2±132.5
Fish (g/day)	19.4±23.2	21.9±26.3
Fibre (g/day)	20.5±22.6	19.8±22.2
Sodium (mg/day)	2098.4±520.9	2154.9±642.9
Soft drinks (mL/day)	252.1±315.8	182.0±277.2
Moderate-vigorous PA (min/day)	67.8±24.1	48.6±17.8
Never smoked a cigarette (%)	66	67

Values are means and SDs or percentage.

All dietary indicators have been scaled on a total daily energy intake of 2000 kcal.

PA, physical activity.

and centre. Analyses were conducted for boys and girls separately. All analyses were performed using the Statistical Package for Social Sciences (SPSS, V20.0 for Windows; SPSS, Chicago), and the level of significance was set at  $\alpha=0.05$ .

## RESULTS

Table 1 shows the characteristics of the study participants. None of the adolescents had all seven ideal cardiovascular health components, except one girl. Simultaneous presence of at least four ideal components was found in 87% of boys and 84% of girls.

Higher levels of cardiorespiratory fitness were associated with a higher number of ideal cardiovascular health components in both boys ( $p$  for trend  $<0.001$ ) and girls ( $p$  for trend 0.001) (figure 1). Levels of cardiorespiratory fitness were significantly higher in adolescents meeting at least four ideal components (13% higher in boys,  $p<0.001$ ; 6% higher in girls,  $p=0.008$ ) compared with those meeting less than four ideal components (table 2). Higher levels of cardiorespiratory fitness were associated with a higher number of ideal health behaviours ( $p$  for trend  $<0.001$  in both boys and girls), and with a higher number of ideal health factors in boys ( $p$  for trend 0.001) but not in girls ( $p$  for trend 0.291) (figure 2). Levels of cardiorespiratory

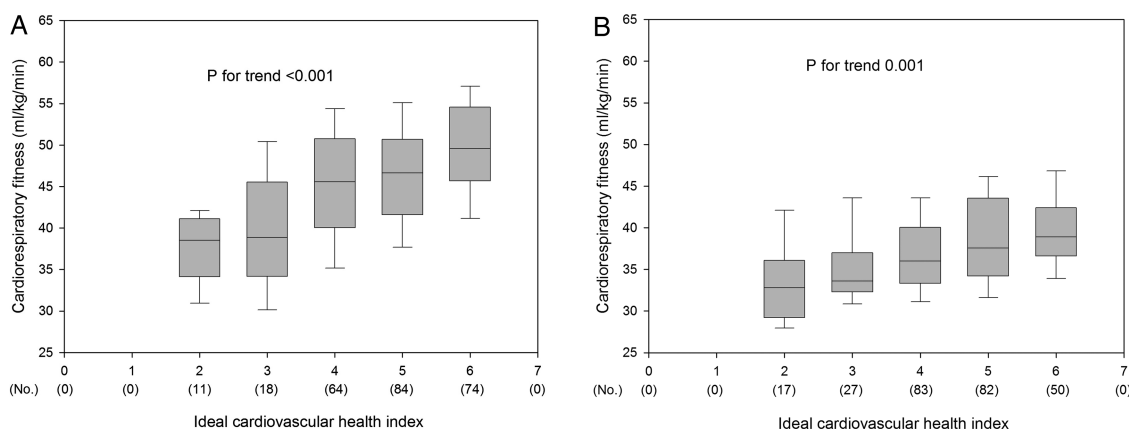
fitness were similar between ideal versus non-ideal glucose or smoking groups in both boys and girls (table 2).

ROC analysis showed a significant discriminating accuracy of cardiorespiratory fitness in identifying a favourable (presence of at least four ideal metrics) ideal cardiovascular health in boys (AUC 0.805, 95% CI 0.726 to 0.883,  $p<0.001$ ) and in girls (AUC 0.694, 95% CI 0.605 to 0.784,  $p<0.001$ ) (figure 3). The cardiorespiratory fitness cut-off levels associated with having at least four ideal components were 43.8 mL/kg/min (optimal pair of sensitivity and specificity 68.9 and 82.8, respectively) in boys and 34.6 mL/kg/min (optimal pair of sensitivity and specificity 74.9 and 59.1, respectively) in girls. Logistic regression analysis showed that boys with levels of cardiorespiratory fitness above 43.8 mL/kg/min had higher OR of having at least four ideal components compared with those with cardiorespiratory fitness levels below this value (OR, 6.437; 95% CI 2.580 to 16.057;  $p<0.001$ ). Girls with cardiorespiratory fitness levels above 34.6 mL/kg/min had higher OR of having at least four ideal components than those with cardiorespiratory fitness levels below this value (OR, 2.756; 95% CI 1.316 to 5.775;  $p=0.007$ ). The results did not change when a different equation to estimate cardiorespiratory fitness was used.<sup>21</sup>

## DISCUSSION

The findings of the present study indicate that cardiorespiratory fitness is positively associated with the ideal cardiovascular health index as determined by AHA in European adolescents. Furthermore, the current study identified a hypothetical cardiorespiratory fitness threshold associated with a more favourable cardiovascular health profile, which seems to be more discriminative for boys than for girls.

Interestingly, the observed cut-off levels for cardiorespiratory fitness obtained in adolescents participating in the HELENA study are similar to those published previously by other studies conducted in past generations of children and adolescents from the USA<sup>9</sup> and different European countries<sup>8 10 11 12 13</sup> with diverse environmental, cultural and social factors. Of note is that previous studies used less comprehensive health indices than the one used in the present study and did not use behaviour-related components. Moreover, the test protocols as well as the prediction equations to estimate cardiorespiratory fitness also differed across studies. Similarities among the study results however reinforce the existence of a cardiorespiratory fitness threshold associated with cardiovascular health in youth. Taken together present and previous findings (see table 3), the



**Figure 1** Association between cardiorespiratory fitness and ideal cardiovascular health index in European adolescents from the Healthy Lifestyle in Europe by Nutrition in Adolescence study. (A) Boys; (B) girls. No., frequency.

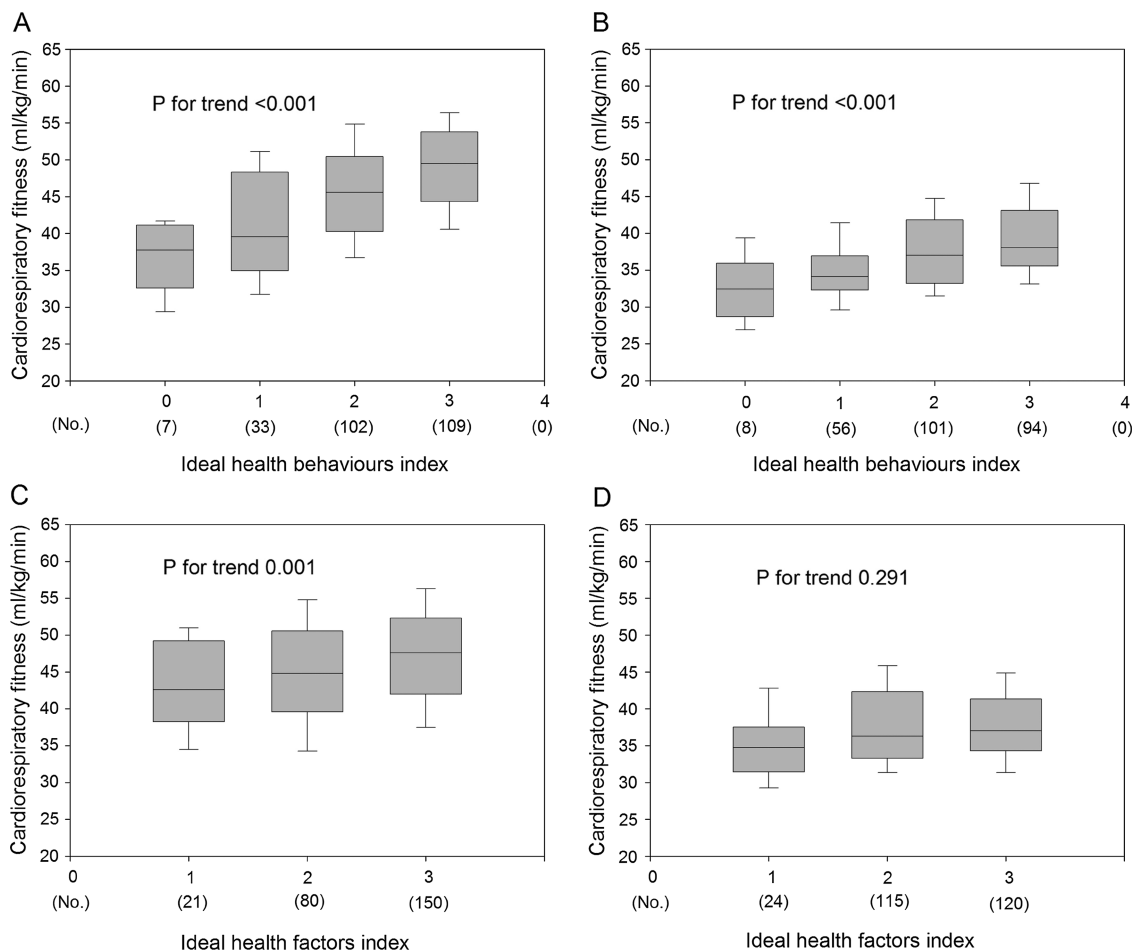
**Table 2** Cardiorespiratory fitness (mL/kg/min) mean and SE estimates by ideal cardiovascular health components in European adolescents (both boys and girls) from the HELENA study

	Boys					Girls				
	Ideal		Non-ideal		p Value*	Ideal		Non-ideal		p Value*
	N/%	Mean±SE	N/%	Mean±SE		N/%	Mean±SE	N/%	Mean±SE	
Health behaviours										
Smoking	166/66	46.3±0.6	85/34	46.7±0.8	0.680	174/67	38.0±0.4	85/33	38.1±0.5	0.852
Body mass index	219/87	47.4±0.5	32/13	40.2±1.1	<b>&lt;0.001</b>	216/83	38.5±0.3	43/17	34.8±0.7	<b>&lt;0.001</b>
Physical activity	179/71	47.5±0.5	72/29	43.7±0.8	<b>&lt;0.001</b>	149/58	38.9±0.4	110/42	36.8±0.5	<b>0.002</b>
Diet	—	—	251/100	46.4±0.5		4/2	37.5±2.4	255/98	38.0±0.4	0.823
Health factors										
Total cholesterol	195/78	47.1±0.5	56/22	44.1±0.9	<b>0.004</b>	138/53	38.0±0.4	121/47	38.0±0.5	0.967
Blood pressure	223/89	46.8±0.5	28/11	43.3±1.4	<b>0.016</b>	228/88	38.2±0.3	31/12	36.2±0.9	<b>0.033</b>
Plasma glucose	210/84	46.5±0.5	41/16	45.9±1.1	0.599	247/95	38.1±0.3	12/5	36.5±1.4	0.269
	≥4 ideal components		<4 ideal components			≥4 ideal components		<4 ideal components		
Presence of ideal components	222/88	47.1±0.5	29/12	40.7±1.3	<b>&lt;0.001</b>	215/83	38.4±0.3	44/17	36.2±0.8	<b>0.008</b>

\*From analysis of covariance with age as covariate and centre as random factor.  
HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence.  
Bold numbers indicate statistically significant results.

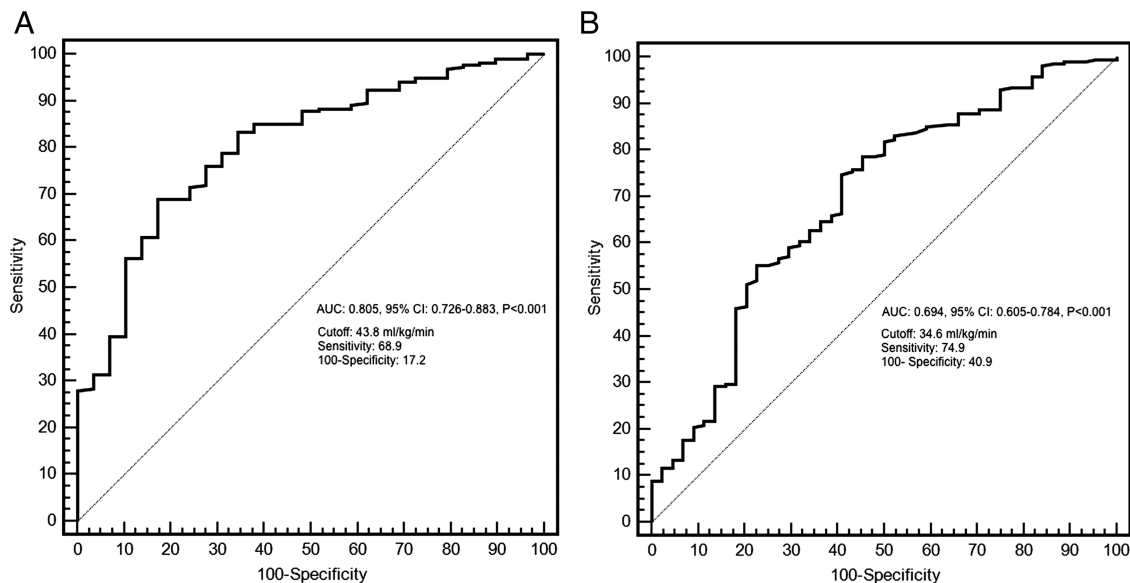
estimated cardiorespiratory fitness levels for optimum cardiovascular health in children and adolescents seem to fall between 40 and 47 mL/kg/min for boys and between 35 and 42 mL/kg/min for girls.

Schools are a convenient setting to promote a healthy lifestyle among young populations and could collect this information to encourage children to be more physically active to achieve and go beyond the health-related cardiorespiratory fitness



**Figure 2** Levels of cardiorespiratory fitness across ideal health behaviours (smoking, body mass index, physical activity and diet) and factors (total cholesterol, blood pressure and plasma cholesterol) score in European adolescents from the Healthy Lifestyle in Europe by Nutrition in Adolescence study. (A and C) Boys; (B and D) girls. No., frequency.





**Figure 3** Receiver operating characteristic curve summarising the potential of cardiorespiratory fitness to identify ideal cardiovascular health status (simultaneous presence of at least four ideal components) in European adolescents from the Healthy Lifestyle in Europe by Nutrition in Adolescence study. (A) Boys; (B) girls. AUC, area under the curve.

thresholds. Moreover, whereas the information given by the assessment of cardiorespiratory fitness in the schools is not diagnostic, it could be used as part of surveillance and/or screening systems to identify youth with poor health behaviours who might benefit from intervention programmes. As such, this has potentially clinical and public health implications. Unfortunately, despite the relevant information provided by a relatively simple assessment of cardiorespiratory fitness, such data rarely become available or are not used by public health and clinical practitioners for purposes of health promotion or disease prevention.<sup>9</sup> Physicians have access to measures of CVD risk factors such as fasting blood samples and blood pressure; however, some of these procedures are invasive, expensive and not suitable for CVD risk screening among large populations of children and adolescents. The origins of CVD are found in childhood,<sup>4</sup> and cardiorespiratory fitness levels at childhood and adolescence are associated with cardiovascular health during these years and later in life;<sup>1 2</sup> thus lifestyle modification focused on enhancing physical activity and increasing fitness might help improve their cardiovascular health.

Meeting all seven ideal cardiovascular components is the ultimate target, yet we observed that cardiorespiratory fitness levels were already higher (13% and 6% in boys and girls, respectively) when at least four ideal cardiovascular health components were met. In the present study, we observed that the likelihood of having four or more ideal cardiovascular health components was 6.4 and 2.7 times higher in boys and girls, respectively, meeting the health-related cardiorespiratory fitness levels (43.8 mL/kg/min in boys and 34.6 mL/kg/min in girls) than in those not meeting these levels. We previously showed similar results in Spanish adolescents<sup>12</sup> as well as in Swedish and Estonian children aged 9–10 years.<sup>8</sup> Children who did not meet the health-related levels (42.1 and 37.0 mL/kg/min in boys and girls, respectively) were three times more likely to have a lower CVD risk score compared with those who did not meet the standards.<sup>8</sup> These findings are also similar to those observed in the National Health and Nutrition Examination Survey (NHANES).<sup>9</sup> Lobelo *et al*<sup>9</sup> showed that higher levels of cardiorespiratory fitness were associated with a healthier cardiovascular profile in adolescents. Moreover, they

showed that boys who met the fitness levels were between four and five times more likely to have a low CVD risk compared with those who did not meet the standards. Comparable results were found (i) in 4500 children and adolescents from Denmark, Estonia, Norway and Portugal, who were tested as part of the European Youth Heart Study (EYHS);<sup>10</sup> (ii) in 16 619 English children from the SportsLinX Project<sup>11</sup> and (iii) in 450 Portuguese adolescents.<sup>13</sup> All the aforementioned studies calculated mathematically the cardiorespiratory fitness levels associated with a more favourable cardiovascular profile, which turned out to be similar to the health-related cardiorespiratory fitness thresholds suggested by worldwide recognised organisations such as the European Group of Pediatric Work Physiology<sup>5</sup> or the Cooper Institute for Aerobics Research<sup>6 7</sup> (table 3).

Cardiorespiratory fitness is influenced by several factors, including genetics. It might be argued that there may be some shared inherent qualities for both better fitness and improved cardiovascular health; however, recent reports suggest that this assumption should be revisited.<sup>28</sup> Other facts such as sex, age, body composition and health status are known to influence cardiorespiratory fitness level, yet its principal modifiable determinant is habitual physical activity.<sup>29</sup> Findings from exercise-based intervention studies indicate that cardiorespiratory fitness levels can be improved in youth through aerobic training.<sup>29</sup> Moreover, aerobic exercise interventions have shown to improve blood lipid profile, body fatness and other cardiometabolic risk factors in youth.<sup>30</sup> School-based interventions to improve physical activity participation among youths who fail to meet the health-related cardiorespiratory fitness levels are warranted as part of programmes aiming to improve youth's cardiovascular health.

Limitations of this study include its cross-sectional design, which precludes definitive causal attributions. Another limitation is the use of a questionnaire to assess physical activity, which was previously pilot-tested and validated.<sup>24</sup> The HELENA study assessed physical activity by both questionnaire and accelerometry. Nevertheless, results were materially the same when using data from accelerometry (data not shown). In addition, the difficulty of accurate assessment of dietary intake must also be considered as a potential limitation, especially among adolescents,

**Table 3** Health criterion-reference standards for cardiorespiratory fitness in children and adolescents

Study/institution	Methodology	Outcome variable	Cardiorespiratory fitness test	Sex	Age (years)	N	Cardiorespiratory fitness (mL/kg/min)	AUC (95%CI)
Bell <i>et al</i> <sup>5</sup> European Group of Pediatric Work Physiology	Expert judgement		–	Boys	Adolescents	40	–	–
FITNESSGRAM <sup>6</sup> The Cooper Institute for Aerobics Research	Regressions	Linked to adult mortality/chronic disease risk	–	Girls	Adolescents	35	–	–
				Boys	12–19	42	–	–
				Girls	12	37	–	–
					13	36	–	–
					≥14	35	–	–
FITNESSGRAM, The Cooper Institute, Revision 8.6 and 9.x 2008 <sup>7</sup>		Healthy fitness zone linked to adult mortality/chronic disease risk	–	Boys	10–11	40.2	–	–
					12	40.3	–	–
					13	41.1	–	–
					14	42.5	–	–
					15	43.6	–	–
					16	44.1	–	–
					17	44.2	–	–
					>17	44.3	–	–
				Girls	10–11	40.2	–	–
					12	40.1	–	–
					13	39.7	–	–
					14	39.4	–	–
					15	39.1	–	–
					16	38.9	–	–
					17	38.8	–	–
					>17	38.6	–	–
Mesa <i>et al</i> <sup>12</sup> (AVENA)	ROC curve	TG, HDLc, LDLc, glucose	20 m shuttle run test VO <sub>2</sub> max estimated	Boys	13–18.5	248	45–47	0.716 (0.650 to 0.783)
				Girls	13–18.5	212	–	0.506 (0.422 to 0.591)
Ruiz <i>et al</i> <sup>8</sup> (EYHS)	ROC curve	Cardiovascular risk factors (insulin, glucose, HDLc, TG, sum of five skinfolds, BP)	Maximal cycle ergometer test. VO <sub>2</sub> max estimated	Boys	9–10	429	42	0.67 (0.61 to 0.73)
				Girls	9–10	444	37	0.68 (0.62 to 0.73)
Lobelo <i>et al</i> <sup>9</sup> (NHANES 1999–2002)	ROC curve	Cardiovascular risk factors (systolic BP, triceps and subscapular skinfolds, HOMA, TG, TC/HDLc)	Submaximal walking treadmill test. VO <sub>2</sub> max estimated	Boys	12–15	308	44	0.769 (0.678 to 0.860)
					16–19	369	40	0.715 (0.639 to 0.791)
				Girls	12–15	315	36	0.538 (0.415 to 0.662)
					16–19	255	36	0.539 (0.382 to 0.696)
Adegboye <i>et al</i> <sup>10</sup> (EYHS)	ROC curve	Cardiovascular risk factors (systolic BP, TG, TC/HDLc, HOMA, sum of four skinfolds)	Maximal cycle ergometer test. VO <sub>2</sub> max estimated	Boys	8–11	1219	43.6	0.68
					14–17	1049	46.0	0.55
				Girls	8–11	1181	37.4	0.67
					14–17	1051	33.0	0.69
Moreira <i>et al</i> <sup>13</sup>	ROC curve	Cardiovascular risk factors (waist and hip circumference, glucose, TC, HDLc, LDLc, TG, BP)	20 m shuttle run test. VO <sub>2</sub> max estimated	Boys	10–18	195	41.8	0.648 (0.576 to 0.716)
				Girls	10–18	255	39.5	0.654 (0.591 to 0.713)
Welk <i>et al</i> <sup>14</sup> (NHANES 1999–2002)	ROC curve	Waist circumference, systolic blood pressure/diastolic BP, HDLc, TG, and glucose	Submaximal walking treadmill test. VO <sub>2</sub> max estimated	Boys	12–18	649	40–44	0.831
				Girls	12–18	591	38–40	0.772
Boddy <i>et al</i> <sup>11</sup> (SportsLinX)	ROC curve	BMI Waist circumference %BF BMI Waist circumference %BF	20 m shuttle run test. VO <sub>2</sub> max estimated	Boys	9–10	6810	46.6	0.782 (0.770 to 0.794)
						3771	46.6	0.736 (0.720 to 0.753)
						6252	46.6	0.800 (0.787 to 0.813)
				Girls	9–10	6676	41.9	0.582 (0.740 to 0.764)
						3843	41.9	0.720 (0.704 to 0.736)
						6149	41.9	0.772 (0.758 to 0.787)
								0.772 (0.758 to 0.787)
Present study (HELENA study)	ROC curve	Ideal cardiovascular health <sup>15</sup> (smoking, BMI, physical activity, diet, TC, BP, glucose)	20 m shuttle run test. VO <sub>2</sub> max estimated	Boys	12.5–17.5	251	43.8	0.805 (0.726 to 0.883)
				Girls	12.5–17.5	259	34.6	0.694 (0.605 to 0.784)

AUC, area under the curve; AVENA, Alimentación y Valoración del Estado Nutricional de los Adolescentes; %BF, per cent body fat; BMI, body mass index; BP, blood pressure; CRF, cardiorespiratory fitness; EYHS, European Youth Heart Study; HDLc, high-density lipoprotein cholesterol; HELENA, Healthy Lifestyle in Europe by Nutrition in Adolescence; HOMA, homeostasis model assessment; LDLc, low-density lipoprotein cholesterol; NHANES, National Health and Nutrition Examination Survey; ROC, receiver operating characteristic; TC, total cholesterol; TG, triglycerides; WC, waist circumference.

where misreporting is a common problem.<sup>19</sup> We only had two non-consecutive days 24 h dietary recalls. When considering the daily fish intake, this might lead to false non-consumers, that is, adolescents consuming fish but not on these two 24 h recall days. It should also be noted that the formation of the ideal cardiovascular health score relies on the use of binary variables and on the assumption that all health behaviours and factors contained in this index contribute the same to the final score.

In conclusion, the present study provides health-related cardiorespiratory fitness thresholds associated with a more favourable cardiovascular health profile in youth.

## Key messages

### What is known on this subject?

Cardiorespiratory fitness is a marker of cardiovascular health during childhood and adolescence, and a predictor of the cardiovascular profile later in life.

### What might this study add?

The present study identifies a cardiorespiratory fitness threshold associated with a favourable cardiovascular health profile in adolescents.

### How might this impact on clinical practice?

The fitness thresholds could be used by paediatricians, physical education teachers or other health agents to measure as part of surveillance and/or screening systems to identify youth with poor health behaviours who could benefit from intervention programmes.

## Author affiliations

<sup>1</sup>Department of Physical Education and Sports, Faculty of Sport Sciences, PROMoting FITness and Health through physical activity research group (PROFIT), University of Granada, Granada, Andalusia, Spain

<sup>2</sup>Department of Biosciences and Nutrition at NOVUM, Unit for Preventive Nutrition, Karolinska Institutet, Huddinge, Sweden

<sup>3</sup>Department of Public Health, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium

<sup>4</sup>International Agency for Research on Cancer (IARC/WHO), Lyon, France

<sup>5</sup>Department of Medical Physiology, School of Medicine, University of Granada, Granada, Spain

<sup>6</sup>Department of Education, Area of Physical Education and Sport, University of Almería, Almería, Spain

<sup>7</sup>Department of Nutrition and Food Science, University of the Basque Country, UPV/EHU, Vitoria, Spain

<sup>8</sup>Inserm, UMR744; Institut Pasteur de Lille; Lille, Univ Lille Nord de France, Lille; UDLS, Lille, France

<sup>9</sup>GENUD "Growth, Exercise, NUtrition and Development" Research Group, Universidad de Zaragoza, Spain

<sup>10</sup>Faculty of Health and Sport Science (FCS), Department of Physiatry and Nursing, Universidad de Zaragoza, Ronda Misericordia 5, 22001-Huesca, Spain

<sup>11</sup>Agricultural Research Council—Research Center on Food and Nutrition—(C.R.A. NUT formerly INRAN), Rome, Italy

<sup>12</sup>Department of Nutrition and Dietetics, Harokopio University, Athens, Greece

<sup>13</sup>ImFINE Research Group. Facultad de Ciencias de la Actividad Física y del Deporte-INEF, Universidad Politécnica de Madrid, Madrid, Spain

<sup>14</sup>CIBER: CB12/03/30038 Fisiopatología de la Obesidad y la Nutrición, CIBERobn, Instituto de Salud Carlos III (ISCIII), Spain

<sup>15</sup>Immunonutrition Research Group, Department of Metabolism and Nutrition, Instituto del Frio, Institute of Food Science, Technology and Nutrition, Spanish National Research Council, Madrid, Spain

<sup>16</sup>Department of Pediatrics, Division of Clinical Nutrition, Medical University of Vienna, Vienna, Austria

<sup>17</sup>Department of Pediatrics, University of Pecs, Pecs, Hungary

<sup>18</sup>Preventive Medicine and Nutrition Unit, School of Medicine, University of Crete, Crete, Greece

<sup>19</sup>Faculty of Health Sciences, University of Zaragoza, Zaragoza, Spain

**Acknowledgements** We thank the children and adolescents who participated in the study and their parents and teachers for their collaboration. We also acknowledge the members involved in fieldwork for their efforts, particularly Anke Carstensen and Petra Pickert for their work in the blood sample laboratory.

**Collaborators** HELENA Project Group: list included in online supplementary appendix.

**Contributors** JRR wrote the manuscript and performed the statistical analysis. IH, MC-G, EGA, IL, AM, GV-R, AP, YM, MG-G, AM, KW, DM, AK, MS, LAM, MJC and FBO contributed to the interpretation and discussion of the results. All authors contributed to the interpretation and discussion of the results, and critically revised the drafted manuscript.

**Funding** The HELENA project was supported by the European Community Sixth RTD Framework Programme (contract FOOD-CT-2005-007034). The data for this study were gathered under the aegis of the HELENA project, and further analysis was additionally supported by the Spanish Ministry of Economy and Competitiveness (grants RYC-2010-05957 and RYC-2011-09011), the Spanish Ministry of Health: Maternal, Child Health and Development Network (grant RD08/0072) and the Fondo Europeo de Desarrollo Regional (MICINN-FEDER).

**Disclaimer** The content of this paper reflects the author's views alone, and the European Community is not liable for any use that may be made of the information contained herein.

**Competing interests** None.

**Patient consent:** All adolescents and their parents or guardians signed an informed written consent before being enrolled in the study.

**Ethics approval** The corresponding local Human Research Review Committees of the centres involved approved the study protocol.

**Provenance and peer review** Not commissioned; externally peer reviewed.

## REFERENCES

- Ortega FB, Ruiz JR, Castillo MJ, *et al.* Physical fitness in childhood and adolescence: a powerful marker of health. *Int J Obes (Lond)* 2008;32:1–11.
- Ruiz JR, Castro-Pinero J, Artero EG, *et al.* Predictive validity of health-related fitness in youth: a systematic review. *Br J Sports Med* 2009;43:909–23.
- Hogstrom G, Nordstrom A, Nordstrom P. High aerobic fitness in late adolescence is associated with a reduced risk of myocardial infarction later in life: a nationwide cohort study in men. *Eur Heart J* 2014;35:3133–40.
- Berenson GS, Srinivasan SR, Bao W, *et al.* Association between multiple cardiovascular risk factors and atherosclerosis in children and young adults. The Bogalusa Heart Study. *N Engl J Med* 1998;338:1650–6.
- Bell RD, Macek M, Rutenfranz J, *et al.* Health indicators and risk factors of cardiovascular diseases during childhood and adolescence. In: Rutenfranz J, Mocelin R, Klimt F, eds. Human Kinetics, Illinois, USA. *Children and Exercise XII*. 1986:39–42.
- FITNESSGRAM. FITNESSGRAM Web site [Internet]. [cited 2013 October 29]. <http://www.fitnessgram.net/home/>
- Welk GJ, Blair SN. Health benefits of physical activity and fitness in children. In: Welk GJ, Meredith MD, eds. *Fitnessgram/activitygram reference guide (pp. Internet Resource)*. Dallas, TX: The Cooper Institute, 2008.
- Ruiz JR, Ortega FB, Rizzo NS, *et al.* High cardiovascular fitness is associated with low metabolic risk score in children: the European Youth Heart Study. *Pediatr Res* 2007;61:350–5.
- Lobelo F, Pate RR, Dowda M, *et al.* Validity of cardiorespiratory fitness criterion-referenced standards for adolescents. *Med Sci Sports Exerc* 2009;41:1222–9.
- Adegboye AR, Anderssen SA, Froberg K, *et al.* Recommended aerobic fitness level for metabolic health in children and adolescents: a study of diagnostic accuracy. *Br J Sports Med* 2011;45:722–8.
- Boddy LM, Thomas NE, Fairclough SJ, *et al.* ROC generated thresholds for field-assessed aerobic fitness related to body size and cardiometabolic risk in schoolchildren. *PLoS ONE* 2012;7:e45755.
- Mesa JL, Ruiz JR, Ortega FB, *et al.* Aerobic physical fitness in relation to blood lipids and fasting glycaemia in adolescents: influence of weight status. *Nutr Metab Cardiovasc Dis* 2006;16:285–93.
- Moreira C, Santos R, Ruiz JR, *et al.* Comparison of different VO(2max) equations in the ability to discriminate the metabolic risk in Portuguese adolescents. *J Sci Med Sport* 2011;14:79–84.
- Welk GJ, Laurson KR, Eisenmann JC, *et al.* Development of youth aerobic-capacity standards using receiver operating characteristic curves. *Am J Prev Med* 2011;41: S111–16.
- Lloyd-Jones DM, Hong Y, Labarthe D, *et al.* Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. *Circulation* 2010;121:586–613.

- 16 Laitinen TT, Pakkala K, Magnussen CG, *et al.* Ideal cardiovascular health in childhood and cardiometabolic outcomes in adulthood: the Cardiovascular Risk in Young Finns Study. *Circulation* 2012;125:1971–8.
- 17 Folsom AR, Yatsuya H, Nettleton JA, *et al.* Community prevalence of ideal cardiovascular health, by the American Heart Association definition, and relationship with cardiovascular disease incidence. *J Am Coll Cardiol* 2011;57:1690–6.
- 18 Pakkala K, Hietalampi H, Laitinen TT, *et al.* Ideal cardiovascular health in adolescence: effect of lifestyle intervention and association with vascular intima-media thickness and elasticity (the Special Turku Coronary Risk Factor Intervention Project for Children [STRIP] study). *Circulation* 2013;127:2088–96.
- 19 Moreno LA, De Henauw S, Gonzalez-Gross M, *et al.* Design and implementation of the Healthy Lifestyle in Europe by Nutrition in Adolescence Cross-Sectional Study. *Int J Obes (Lond)* 2008;32(Suppl 5):S4–11.
- 20 Ortega FB, Artero EG, Ruiz JR, *et al.* Reliability of health-related physical fitness tests in European adolescents. The HELENA Study. *Int J Obes (Lond)* 2008;32(Suppl 5):S49–57.
- 21 Ruiz JR, Silva G, Oliveira N, *et al.* Criterion-related validity of the 20-m shuttle run test in youths aged 13–19 years. *J Sports Sci* 2009;27:899–906.
- 22 Cole TJ, Freeman JV, Preece MA. British 1990 growth reference centiles for weight, height, body mass index and head circumference fitted by maximum penalized likelihood. *Stat Med* 1998;17:407–29.
- 23 Cole TJ, Bellizzi MC, Flegal KM, *et al.* Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000;320:1240–3.
- 24 Hagstromer M, Bergman P, De Bourdeaudhuij I, *et al.* Concurrent validity of a modified version of the International Physical Activity Questionnaire (IPAQ-A) in European adolescents: The HELENA Study. *Int J Obes (Lond)* 2008;32(Suppl 5):S42–8.
- 25 Vereecken CA, Covents M, Sichert-Hellert W, *et al.* Development and evaluation of a self-administered computerized 24-h dietary recall method for adolescents in Europe. *Int J Obes (Lond)* 2008;32(Suppl 5):S26–34.
- 26 FAO/WHO. FAO/WHO fruit and vegetables recommendation. 2004. [http://www.who.int/dietphysicalactivity/publications/fruit\\_vegetables\\_report.pdf](http://www.who.int/dietphysicalactivity/publications/fruit_vegetables_report.pdf)
- 27 Zweig MH, Campbell G. Receiver-operating characteristic (ROC) plots: a fundamental evaluation tool in clinical medicine. *Clin Chem* 1993;39:561–77.
- 28 Gomez-Gallego F, Ruiz JR, Buxens A, *et al.* Are elite endurance athletes genetically predisposed to lower disease risk? *Physiol Genomics* 2010;41:82–90.
- 29 Parikh T, Stratton G. Influence of intensity of physical activity on adiposity and cardiorespiratory fitness in 5–18-year-olds. *Sports Med* 2011;41:477–88.
- 30 Gutin B, Owens S. The influence of physical activity on cardiometabolic biomarkers in youths: a review. *Pediatr Exerc Sci* 2011;23:169–85.



## **HELENA Study Group:**

**Co-ordinator:** Luis A. Moreno.

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

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

**Project Manager:** Pilar Meléndez.

### **1. Universidad de Zaragoza (Spain)**

Luis A. Moreno, Jesús Fleta, José A. Casajús, Gerardo Rodríguez, Concepción Tomás, María I. Mesana, Germán Vicente-Rodríguez, Adoración Villarroja, Carlos M. Gil, Ignacio Ara, Juan Revenga, Carmen Lachen, Juan Fernández Alvira, Gloria Bueno, Aurora Lázaro, Olga Bueno, Juan F. León, Jesús M<sup>a</sup> Garagorri, Manuel Bueno, Juan Pablo Rey López, Iris Iglesia, Paula Velasco, Silvia Bel.

### **2. Consejo Superior de Investigaciones Científicas (Spain)**

Ascensión Marcos, Julia Wärnberg, Esther Nova, Sonia Gómez-Martinez, Ligia Esperanza Díaz, Javier Romeo, Ana Veses, Mari Angeles Puertollano, Belén Zapatera, Tamara Pozo.

### **3. Université de Lille 2 (France)**

Laurent Beghin, Christian Libersa, Frédéric Gottrand, Catalina Iliescu, Juliana Von Berlepsch.

### **4. Research Institute of Child Nutrition Dortmund, Rheinische Friedrich-Wilhelms-Universität Bonn (Germany)**

Mathilde Kersting, Wolfgangichert-Hellert, Ellen Koeppen.

### **5. Pécsi Tudományegyetem (University of Pécs) (Hungary)**

Dénes Molnar, Eva Erhardt, Katalin Csernus, Katalin Török, Szilvia Bokor, Mrs. Angster, Enikő Nagy, Orsolya Kovács, Judit Repásky.

### **6. 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.

### **7. 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.

### **8. 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.

**9. Istituto Nazionale 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, Raffaella Piccinelli, Angela Polito, Raffaella Spada, Stefania Sette, Maria Zaccaria

**10. University of Napoli "Federico II" Dept of Food Science (Italy)**

Luca Scalfi, Paola Vitaglione, Concetta Montagnese.

**11. Ghent University (Belgium)**

Ilse De Bourdeaudhuij, Stefaan De Henauw, Tineke De Vriendt, Lea Maes, Christophe Matthys, Carine Vereecken, Mieke de Maeyer, Charlene Ottevaere

**12. Medical University of Vienna (Austria)**

Kurt Widhalm, Katharina Phillipp, Sabine Dietrich, Birgit Kubelka Marion Boriss-Riedl.

**13. 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.

**14. Institut Pasteur de Lille (France)**

Jean Dallongeville, Aline Meirhaeghe.

**15. Karolinska Institutet (Sweden)**

Michael Sjöström, 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.

**16. 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.

**17. Campden & Chorleywood Food Research Association (United Kingdom)**

Chantal Gilbert, Sarah Thomas, Elaine Allchurch, Peter Burgess.

**18. SIK - Institutet foer Livsmedel och Bioteknik (Sweden)**

Gunnar Hall, Annika Astrom, Anna Sverkén, Agneta Broberg.

**19. Meurice Recherche & Development asbl (Belgium)**

Annick Masson, Claire Lehoux, Pascal Brabant, Philippe Pate, Laurence Fontaine.

**20. Campden & Chorleywood Food Development Institute (Hungary)**

Andras Sebok, Tunde Kuti, Adrienn Hegyi.

**21. Productos Aditivos SA (Spain)**

Cristina Maldonado, Ana Llorente.

**22. Cárnicas Serrano SL (Spain)**

Emilio García.

**23. Cederroth International AB (Sweden)**

Holger von Fircks, Marianne Lilja Hallberg, Maria Messerer

**24. Lantmännen Food R&D (Sweden)**

Mats Larsson, Helena Fredriksson, Viola Adamsson, Ingmar Börjesson.

**25. European Food Information Council (Belgium)**

Laura Fernández, Laura Smillie, Josephine Wills.

**26. Universidad Politécnica de Madrid (Spain)**

Marcela González-Gross, Jara Valtueña, David Jiménez-Pavón, Ulrike Albers, Raquel Pedrero, Agustín Meléndez, Pedro J. Benito, Javier Calderón, Juan José Gómez Lorente, David Cañada, Alejandro Urzanqui, Juan Carlos Ortiz, Francisco Fuentes, Rosa María Torres, Paloma Navarro.